REPORT OF THE CASE STUDY

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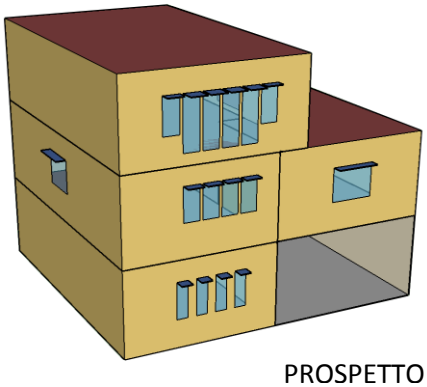
Geometry of the building

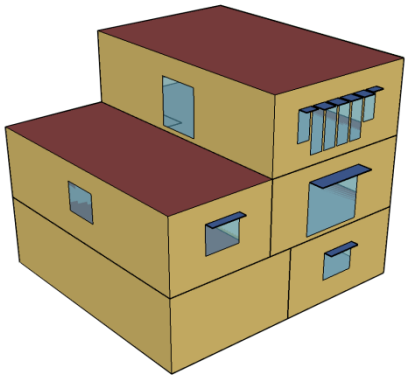
The building is a single family villa on three floors, located in the outskirt of Bologna. At the ground floor we find the garage and the tavern, while the first floor is the most frequented space where kitchen, living room and two bedrooms find place. Last floor has other two bedrooms. The case study considered is located in Bologna, for running the simulation it has been used the weather data are from the weather station of Bologna Borgo Panigale.

Building Area

	Area [m2]
Total Building Area	242.59
Net Conditioned Building Area	242.59
Unconditioned Building Area	0.00



PROSPETTO NORD-EST



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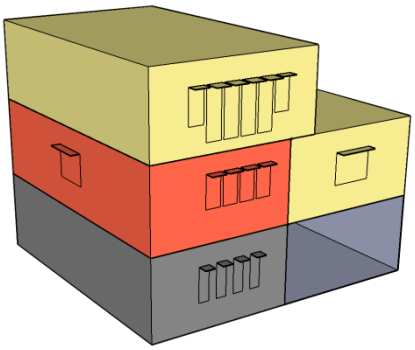

The construction has been subdivided into three thermal zones due to the functions of the rooms and the distribution of the thermostats: the first zone on the ground floor (the tavern); the second one is composed by the living room and the kitchen; and the last one it's dedicated to the sleeping area which are both on the first and the second floor.

The following tables show the square meters of each surface, wall and windows, on each side of the building and on each thermal zone.

Window-Wall Ratio

	Total	North (315 to 45 deg)	East (45 to 135 deg)	South (135 to 225 deg)	West (225 to 315 deg)
Gross Wall Area [m2]	300.81	63.83	70.62	95.74	70.62
Above Ground Wall Area [m2]	300.81	63.83	70.62	95.74	70.62
Window Opening Area [m2]	34.75	5.56	12.33	1.80	15.06
Gross Window-Wall Ratio [%]	11.55	8.71	17.46	1.88	21.33
Above Ground Window-Wall Ratio [%]	11.55	8.71	17.46	1.88	21.33

Zone Summary

	Area [m2]	Conditioned (Y/N)	Part of Total Floor Area (Y/N)	Volume [m3]	Multipliers	Above Ground Gross Wall Area [m2]	Underground Gross Wall Area [m2]	Window Glass Area [m2]	Opening Area [m2]	Lighting [W/m2]	People [m2 per person]	Plug and Process [W/m2]
THERMAL ZONE 1	57.79	Yes	Yes	176.16	1.00	65.56	0.00	3.88	3.88	12.5938	9.29	0.7535
THERMAL ZONE 2	64.32	Yes	Yes	196.06	1.00	68.70	0.00	10.33	10.33	10.6563	17.70	7.6424
THERMAL ZONE 3	120.47	Yes	Yes	367.20	1.00	166.54	0.00	20.55	20.55	10.6563	19.56	6.8889
Total	242.59			739.41		300.81	0.00	34.75	34.75	11.1179	15.15	5.6270
Conditioned Total	242.59			739.41		300.81	0.00	34.75	34.75	11.1179	15.15	5.6270

Cities considered in simulations

The performance of the building has been analysed in two different cities, located in two different climate zones, and the results have been compared.
Firstly the performance has been evaluated in **Bologna** (Italy), the current position of the building, which is characterized by a temperate climate and then the calculations have been repeated in **Kiruna** (Sweden), which has a sub-Arctic climate.

