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Energy analysis of „Safe house“ building and energy improvement by heat pump implementation

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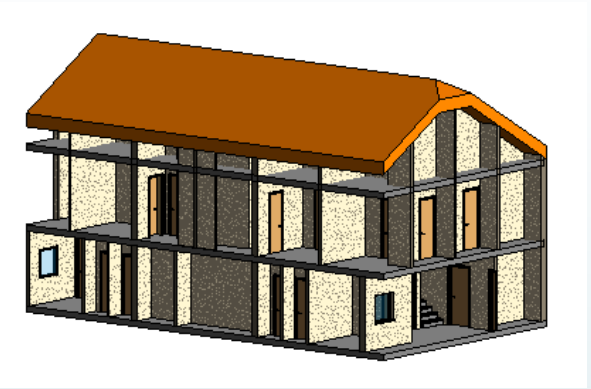
Introduction

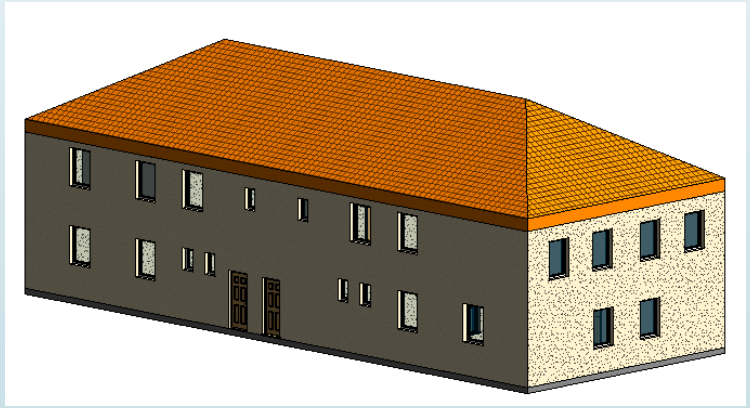
Energy efficiency

- Energy consumption
- EPBD (Energy Performance Building Directive)
- Obligations



Concept and main goals

- Safe house: A = 411 m^2
- Heat pump implementation
- Design of new heating system
- Energy performances of Safe house
- Savings: energy and money



Thermal transmittance (U-Values)

Nontransparent surface:

$$U = \frac{1}{R_{si} + \sum_i^n \frac{\delta_i}{\lambda_i} + R_{se}} \quad [W/(m^2K)]$$

Transparent surface:

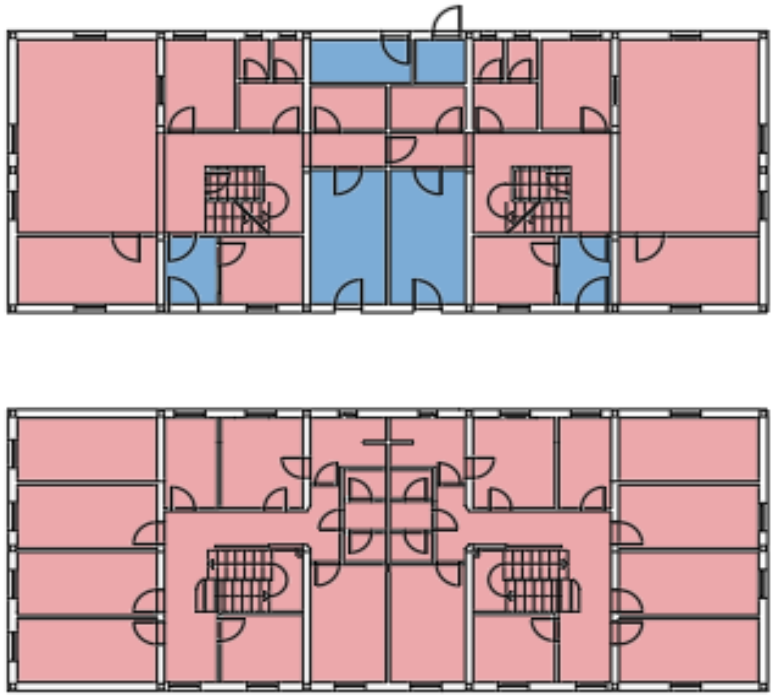
$$U = \frac{A_g \cdot U_g + A_f \cdot U_f + l_g \cdot \psi_g}{A_g + A_f} \quad [W/(m^2K)]$$

