Investigation of the Air Heating Concept for Norwegian Passive Houses

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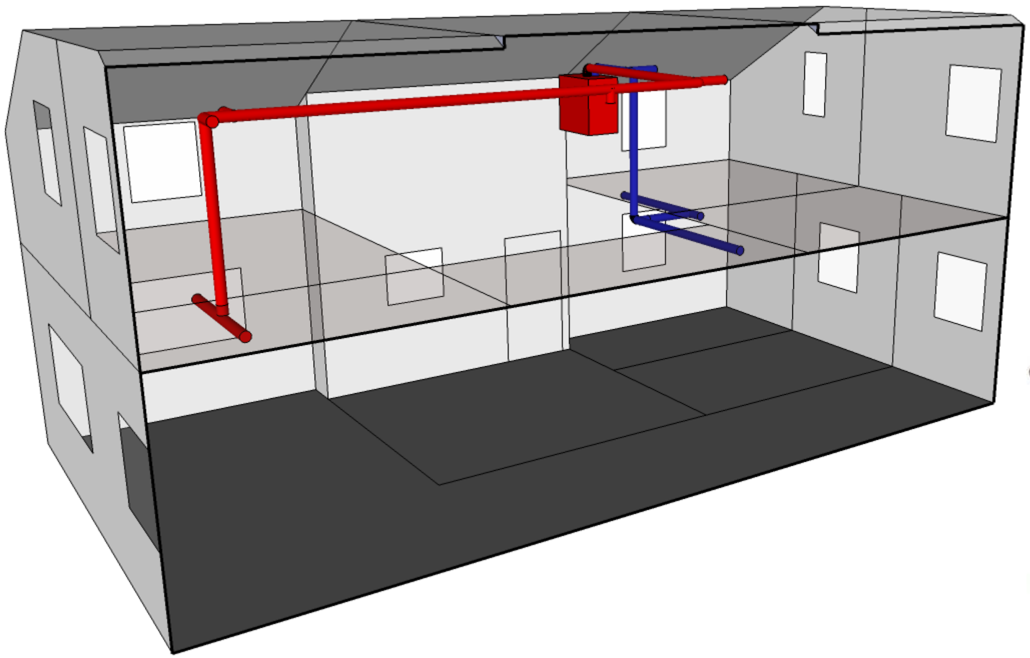
CENTRE FOR ENVIRONMENT-FRIENDLY ENERGY RESEARCH

Background

- Air heating often associated to the passive house concept
- The idea is to perform the space-heating distribution using the ventilation air at standard hygienic flow rates
- Usually one centralized heating coil placed after the heat recovery unit



Research questions (1)

• The Norwegian passive house standard (NS 3700) translates the German passive house concept to the Norwegian context

• Nevertheless, the NS 3700 was not made dependent on the air heating

• **What is the air heating potential in Norwegian passive houses?**

• In fact, many technical questions:

1. What is the **maximal air heating temperature** ($T_{AH,max}$) required as a function of the building shape and location? How to evaluate it for a given project?
2. How efficient is the **mixing in the room**? How are the temperature stratification and the ventilation effectiveness?
3. What is the **temperature distribution** between rooms? Influence of the control, internal and solar gains and the heat losses from the ventilation ducts?
4. What is the $T_{AH,max}$ as regards **health hazard/IAQ**?