	Maximum Dry Bulb [C]	Daily Temperature Range [deltaC]	Humidity Value	Humidity Type	Wind Speed [m/s]	Wind Direction
BOLOGNA-BORGO PANIGALE ANN CLG .4% CONDNS DB=>MWB	34.10	11.10	23.10	Wetbulb [C]	2.80	70.00
BOLOGNA-BORGO PANIGALE ANN CLG .4% CONDNS DP=>MDB	28.40	11.10	23.00	Dewpoint [C]	2.80	70.00
BOLOGNA-BORGO PANIGALE ANN CLG .4% CONDNS ENTH=>MDB	31.50	11.10	75800.00	Enthalpy [J/kg]	2.80	70.00
BOLOGNA-BORGO PANIGALE ANN CLG .4% CONDNS WB=>MDB	31.30	11.10	24.90	Wetbulb [C]	2.80	70.00
BOLOGNA-BORGO PANIGALE ANN HTG 99.6% CONDNS DB	-4.80	0.00	-4.80	Wetbulb [C]	1.40	220.00
BOLOGNA-BORGO PANIGALE ANN HTG WIND 99.6% CONDNS WS=>MCDB	6.20	0.00	6.20	Wetbulb [C]	8.20	220.00
BOLOGNA-BORGO PANIGALE ANN HUM_N 99.6% CONDNS DP=>MCDB	0.90	0.00	-10.20	Dewpoint [C]	1.40	220.00

KIRUNA ANN CLG .4% CONDNS DB=>MWB	22.00	7.80	14.00	Wetbulb [C]	3.60	190.00
KIRUNA ANN CLG .4% CONDNS DP=>MDB	16.70	7.80	13.40	Dewpoint [C]	3.60	190.00
KIRUNA ANN CLG .4% CONDNS ENTH=>MDB	19.40	7.80	44200.00	Enthalpy [J/kg]	3.60	190.00
KIRUNA ANN CLG .4% CONDNS WB=>MDB	19.40	7.80	15.20	Wetbulb [C]	3.60	190.00
KIRUNA ANN HTG 99.6% CONDNS DB	-30.10	0.00	-30.10	Wetbulb [C]	1.80	210.00
KIRUNA ANN HTG WIND 99.6% CONDNS WS=>MCDB	1.50	0.00	1.50	Wetbulb [C]	13.70	210.00
KIRUNA ANN HUM_N 99.6% CONDNS DP=>MCDB	-30.00	0.00	-33.10	Dewpoint [C]	1.80	210.00

Constructions sets

The performances of the building have been calculated over three different type of wall, floor and roof packages to better understand the differences in heating and cooling energy demand on the base of the climate and the construction.

The first option is the one utilized for constructing the real building.

The second option is a thick wood package for both wall and roof.

All the components of the packages will be shown in the sensitive analysis to better understand the situation of each simulation.

Sensitive analysis

The energy demand of the building has been evaluated in the following cases to analyse the differences and see which option is the more efficient.

1) First construction set

TRASMITTANZA PARETI VERTICALI

Componente edilizio

	strato	spessore	conduttività termica	calore specifico	densità	resistenza termica	aria?
		d mm	*λ* W/(m·K)	*c* J/(kg·K)	*ρ* kg/m³	*R* m²·K/W	
lato interno						0,130	x
1	Intonaco in gesso	2	0,35	1090	1200	0,006	
2	Mattoni in calcestruzzo calcestruzzo aerato autoclavato	100	0,15	880	400	0,667	
3	Lastra in polietilene	2	0,034	1450	20	0,059	
4	Sughero	180	0,04	1800	100	4,500	
5	Mattoni forati	140	0,3	840	800	0,467	
6	Legno di pino	40	0,12	1660	550	0,333	
7						0,000	
8						0,000	
9						0,000	
10						0,000	
lato esterno						0,040	x

UNI EN ISO 13786:2001
Trasmittanza in condizioni stazionarie
U 0,161 W/(m²·K)

Trasmittanza termica periodica
|*Yie*| 0,01 W/(m²·K)

TRASMITTANZA MASSIMA (ZONA E)
0,34 W/(m²·K)