Boundry types of heating area	U[W/(m²K)]	U_{max}[W/(m²K)]	Satisfy
Exterior wall	0,28	0,40	YES
Ground floor Type 1	0,56	0,40	NO
Ground floor Type 2	1,32	0,40	NO
Floor	1,33	0,40	NO
Ceiling (under the roof area)	1,72	0,40	NO
Interior wall	1,3	0,55	NO
Interior doors	2,3		
Windows	1,8	1,50	NO

Heat loss calculation

- SRPS EN 12831:2003
- Total heat loss:

$$\Phi_{HL} = \sum \Phi_{T,i} + \sum \Phi_{V,i} + \sum \Phi_{RH,i} \quad [\mathrm{W}]$$



Heating area

- External temperature (Belgrade): θ_e = -12,1°C
- Room temperature: $\theta_{int,i}$ = 20°C
- Storages and entrances: θ_{np} = 12°C
- Roof area: θ_{ra} = -6°C
- Total heat loss of building:

$$\Phi_{HL,i} \cong 36\ \mathrm{kW}$$

Heat emitting units

- Temperature flow/return: 55/40 °C
- Radiators - Global VOX:

  VOX 600, VOX 700 i VOX 800
- Towel Warmer - STARPAN 1600/600

- Radiator lockshield for presetting:

  - IMI-Heimeier, type Regulux
- Termostatic heads for local control

  - IMI-Heimeier, type K

Calculation of piping system

- KAN-therm plastic pipes
- Under the ceiling of ground floor
- Definement of diameters:

1. method:

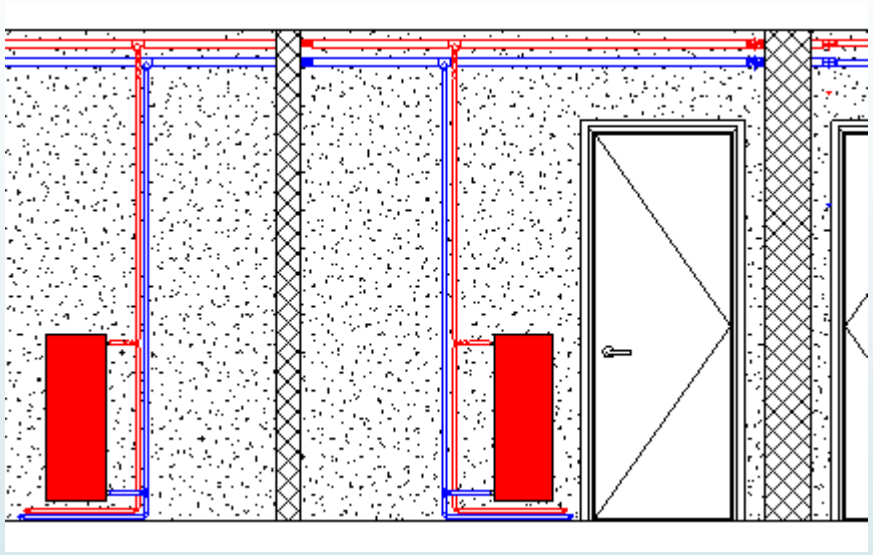
$$w = \frac{4 \cdot \dot{m}}{{d_u}^2 \pi \cdot \rho} \quad [\mathrm{m/s}]$$

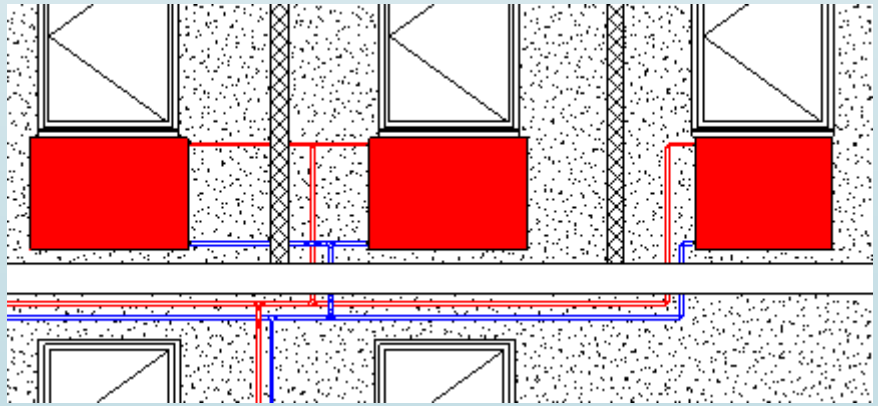
2. method:

$$R = \lambda \cdot \frac{\rho \cdot w^2}{2 \cdot d_u} \quad [\mathrm{Pa/m}]$$

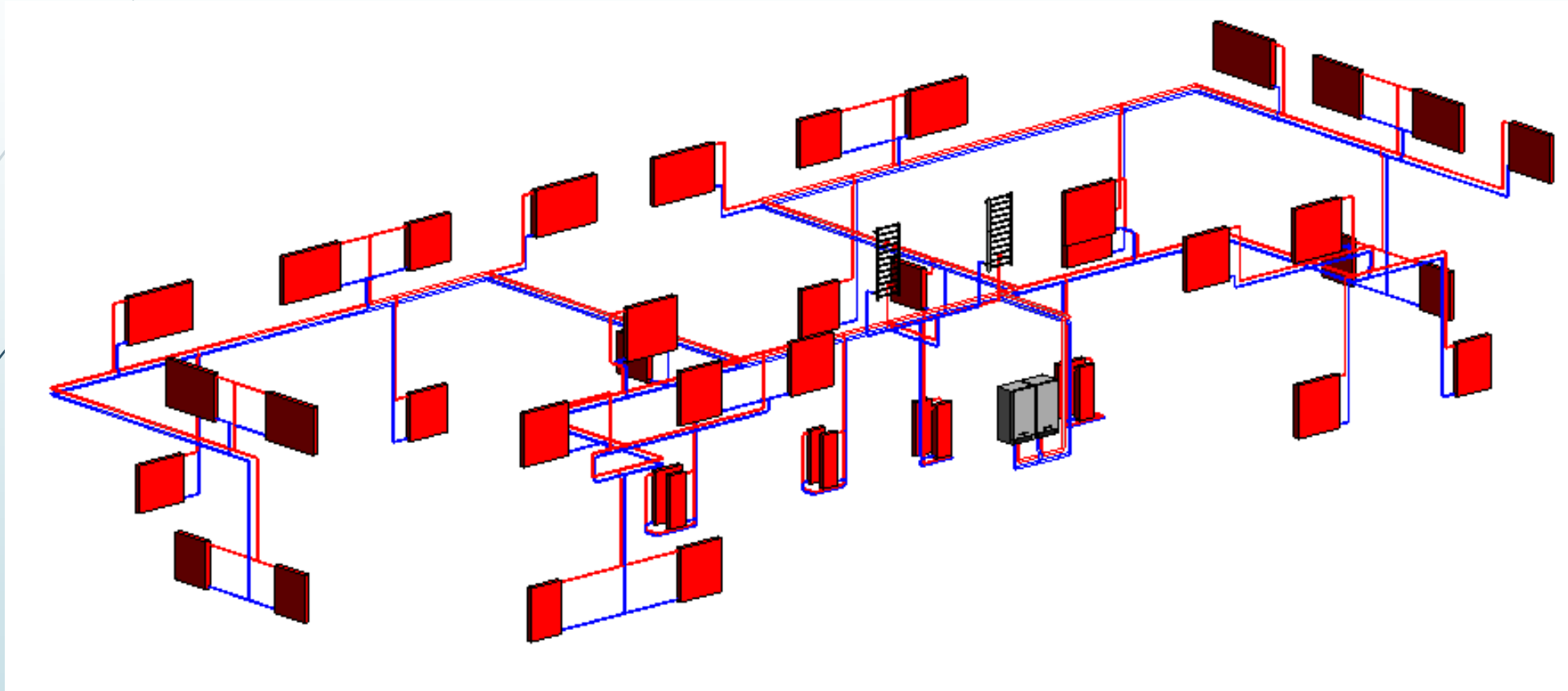
- Total pressure drop: $\Delta p_{uk} = R \cdot l + Z \quad [\mathrm{Pa}]$
- Pressure drop of the furthest heating unit:

$$\Delta p \cong 9 \quad [\mathrm{kPa}]$$



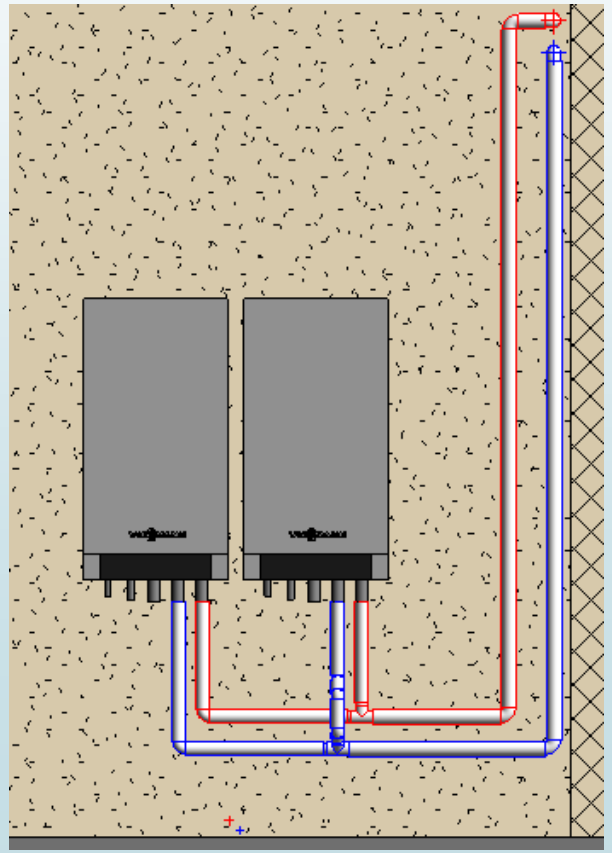


Isometric view



Heat pump and equipment

- Two parallel connected air source heat pumps:
  - Viessmann, Vitocal 200-S, 2x16 kW
- Extreme conditions – electric heaters
- Boiler for water instalation heating:
  - Viessmann, Vitocell 100-E, type SVP
- Boiler for domestic hot water:
  - Viessmann, Vitocell 100-V, type CVW
- Expansion vessel:
  - Elbi, 18 l, ER18-CE



Annual heat losses calculation

- Calculation method – Heating Degree Days (HDD):

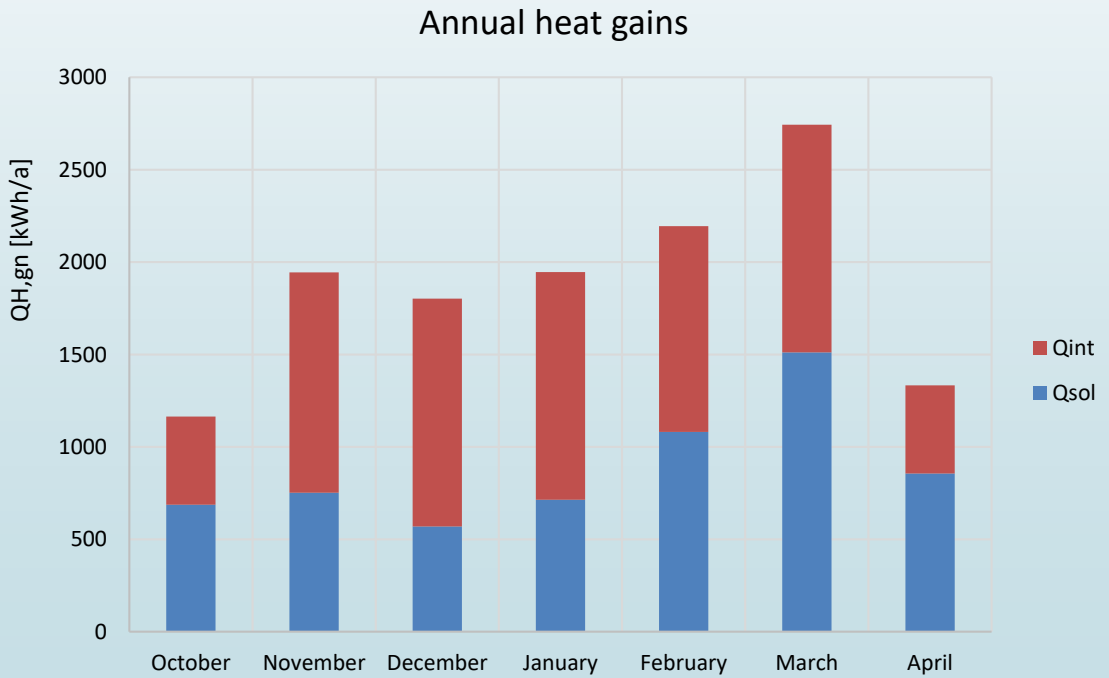
$$Q_{H,ht} = (H_T + H_V) \cdot HDD \cdot n_{sati} \cdot 10^{-3} \quad [\text{kWh/a}]$$

