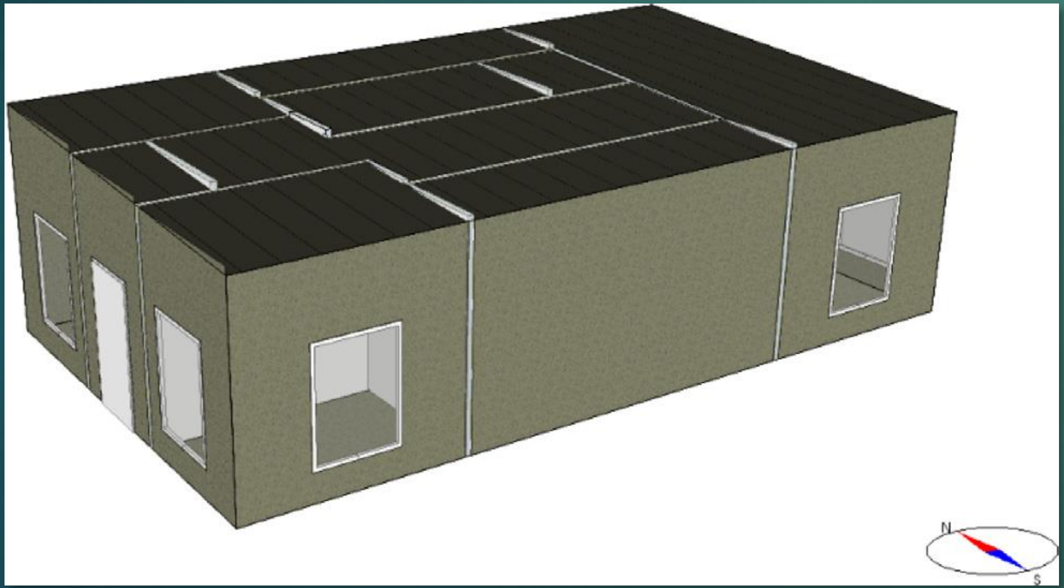
Temperatuurikihistumine ja küttesüsteemide efektiivsus TTÜ katsemaja uuringu põhjal



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EHITUSE JA ARHITEKTUURI INSTITUUT

Measurements at the TTÜ nZEB technological test facility

Aim of the study:

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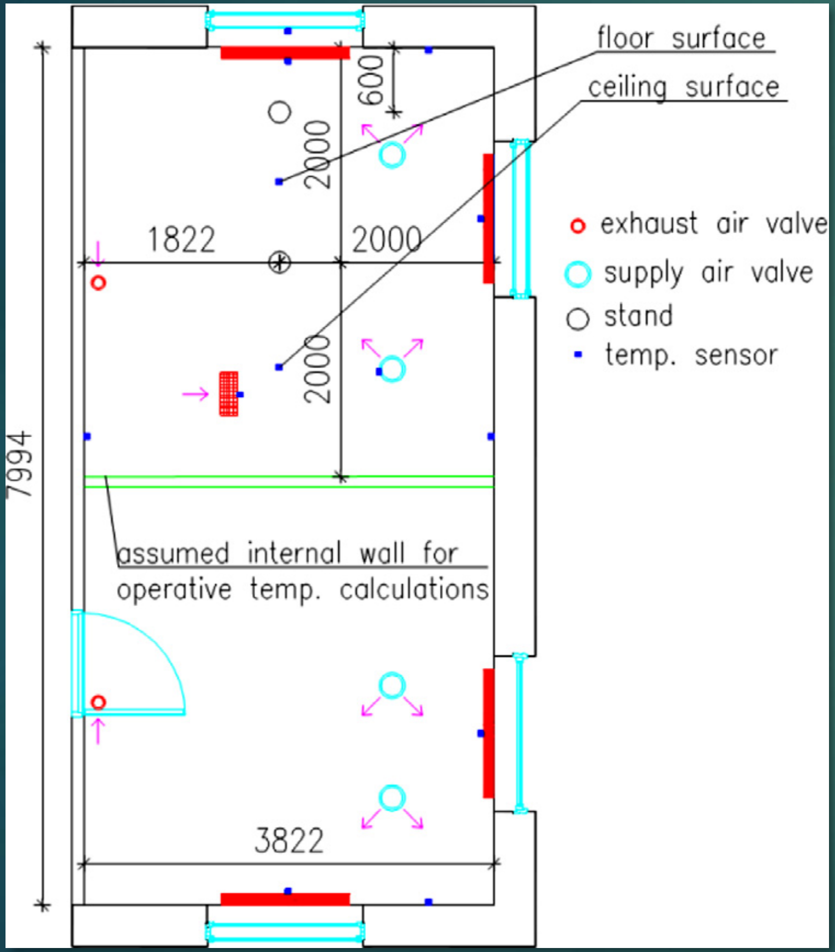
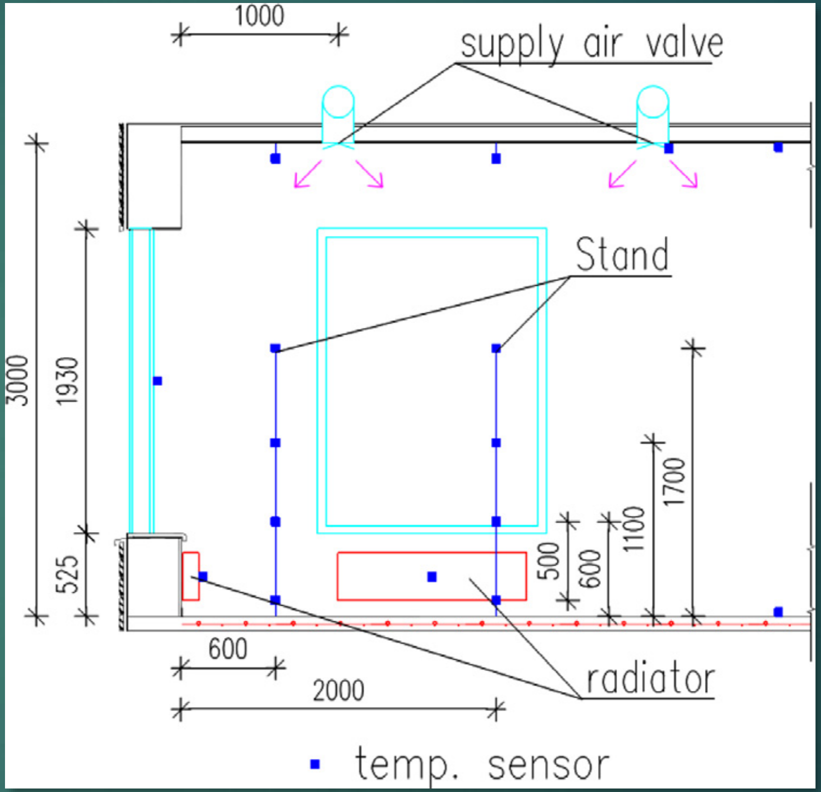
Method:

1) measure the vertical T gradient induced by:
i) radiator, ii) underfloor iii) air heating
2) calculate numerically the annual emission losses