TRASMITTANZA COPERTURA OBLIQUA

Componente edilizio

	strato	spessore	conduttività termica	calore specifico	densità	resistenza termica	aria?
		d mm	*λ* W/(m·K)	*c* J/(kg·K)	*ρ* kg/m³	*R* m²·K/W	
lato interno						0,130	x
1	Intonaco in gesso	2	0,35	1090	1200	0,006	
2	Legno di pino	80	0,12	1660	580	0,667	
3	Pannello in lana di roccia	40	0,038	840	175	1,053	
4	Lastra in polietilene	2	0,34	1450	20	0,006	
5	Sughero	200	0,04	1800	100	5,000	
6	Tegole in terracotta	20	1	800	2000	0,020	
7						0,000	
8						0,000	
9						0,000	
10						0,000	
lato esterno						0,040	x

UNI EN ISO 13786:2001
Trasmittanza in condizioni stazionarie
U 0,144 W/(m²·K)

Trasmittanza termica periodica
|*Yie*| 0,02 W/(m²·K)

TRASMITTANZA MASSIMA (ZONA E)
0,3 W/(m²·K)

TRASMITTANZA SOLAIO INTERNO

Componente edilizio

	strato	spessore	conduttività termica	calore specifico	densità	resistenza termica	aria?
		d mm	*λ* W/(m·K)	*c* J/(kg·K)	*ρ* kg/m³	*R* m²·K/W	*a*
lato interno						0,13	x
1	Magrone in calcestruzzo	80	0,55	880	2200	0,145	
2	Strato bituminoso	8	0,16	1400	1100	0,05	
3	Polipropilene "Igloo" con getto in Lecacem	180	0,5	1800	910	0,36	
4	Strato di scorrimento	1	0,16	890	40	0,006	
5	Pacchetto isolante	100	0,022	1340	30	4,545	
6	Pacchetto per supporto riscaldamento radiante	60	0,031	1340	30	1,935	
7	Massetto per riscaldamento a pavimento	40	1,83	880	400	0,022	
8	Piastrelle in ceramica	17	1	800	2300	0,017	
lato esterno						0,04	x

UNI EN ISO 13786:2001
Trasmittanza in condizioni stazionarie
U 0,138 W/(m²·K)

Trasmittanza termica periodica
|*Yie*| 0,01 W/(m²·K)

TRASMITTANZA MASSIMA (ZONA E)
0,3 W/(m²·K)

	Electricity [GJ]	Natural Gas [GJ]	Additional Fuel [GJ]	District Cooling [GJ]	District Heating [GJ]	Water [m3]
Heating	0.00	0.00	0.00	0.00	39.80	0.00
Cooling	0.00	0.00	0.00	8.45	0.00	0.00
Interior Lighting	31.32	0.00	0.00	0.00	0.00	0.00
Exterior Lighting	0.00	0.00	0.00	0.00	0.00	0.00
Interior Equipment	23.28	0.00	0.00	0.00	0.00	0.00

BOLOGNA

	Electricity [GJ]	Natural Gas [GJ]	Additional Fuel [GJ]	District Cooling [GJ]	District Heating [GJ]	Water [m3]
Heating	0.00	0.00	0.00	0.00	144.71	0.00
Cooling	0.00	0.00	0.00	0.02	0.00	0.00
Interior Lighting	31.32	0.00	0.00	0.00	0.00	0.00
Exterior Lighting	0.00	0.00	0.00	0.00	0.00	0.00
Interior Equipment	23.28	0.00	0.00	0.00	0.00	0.00

KIRUNA

Comparing the two results it can be easily seen that in Bologna the cooling energy demand is of course higher than in Kiruna, where it is nearly 0 GJ, but the heating energy demand is way more different, seeing the demand in Kiruna higher than the one in Bologna (144 GJ > 39.8 GJ).

2) Second Construction set, modifying only the vertical closure and keeping the roof of the first.

TRASMITTANZA PARETE VERTICALE PACCHETTO 2

Componente edilizio							
strato		spessore	conduttività termica	calore specifico	densità	resistenza termica	aria?
		d mm	*λ* W/(m·K)	*c* J/(kg·K)	*ρ* kg/m³	*R* m²·K/W	*a*
lato interno						0,13	x
1	LEGNO DI PINO	100	0,12	1660	580	0,833	
2	SUGHERO	250	0,04	1800	100	6,250	
3	Lastra in polietilene	2	0,34	1450	20	0,006	
4	Pannello in lana di roccia	40	0,038	840	175	1,053	
5	LEGNO DI PINO	140	0,12	1660	580	1,167	
6							
7							
8							
lato esterno						0,04	x

