4. Commercial building functional model

4.1. Descripcion of geometry

For the third type of prototype a commercial building – a supermarket - has been chosen. It is one floor high, most of the area is occupied by the retail area, the rest with warehouse and office area. At the back of the building a supply area with roof and ramp is located, seen in Fig. 4.1.1.

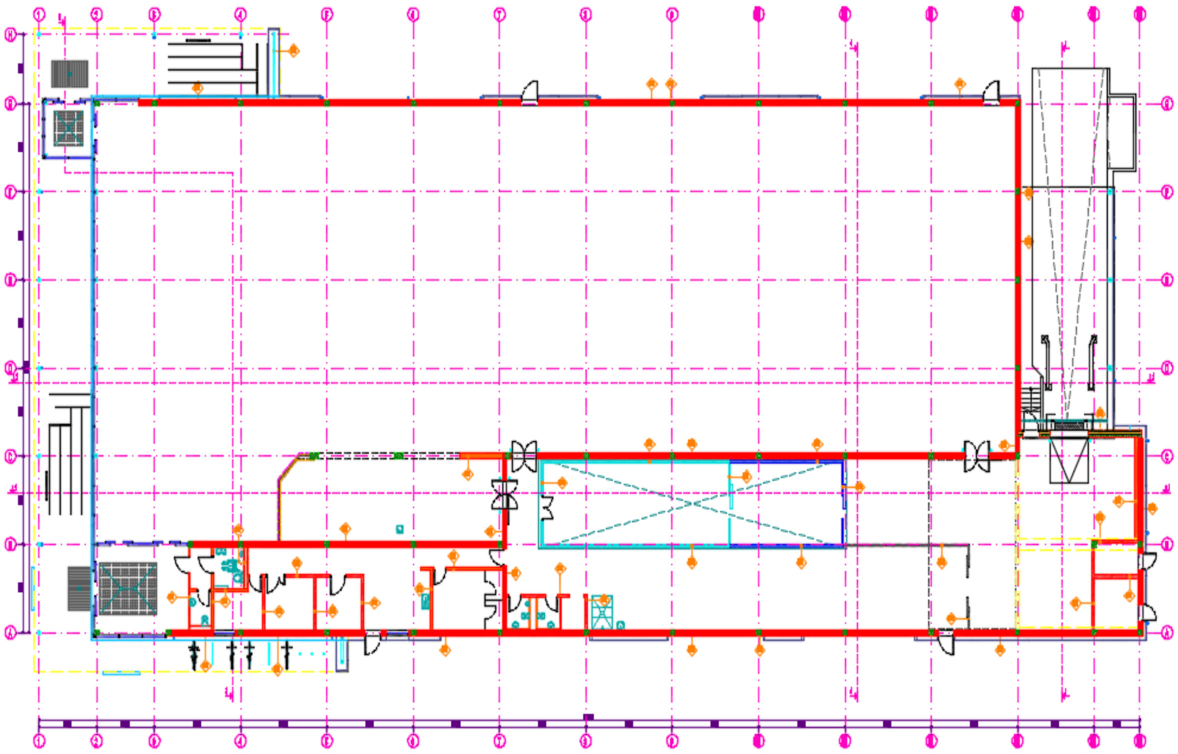

Fig. 4.1.1. *Plan of the commercial building.*

4.1.1. Base solution

Constructive solution of the building consists of pad foundation for vertical concrete columns that supports steel trusses, floor is made as concrete slab-on-ground, non-loadbearing walls are made from aerated concrete blocks. Painted steel cladding for façade covering is chosen, Fig. 4.1.2. Roof consists of profiled steel sheets, insulation and bituminous roll material roof covering. Aluminium glazed façade is used for windows and doors.

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Fig. 4.1.2. *Facades of the commercial building.*

Wall envelope consists of aerated concrete blocks with low density (375 kg/m^3), that has low thermal conductivity – 0,085 W/(m*K). Interior finishing – gypsum board. For insulation – mineral wool insulation 180 mm thick with extra wind barrier membrane, insulation is fitted between steel profile façade frame, that is used to fix the outer finishing – painted steel cladding, (Fig. 4.1.3.). Total U value of the wall is 0.11 W/(m^2*K), Table 4.1.1.

Table 4.1.1. *Wall envelope.*

Layer	Lambda decl. + correction, W/(m*K)	Thickness, mm
Gypsum board	0.25	12
Bauroc EkoTherm	0.084	375
Rockwool Rockmin	0.039	180
R constr.	m^2*K/W	9.13
R surface	m^2*K/W	0.26
U total	**W/(m^2*K)**	**0.11**

