POLITECNICO DI MILANO
Piacenza

School of Architecture, Urban Planning and Construction Engineering
Master of Science in Sustainable Architecture and Landscape Design

ENERGETIC EVALUATION OF AN OFFICE BUILDING

Professors:

Renzo Marchesi
Behzad Najafi

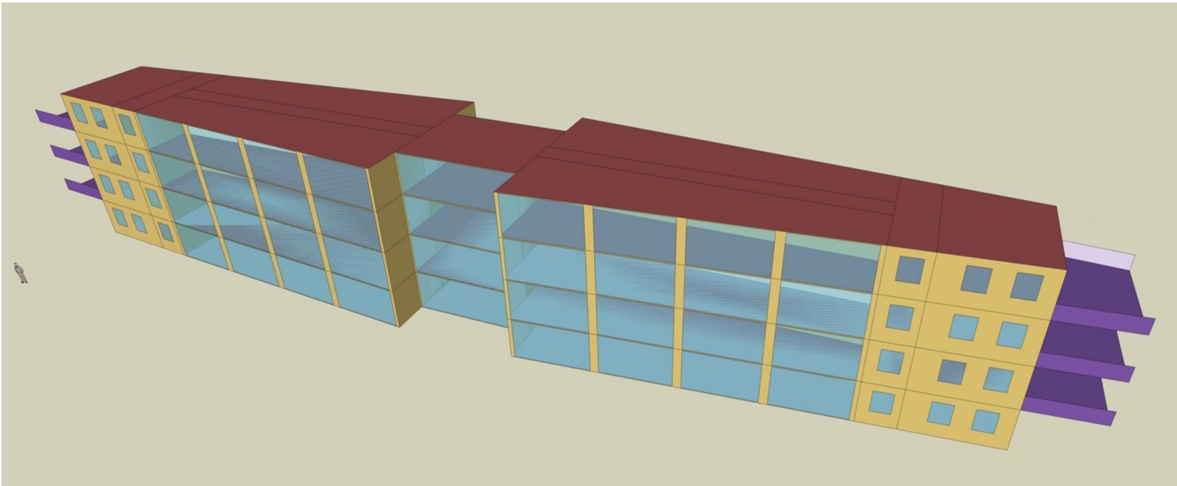
Laura Benatti
Sarah Casaburo
Matilde Dei Vecchi
Annalisa Fava
Habib Trad

