

POLITECNICO DI MILANO



Faculty of Piacenza

SCHOOL OF ARCHITECTURE, URBAN PLANNING AND CONSTRUCTION ENGINEERING
MASTER OF SUSTAINABLE ARCHITECTURE AND LANDSCAPE DESIGN

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Technical Assignment - TECHNICAL ENVIRONMENTAL SYSTEMS

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Simulation of Building Energy Performance

The project has the purpose to analyse the energy performance of a building in relation with its conditioning system (heating and cooling) and electricity consumption. In order to do that, we approached the assignment with some comparative analysis working with the following software: Energy plus, Sketch Up and Open Studio.

For the comparative analyses, three different cities were chosen, with three different temperatures: low, medium and high. The first one is Oslo, located in the north of Europe, in a place with low temperatures during all the year; for medium temperature, it was chosen Piacenza, while Acapulco is the high temperature choice.

Then it was required the modelling of a building in order to try the effects that these three cities' conditions have on it. So a prototype model was built in Sketch up and the choosen shape is rectangular, with a curve in one of the corner. The dimension of the building is 10 x 11.75 m and it is four storeys high; the ground floor is 3 m high and the other 3 floors are 2.50 m high.

The prototype is an office building which contains five different thermal areas: offices, kitchen, staircase, bathrooms, and corridor.

As a second thing, wall components were added in Open Studio. The components chosen for the wall were:

- stucco (thickness = 2.5 cm),
 - concrete block cells insulated (thickness = 25.4 cm),
 - wall insulation (thickness = 7.94 cm),
 - brick-fired clay (thickness = 10.16 cm),
 - gypsum (thickness = 0.013 cm),
- for a total thickness of 46.013 cm.

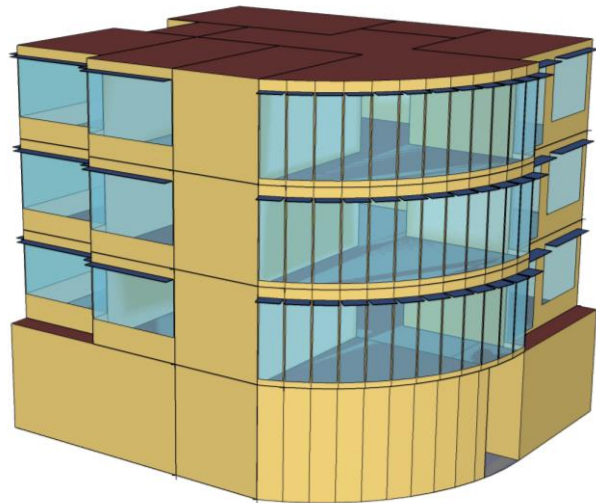


Image 1: Prototype in Sketch up

1. Simulation of the Building in Oslo

The city of Oslo is the capital and the most populated city from the country of Norway. The city is located in the southern part of the country in the latitude 59.9 and longitude 10.62 with an elevation of 17 m.

According to the analysis the total site Energy required from this Building of 460 m² is 387,45 GJ: this means 821,18 MJ/sm.

	Total Energy [GJ]	Energy Per Total Building Area [MJ/m ²]	Energy Per Conditioned Building Area [MJ/m ²]
Total Site Energy	387.45	821.18	821.18
Net Site Energy	387.45	821.18	821.18
Total Source Energy	1348.52	2858.10	2858.10
Net Source Energy	1348.52	2858.10	2858.10

Image 2: Energy Consumption chart for Oslo.

