AIVC

OPPTRE Energioppgradering av småhus i tre til nesten nullenerginivå

Norwegian University of Science and Technology

Temperature Zoning in Highly-Insulated Buildings

Colder Bedrooms in Winter with Warm Living Rooms

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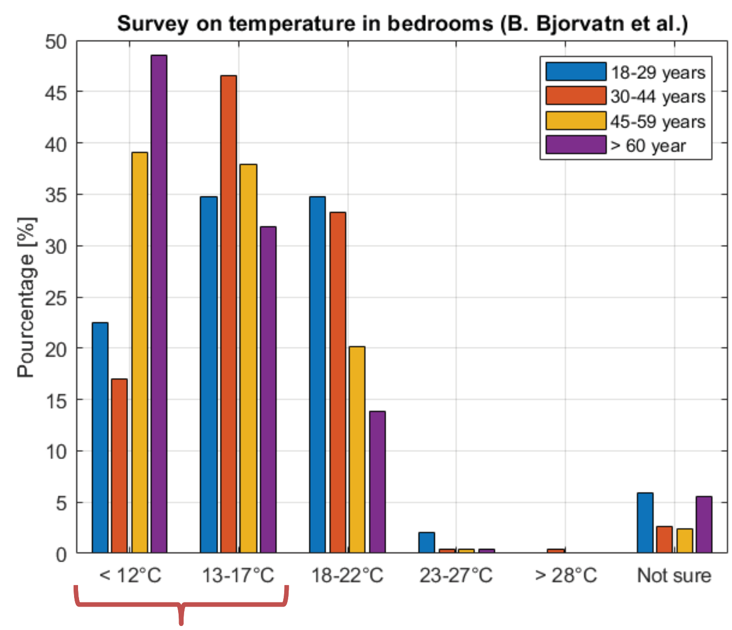
Need for Colder Bedrooms in Norway (1)

- Without considering a specific building energy performance
- Survey (Bjorvatn et al. 2017)
  - 1001 Norwegians selected randomly
  - 70% with bedroom temperature < 18°C
  - Many with bedroom temperature < 12°C



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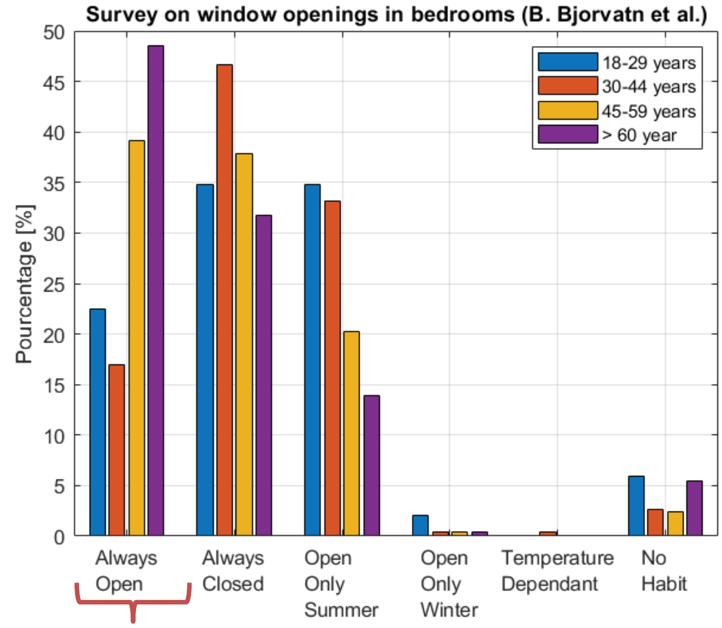
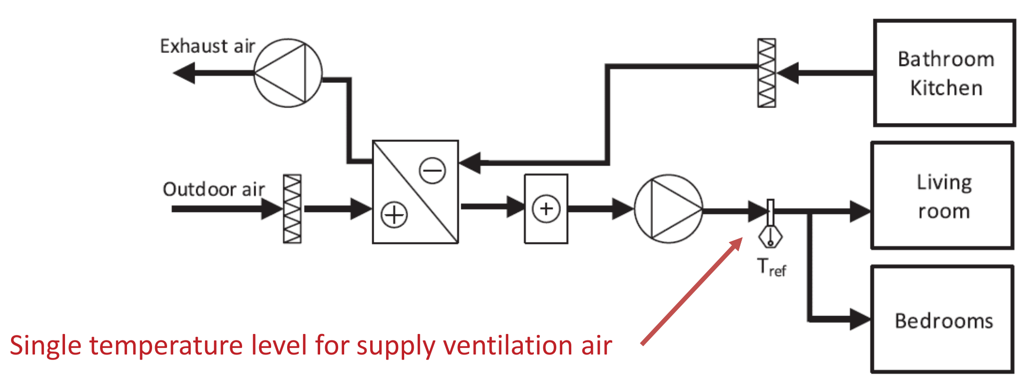
Need for Colder Bedrooms in Norway (2)