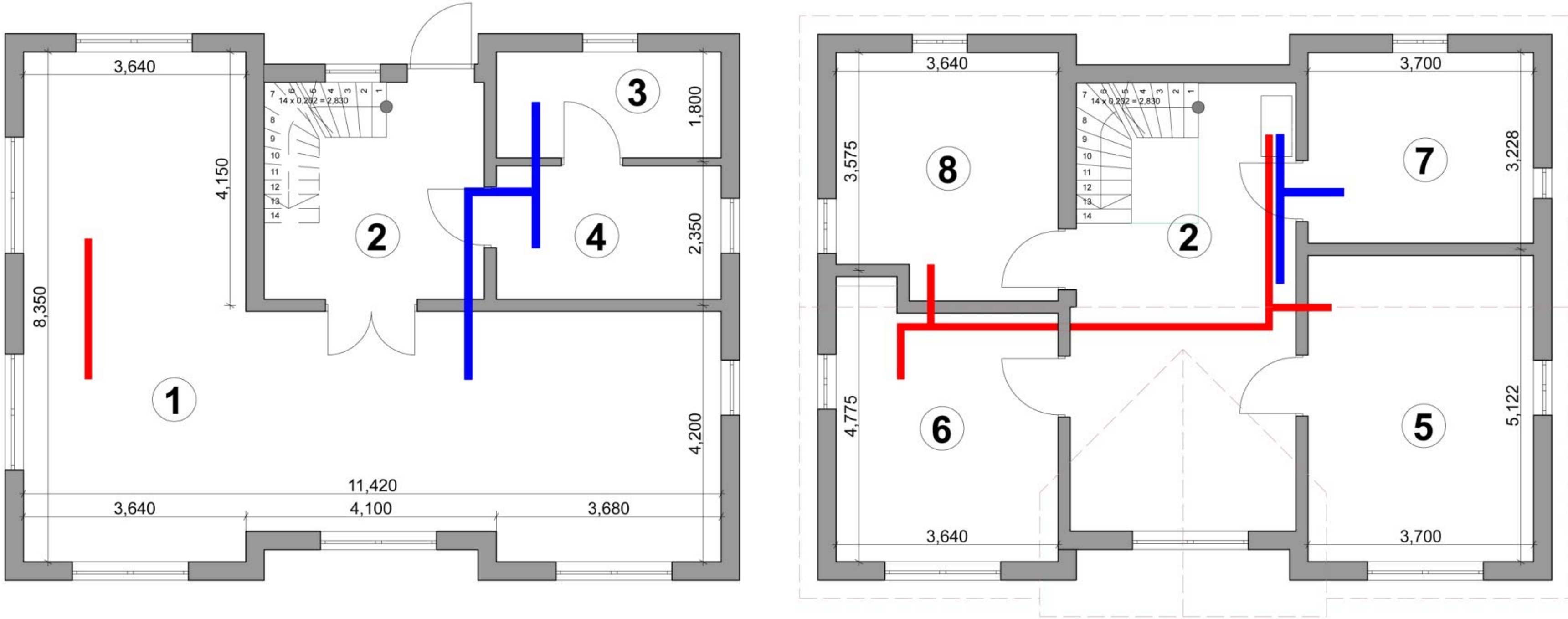
Research questions (2)

- **Assume a centralized air-heating system: one heating coil**
- Assume hygienic flow rates (Vn) : maximum 50% above if forcing

- **Focus on questions (1) and (3)**
- Assume perfect behavior for questions (2) and (4):
  - Assume perfect mixing in each room
  - Assume 50-55°C as maximal for health hazard
- Investigations using detailed dynamic simulations is consistent
  - Using TRNSYS for the thermal part
  - Using TRNFLOW for the ventilation part (ventilation-network approach)

Detached house geometry

- Typical typology for Norway
- Single-family, detached house
- Ventilation network and flow rates designed by Flexit®



Detached house parameters (1)

- 3 building locations : Oslo, Bergen and Karasjok

	θ_{ym} [°C]	$I_{tot,rad}$ [W/m²]	$\theta_{SH,dim}$ [°C]	Q_{max} [kWh/m².y]	HDD18° [°C.day]	ASHRAE Climate zone
Oslo	6.3	110	-20.0	19.2	4423	*Cold*
Bergen	7.5	87	-11.7	19.1	3858	*Cool*
Karasjok	-2.5	79	-48.0	41.6	7538	*Subarctic*

- Adaptation of the envelope performance for each location (NS 3700)

	$U_{ext,wall}$ [W/m².K]	U_{roof} [W/m².K]	U_{slab} [W/m².K]	U_{win} [W/m².K]	ψ'' [W/m².K]	η_{exch} [%]	n_{50} [1/h]	Q_{net} [kWh/m².y]	P_{SH} [W/m²]
Oslo	0.15	0.12	0.11	0.72	0.03	85	0.6	18.9	16.6
Bergen	0.15	0.16	0.11	0.80	0.03	85	0.6	16.0	11.7
Karasjok	0.12	0.09	0.08	0.72	0.03	85	0.6	41.0	26.3
NS 3700*	0.15	0.13	0.15	0.80	0.03	80	0.6	-	-