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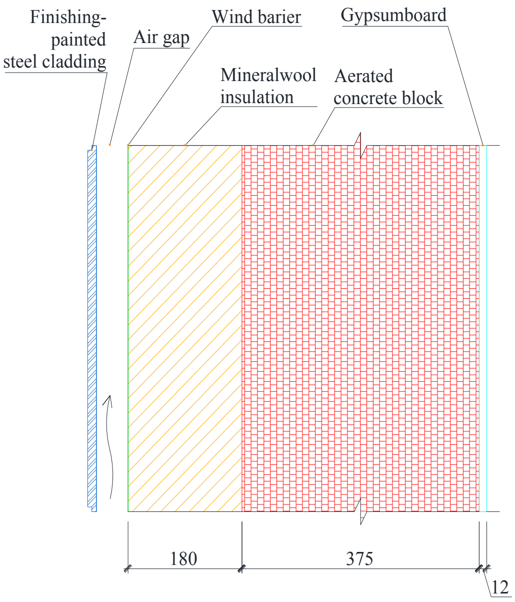

Fig. 4.1.3. *Wall envelope section.*

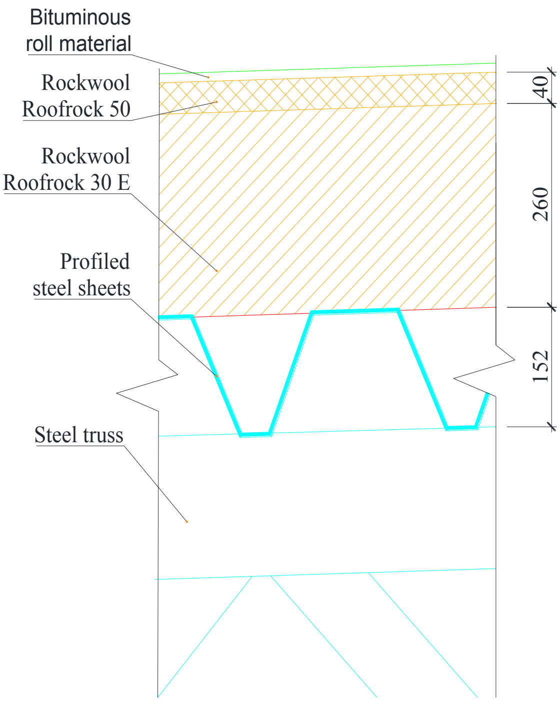

Table 4.1.2. *Roof envelope.*

Layer	Lambda decl. + correction, W/(m*K)	Thickness , mm
Rockwoll Roofrock 30 E	0.038	260
Rockwoll Roofrock 80	0.039	40
Roof material	0.13	7
R constr.	m^2*K/W	7.92
R surface	m^2*K/W	0.14
U total	**W/(m^2*K)**	**0.12**

Fig. 4.1.4. *Roof envelope section.*

Roof envelope consists of bearing profiled steel sheets, two insulation layers with different densities, total height 300mm and bituminous roll roof covering, Fig. 4.1.4. Total U value of the roof envelope is 0.12 W/(m^2*K), Table 4.1.2.

Floor envelope consists of load bearing gravel layer, 250 mm thick, that rests on ground, on top of the gravel a 200 mm thick XPS 300 insulation layer, moisture barrier, concrete slab, concrete levelling layer and tile finishing (Fig. 4.1.5.), U value 0.17 W/(m²*K), Table 4.1.3.

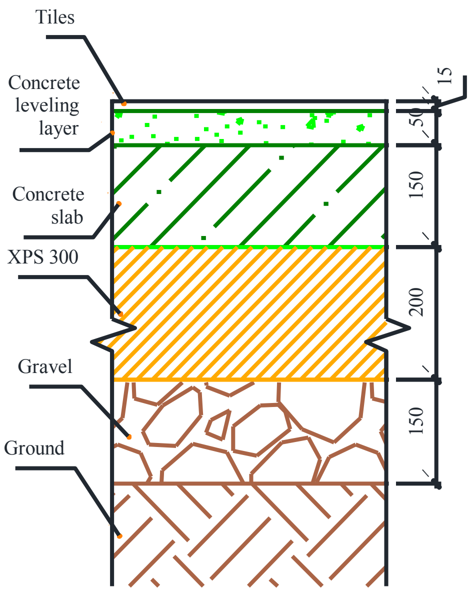

Fig. 4.1.5. *Floor envelope section.*

Table 4.1.3. *Floor envelope.*

Layer	Lambda decl. + correction, W/(m*K)	Thickness, mm
Tiles	2	14
Concrete levelling layer	2	50
Concrete slab	2	150
XPS 300	0.036	200
Gravel	2	250
R constr.	m²*K/W	5.79
R surface	m²*K/W	0.21
U total	**W/(m²*K)**	**0.17**

4.1.2. Alternative solutions

Sandwich panels

One of the alternative solutions for commercial buildings are sandwich panels – panels with insulation layer protected from both sides by steel sheets. Such solutions are very economical and doesn’t require for different load bearing construction solution, also the base solution façade finishing – steel cladding can be attached to the panels.

Typical sandwich panel solution is with either mineral wool or EPS layer, but nowadays PUR and PIR insulation is also used, to reduce the thickness of the panel [16]. In Table 4.1.4. panels with various insulation layers are summarised to achieve at least the base U value of 0.11 W/(m²*K).

As can be seen from the table, PIR panels have the lowest thickness of 175 mm, PUR panel thickness is 200 mm, EPS NEO 275 mm. Theoretical mineral wool panel thickness should be 375 mm, but such panels are not produced currently.

