Ventilated window with integrated PCM solar collector

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PCM ventilation system

- Background
- System descriptions
- Case studies
- Discussions

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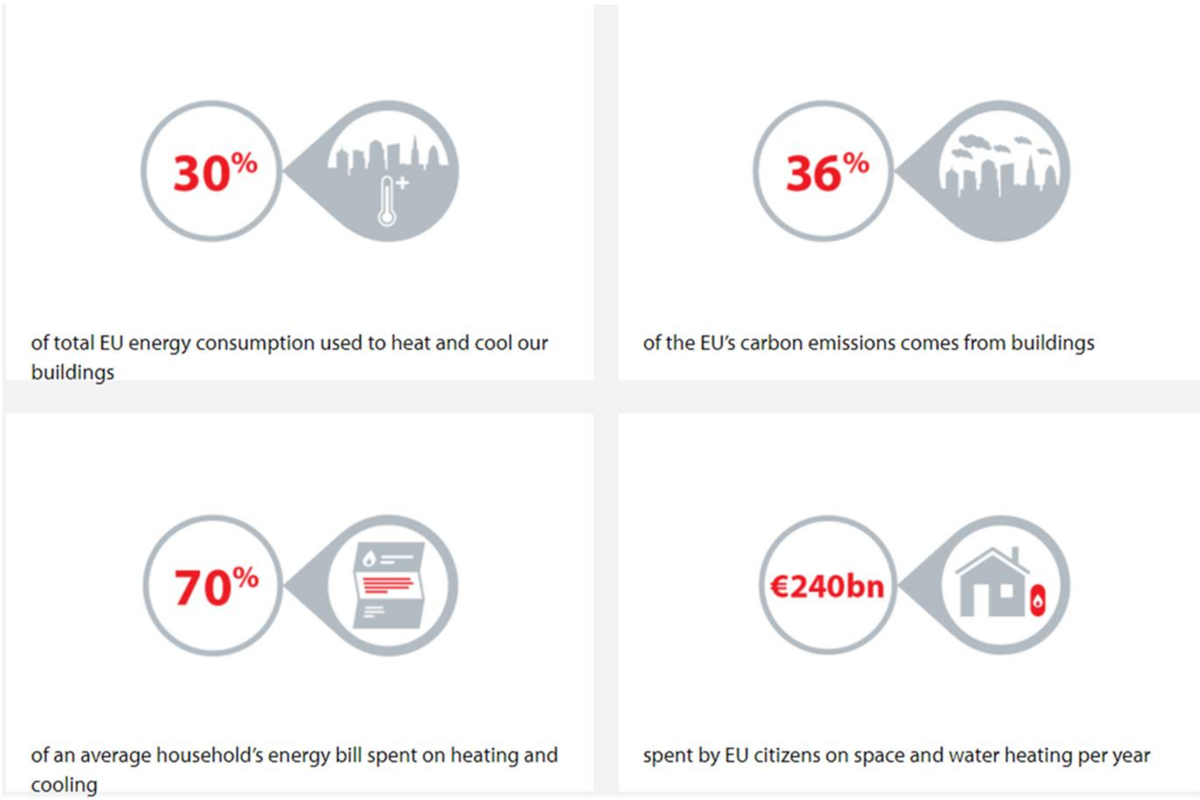
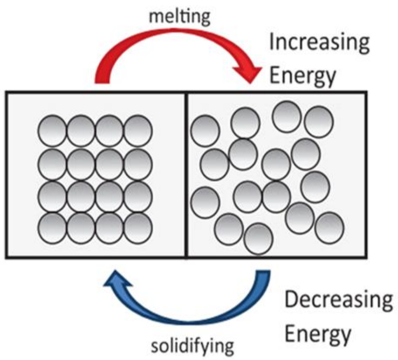
Building energy consumption states