- Without considering a specific building energy performance
- Survey (Bjorvatn et al. 2017)
  - 1001 Norwegians selected randomly
  - Many keep bedroom windows always open, especially with age above 45



Temperature Zoning in nZEB (1)

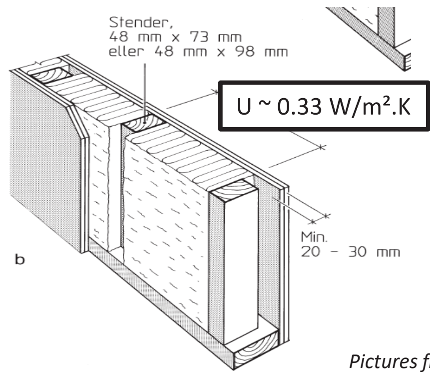
- Limited temperature zoning in highly-insulated building envelopes
  - Highly-insulated external walls and high-performance windows
  - Centralized one-zone balanced mechanical ventilation with efficient heat recovery

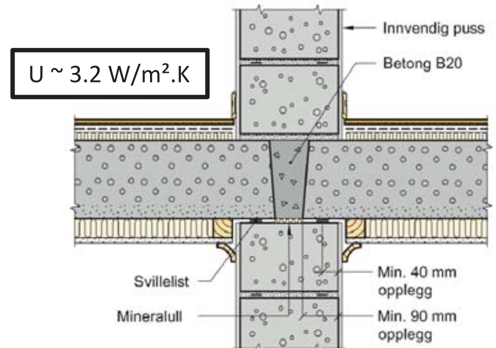


Pictures from Berge et al., Building and Environment 2016

Temperature Zoning in nZEB (2)

- Influence of building construction mode
  - Partition walls insulated in lightweight constructions
  - Positive effect on temperature zoning
  - Many lightweight wooden constructions in Norway





Pictures from SINTEF Byggforskserien

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Temperature Zoning in nZEB (3)

- Experience of indoor thermal environment in Norwegian passive houses
  - Based on questionnaires and field measurements
  - ~100 dwellings (Berge et al. 2016, Thomsen et al. 2017)

- Regarding bedrooms
  - Many occupants 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 control the supply ventilation air temperature correctly to get colder bedrooms

- Regarding living areas
  - Desired indoor temperature is often between 22°C and 24°C