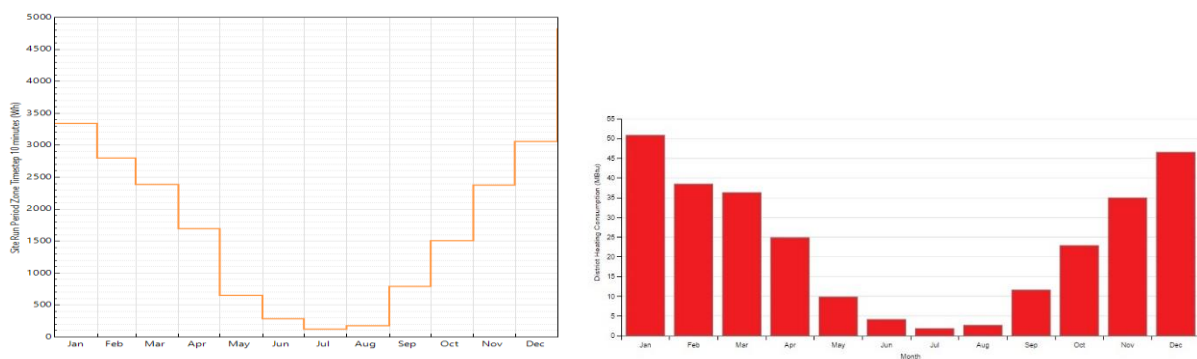


Image 3: Energy Consumption by heating per month.

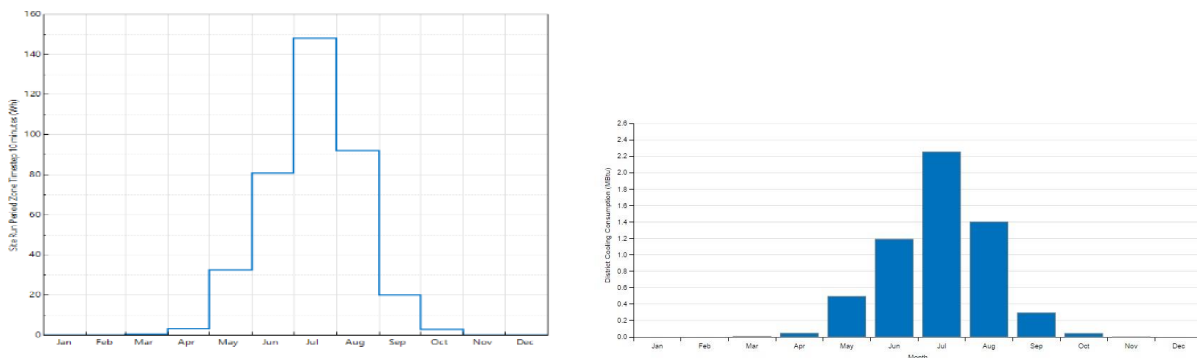


Image 4: Energy Consumption by cooling per month.

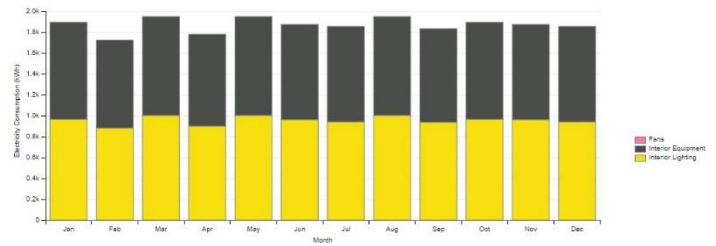
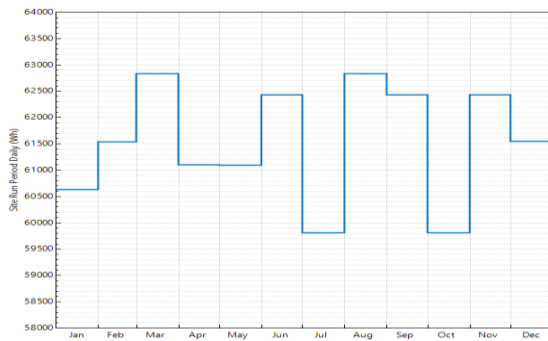


Image 5: Energy Consumption by electricity per month.