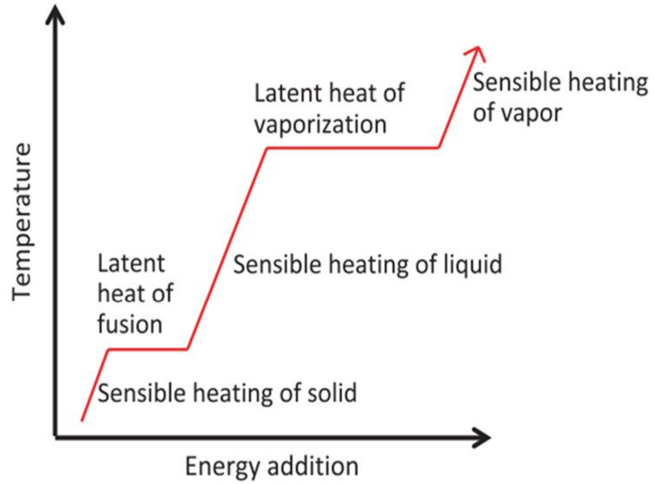


http://www.danfoss.com/buildingefficiency/#/

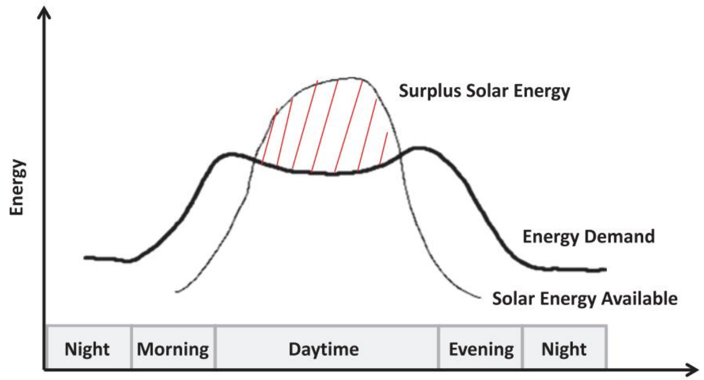
PCM introduction

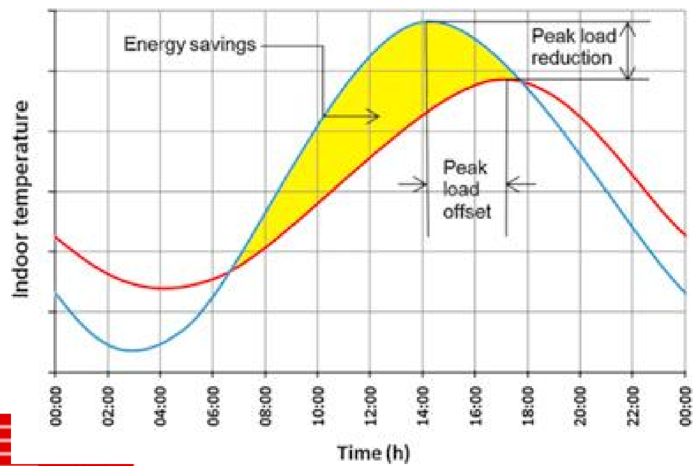


+	−