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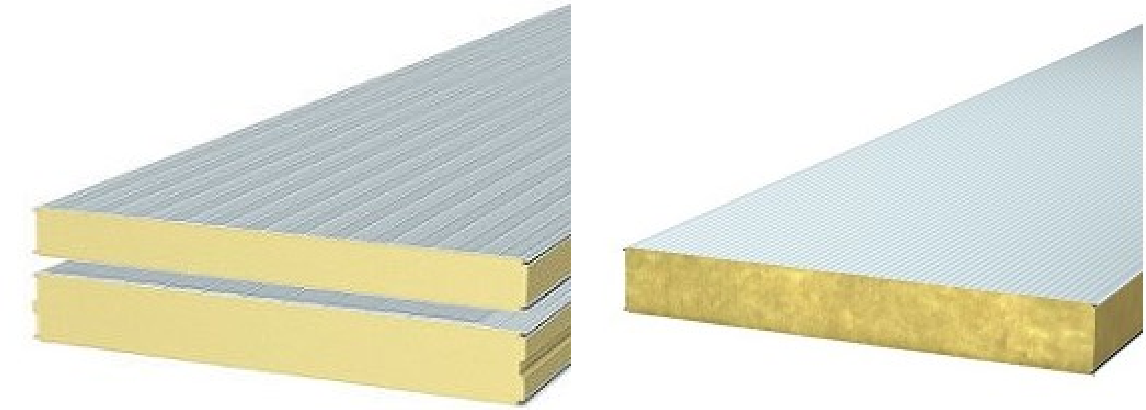

Fig. 4.1.6. *Sandwich panels with PIR (left) and mineral woll (right) insulation layer.*

Table 4.1.1. *Various sandwich panel insulation layers.*

Layer	Lambda decl. + correction	Thickness,	R constr.	R surface	**U total**
	W/(m*K)	mm	m^2*K/W	m^2*K/W	**W/(m^2*K)**
PUR sandwich panel	0.021	200	9.52	0.26	0.10
PIR sandwich panel	0.020	175	8.75	0.26	0.11
MW sandwich panel	0.042	375	8.93	0.26	0.11
EPS NEO sandwich panel	0.032	275	8.59	0.26	0.11

CLT panel solution

Another alternative solution is to change the constructive solution to Cross-Laminated Timber (CLT) construction, described in Section 2.1. In such case total thickness of the wall envelope without cladding would be 578 mm, 375 mm for loose insulation layer, to achieve U=0.11 W/(m^2*K).

Table 4.1.5. *Wall envelope with alternative CLT panels.*

Layer	Lambda decl. + correction, W/(m*K)	Thickness, mm
Gypsum board	0.25	13
Wood fibre board	0.055	50
CLT panel	0.2	90
Cellulose/wood wool insulation	0.038	375
Wood fibre board	0.055	50
R constr.	m^2*K/W	9.16
R surface	m^2*K/W	0.26
U total	**W/(m^2*K)**	**0.11**

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4.2. HVAC

This part of research is devoted to demonstration of engineer systems design effect on the energy balance of the building.

4.2.1. Case study

A new single- floor commercial building with a total area of 2000 m2, (commercial hall occupies 1354m2) situated in Riga, Latvia.

On the design stage, following terms of calculation were used. (Table 4.2.1)

- Heating period, incl. For AHU equipment -20.7 ˚C
- Conditioning period + 27 ˚C, 65% RH
- AHU direct cooling compressor / condenser equipment +35 ˚C.

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Table 4.2.1. *Terms of calculation.*

System	Heating agent	Temperature
Heating: radiators, ventilator heaters	water	+60/40 ˚C
AHU heating air wheels	Ethylene glycol	+40/30 ˚C

Indoor air parameters are in accordance with II air quality class. Mechanical supply/return ventilation parameters are in accordance II air quality class. Fig.4.2.1. *HVAC plan,* Fig*. 4.2.2. HVAC scheme.*