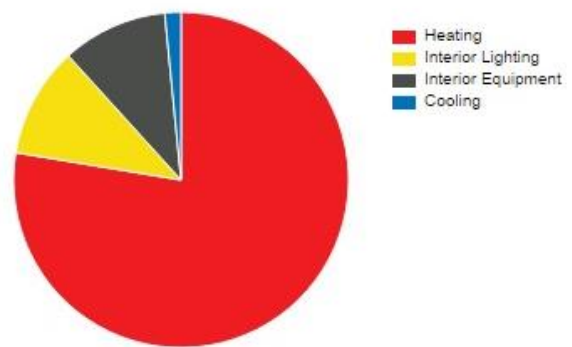
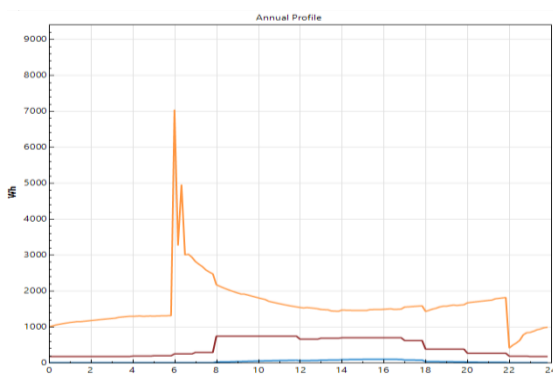


Image 6: Energy Consumption by electricity per month.

The analysis results show that the critical month for energy consumption for cooling the building in Oslo is in July with 150 Wh, while for the heating system the critical month is December with 5000 Wh. July is by far the most demanding month for the cooling system when temperatures can rise until 30°C. The energy consumption for the electricity demand is high because of the function of the building (offices).

2. Simulation of the Building in Acapulco

The city of Acapulco is located in the Pacific coast of Mexico, in the latitude 16.77 and longitude -99.75, with an elevation of 5 m above sea level.

According to the analysis, the total site energy required is 298.34 GJ for the 460 m² of the building: this means 648.57 MJ/m².

	Total Energy [GJ]	Energy Per Total Building Area [MJ/m2]	Energy Per Conditioned Building Area [MJ/m2]
Total Site Energy	298.34	632.31	632.31
Net Site Energy	298.34	632.31	632.31
Total Source Energy	485.35	1028.67	1028.67
Net Source Energy	485.35	1028.67	1028.67

Image 7: Energy consumption chart for Acapulco.

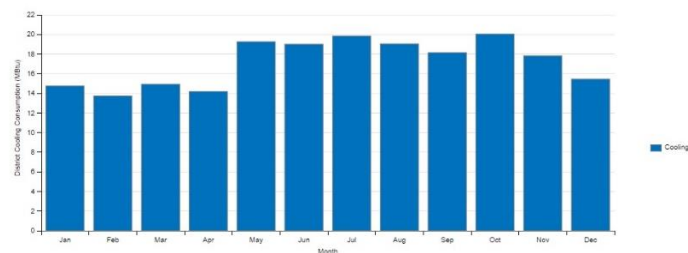
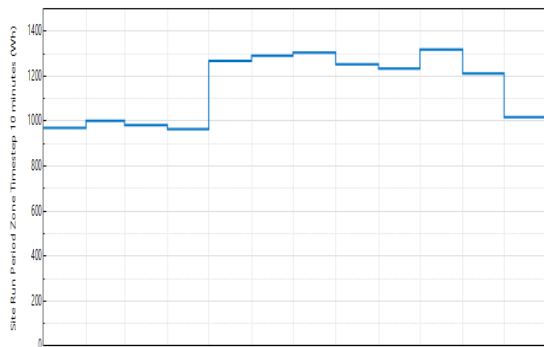


Image 8: Energy consumption by cooling per month.

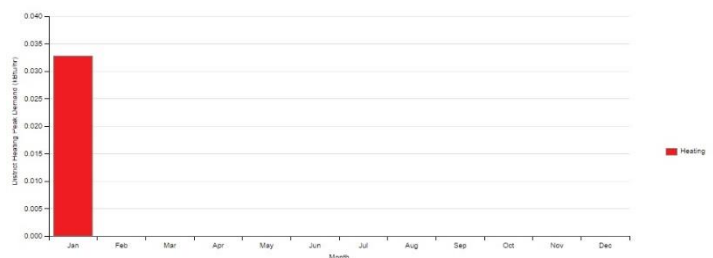


Image 9: Energy consumption by heating per month.