High latent heat	Low thermal conductivity
High energy density	Cost



Thermal Energy Storages in buildings

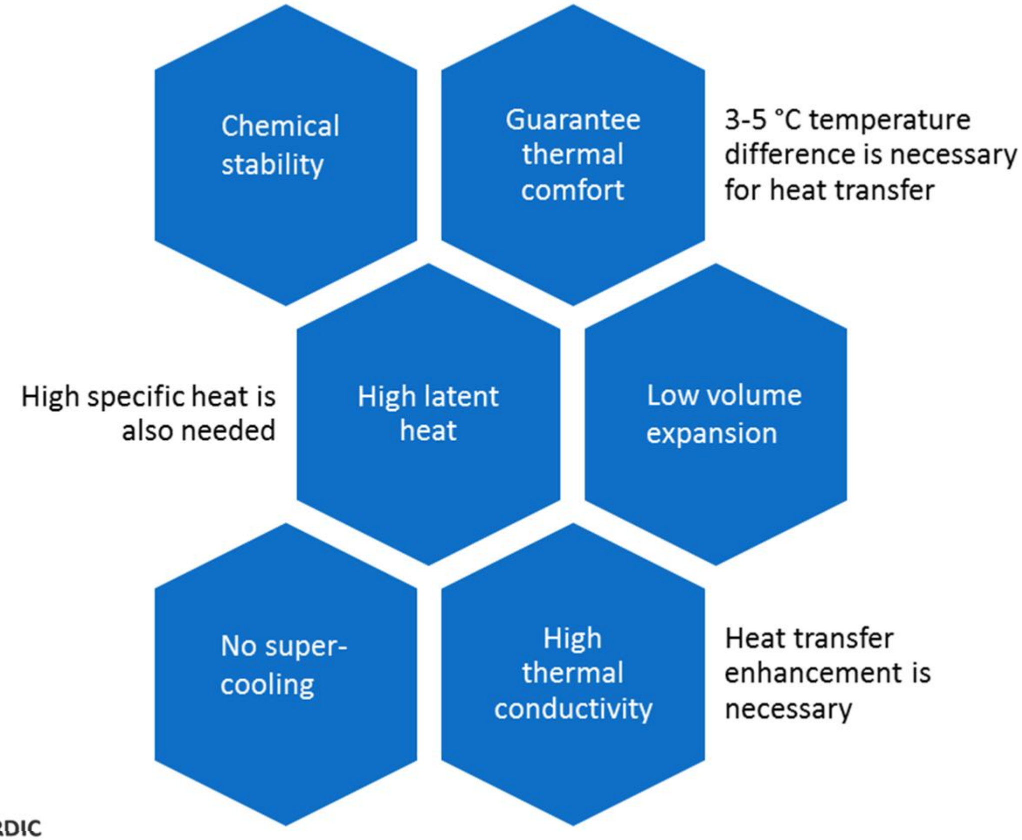




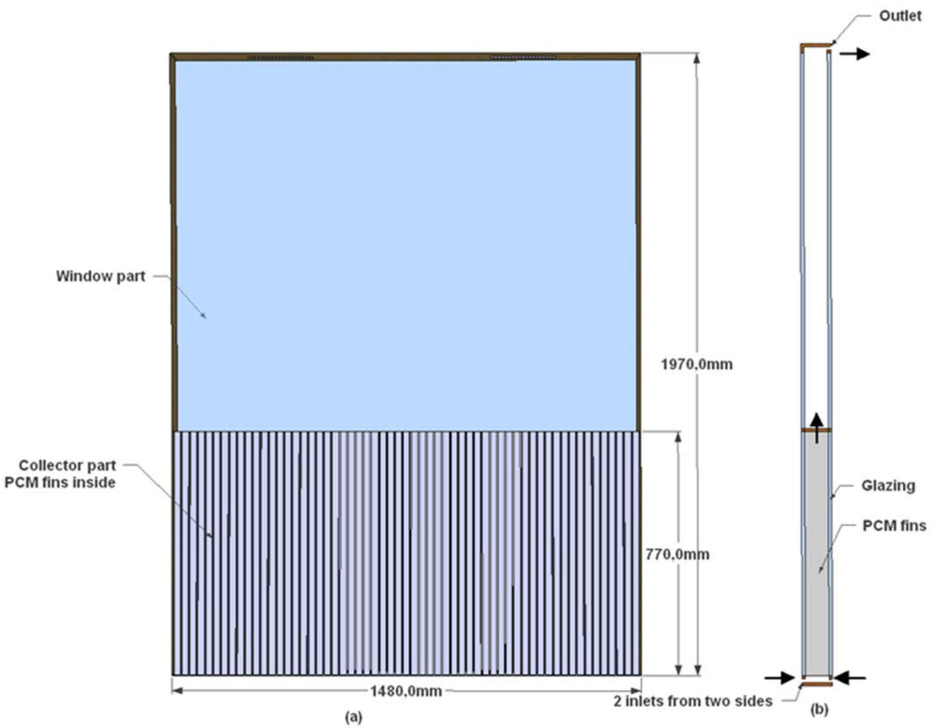
Thermal energy storage(TES):