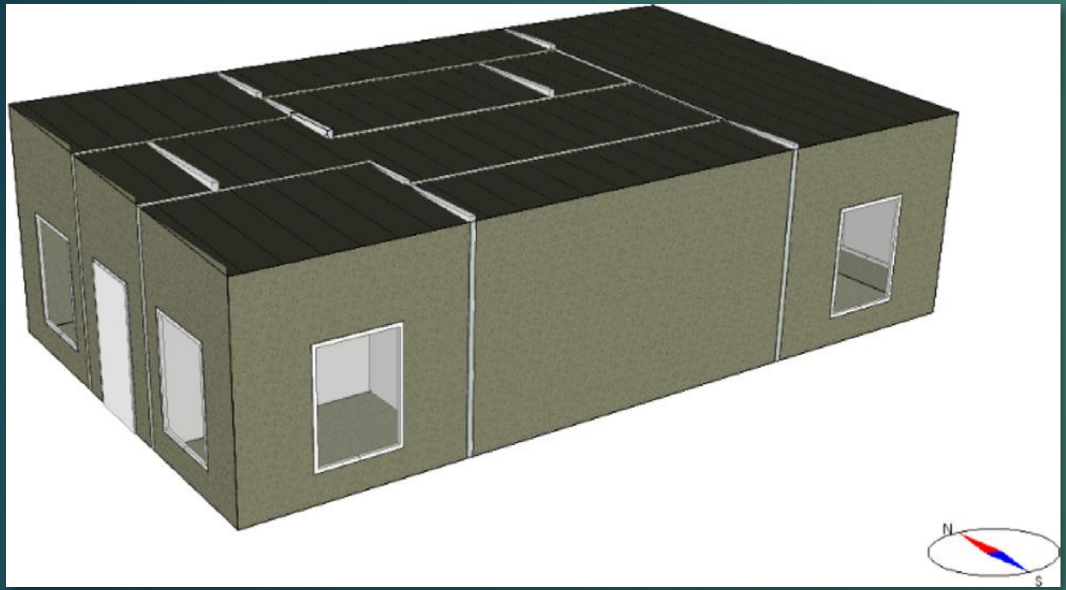
TTÜ technological test facility





- Supply water T compensated by the outdoor air T
- Radiator: low-T heating curve 45/35C
- UFH: 34/27C
- Air heating: 40/30C

Energy simulation model of the TTÜ technological test facility



- IDA-ICE finite difference method software
- Indoor T setpoint: T_{in} =21C
- Annual simulation using Estonian climate data
- **Simulation of space heating and supply air heating needs with measured T gradients**

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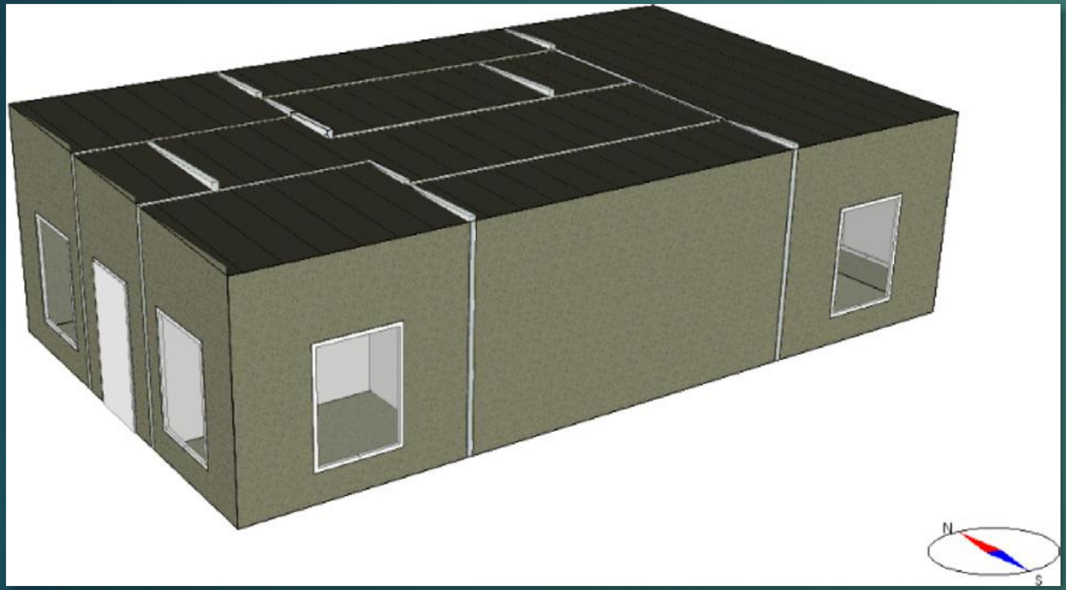