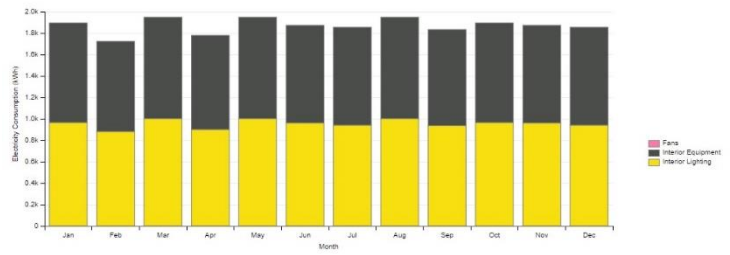
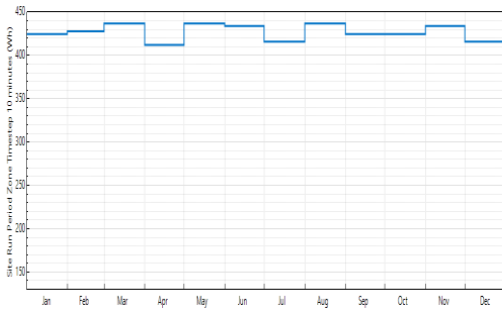


Image 10: Energy Consumption by electricity per month.

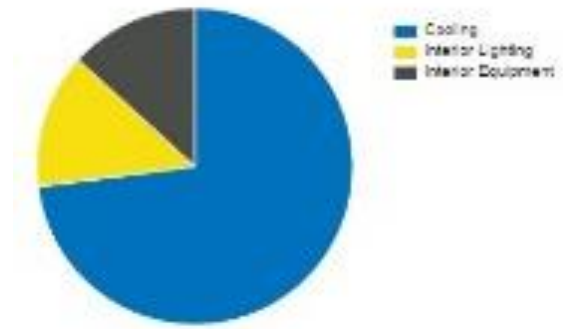
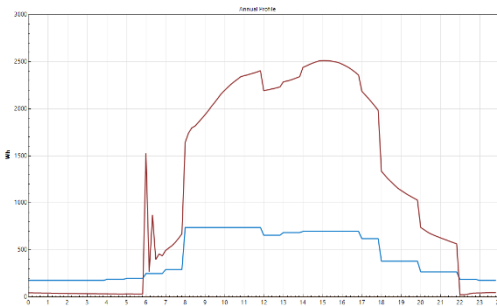


Image 11: Energy Consumption by electricity, heating and cooling per year.

The analysis show that the critical month for energy consumption in cooling is October with a value of 1.32 kWh, but it has to be considered that, from May to November, the value of energy consumptions has undergone few changes.

On the other hand, for the heating system January is the month that shows a higher level of energy consumptions, registering a value of 3.5×10^{-4} Wh.

The energy consumption for internal equipment is always very high, because the use of the building is for offices and they require a constant amount of energy during all the year.

3. Simulation of the Building in Piacenza

The city of Piacenza is in the north part of Italy, in the latitude 44.92 and longitude 9.73 with an elevation of 134 meters. According to the analysis the total site energy required is 284,52 GJ for the 460 sm of the building. This means 603,02 MJ/sm.

	Total Energy [GJ]	Energy Per Total Building Area [MJ/m2]	Energy Per Conditioned Building Area [MJ/m2]
Total Site Energy	284.52	603.02	603.02
Net Site Energy	284.52	603.02	603.02
Total Source Energy	922.69	1955.57	1955.57
Net Source Energy	922.69	1955.57	1955.57