- ***Peak hour shifting*** - saving money
- ***Heat storage/night cooling*** - decrease facility size and cost
- ***Isothermally phase change process*** – good for comfort

Select of PCMs in Building application



PCM heat exchanger +ventilated Window



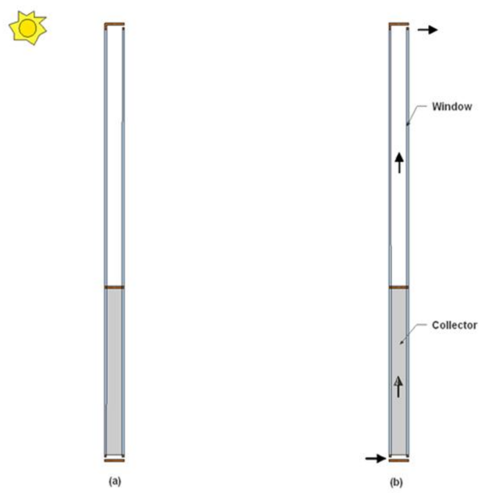
-What's the importance of PCM in thermal mass and light weight buildings?

-What's the ventilation system with PCM heat exchanger?

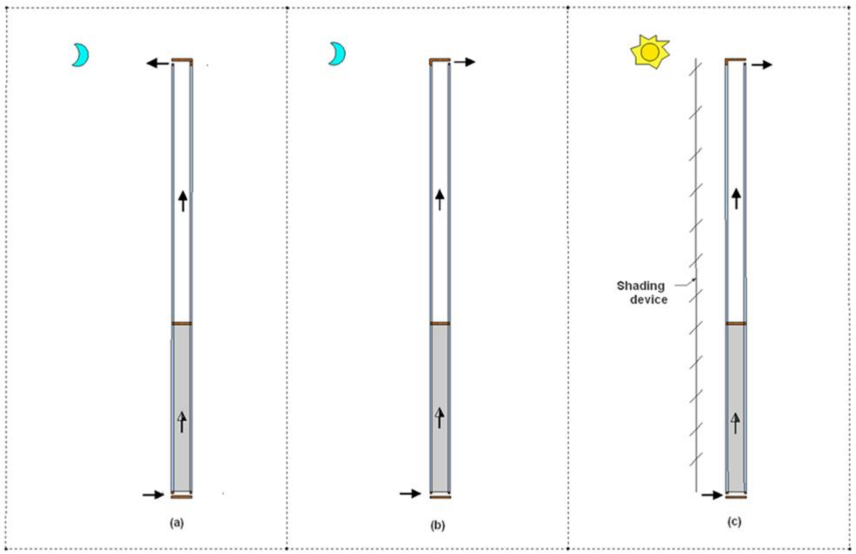
-What are the functions of this PCM ventilated system?

-What's the advantages of this system?

Control Strategies



Winter operation modes



Summer operation modes

Methods

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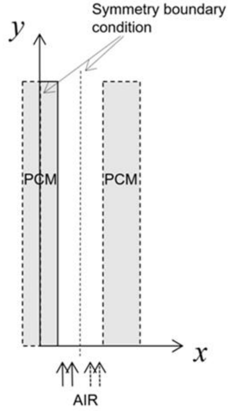
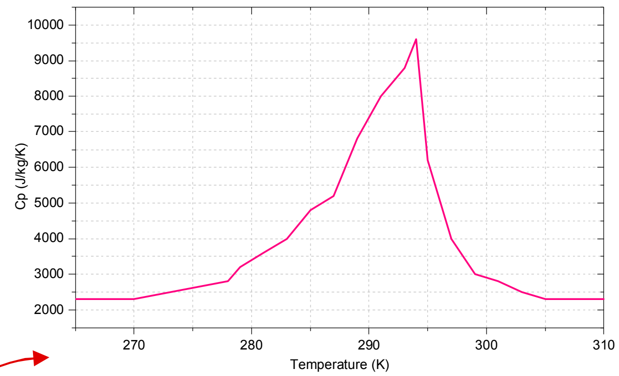