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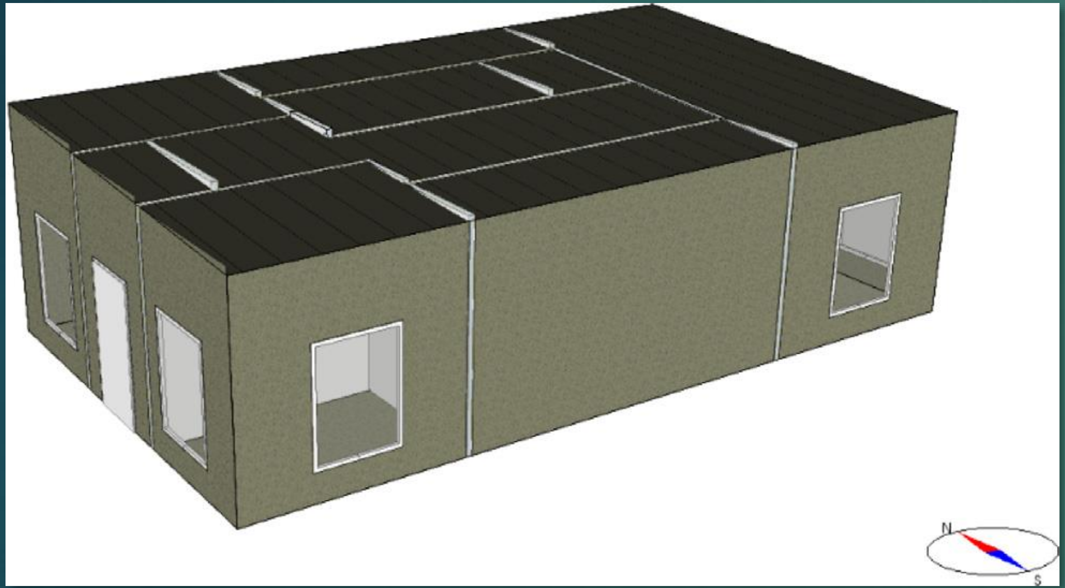

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- T_{op} computed according to the standard ISO 7726:1998, average of mean rad. T and T_{in}

Air temperature gradient (0.6m)

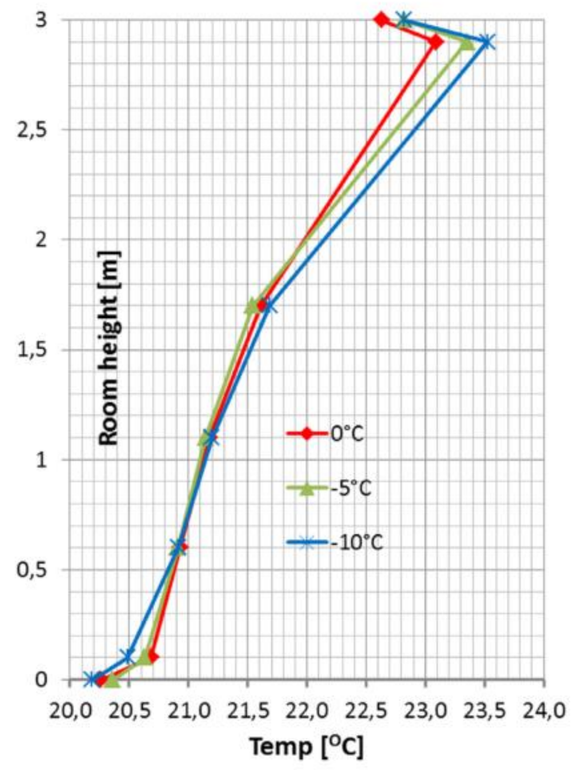

Fig. 5. Air heating temperature gradient at 0.6 m from external wall.