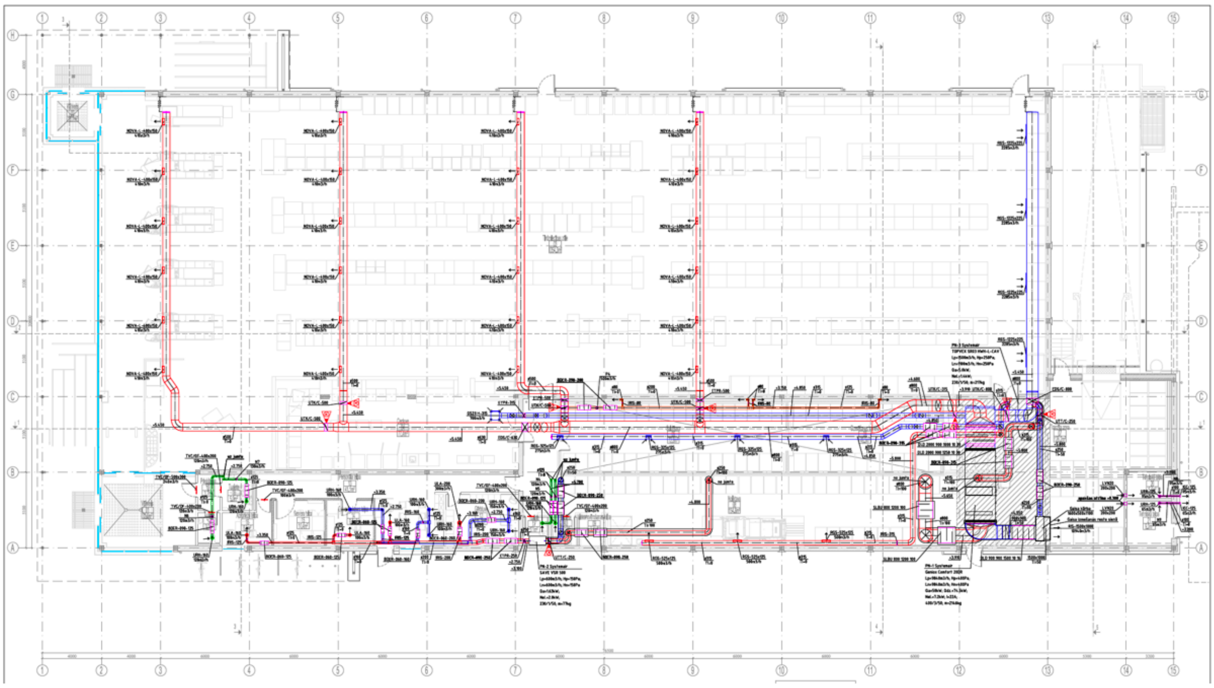

Fig. 4.2.1. *HVAC plan.*

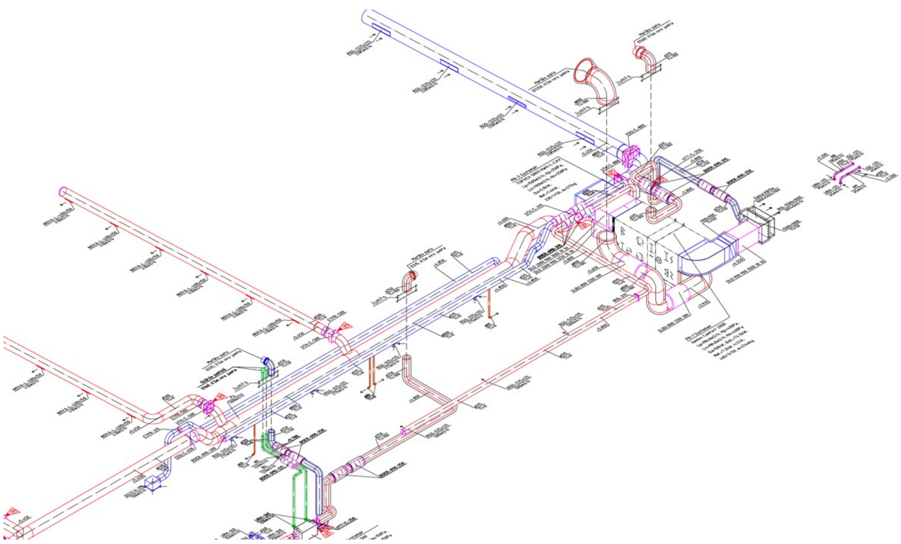

Fig. 4.2.2. *HVAC scheme.*

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Ventilation equipment PN1 consist of:

- Noise wipers in air ducts
- Insulated shut-off valves with executive mechanism
- Rotor heat recovery heat exchangers, efficiency 82.1%
- - Recirculation section with motorized valves
- Supply, exhaust fan with EC motors. Ls=9840m3/h, H=400Pa, Le=9840m3/h, H=400Pa,
- Two direct evaporative coolers Qk=74,5kW
- 40% ethylene glycol heater +40/30 ˚C Q=50kW
- automation with the ability to regulate airflow according to CO2 concentration, system pressure and air volume

Ventilation equipment PN2 consist of:

- Rotor heat recovery heat exchangers, efficiency 81%
- Insulated shut-off valves with executive mechanism
- Supply, exhaust fan with EC motors. Ls=600m3/h, H=150Pa, Le=600m3/h, H=400Pa,
- Electrical heater
- automation with the ability to regulate airflow according to CO2 concentration, system pressure and air volume

Conditioning/ heating provided by direct evaporative VRV Freon system, split conditioners.