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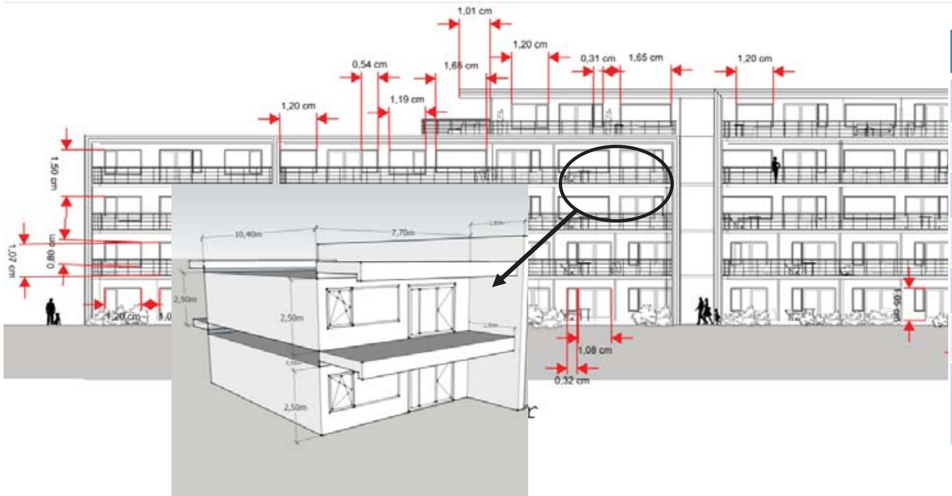
Temperature Zoning: example apartment (1)

- Two identical apartments from *Miljøbyen Granåsen* project in Trondheim

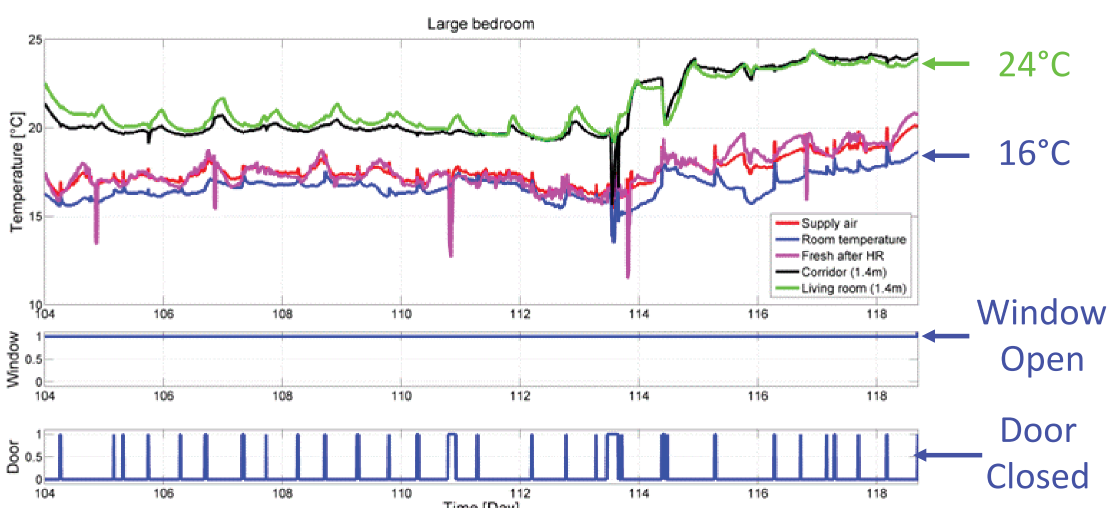


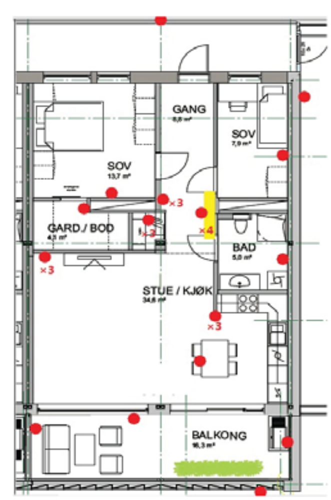
Thermal property	Value
U external walls	0.17 W/m².K
U wall to atrium	0.16 W/m².K
U between flats	0.25 W/m².K
U internal walls	0.49 W/m².K
Thermal bridges	0.02 W/m².K
Infiltration (design)	0.6 ach at 50 Pa
Ventilation CAV (one AHU per flat)	1.5 m³/m².h 85% rated efficiency

Georges et al. 2016

Temperature Zoning: example apartment (2)