$T_{air} = 25 \div 28\ C$

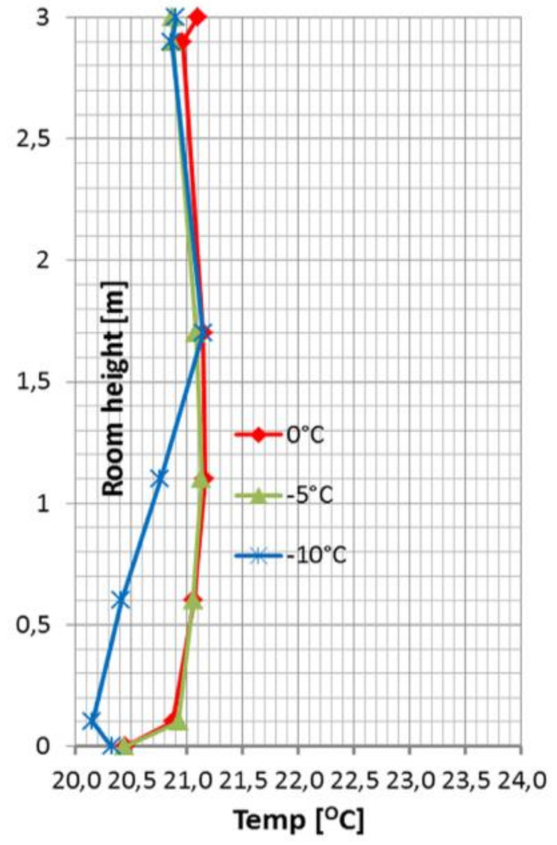

Fig. 7. Radiator heating gradient at 0.6 m from external wall.

$T_{rad} = 22 \div 26\ C$

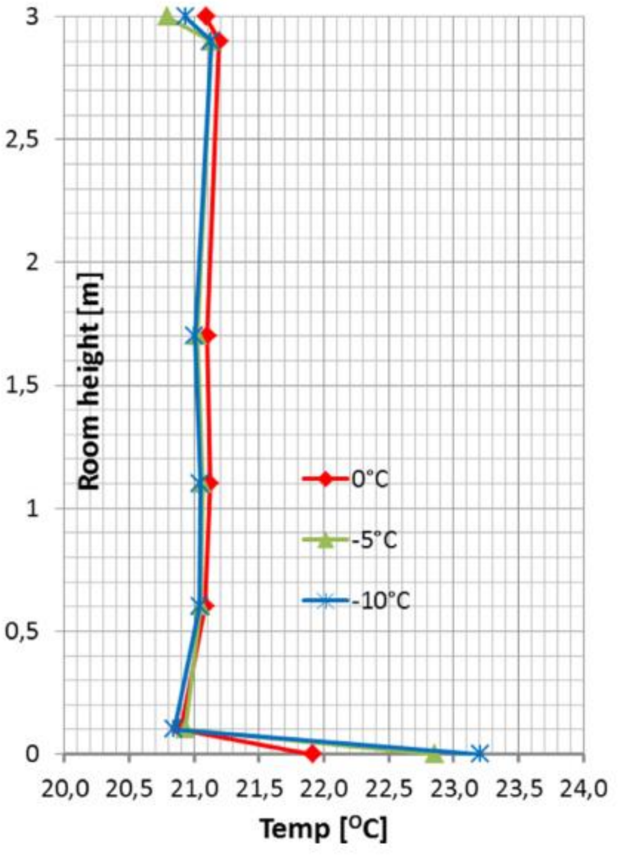

Fig. 9. Floor heating gradient at 0.6 m from external wall.

$T_{floor} = 21 \div 23\ C$

Air temperature gradient (2m)

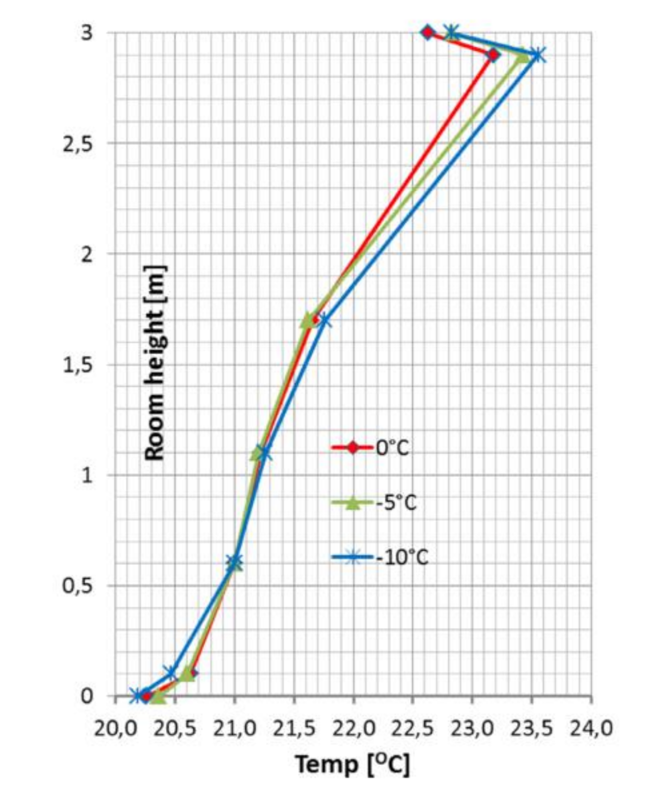

Fig. 6. Air heating temperature gradient at 2 m from external wall.