(Fig. 4.2.3. Scheme of the heater)

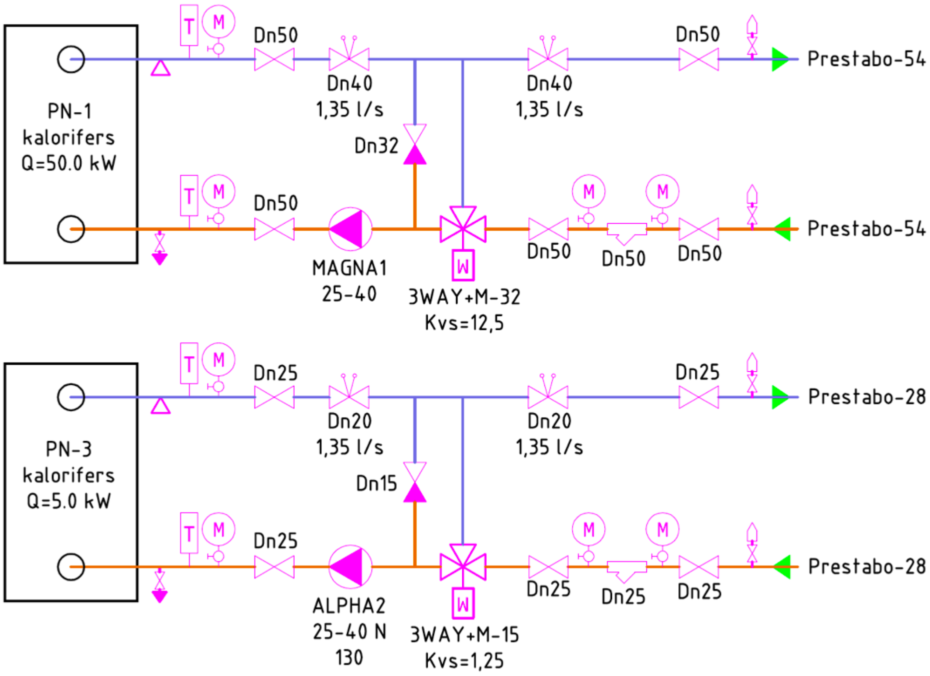

Fig. 4.2.3. *Scheme of the heater.*

4.3. Simulation

A new single- floor commercial building with a total area of 2000 m2, (commercial hall occupies 1354m2) situated in Riga, Latvia. (Fig. 4.3.1. Visualization of commercial building).