Detached house parameters (2)

- 5 building construction modes: from *very-light* to *very-heavy*
- Influence the insulation level in internal partition walls/ceilings

Construction Type	Inertia Type	Inertia [MJ/K]	U_{floor} [W/m².K]	U_{part} [W/m².K]	$U_{bearing}$ [W/m².K]
Masonry heavy	*Very-heavy*	86	1.6	3.2	2.8
Mixed wood-masonry	*Heavy*	41	1.6	0.33	2.8
Wooden heavy	*Medium*	35	0.23	0.33	2.8
Masonry light	*Light*	26	0.21	0.33	1.1
Wooden light	*Very-Light*	14	0.21	0.33	0.25

- 4.2 W/m² internal gains: different profiles in space and time
  - –Constant and uniform (by default)
  - –Synthetic gains changing in space and time (following statistics in Norway)
- No solar shading by default but external blinds can be applied

Air-heating parameter

•Constant heating applied at 21°C in the living room

•Thermal losses from ventilation ducts:

- Without thermal losses (default case)
- Not insulated ducts
- Ducts with 5cm mineral wool insulation

Simulation scenario

1. Standard Design Conditions (**STD**) :
   – Using design outdoor temperature: a cold wave (here 3 coldest days in 30 years)
   – No solar gains
   – Internal gains left as a free parameter

2. *2.* Usual operating conditions (**TMY**) :
   – All-year simulation using a typical meteorological year from Meteonorm
   – Solar gains
   – Internal gains left as a free parameter

• Large sensitivity analysis with a total of ~700 simulations using a 1 min time step