Image 12: Energy consumption chart for Piacenza

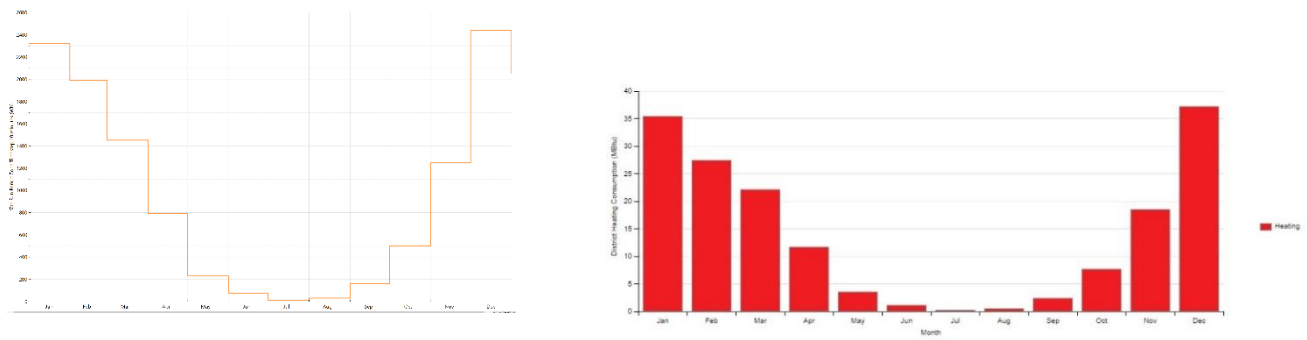


Image 13: Energy consumption by heating per month.

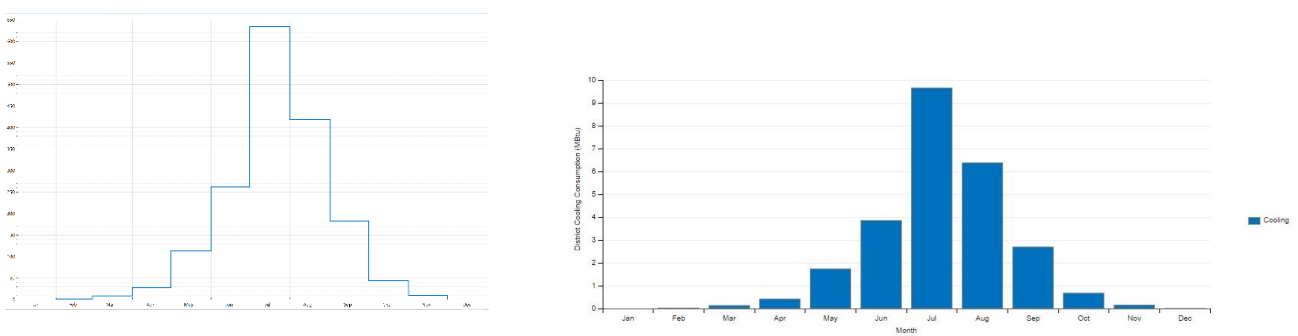


Image 14: Energy consumption by cooling per month.

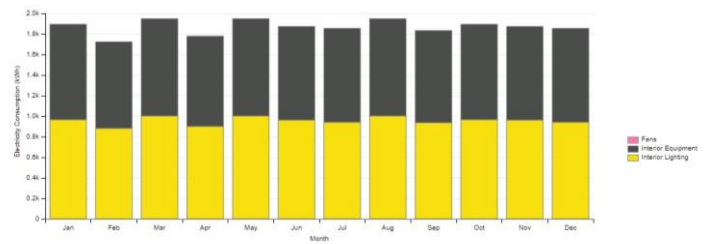
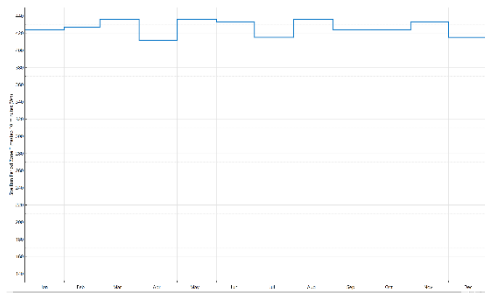


Image 15: Energy consumption by electricity per month.

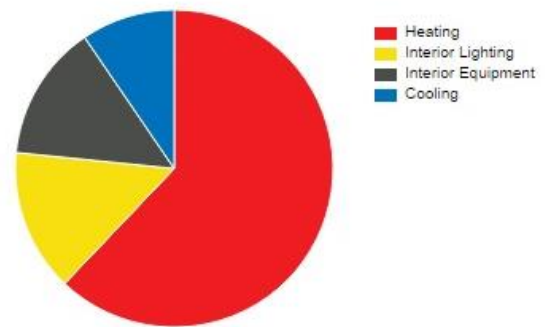
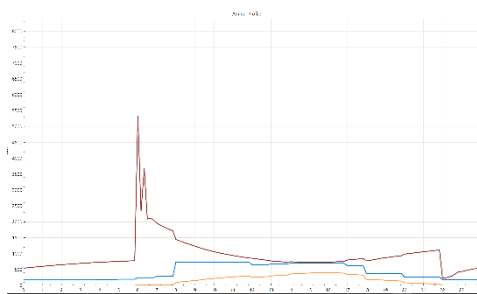


Image 16: Energy consumption by electricity per month.