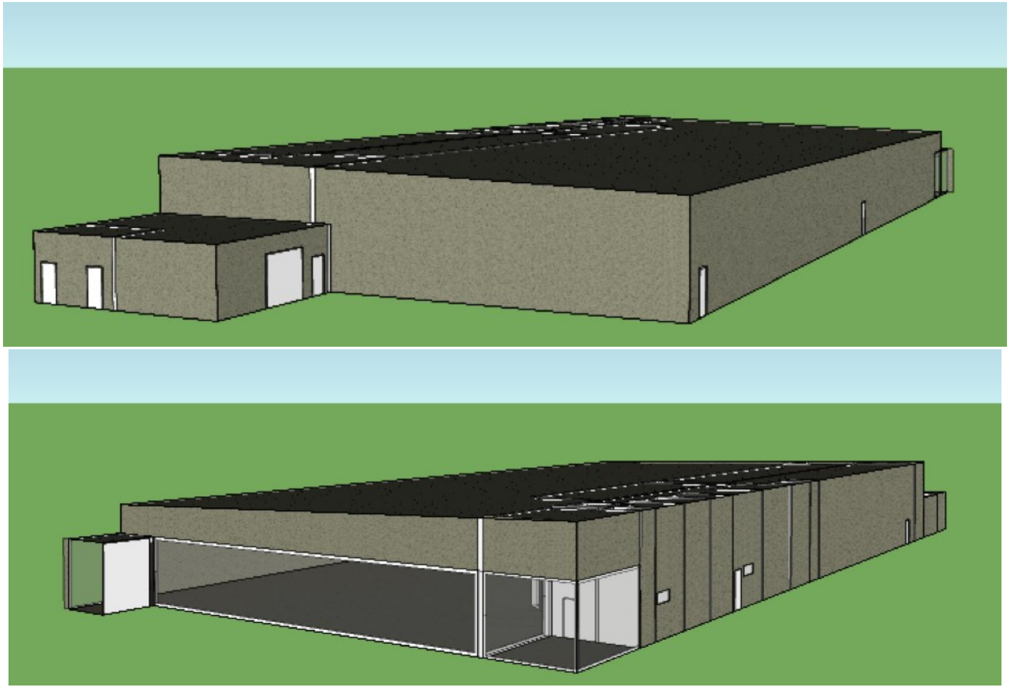

Fig. 4.3.1. *3D visualization of commercial building.*

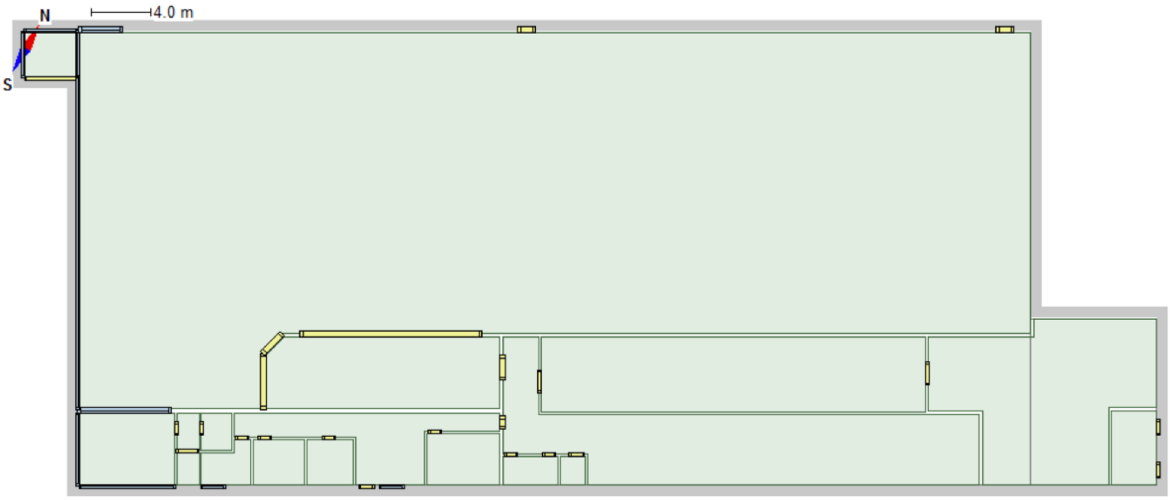

Fig. 4.3.2. *Floor plan of the commercial building.*

Using simulation program opportunities temperature graphic and power required by this building are shown on Fig. 4.3.3. and Fig. 4.3.4.

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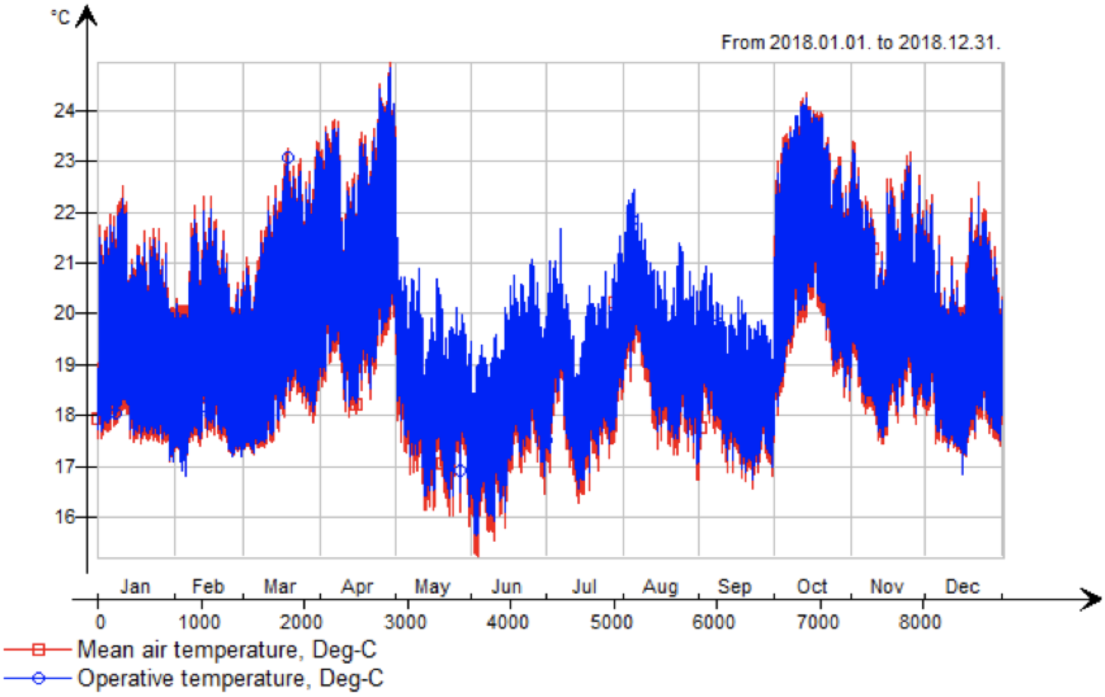