Calculation domain



Fictive heat capacity

Energy equation:

$$\frac{\partial T}{\partial t} = \frac{\lambda}{\rho Cp(T)} \nabla^2 T$$

Boundary conditions:

$-n \cdot q = 0$ for symmetry heat transfer boundary condition

$u \cdot n = 0$ for symmetry fluid property boundary condition

$$T(x, y, 0) = 300.15\text{K}$$

$$T(x, 0, t) = 273.15\text{K}$$

$$Q(x, y, t) = 106\ \text{m}^3/\text{h}$$

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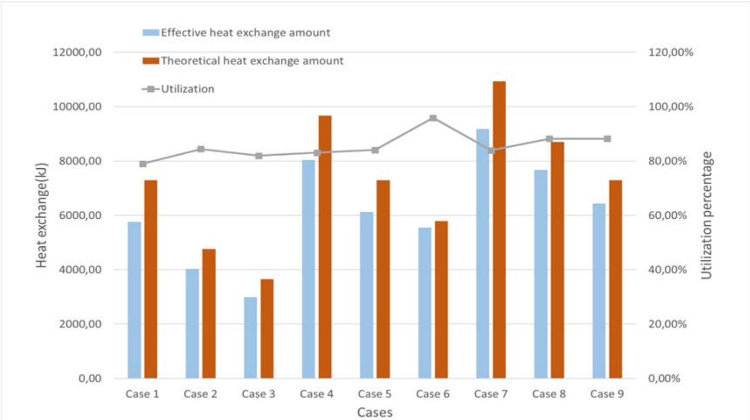
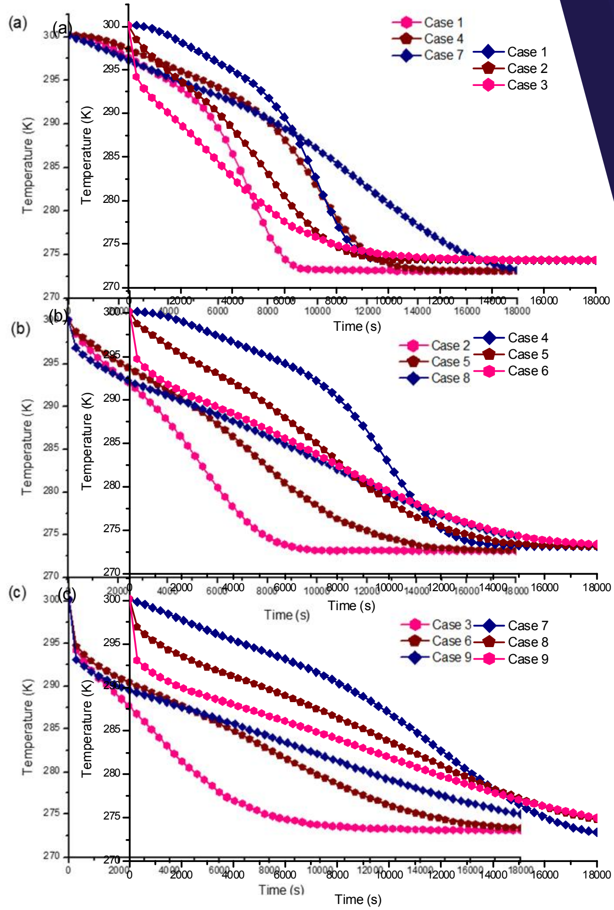
Case study 1

Case study with different fin thickness and air gap thickness

Case	Fin thickness (mm)	Air gap thickness (mm)	Fin number	Fin depth (mm)	Air flow rate (m³/h)	Air velocity in gap (m/s)	Total fin surface area (m²)	Total PCM volume(m³
1	5	5	106			0.75	22.30	0.052
2	5	10	70			0.56	14.73	0.034
3	5	15	53			0.50	11.15	0.026
4	10	5	70			1.11	15.69	0.069
5	10	10	53	75	106	0.75	11.88	0.052
6	10	15	42			0.62	9.42	0.041
7	15	5	53			1.50	12.62	0.078
8	15	10	42			0.93	10.00	0.062
9	15	15	35			0.76	7.86	0.052