Average T grad: +1.01 K/m

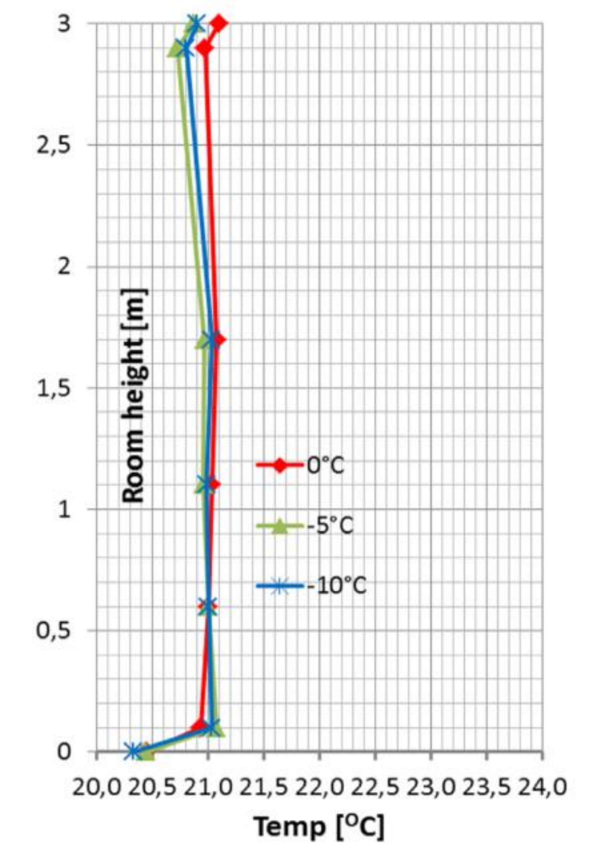

Fig. 8. Radiator heating gradient at 2 m from external wall.

Average T grad: -0.06 K/m

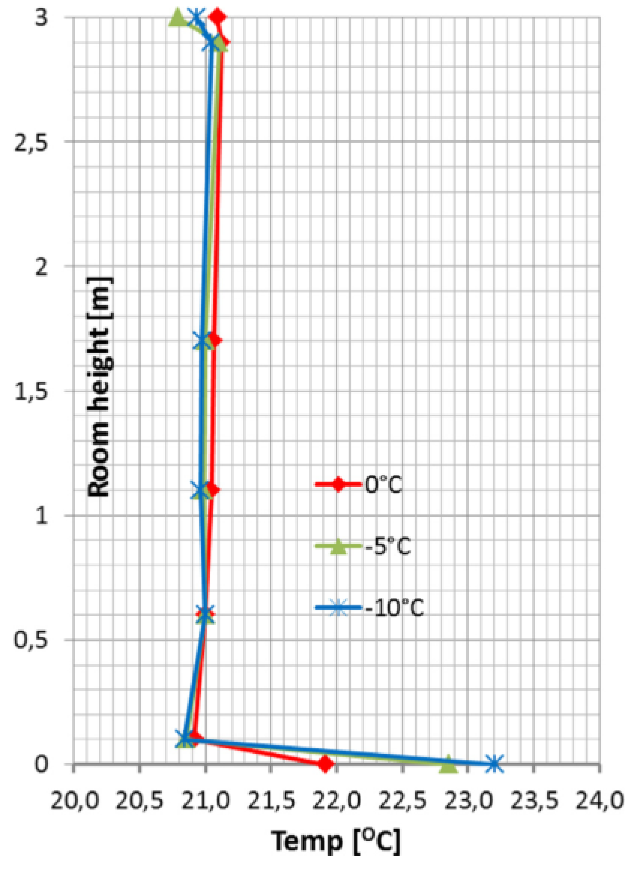

Fig. 10. Floor heating gradient at 2 m from external wall.