- Measurement during two weeks in a passive house apartment

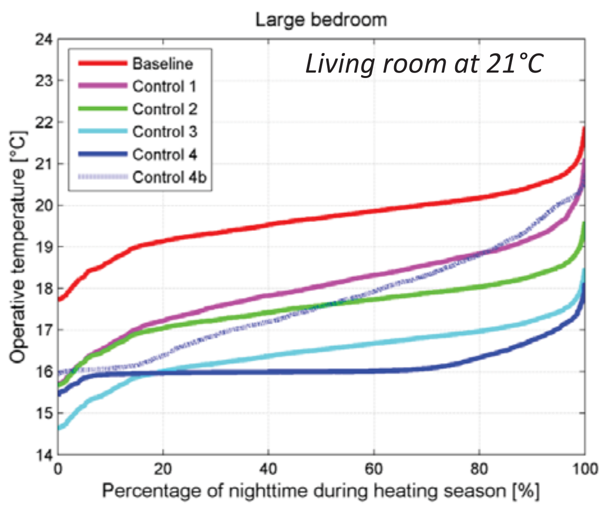


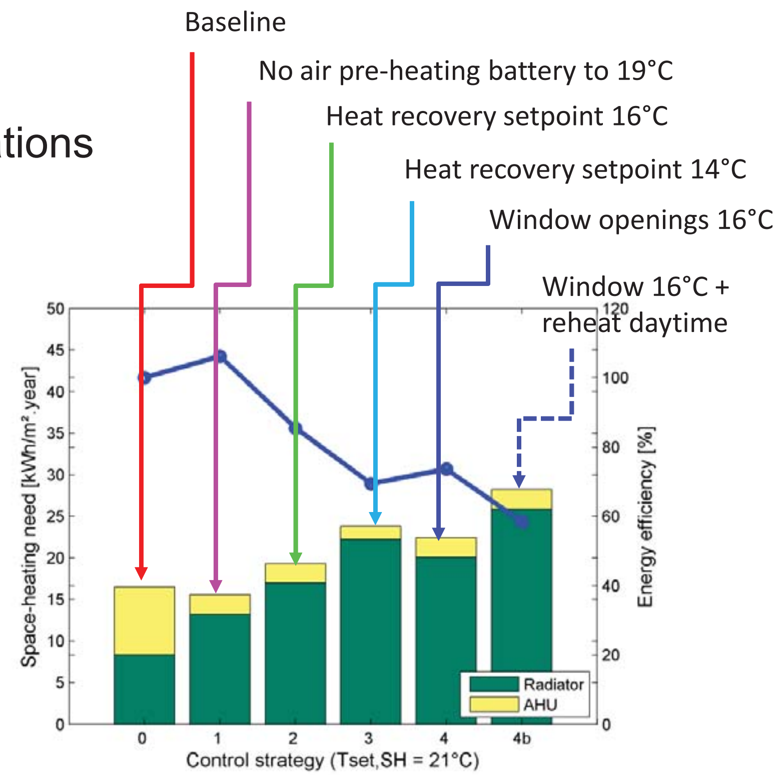


Georges et al. 2016

Is it due to control?

- Based on calibrated dynamic simulations
  - Multi-zone simulations in IDA ICE with embedded ventilation network