No.	Month	n	HDD	H_t	H_v	H_t+H_v	$Q_{H,ht}$
-	-	-	-	W/K	W/K	W/K	kWh/a
1	October	24	101	712,00	231,7	943,7	2288
2	November		373				8448
3	December		531				12026
4	January		585				13249
5	February		458				10373
6	March		370				8380
7	April		102				2310
Σ							57075

Annual heat gains calculation

- Annual heat gains: $Q_{H,gn} = Q_{int} + Q_{sol}$ [kWh/a]
- Internal heat gains from people and electric units

Month	Q_{int}	Q_{sol}	$Q_{H,gn}$
-	kWh/a	kWh/a	kWh/a
October	477	687	1165
November	1193	752	1945
December	1232	570	1802
January	1232	714	1946
February	1113	1081	2194
March	1232	1511	2744
April	477	856	1333
Σ	6957	6172	13367



Energy need for heating

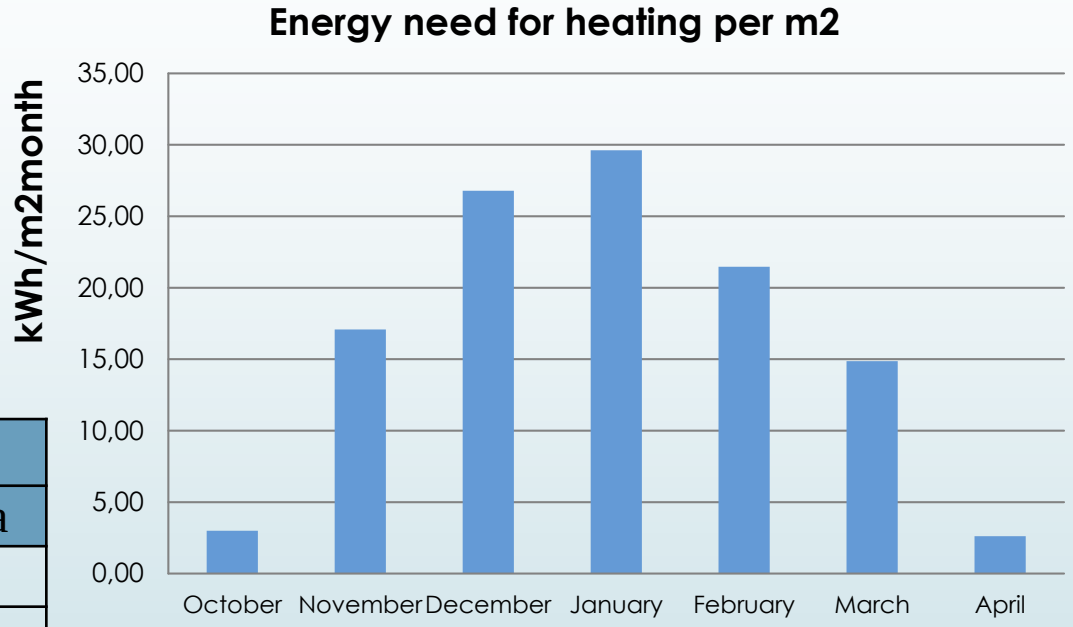
- Annual energy need for heating:

$$Q_{H,nd} = Q_{H,ht} - \eta_{H,gn} \cdot Q_{H,gn} \quad [\text{kWh/a}]$$

- Energy need for heating per m^2:

$$q_{H,nd} = \frac{Q_{H,nd}}{A_f} \quad [\text{kWh/m}^2\text{a}]$$

Month	$Q_{H,ht}$	$Q_{H,gn}$	$\eta_{H,gn}$	$Q_{H,nd}$	$q_{H,nd}$
-	kWh/a	kWh/a	-	kWh/a	kWh/m^{2}a
October	2288	1165	0,98	1146	3
November	8448	1945		6542	17
December	12026	1802		10260	27
January	13249	1946		11342	30
February	10373	2194		8223	21
March	8380	2744		5691	15
April	2310	1333		1004	3
Σ	57075			**44208**	**115**



Energy class and measures for improvement

- Relative value of annual energy need for heating:

$$Q_{H,nd,rel} = \left(\frac{q_{H,nd}}{q_{H,nd,max}}\right) \cdot 100 \quad [\%]$$

$Q_{H,nd}$	44208	kWh/a
$q_{H,nd}$	115	kWh/m^{2}a
$Q_{H,nd,rel}$	165	%
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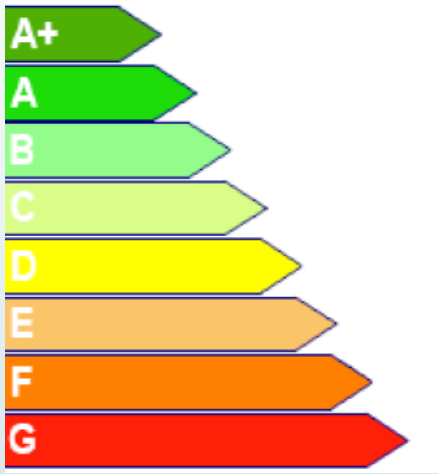


- Thermal insulation for ground floor, floor and interior walls
- Substitute interior doors
- **Substitute electric heaters with heat pump system**
- Implementation solar collectors for domestic hot water

Energy savings and reduction of CO_2 emissions

Electric Heaters

- Anually delivered energy for heating:

$$Q_{H,del} = Q_{H,nd} + Q_{H,nd,ls} = 54578 \text{ [kWh/a]}$$

- Annually primary energy:

$$E_{prim} = (Q_H + Q_{el}) \cdot f_{el} = 160317 \text{ [kWh/a]}$$

- Annual emission of CO_2:

$$CO_2 = E_{prim} \cdot f_{CO_2,el} = 84968 \text{ [kg/a]}$$

- Annual emission of CO_2 per m^2:

$$CO_2^* = \frac{CO_2}{A_f} = 222 \text{ [kg/(m}^2\text{a)]}$$

Heat pump

- Anually delivered energy for heating:

$$Q_{H,del} = Q_{H,nd} + Q_{H,nd,ls} = 46031 \text{ [kWh/a]}$$

- Annually primary energy:

$$E_{prim} = Q_H \cdot \frac{f_{el}}{COPgod} + (Q_{aux} + Q_{el}) \cdot f_{el} = 50587 \text{ [kWh/a]}$$