The analysis show that the critical month for energy consumption in cooling is July with 630 Wh and for the heating system December is the critical month with 2450 Wh. July is by far the most demanding month for the cooling system where temperatures can rise until 33°C. The energy consumption for the electricity is also high, because the schedule program for the building is for offices.

3.1 Simulation of the Building in Piacenza: CASE B

After having compared all the results, the building settled in Piacenza was changed to see the variations between different stratigraphies applied on the same building located in the same place.

In this case, a smaller wall insulation of 3.3 cm is added and, instead of a concrete block of 10 inches with cells insulated, it was chosen a brick fired clay of 4 inches for the exterior part.

	Total Energy [GJ]	Energy Per Total Building Area [MJ/m ²]	Energy Per Conditioned Building Area [MJ/m ²]
Total Site Energy	313.79	665.06	665.06
Net Site Energy	313.79	665.06	665.06
Total Source Energy	1011.52	2143.84	2143.84
Net Source Energy	1011.52	2143.84	2143.84

Image 17: Energy consumption chart for Piacenza, second customize construction set.

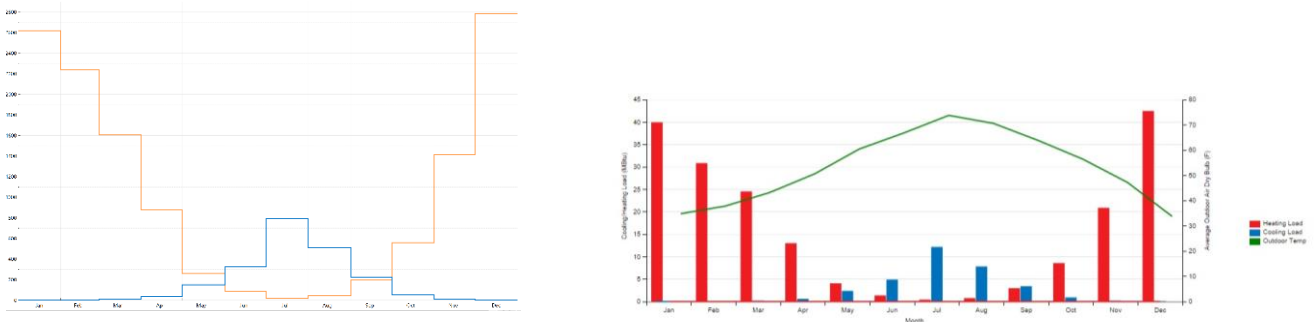


Image 18: Energy consumption by cooling and heating per month.

The analysis show an increase in the energy consumption in heating, in fact in December, which is the most heatig demanding month, the level is now 2800 Wh (2.8 Kwh) against the 2450 Wh (2.45 kWh) of the previous customized construction set, so it means that the building is now improved.

3.2 Simulation of the Building in Piacenza: CASE C

In this last case, the insulation was reduced for the construction of the wall and also the brick fired clay 4 inches used for case B was replaced by a concrete block of 10 inches with cells empty.

	Total Energy [GJ]	Energy Per Total Building Area [MJ/m ²]	Energy Per Conditioned Building Area [MJ/m ²]
Total Site Energy	296.04	627.43	627.43
Net Site Energy	296.04	627.43	627.43
Total Source Energy	960.65	2036.04	2036.04
Net Source Energy	960.65	2036.04	2036.04

Image 19: Energy consumption chart for Piacenza, third customize construction set.