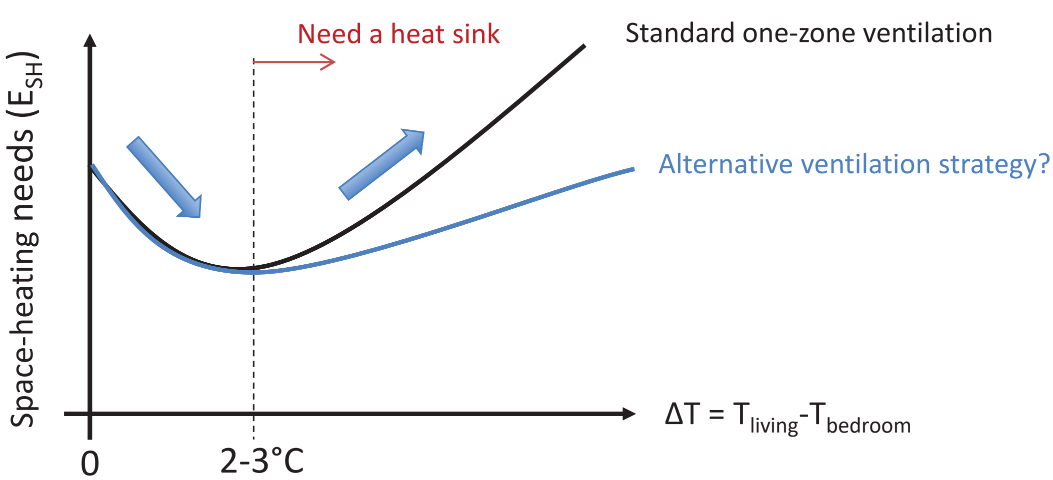




 Georges et al. 2016 OPPTRE NTNU

Conclusions for Lightweight Construction

- Based on measurements and simulations
  - Apartment block, terraced and detached houses at Norwegian passive house level



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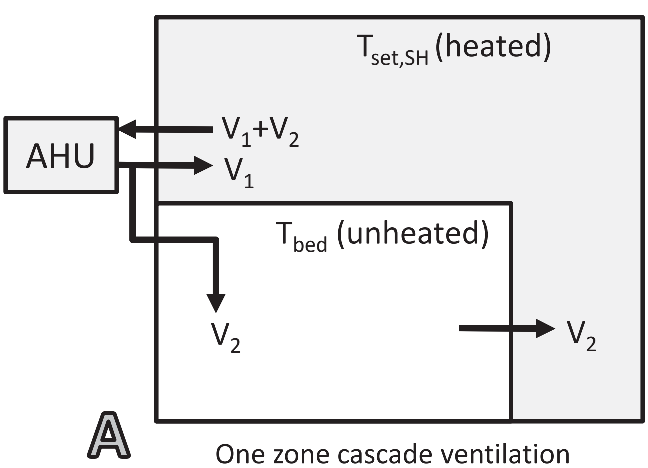
Temperature Zoning: research question

- Research showed that
  - Large temperature zoning leads to significant increase of space-heating needs (ΔE_{SH})
  - Control alone cannot decrease bedroom temperature without large ΔE_{SH}
  - Something should be changed in the building concept, like the ventilation strategy

- How to reduce ΔE_{SH} with large temperature zoning?
  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 (P) from heated to unheated rooms



One zone cascade ventilation

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

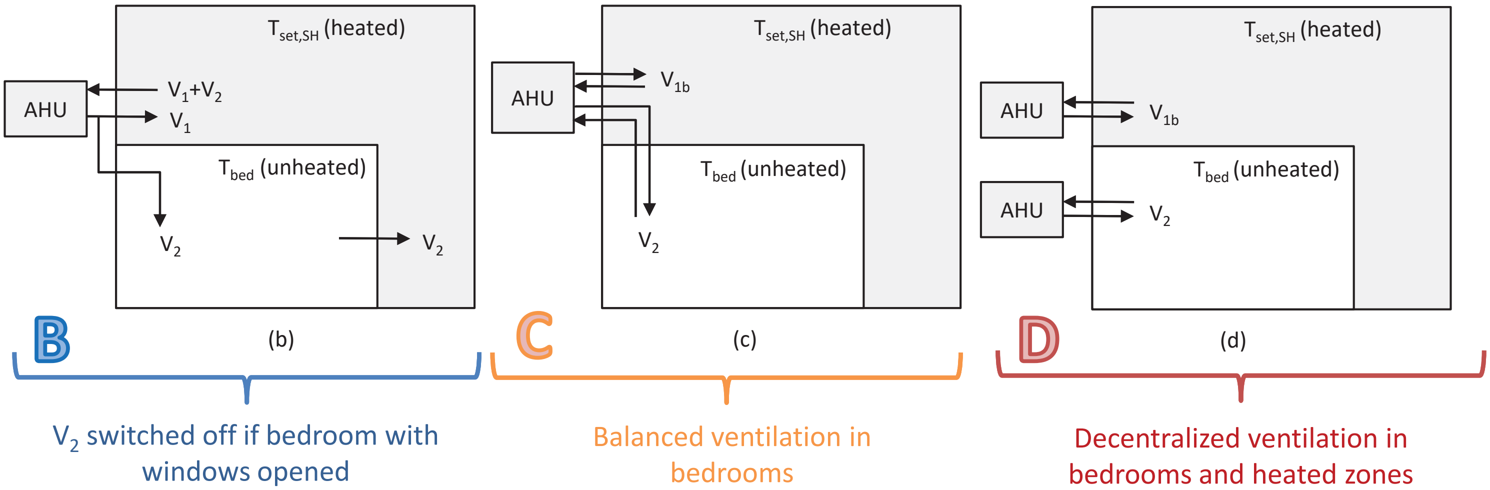
- When open bedroom window, nothing changes for heated zone except