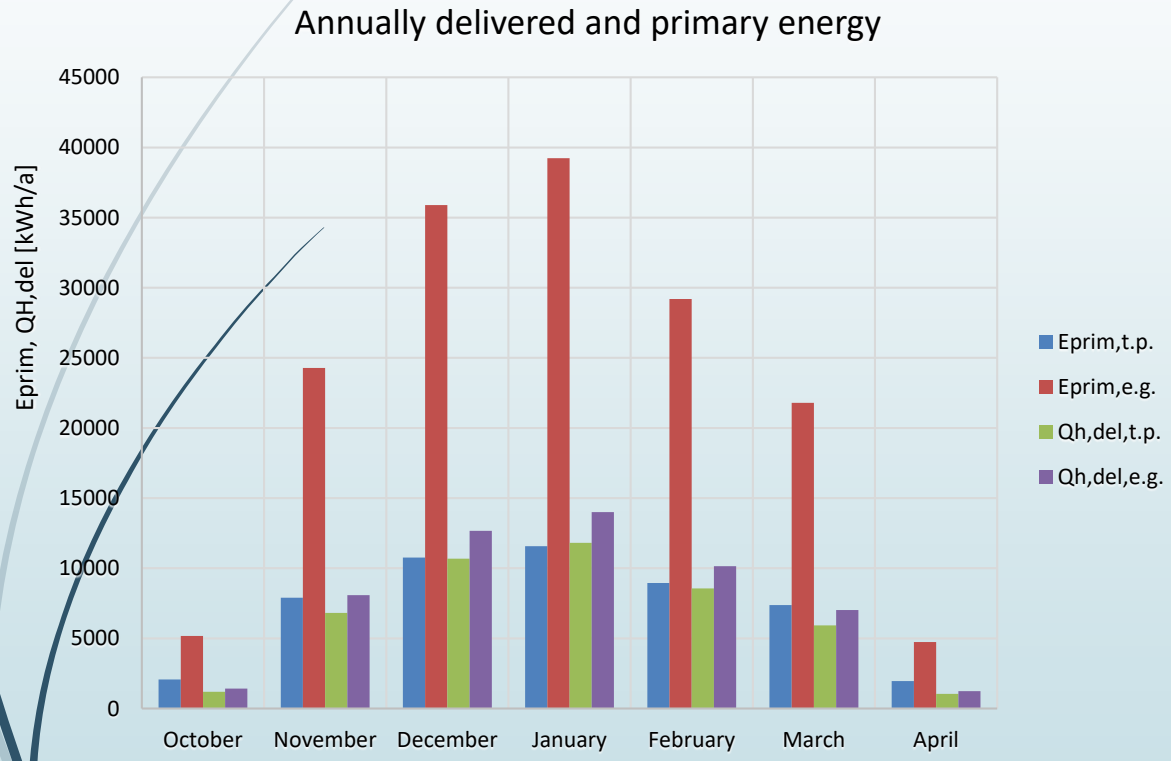
- Annual emission of CO_2:

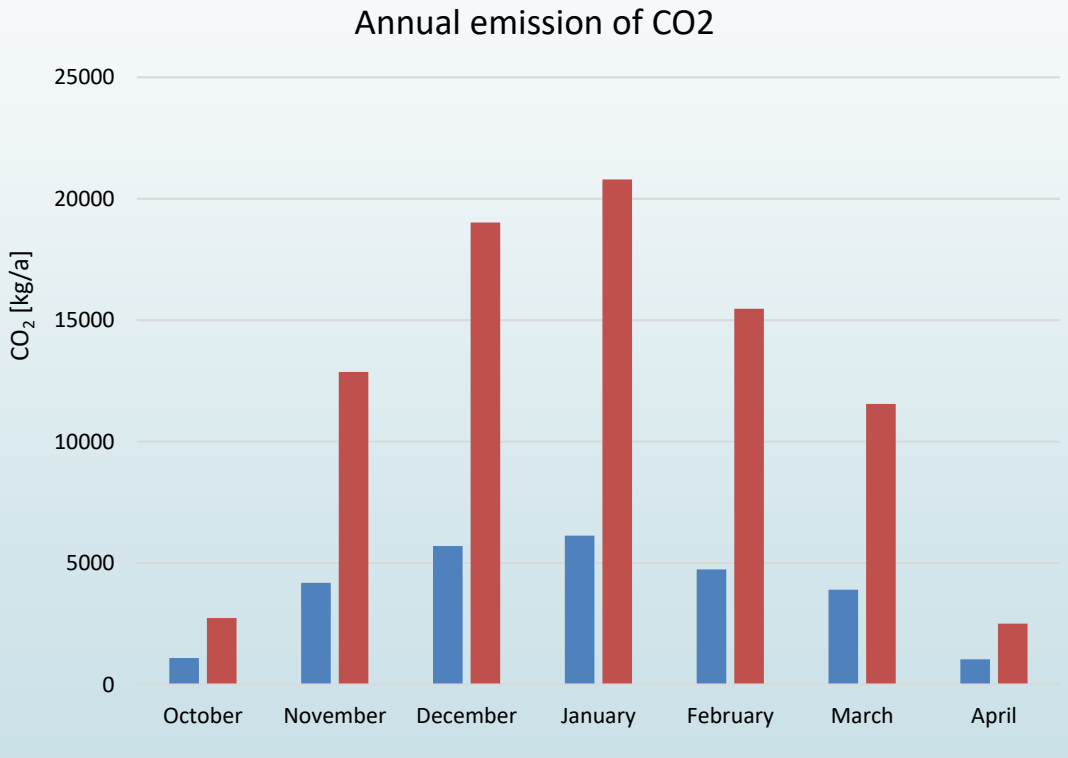
$$CO_2 = E_{prim} \cdot f_{CO_2,el} = 26811 \text{ [kg/a]}$$