Average T grad: +0.07 K/m

Operative temperature corrections

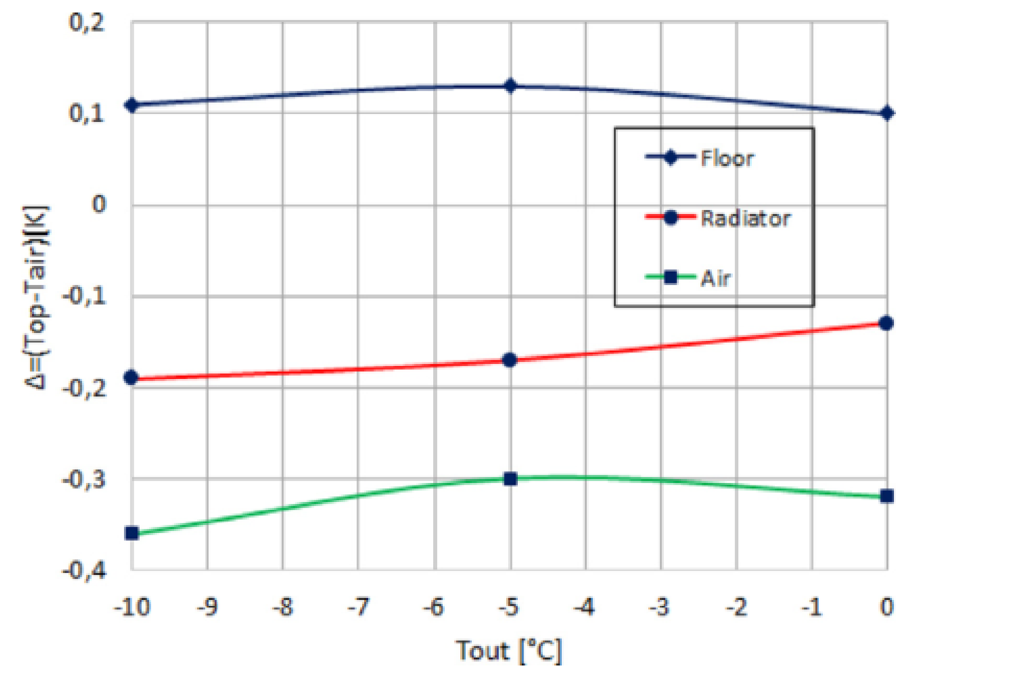

Fig. 12. Operative temperature corrections, occupant location in the centre of the room, 2 m from the external wall.

2m from external wall

Operative T variation depends more on the position than on T_{out}.

Average: +0.32K air heating, -0.12K floor heating, +0.16K radiator

Energy need simulations

Table 3
Energy need simulation results for three heating emission systems.

		kWh/m^2		
		Air	Radiator	Floor
Case 1 (average temperature)	**Total energy need:**	**36.6**	**34.4**	**34.5**
	incl. Space heating	–	*30.1*	*30.3*
	incl. Supply air heating	*36.6*	*4.3*	*4.2*
	Av.indoor temp. °C	*21.54*	*21.00*	*21.03*
	temp.gradient °C/m	*0.00*	*0.00*	*0.00*
Case 2 (temperature gradient)	**Total energy need:**	**36.2**	**34.5**	**34.4**
	Space heating	–	*30.3*	*30.3*
	Supply air heating	*36.2*	*4.2*	*4.1*
	Av.indoor temp. °C	*21.00*	*21.00*	*21.00*
	temp.gradient °C/m	*1.01*	*−0.06*	*0.07*
Case 3 (Case 1 + operative temp. correction)	**Total energy need:**	**38.0**	**35.0**	**34.0**
	Space heating	–	*31.0*	*29.6*
	Supply air heating	*38.0*	*4.0*	*4.4*
	Av.indoor temp. °C	*21.86*	*21.16*	*20.91*
	temp.gradient °C/m	*0.00*	*0.00*	*0.00*
Case 4 (Case 2 + operative temp. correction)	**Total energy need:**	**37.8**	**35.1**	**34.0**
	Space heating	–	*31.2*	*29.7*
	Supply air heating	*37.8*	*3.9*	*4.3*
	Av.indoor temp. °C	*21.32*	*21.16*	*20.88*
	temp.gradient °C/m	*1.01*	*−0.06*	*0.07*

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Energy saving potential of UFH: -1% emission losses in case 3 (wrt ideal heater)

Total emission losses

Table 4
Temperature variation considering emission losses with three heat emission systems for the TUT test facility.