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

Georges et al. 2019

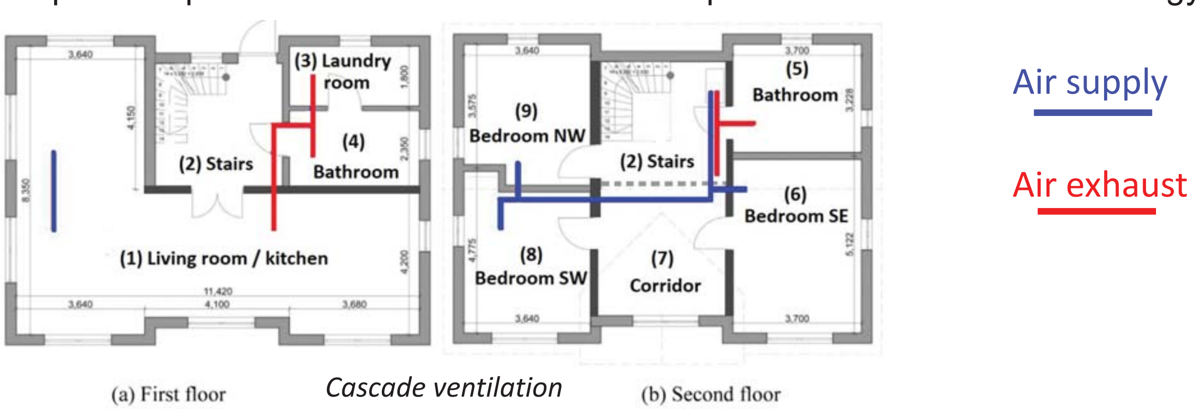
Alternative ventilation strategies

- To reduce the ventilation contribution on ΔE

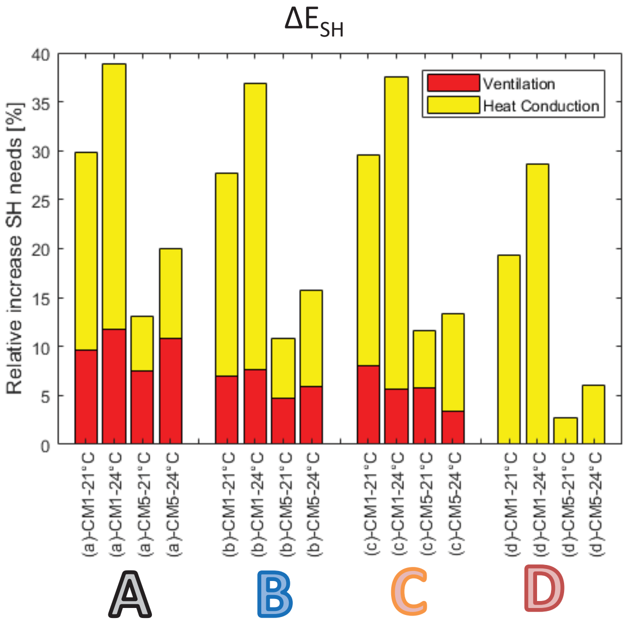


Simulation Case Study

- Detached Passive House
  - 173 m² located in Oslo
  - With different construction modes (lightweight to heavy)
  - Simulated in IDA-ICE with embedded ventilation network
  - CAV with pre-accepted airflow rates from TEK17 adapted for each ventilation strategy