• Most representative results only reported

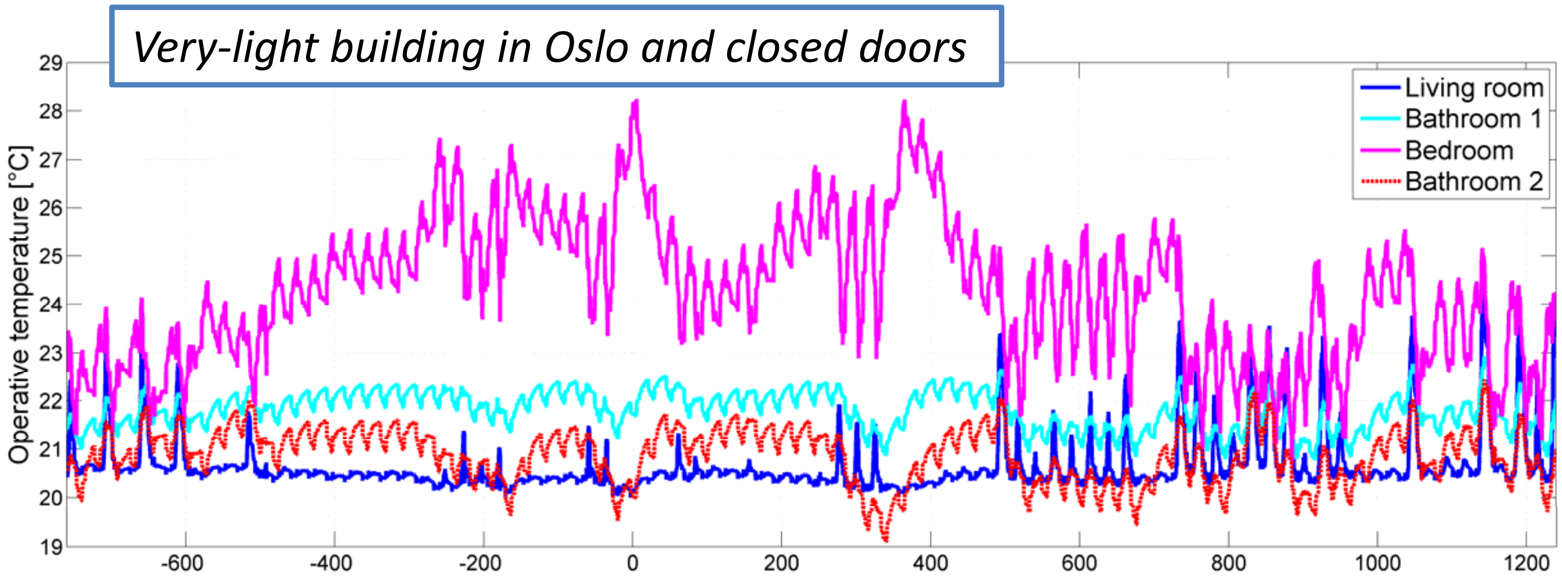
Comparing maximal T_{AH} in STD and TMY

- Constant gains, closed internal doors and no duct losses

Simulation method			Multi-zone		Multi-zone		
Operating conditions			**STD**		**TMY**		
V	Gains [W/M²]	Climate		T_{AH} [°C]		$T_{AH,MAX}$ [°C]	$T_{AH,95\%}$ [°C]
V_n	0.0	Oslo	⊗	-	□	[51.1;55.0]	[46.5;52.3]
		Bergen	⊗	-	⊕	[45.6;50.6]	[42.0;45.9]
		Karasjok	⊗	-	⊗	-	-
	4.2	Oslo	□	[49.5;55.0]	⊕	[41.2;48.7]	[36.7;41.4]
		Bergen	⊕	[42.7;47.1]	⊕	[35.8;40.0]	[32.6;35.3]
		Karasjok	⊗	-	⊗	-	-
3/2 V_n	0.0	Oslo	⊕	[45.9;50.5]	⊕	[40.4;45.6]	[37.6;41.1]
		Bergen	⊕	[41.2;44.6]	⊕	[37.0;40.1]	[34.8;37.2]
		Karasjok	⊗	-	⊕	[48.0;52.9]	[45.7;49.2]
	4.2	Oslo	⊕	[40.0;44.0]	⊕	[34.0;38.7]	[31.3;34.3]
		Bergen	⊕	[35.3;38.0]	⊕	[30.7;33.3]	[28.6;30.2]
		Karasjok	□	[49.9;55.0]	⊕	[45.1;49.8]	[38.7;44.1]