Heat exchange amount and PCM utilazation of 9 cases



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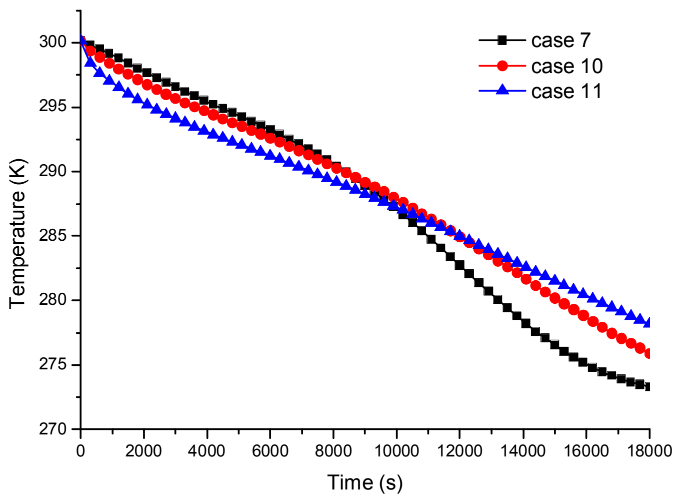
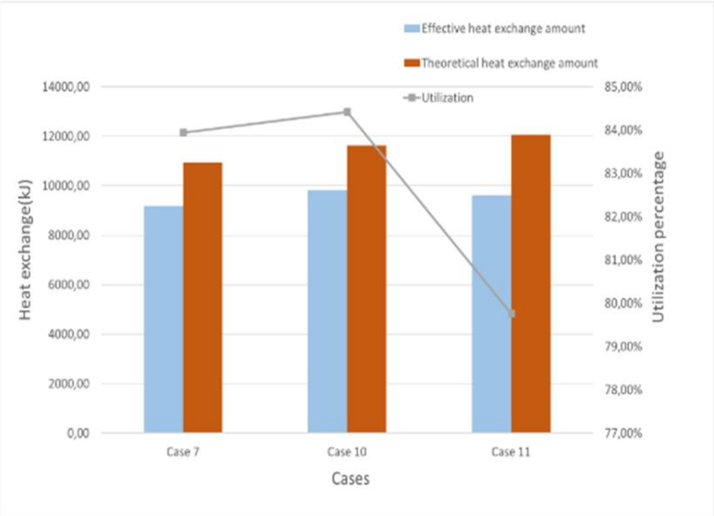
Case study 2

Case study with increased plate thickness

Case	Fin thickness (mm)	Air gap thickness (mm)	Fin depth (mm)	Air flow rate (m^3/h)	Air velocity in gap (m/s)	Total fin surface area (m^2)	Total PCM volume(m^3)
7	15	5			1.50	12.62	0.078
10	20	5	75	106	1.78	10.58	0.083
11	25	5			2.12	9.30	0.086



Outlet air temperature of 3 cases



Heat exchange amount and PCM utilazation of 3 cases

Case study 3

Orthogonal basis analysis

Experiments	Thickness of PCM plates(D, mm)	Temperature difference between inlet air and phase change temperature(T, °C)	Air flow rate(Q, m/m3)	Discharge time(t, h)
1	10	6	100	8,66
2	10	6	150	7,62
3	10	10	100	7,48
4	10	10	150	6,52
5	15	6	100	11,21
6	15	6	150	9,82
7	15	10	100	9,50
8	15	10	150	8,22

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	15,793[a]	6	2,632	23397,000	,005
Intercept	595,643	1	595,643	5294601,000	,000
D	8,968	1	8,968	79712,111	,002
Q	2,726	1	2,726	24232,111	,004
T	3,906	1	3,906	34720,111	,003
DQ	,056	1	,056	498,778	,028
TQ	,005	1	,005	40,111	,100
DT	,133	1	,133	1178,778	,019
Error	,000	1	,000		
Total	611,436	8			
Corrected Total	15,793	7			