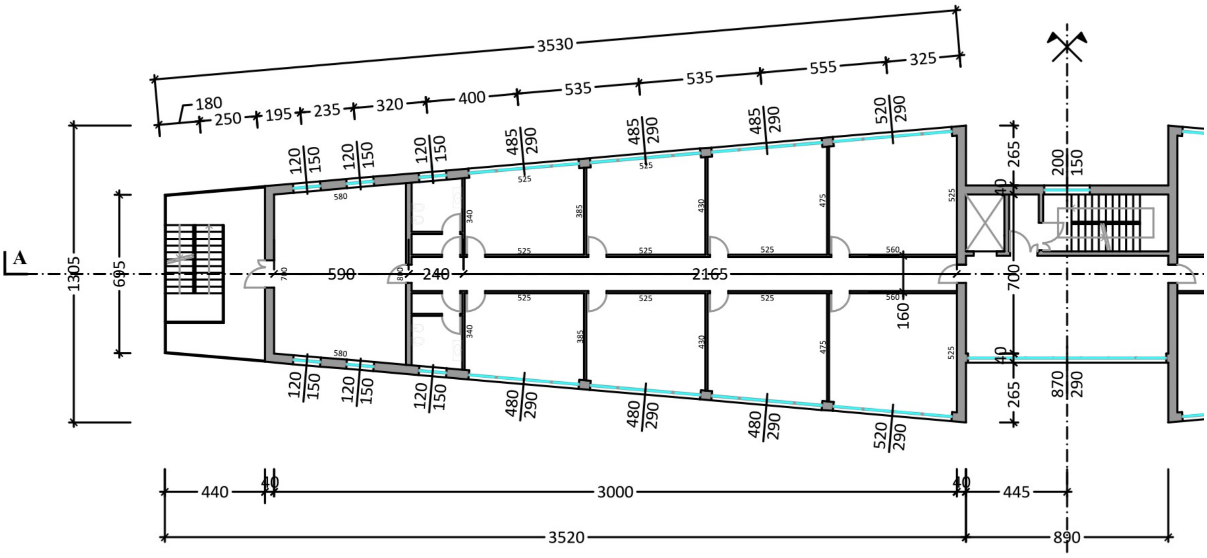
Academic Year 2017/2018

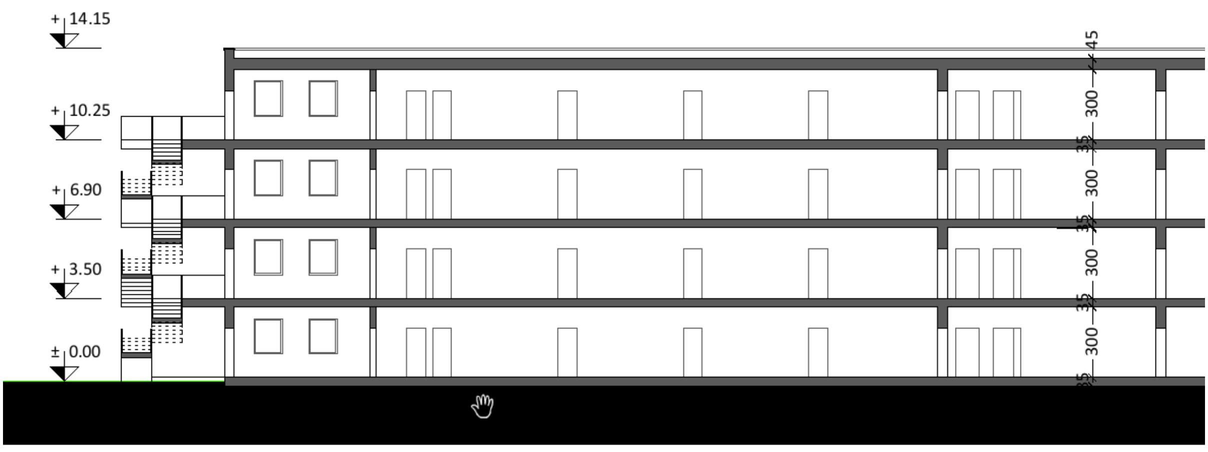
DESCRIPTION

The analyzed building is an office building located in Milan, Italy, built in the ‘60s.

The building has four floors and has a volume of 731 m³: the central volume is constituted by the stairwell and the elevator shaft, at either side of this volume there are the offices while at both the ends there are the conference halls.
The openings are really wide in the north and south façade (4,80 m x 2,90 m) while the ones in the east and west facades are emergency exits with emergency stairs.







SEZIONE A-A

SCHEDULE

Nowadays the building is used from 8:00 am till 7:00 pm. In this way, the heating and cooling system during winter and summer, as well as the lighting system are mostly operated during these dedicated hours.

WALL CHARACTERISTICS

The cross sections of the external walls, internal walls facing unheated rooms, slabs adjacent to the ground as well as on different levels, and roof slabs have been defined.

External wall

Material	Thickness [cm]	Conductibility [W/mK]	Density [kg/m^3]	Specific heat [J/kg K]
Plaster	1.5	0.9	1800	840
Reinforced concrete	25	1.91	2400	850
Foam core	4	0.036	30	1340
Bricks	8	0.8	1800	840
Plaster	1.5	0.9	1800	840

Internal wall

Material	Thickness [cm]	Conductibility [W/mK]	Density [kg/m^3]	Specific heat [J/kg K]
Dry wall	2.5	0.21	900	840
Cavity wall	8	0.5	1.2	1000
Dry wall	2.5	0.21	900	840

First floor Slab

Material	Thickness [cm]	Conductibility [W/mK]	Density [kg/m^3]	Specific heat [J/kg K]
Internal pavement	4	0.93	1800	840
Concrete screed	4	0.036	30	1340
Foam core	10	0.083	600	880
Lightweight slab	26	0.74	1800	840
Concrete slab	1.5	0.9	1800	840

Inter floor Slab

Material	Thickness [cm]	Conductibility [W/mK]	Density [kg/m^3]	Specific heat [J/kg K]
Pavement	4	0.93	1800	840
Concrete screed	4	0.036	30	1340
Lightweight slab	10	0.083	600	880
Concrete and masonry slab	26	0.74	1800	840
Plaster	1.5	0.9	1800	840

Roof Slab

Material	Thickness [cm]	Conductibility [W/mK]	Density [kg/m^3]	Specific heat [J/kg K]
Concrete screed + sheeting	4	0.93	1800	840
Foam core	4	0.036	30	1340
Lightweight slab	10	0.083	600	880
Concrete and masonry slab	26	0.74	1800	840
Plaster	1.5	0.9	1800	840

WINDOW CHARACTERISTICS

The windows in the building are characterized by a thermal transmittance equal to 2,7 W/m²K, by a solar factor equal to 0,6 and a transmission coefficient of the visible radiation equal to 0,4.