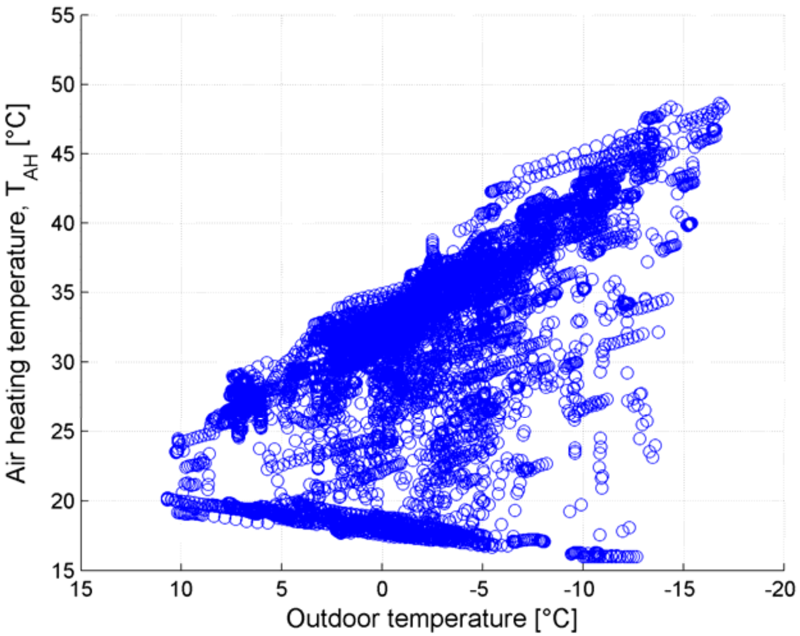
Conclusions

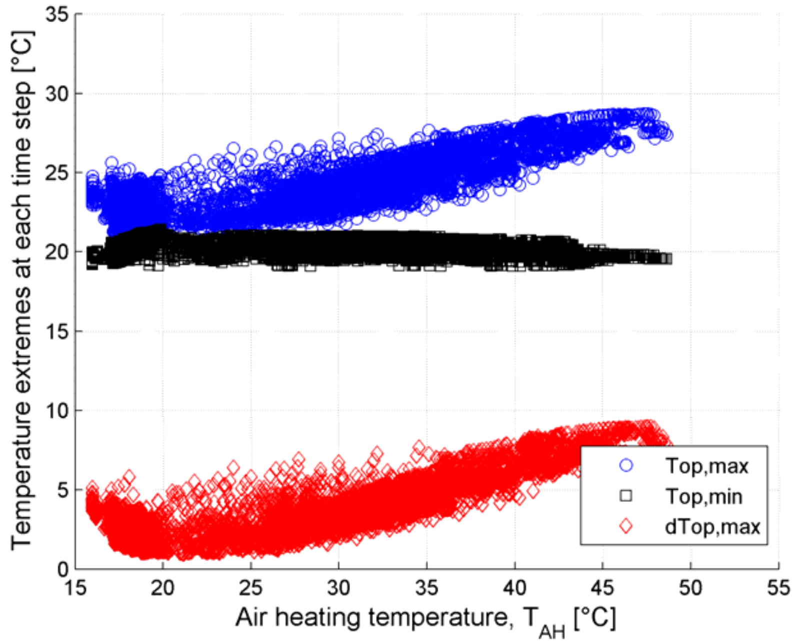
- Air heating possible? *The colder the climate, the more difficult it is*
- STD conditions are much more severe than TMY
- Zones with highest temperature are bedrooms and lowest temperatures are found in bathrooms
- The higher the internal insulation in partition walls, the higher the temperature difference between rooms
- Opening the internal doors is an efficient way to homogenize temperature but bedrooms are still quite hot (i.e. ~23°C)



Oslo in TMY: constant gains, no duct losses

- T_{AH} is maximal when it is the coldest outside without sun
- Maximal temperature difference in the building when T_{AH} is maximal
- Conclusion : *a cold day without sun makes sense to design the air heating*





Conclusions : design of air heating

- **Cold day without sun** representative of the most severe configuration
  - Highest T_{AH} and largest temperature difference between rooms
- What **outdoor temperature** should we use for design?
  - STD temperature extreme (very conservative), can exclude air heating too quickly
  - Can select a less extreme design temperature using a trade-off with security
  - It makes sense if a backup heating system is present (as a wood stove)
- What **internal gains** should we use for design?
  - In usual operating conditions, some periods of the day can have low gain magnitude
  - Select a low gain value for design, to evaluate maximal T_{AH} (e.g. no gain at all)
  - But the gain distribution influences the temperature distribution between rooms
- Should we consider the **thermal losses from ventilation ducts**?
  - Important if pipes are not well insulated (e.g. small effect using 5 cm mineral wool)
  - Important to estimate the maximal T_{AH} and the temperature distribution
- Must consider the **construction mode** to know the temperature distribution

Conclusions for the specific detached house typology

- **Centralized** air-heating strategy covering **all the needs** no well adapted
  - Except for the milder climate of Bergen, T_{AH} are high (> 40°C)
  - Temperatures are even prohibitive for Karasjok, with T_{AH} close to 55°C
  - Even for the mild climate of Bergen, the temperature is rather high in bedrooms
  - For all climates, the centralized approach does not give much flexibility to the user (to adapt temperature locally or correct strong temperature differences)

- Possible improvements:
  - To have more heating coils rather than one centralized
  - To have a peak-heating system for coldest days
  - But then is the space-heating distribution simplified anymore?