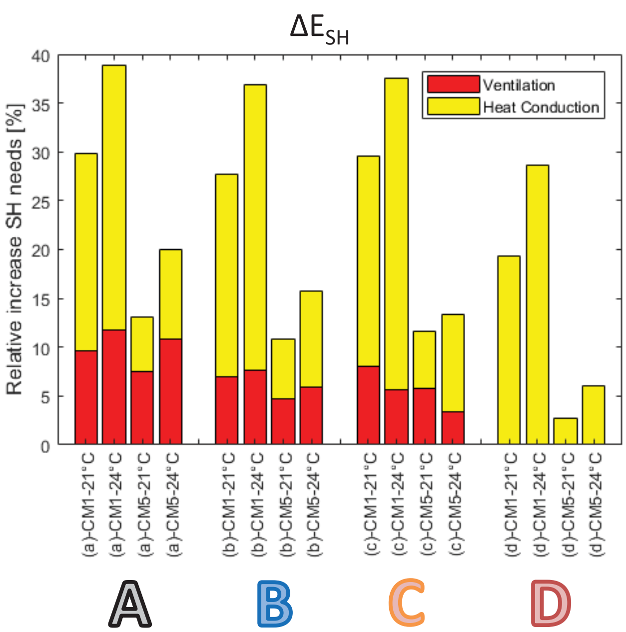


Steady-State Analysis



- Setup
  - Outdoor temperature selected to give typical temperature zoning
  - Heavy-weight (CM1) and Lightweight (CM5) constructions
  - Two different set-point temperature in living areas (21 and 24°C)
  - Increase of space-heating needs analyzed ΔE_{SH} due to window opening in bedrooms
- Conclusions (1)
  - Heat conduction > ventilation effect in heavy-weight buildings (CM1)
  - Heat conduction ≈ ventilation effect in light-weight construction (CM5)

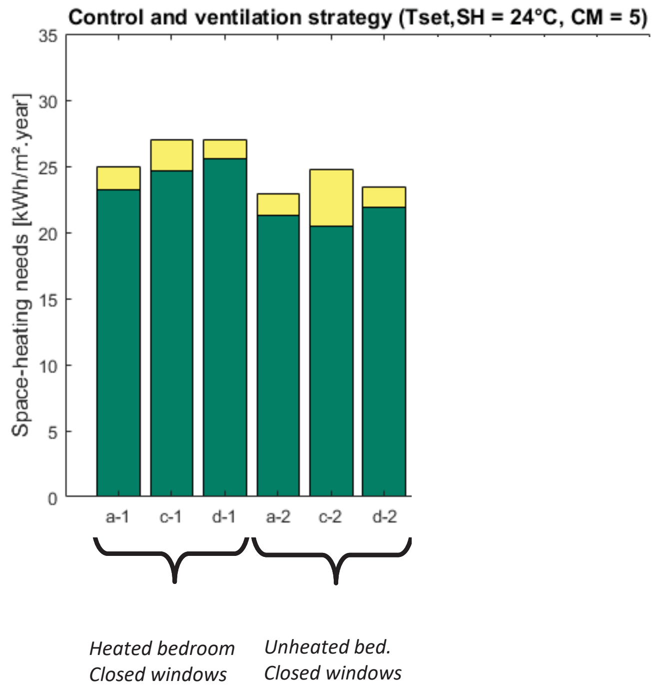
Steady-State Analysis



- Conclusions (2)
  - Moderate reduction of ventilation effect for strategies (B) and (C) compared to (A)
  - No ventilation effect with strategy (D)
  - Heat conduction part left almost unchanged between A, B, C and D

Yearly Dynamic Simulation

- Setup
  - Lightweight construction (CM5)
  - Set-point temperature in living area of 24°C
  - Compare different strategies for control
- Conclusion with closed bedroom windows
  - Higher ventilation airflow rates in (C and D) compared to A (from pre-accepted building code TEK17)
  - Slightly higher space-heating needs without cascade ventilation (C and D)