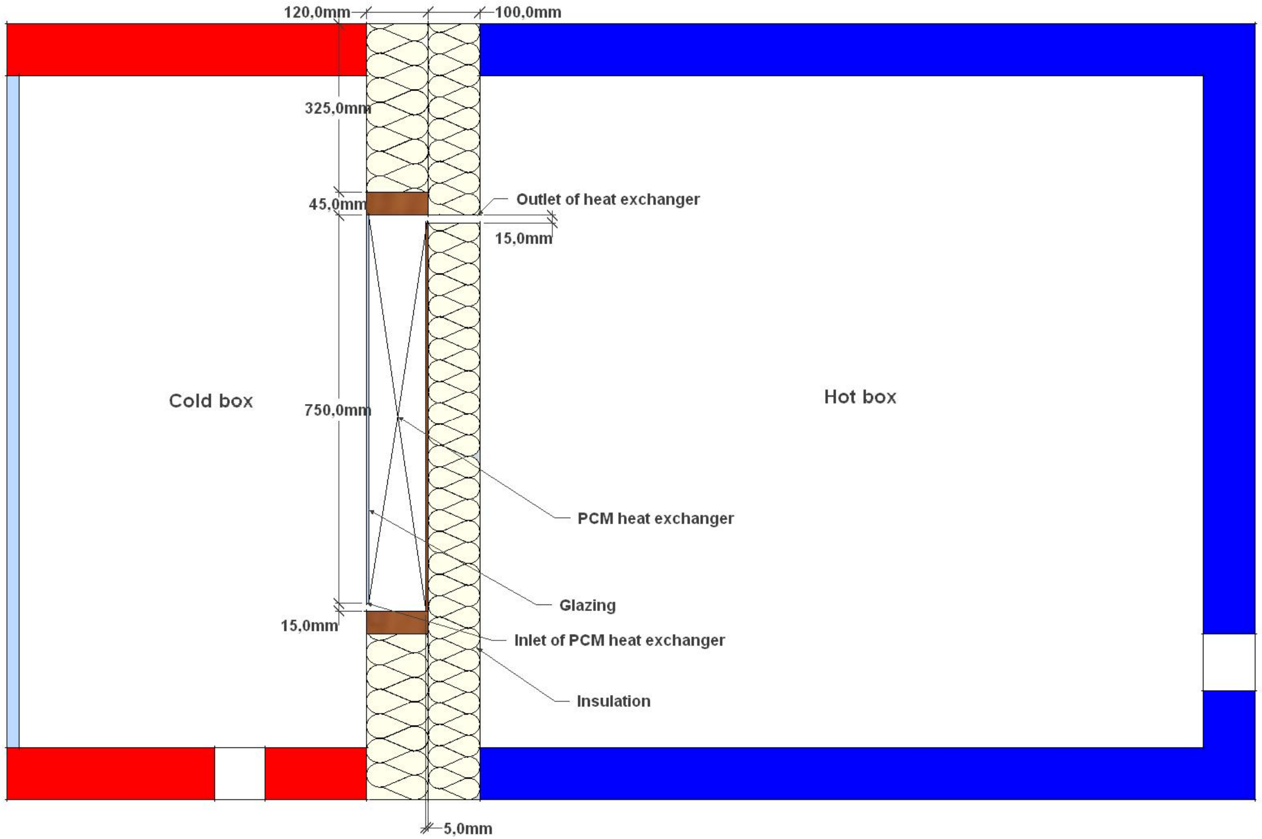
a. R Squared = 1,000 (Adjusted R Squared = 1,000)

Analysis of variance

Disscussions

- 2 stages in discharge processes(surface domain stage and volume domain stage).
- Larger plate thickness and smaller air gap thickness result in higher heat exchange amount.
- There is limitation of the plate thickness.
- Mechanical ventilation is needed only in cases with air gap thickness equal to 5mm.
- The system has the potential to completely or partly substitute the air-conditioning and heating system.

Future works



Experimental verification of the heat transfer process

Thank you!

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