THERMAL ZONES

Dividing the 3D model, designed with SketchUp, in thermal zones, it was possible to identify the parameters of internal supply/intake, ventilation flow, set-point temperature of heating and cooling and internal lighting.

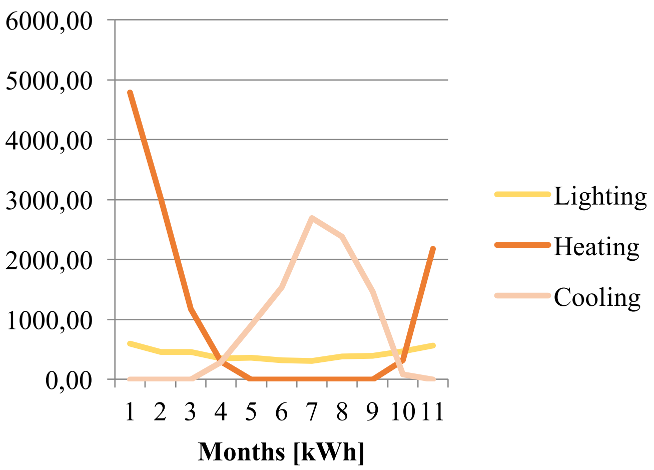
Typology: Conference hall	
Total internal intake	8 W/m^2 (medium value, 24h/24h)
Ventilation flow	0.8 vol/h (medium value, 24h/24h)
Set-point heating temperature	20 °C
Set-point cooling temperature	26 °C

Typology: Offices	
Total internal intake	6 W/m^2 (medium value, 24h/24h)
Ventilation flow	0.8 vol/h (medium value, 24h/24h)
Set-point heating temperature	20 °C
Set-point cooling temperature	26 °C

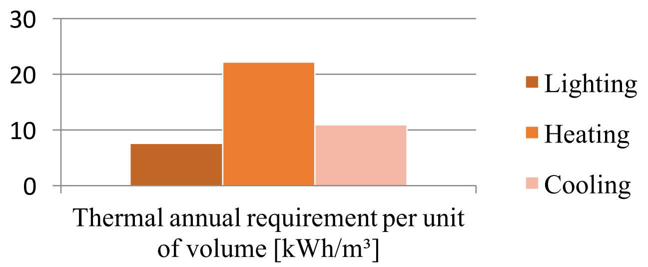
Typology: Distribution	
Total internal intake	6 W/m^2 (medium value, 24h/24h)
Ventilation flow	0.8 vol/h (medium value, 24h/24h)
Set-point heating temperature	Unheated ambient
Set-point cooling temperature	Uncooled ambient

RESULTS

These are the results we obtained from the base building. Both walls and windows have high transmittance, so they are not performing enough. Also, the lighting requirement is low because of of the big windows that let the light enter during the working hours.



Month	Lighting (kwh)	Heating (kwh)	Cooling (kwh)
January	602.46	4790.06	0.00
February	457.42	3020.45	0.00
March	458.42	1174.65	1.32
April	354.23	297.12	285.96
June	362.26	0.00	894.63
July	320.13	0.00	1541.67
August	311.71	0.00	2689.49
September	379.63	0.00	2388.26
October	394.14	0.00	1466.53
November	471.87	315.36	85.50
December	563.57	2179.65	0.00



Thermal annual requirement per unit of volume [kWh/m³]		
Lighting	Heating	Cooling
7.53	22.13	10.93

PROPOSAL

We thought about two different kinds of interventions: the first one concerns a work on the coat of the building and the other one works on the transparent components.

We tried to analyze the coat or surface and the different energetic results that we obtain changing the wall's characteristics. To do that we studied different typologies of the external building walls.