Loss type	Air		Radiator		Floor			
					mid floor		ground floor	
	K	%	K	%	K	%	K	%
Vertical temperature gradient	0.54	6.20	0.00	0.00	0.03	0.35	0.03	0.35
Embedded	n/a	n/a	n/a	n/a	0.57	6.55	0.78	8.96
Control (PI control)	0.00	0.00	0.04	0.46	0.00	0.00	0.00	0.00
Operative temp. correction	0.32	3.68	0.16	1.84	−0.12	−1.38	−0.12	−1.38
Total (air temp. control)	0.54	6.20	0.04	0.46	0.60	6.90	0.81	9.31
Total (including op. temp. correction)	**0.86**	**9.88**	**0.20**	**2.30**	**0.48**	**5.52**	**0.69**	**7.93**

$$\theta_{int;inc} = \theta_{int;ini} + \Delta\theta_{str} + \Delta\theta_{ctr} + \Delta\theta_{emb} + \Delta\theta_{rad} + \Delta\theta_{im} + \Delta\theta_{hydr} + \Delta\theta_{roomaut} ,$$

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Radiators have the lowest losses! Overall advantage in annual energy demand

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- Different heat emitters must be compared with inclusion of ΔT_{op}

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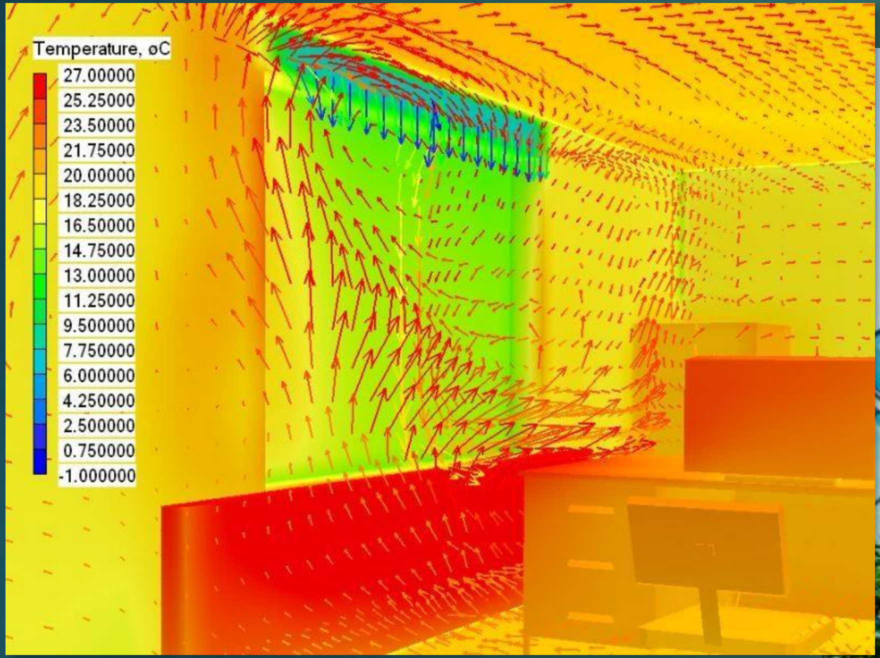
- 3) Structural differences between lightweight and heavyweight buildings are crucial in calculations for the energy performance of heating systems.

THANK YOU FOR YOUR ATTENTION!



- Mikk Maivel, Andrea Ferrantelli, Jarek Kurnitski, *Experimental determination of radiator, underfloor and air heating emission losses due to stratification and operative temperature variations*, **Energy & Buildings 166 (2018) 220–228**

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