Fig. 4.3.3. *Temperature graphic.*

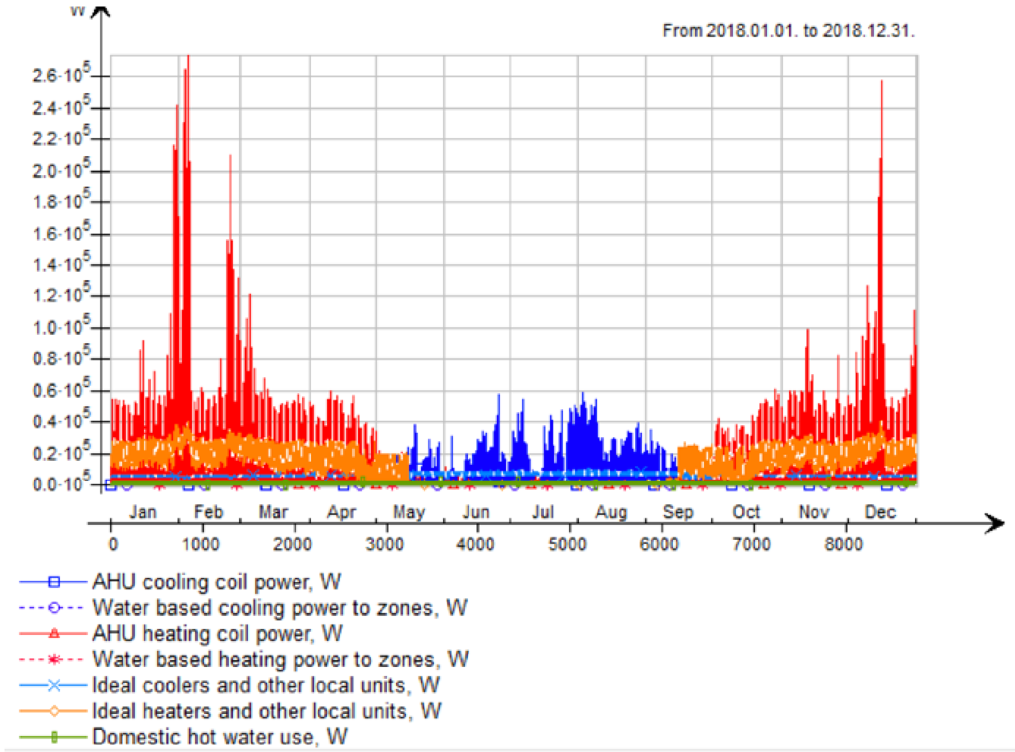

Fig. 4.3.4. *Floor plan of the commercial building.*

4.3.1. NZeb friendly proposal

As for the buildings of shopping centers, the status of a nZEB building is a challenge in Latvia, as traditionally district heating or gas boiler houses as designed, it was decided to use on-line simulation opportunities to integrate PV panels and improve quality of the project by usage of renewable energy. Table 4.3.1. demonstrates parameters of PV panels suitable for this case study. Sun altitude angle is shown on Fig. 4.3.5. [10]

Table 4.3.1. *Parameters of PV panel system.*

Component overview (annual values)

Photovoltaics Roof plan 1	**Bifacial 200**	
Number of modules		650
Total nominal power generator field	kW	130
Total gross area	m²	1,181.82
Tilt angle (hor.=0°, vert.=90°)	°	57
Orientation (E=+90°, S=0°, W=-90°)	°	0
Inverter 1: Name		Inverter 80k
Manufacturer		Anonymous
Inverter 2: Name		Inverter 2100
Manufacturer		Anonymous
Manufacturer		Anonymous
Energy production AC [Qinv]	kWh	126,644

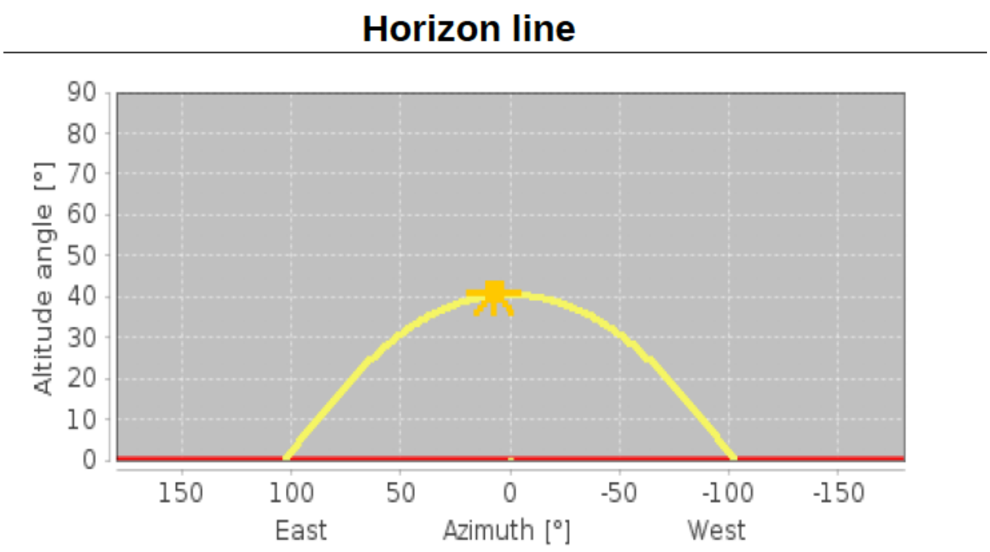

Fig. 4.3.5. *Sun altitude angle.*

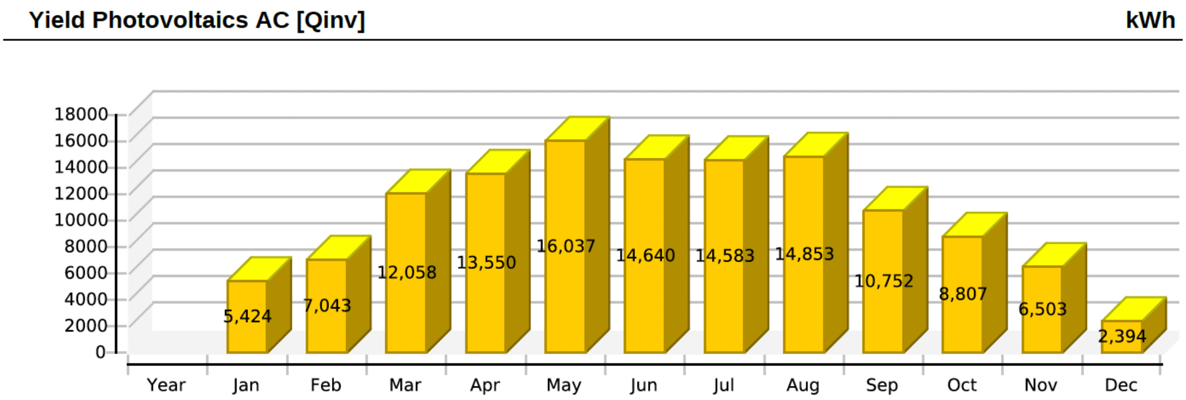

Fig. 4.3.6. *PV panels productivity.*

Table 4.3.2. *Annual values.*

Overview photovoltaics (annual values)