Solutions:

A) External insulation (10 cm)

Material	Thickness [cm]	Conductibility [W/mK]	Density [kg/m^3]	Specific heat [J/kg K]
Plaster of gypsum	1.5	0.29	600	100
Bricks	8	0.8	1800	840
Reinforced concrete	25	1.91	2400	850
Expanded polyethylene	10	0.050	30	2100
Plaster of gypsum	1.5	0.29	600	100

B) External insulation (15 cm)

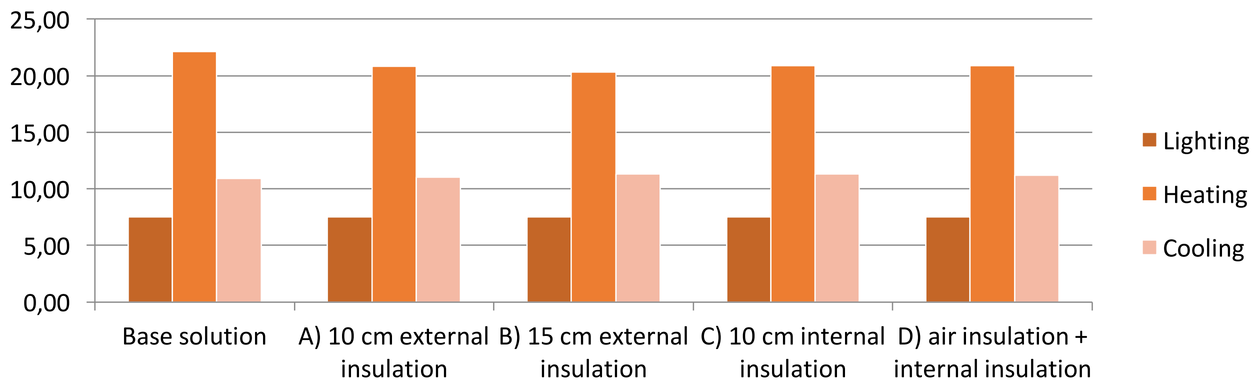
Material	Thickness [cm]	Conductibility [W/mK]	Density [kg/m^3]	Specific heat [J/kg K]
Plaster of gypsum	1.5	0.29	600	100
Bricks	8	0.8	1800	840
Reinforced concrete	25	1.91	2400	850
Expanded polyethylene	15	0.050	30	2100
Plaster of gypsum	1.5	0.29	600	100

C) Internal insulation (10 cm)

Material	Thickness [cm]	Conductibility [W/mK]	Density [kg/m^3]	Specific heat [J/kg K]
Plaster of gypsum	1.5	0.29	600	100
Expanded polyethylene	10	0.050	30	2100
Bricks	8	0.8	1800	840
Reinforced concrete	25	1.91	2400	850
Plaster of gypsum	1.5	0.29	600	100

D) Air insulation (5cm) + external insulation (5cm)

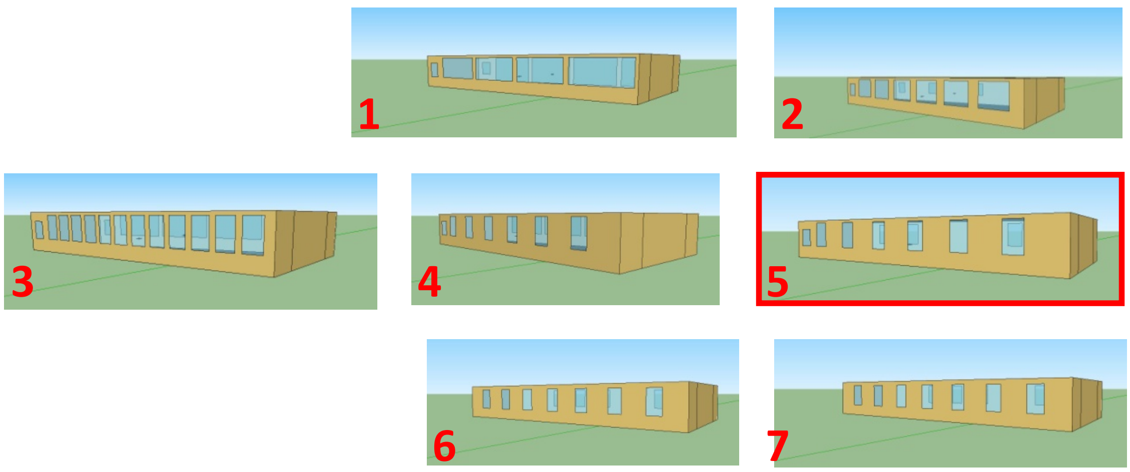
Material	Thickness [cm]	Conductibility [W/mK]	Density [kg/m^3]	Specific heat [J/kg K]
Plaster of gypsum	1.5	0.29	600	100
Bricks	8	0.8	1800	840
Air interspace	5	0.026	1.3	1008
Reinforced concrete	25	1.91	2400	850
Expanded polyethylene	5	0.050	30	2100
Plaster of gypsum	1.5	0.29	600	100