UNI EN ISO 13786:2001		
Trasmittanza in condizioni stazionarie		
U	0,138	W/(m²·K)
Trasmittanza termica periodica		
|Yie|	0,01	W/(m²·K)
TRASMITTANZA MASSIMA (ZONA E)		
0,3 W/(m²·K)		

BOLOGNA

	Electricity [GJ]	Natural Gas [GJ]	Additional Fuel [GJ]	District Cooling [GJ]	District Heating [GJ]	Water [m3]
Heating	0.00	0.00	0.00	0.00	138.68	0.00
Cooling	0.00	0.00	0.00	0.01	0.00	0.00
Interior Lighting	31.32	0.00	0.00	0.00	0.00	0.00
Exterior Lighting	0.00	0.00	0.00	0.00	0.00	0.00
Interior Equipment	23.28	0.00	0.00	0.00	0.00	0.00

KIRUNA

In this simulations the results show that just changing the wall package we already have a more performing building which decreases the energy demand for both cities cases. To note the higher decrease happening for heating in Kiruna (-6GJ) than the one happening in Bologna (only 1 GJ), same saving that we have in the cooling in Bologna.

3) Second set of construction, changing the external wall and the roof.

TRASMITTANZA tetto PACCHETTO 2

Componente edilizio							
strato		spessore	conduttività termica	calore specifico	densità	resistenza termica	aria?
		d mm	*λ* W/(m·K)	*c* J/(kg·K)	*ρ* kg/m³	*R* m²·K/W	*a*
lato interno						0,13	x
1	LEGNO DI PINO	80	0,12	1660	580	0,667	
2	SUGHERO	180	0,04	1800	100	4,500	
3	Lastra in polietilene	2	0,34	1450	20	0,006	
4	sughero	200	0,04	1800	100	5,000	
5	LEGNO DI PINO	140	0,12	1660	580	1,167	
6							
7							
8							
lato esterno						0,04	x

UNI EN ISO 13786:2001

Trasmittanza in condizioni stazionarie

U 0,138 W/(m²·K)

Trasmittanza termica periodica

|Yie| 0,01 W/(m²·K)

TRASMITTANZA MASSIMA (ZONA E)

0,3 W/(m²·K)

BOLOGNA

	Electricity [GJ]	Natural Gas [GJ]	Additional Fuel [GJ]	District Cooling [GJ]	District Heating [GJ]	Water [m3]
Heating	0.00	0.00	0.00	0.00	36.64	0.00
Cooling	0.00	0.00	0.00	7.15	0.00	0.00
Interior Lighting	31.32	0.00	0.00	0.00	0.00	0.00
Exterior Lighting	0.00	0.00	0.00	0.00	0.00	0.00
Interior Equipment	23.28	0.00	0.00	0.00	0.00	0.00

KIRUNA

	Electricity [GJ]	Natural Gas [GJ]	Additional Fuel [GJ]	District Cooling [GJ]	District Heating [GJ]	Water [m3]
Heating	0.00	0.00	0.00	0.00	38.15	0.00
Cooling	0.00	0.00	0.00	7.63	0.00	0.00
Interior Lighting	31.32	0.00	0.00	0.00	0.00	0.00
Exterior Lighting	0.00	0.00	0.00	0.00	0.00	0.00
Interior Equipment	23.28	0.00	0.00	0.00	0.00	0.00

	Electricity [GJ]	Natural Gas [GJ]	Additional Fuel [GJ]	District Cooling [GJ]	District Heating [GJ]	Water [m3]
Heating	0.00	0.00	0.00	0.00	133.51	0.00
Cooling	0.00	0.00	0.00	0.01	0.00	0.00
Interior Lighting	31.32	0.00	0.00	0.00	0.00	0.00
Exterior Lighting	0.00	0.00	0.00	0.00	0.00	0.00
Interior Equipment	23.28	0.00	0.00	0.00	0.00	0.00

The last simulations with the roof integration shows the more and more high saving in heating demand for the building placed in Kiruna which decreases its demand of 11 GJ. For the building in Bologna we have a saving as well in heating demand but always less than in Kiruna (4 GJ in total compared to the first option). The cooling demand doesn't change considerably.

Conclusions

From this analysis report we can understand that the current wall and roof package used for the building are performing for the climate where the building is located (temperate), because the higher performance package doesn't offer high savings. On the other hand it is clear that if the building was placed in Kiruna the construction set of the current building wouldn't be appropriate and would need to be changed with a more performing one.