Total gross area	1,181.8 m²
Energy production AC [Qinv]	126,644.3 kWh
CO2 savings	67,932 kg

Table 4.3.2. and Fig. 4.3.6. demonstrates profitable performance of PV panels installation for this building. Produced power can cover cooling equipment power consumption.[10]

4.4 Calculation of energy consumption

4.4.1. Energy consumption for a functional model of commercial building

A calculations of energy consumption for the functional model of new supermarket building shows that the initially designed *U*-values for boundary constructions (see Table 4.1.1) and chosen airflow rate for air handling units does not allow to reach required annual heating consumption below 45 kWh/m^2. On the other hand, the project does not include the use of any renewable energy and therefore requirements of nZEB are not met (see section 2.3.2.). Therefore, some changes in input data were made to achieve the nZEB requirements for created functional model of commercial building (Table 4.4.1):

1) other walls was insulated with 18 cm of mineral wool;
2) roof construction was modified, providing bigger insulation material thickness;
3) expected airflow is slightly reduced, decreasing the air exchange rate to 0.88 h^{-1};
4) 50% of expected electricity for lighting is produced by PV panels on the roof.

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Table 4.4.1. *Changes in input parameters to reach the nZEB level for a commercial building.*

Variable parameter	Initially	nZEB case
U-value for other wall, W/m²/K	0.23	0.11
U-value for the roof construction, W/m²/K	0.155	0.12
Planned air change rate, 1/h	0.92	0.85
Use of renewable energy	no	Yes (PV panels)

Made improvements allow to decrease the calculated annual heating energy consumption to 44 kWh/m² and the total primary energy need is now below nZEB's maximum allowed 95 kWh/m² per year. As the next improvement in the heating and primary energy calculations, the use of heat pump for the heating (instead of central heating system) and increasing of glazing *U*-value (e.g. triple glazed constructions) can be analyzed.

A printout from the modelling software *HeatMod* with all the calculation results of energy consumption for a functional model in case of functional model of nZEB commercial building is attached in Annex 4.4.1. As it is seen from comparison of losses and gains (Fig. 4.4.1), the most important role in total heat balance plays internal gains, that in case of supermarket are lighting, commercial equipment (mainly refrigerators, heat from which can be used potentially also for the direct heating) and shop visitors. It is important to note, that information about internal gains is only provisional and the total heating need may change during the real building usage. Therefore, it is very important to check all the energy consumptions after long operating period, as well as record instantaneous sensors readings (temperature, air humidity, power etc.) for control and optimization.

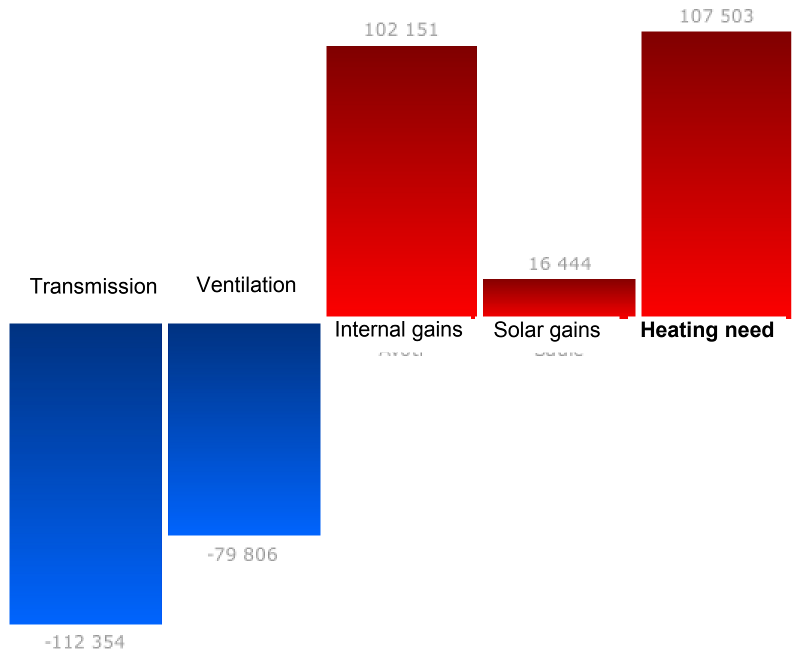

Fig. 4.4.1. *Heat losses and gains in case of commercial building (supermarket).*