- Annual emission of CO_2 per m^2:

$$CO_2^* = \frac{CO_2}{A_f} = 70 \text{ [kg/(m}^2\text{a)]}$$

Energy savings and reduction of CO_2 emissions



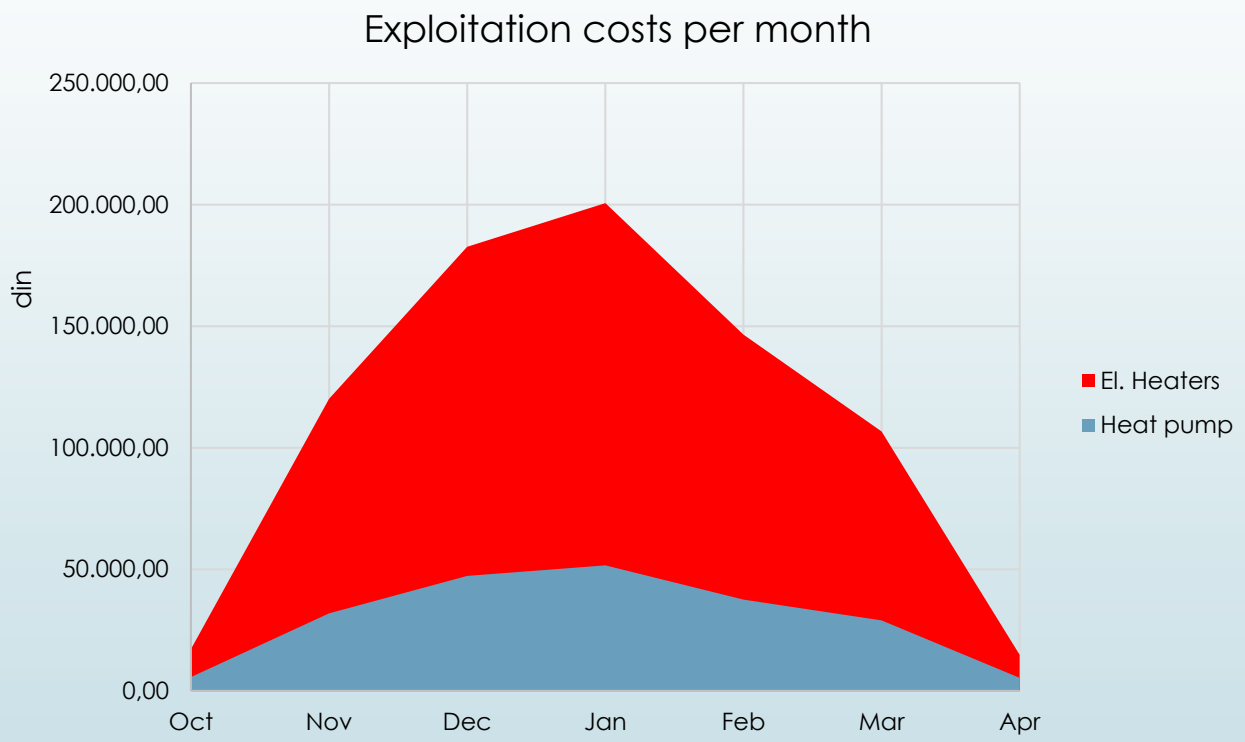


Cost analysis - savings

- Payback Period:

$$PBP = \frac{I}{B} \quad [\text{year}]$$

- Savings in percent: 74 %
- PBP = 6 years



Conclusion

ELECTRIC HEATERS → HEAT PUMP

- Thermal comfort ☑
- Energy savings ☑
- Reduction of CO_2 emissions ☑
- Money savings ☑
- Local and central regulation ☑

THANK YOU !