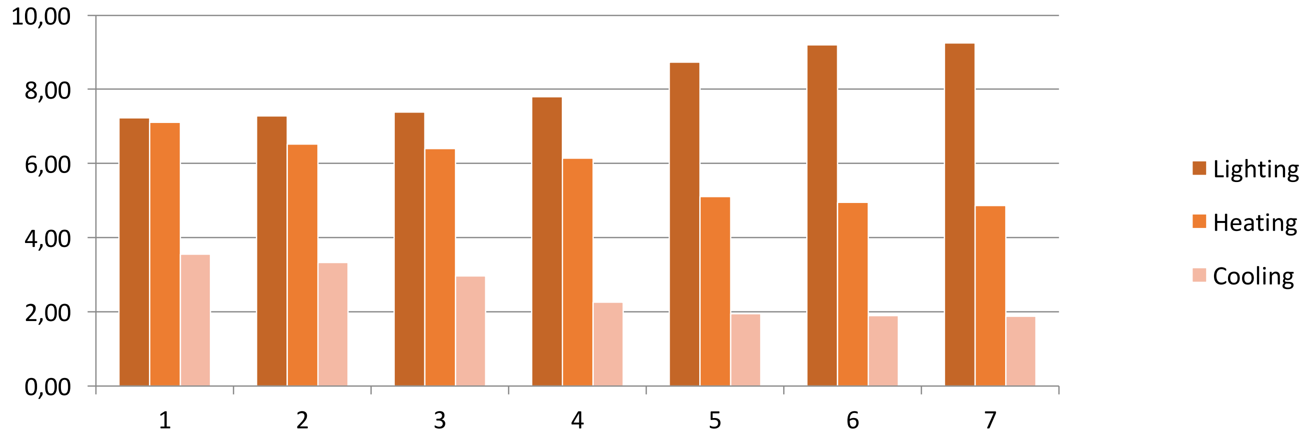


Thermal annual requirement per unit of volume [kWh/m³]			
	Lighting	Heating	Cooling
Base solution	7.53	22.13	10.93
A) 10 cm external insulation	7.53	20.81	11.04
B) 15 cm external insulation	7.53	20.30	11.29
C) 10 cm internal insulation	7.53	20.89	11.30
D) air insulation + internal insulation	7.53	20.87	11.18

Then we modified in different ways the openings on the north and south facades:

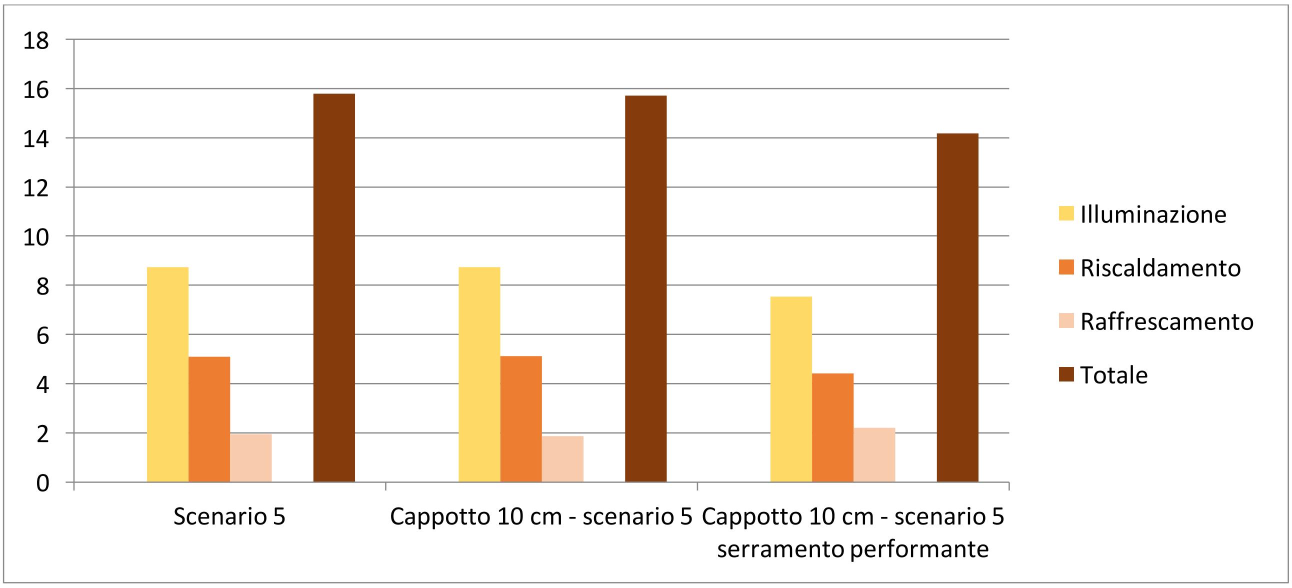
1. Reducing the dimensions and putting the windows at 1m from the slab only in the south facade
2. Reducing the dimensions and putting the windows at 1m from the slab also in the north façade
3. The big windows are divided into 3 minor ones (1.30 m x 2.00 m) in the south façade
4. The original windows are partially removed (only 6 in the south façade remain)
5. **Six windows in each façade (1.30 m x 2.00 m)**
6. Seven windows in each façade (1.20 m x 2.00 m)
7. Regulatory minimum (1/8 R.A.I.): 7 windows in the south façade and 6 in the north one.





	Electric annual consumptions (COP medium = 3) [kWh/m³]			Simulation on one Floor	
	Lighting	Heating	Cooling	Total thermal consumptions	Total
Hypothesis 1	7.23	7.10	3.54	10.65	17.88
Hypothesis 2	7.27	6.53	3.33	9.86	17.13
Hypothesis 3	7.38	6.41	2.96	9.36	16.75
Hypothesis 4	7.81	6.15	2.26	8.42	16.22
Hypothesis 5	8.74	5.10	1.94	7.04	15.78
Hypothesis 6	9.20	4.96	1.90	6.86	16.05
Hypothesis 7	9.25	4.86	1.87	6.73	15.98

We have a reduction of the heating and cooling consumption. However, the lighting requirement increases because of the reduction of the window surfaces.
After that we modified the transparent component with a new more performing one, which has a transmittance equal to 1.5 W/m²K, a solar factor equal to 0,64 and a transmission coefficient of the visible radiation equal to 0,8.
Finally, comparing the two improved solutions of the two earlier analysis and these are the results:



CONCLUSIONS

Annual medium electric consumptions (medium COP=3) [kWh/m³]					
	Lightning	**Heating**	**Cooling**	**Total thermic consumptions**	**Total**
Building	7.53	22.13	10.93	33.06	40.59
External insulation of 10 cm of expanded polyethylene	8.74	5.10	1.94	7.04	15.78
Six windows in each façade (1.30 m x 2.00 m)	8.74	5.11	1.86	6.97	15.71
More performing window	7.55	4.42	2.20	6.62	14.17

60s building with low quality walls and openings. Energetic requirements too high (40,59 kWh/m³ year) due to:

- Low insulation and bad thermal resistance of the walls
- Big windows in both north and south facades create a greenhouse effect during summer and let cold enter during winter
- The windows have a too high thermal transmittance, so the radiation enters inside the building, that is good for the lighting but bad from a thermic point of view

We did many simulations to understand how to reduce the energetic requirements of the building. The hypothesis concern:

The building envelope

Different simulations of typologies and positions of insulation. Proposed solutions show a reduction of the heating and cooling requirement. The best result is given by 15 cm of external insulation.

Dimensions of the openings in the north and south facades

The reduction of the transparent surfaces slightly increases the requirement of lighting, but a huge improvement on the heating and cooling thermal requirements.

Different types of window frames

Replacing the old window frames with new more performing ones, we obtain an improvement of the energetic requirement with a great reduction of the energy consumptions equaling 65%.