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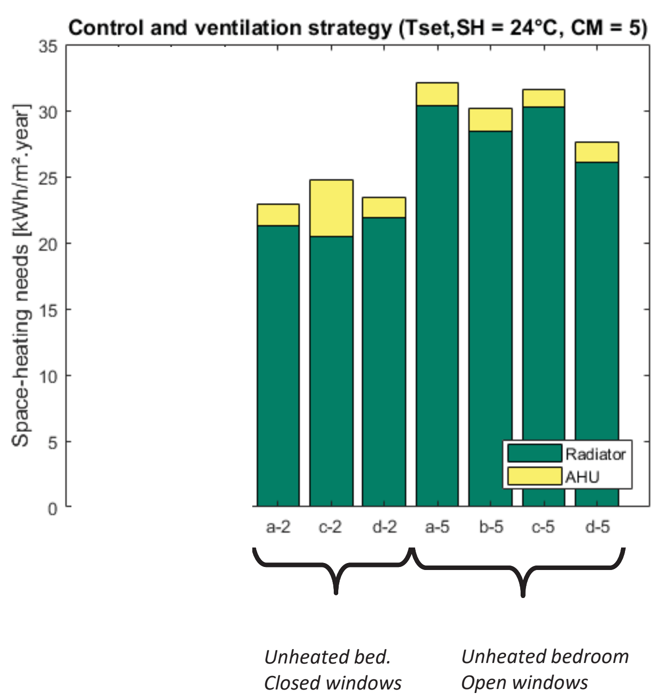
Yearly Dynamic Simulation

- Conclusions open bedroom windows
  - Always an increase of space-heating needs
  - Slightly lower increase for (B) and (C) than (A)
  - Lower increase for decentralized (D) than (A)



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Conclusions (1)

- Highly-insulated building with one-zone balanced mechanical ventilation
- Need to improve energy efficiency with large temperature zoning (> 3°C)
  - Simulations show that it is not a question of control
  - Need to change the building concept
- Important remarks
  - *Buffer zone* with intermediate temperature level effective for zoning
  - Results can be very different with less insulated partition walls (e.g. heavy-weight buildings)

Conclusions (2)

- Regarding the increase of space-heating needs with large zoning (ΔE_{SH})
- Question 1:
  - Heat conduction dominant in heavyweight buildings (non-insulated partition walls)
  - Effect heat conduction and ventilation have the same magnitude for lightweight buildings
  - Ventilation strategy cannot solve the problem alone
- Question 2:
  - Ventilation contribution can be moderately reduced by shutting down supply air in bedrooms of mechanical ventilation when bedroom windows are 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 (D)

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Thank you for your attention!

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Urban Home Ventilation, AIVC seminar, May 2020, Norway

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)

Nominal Ventilation Airflow Rates

- Pre-accepted values from building code TEK17, leading design criteria:
  - Supply airflow in bedrooms in cascade ventilation
  - Exhaust airflow in "wet" rooms without cascade ventilation

Table 2. Ventilation airflow rates for the different ventilation strategies [12].

Zone	Room	With cascade (baseline)		Without cascade**	
		Supply [m^3/h]	Return [m^3/h]	Supply [m^3/h]	Return [m^3/h]
1	Kitchen and Living	104	40	126	36
2	Stairs	0	0	0	0
3	Technical/Laundry	0	40	0	36
4	Bathroom 1st floor	0	64	0	54
5	Bathroom 2nd floor	0	64	0	54
6	Bedroom SE	52	0	52	52
7	Corridor 2nd floor	0*	0	54	0
8	Bedroom SW	26	0	26	26
9	Bedroom NW	26	0	26	26
Total		208	208	284	284

* In strategy (b), this airflow is 104 m^3/h if the supply ventilation air in bedrooms is stopped.
** This corresponds to the strategy (c) and decentralized ventilation (d).