Conclusions and potential improvements

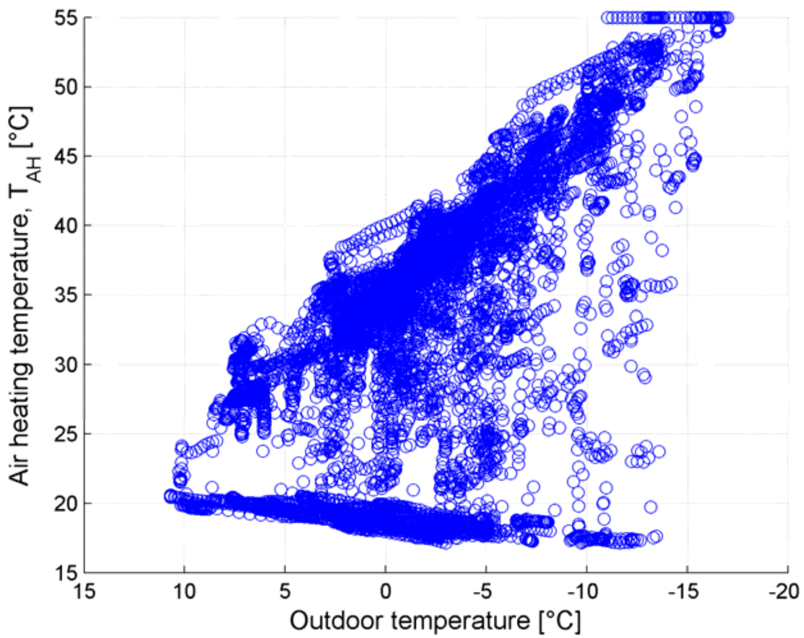
- A simplified formula to evaluate the maximal T_{AH} from the PHPP was tested
  - It assumes a monozone building
  - Proved a realistic estimate to screen the air-heating potential for a given project

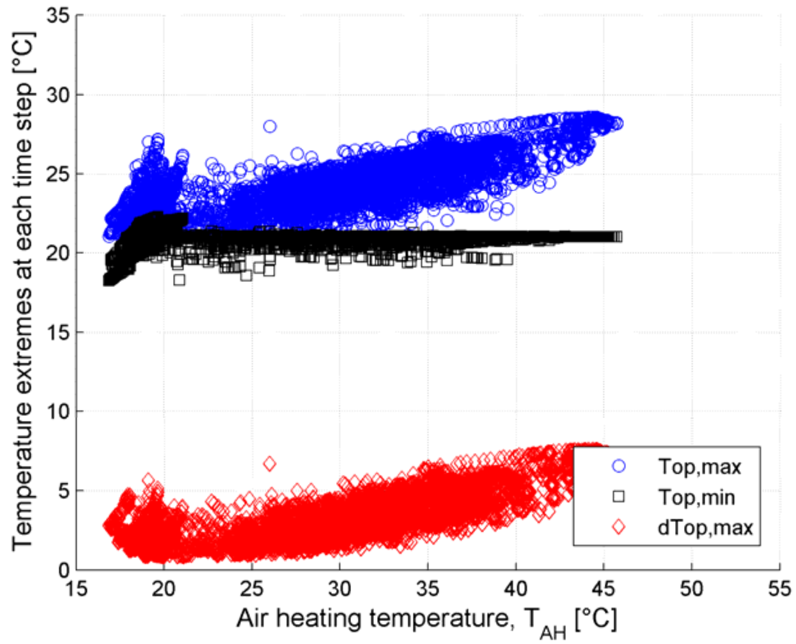
- Still open questions about air heating:
  - Question (2): local air distribution in a room (data exists in literature)
  - Question (4): is the dust carbonization temperature (~50°C) the reference maximal temperature for IAQ questions (e.g. health)

- Validation against experiments and/or CFD
  - Detailed dynamic simulations enable to perform a whole-year thermal comfort assessment at an acceptable computational cost
  - More powerful techniques can be used for the critical configurations detected

Oslo in TMY: constant gains and ducts losses

- Significant without duct insulation: T_{AH} can loose up to ~15°C before ATDs
- But, *in fine*, the maximal T_{AH} is only 2-5°C higher than without losses:
  - Thermal losses from ducts contribute significantly to the heating
  - Increased temperature in room around the living-room (influence the T° distribution)
  - Can be used in design to have higher temperature in specific places (e.g. bathrooms)
- Under control with 5 cm mineral wool around ducts
- A cold day without sun still representative of the most severe configuration





Oslo in TMY: synthetic gains, no duct losses

- A cold day without sun makes sense to design the air heating
- Periods of the day with low gains lead to higher T_{AH} and thus T° differences
- Distribution of internal gains between rooms affects the temperature difference between them (but critical rooms remain the same)