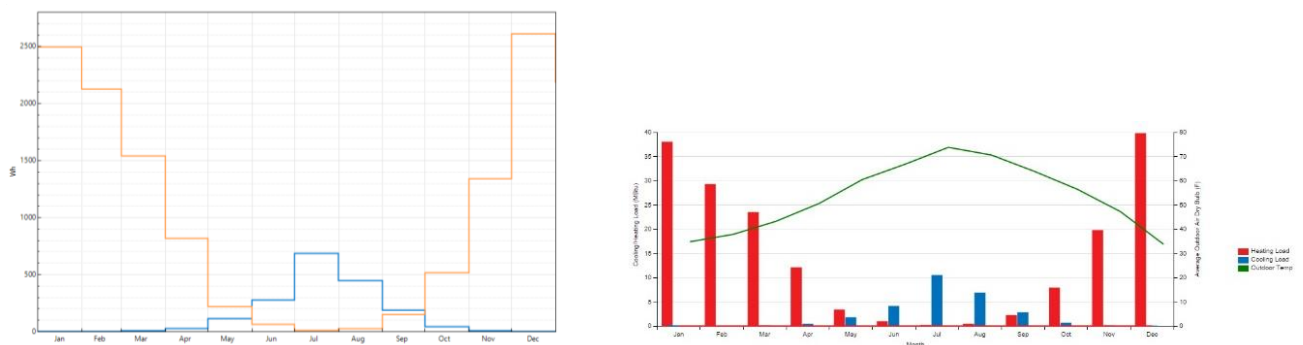


Image 20: Energy consumption by cooling and heating per month

This analysis show a decreasing in the energy consumption in heating for the month of December which is also the most demanding month in this case. Nevertheless, the consumption energy for heating only reaches 2600 Wh (2.6 kWh), which is less than the 2800 Wh (2.8 kWh) obtained in the previous customized construction set for case B, but greater than 2450 Wh (2.45 kWh) from the previous customized construction set for case A.

4. Construction sets resistances

CUSTOMIZED CONSTRUCTION SET 1			
MATERIAL	THICKNESS	CONDUCTIVITY	RESISTANCE
1 IN STUCCO	0.025	0.692	0.037
CONCRETE BLOCK 10 IN - CELLS INSULATED	0.254	0.562	0.452
WALL INSULATION 40	0.079	0.043	1.838
BRICK - FIRED CLAY 4 IN	0.102	0.675	0.151
1/2 IN GYPSUM	0.013	0.160	0.079
TOTAL			2.56

CUSTOMIZED CONSTRUCTION SET 2			
MATERIAL	THICKNESS	CONDUCTIVITY	RESISTANCE
1 IN STUCCO	0.025	0.692	0.037
BRICK - FIRED CLAY 4 IN	0.102	0.675	0.151
WALL INSULATION 31	0.034	0.043	0.780
1/2 IN GYPSUM	0.013	0.160	0.079
TOTAL			1.05

CUSTOMIZED CONSTRUCTION SET 3			
MATERIAL	THICKNESS	CONDUCTIVITY	RESISTANCE
1 IN STUCCO	0.025	0.692	0.037
CONCRETE BLOCK 10 IN - CELLS EMPTY	0.254	0.981	0.259
I01 25MM INSULATION BOARD	0.025	0.030	0.845
CONCRETE BLOCK 10 IN - CELLS EMPTY	0.254	0.981	0.259
1/2 IN GYPSUM	0.013	0.160	0.079
TOTAL			1.48

Conclusions

1. In the case of Oslo, the heating energy consumption is almost 34 times greater than the cooling energy consumption.
2. In case B of Piacenza, the thickness of the insulation was reduced and the concrete blocks cell insulated were changed for blocks fired clay, showing a substantial increase of the heat energy consumption.
3. Comparing the case A and the case C in Piacenza, the energy consumption slightly increase, because the insulation was reduced and it was compensated by changing the brick fired clay with a thickness of 10 cm, for a concrete block with a thickness of 25.4 cm.
4. We can conclude also that this rise in the insulation elements also brings more energy consumption for the cooling systems in the months of high temperatures.
5. If we compare the three models that have been realized in Piacenza it is evident that the wall insulation is the best way to decrease the energy consumption of the building, because increasing the thickness of the wall blocks will not be so efficient.
At the end, for best energy consumption and for design benefits inside the building is preferable to apply a wall insulation that has lower thickness than a concrete block.
6. The resistance in the first customize construction wall set is the highest because of the thickness of the wall insulation.