Energy Efficient Envelope Retrofit: a Case Study for a Bank Data Centre

E. Fabrizio[1,2], M. Filippi[1], M. Perino[1], V. Serra[1],

[1] *Dipartimento di Energetica (DENER), Politecnico di Torino, Torino, I 10129 - Italia*
[2] *Centre de Thermique de Lyon (CETHIL), UMR 5008, INSA de Lyon, Villeurbanne, F 69621 - France*

ABSTRACT

This work is aimed at assessing the economical feasibility of a retrofit intervention consisting into the façade renovation of an office building, built in the 70s and located in Italy near Torino. The office building, characterized by high occupancy rates, very high internal loads, steel structure and light concrete floor, has a glazed envelope presenting relevant signs of degradation and obsolescence.
The energy saving potential of nine renovation alternatives resulting from dynamic simulations has been evaluated with reference to the heating and cooling energy demand. The economic feasibility has been evaluated in terms of annual savings and pay-back period of the investment. Results are presented here.

KEYWORDS

Envelope retrofitting, Transparent façade, Data centre, Building energy simulation, Economic feasibility.

1. INTRODUCTION

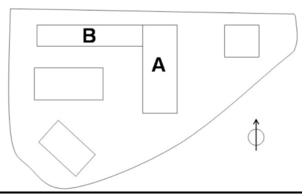
Adoption of light and highly transparent envelope in tertiary buildings is a questionable choice when the climate, as for the Italian one, is characterised by high solar radiation. In particular, when internal gains are relevant, as in a data elaboration centre, solar gain should be avoided. On the other side, transparency means higher architectural appearance and gives a high-tech mark to the building.
For this reason in Italy this kind of envelope is often used, especially in the case of representative office buildings. However, while in new building the last generation of high performance glazing and shading devices is used and the negative effects result minimised, in buildings of 70s and 80s the use of transparent façades caused relevant energy consumption and a poor IEQ. The largest part of these buildings has been or is being retrofitted.
The main problems are experienced by the users, exposed to low radiant temperatures and cold draughts in the winter period and to high solar gains in the summer period. Furthermore the use of VDT has lead to more restrictive requirements for what concern visual comfort, that are rarely satisfied.
Unfortunately in many cases the building owner is interested in evaluating the economical feasibility of a retrofit intervention mainly on the basis of the ratio savings

to investment. The simple renovation of the glazed façade is rarely profitable, being this kind of intervention expensive and slowly repaid (Kaklauskas, 2006).
In this paper the technical and economical feasibility of a retrofit intervention on a data elaboration centre is presented.

2. BUILDING DESCRIPTION

The retrofit assessment concerns an office building of 25.000 m^2 hosting a bank data centre and located in Moncalieri, near Torino (Lat. 45°7', Long. 7°13').
It is made up of two blocks, one oriented E-W (building A) and the other oriented N-S (building B). In Table 1 the main geometric features are presented.

TABLE 1
Geometric data of the buildings

	Conditioned floor area [m^2]	Net volume [m^3]	n. of floors	Height [m]	Façade surface [m^2]	
Building A	12000	36200	6	22	5300	
Building B	13000	56500	4	20	5700	

The building, built in the '70, has a steel structure and light concrete floor. The building envelope is a glazed façade with a double window, having a single glass pane. An internal venetian blind is located between the two glass pane. Opaque elements are insulating board covered on the outside with painted glass. The building has therefore light thermal inertia. The façade presents today relevant signs of degradation and obsolescence; in particular, the main problems regard: poor water and air tightness, poor thermal insulation and ineffective solar shading devices. In figure 1 some pictures of the façade are shown.

Figure 1: View of the façade

3. RETROFIT SOLUTIONS

The retrofit scenarios concerned the renovation of the old façade. It was defined taking into account the requirements of the building owner who asked to compare conventional and not too much expensive solutions, in order to evaluate the economical feasibility of an ordinary retrofit intervention.
Assuming that the performance of a light glazed envelope in terms of thermal loss and solar gain is mainly influenced by the percentage of the glazed part and by the

values of thermal transmittance and total solar energy transmittance, an array of 3x3 solutions was identified:

1) completely glazed façade with string course (A_g/A_{tot} = 90%);
2) bipartite façade with an opaque insulated panel in the lower part (A_g/A_{tot} = 65%);
3) tripartite façade with an opaque insulated panel in the upper and lower part (A_g/A_{tot} = 45%).

As far as window systems are concerned, the following systems were selected:

a) Double glazing (6/12/6) with an external selective glass and an internal low-emittance glass (U= 1.7 W/m^{2}K, *g* = 0.23, TL = 0.5), no shading devices;
b) Double glazing (6/12/6) with an external clear glass and an internal low-emittance glass (U= 1.7 W/m^{2}K, *g* = 0.6, TL = 0.75), external roller shade (TS = 0.07, RS=0.55);
c) Double glazing (6/12/6) with an external clear glass and an internal low-emittance glass (U = 1.7 W/m^{2}K, *g* = 0.6, TL = 0.75), external venetian blind.

The frame is aluminium with thermal break and the opaque panel has a thermal transmittance U = 0.52 W/m^{2}K.

It is important to underline that solutions with the same energy behaviour can perform differently for what concern thermal and visual comfort. Therefore a choice cannot be based simply on the results coming from energy simulations. Especially for what concern visual comfort in a data centre, where all the users work on VDT, the luminance control is one of the most important issues. The most appropriate solution in this direction should be the external venetian blind which is able to completely avoid the direct component of solar radiation (Vosilla, 2006).

4. SIMULATION TOOL, MODELLING ASSUMPTIONS AND INPUT DATA

A dynamic simulation model of the building has been implemented in the EnergyPlus^{TM} simulation tool (Crawley et al., 2001). As a first step, a simulation of the building as built has been performed in order to asses reference values of energy demand for heating and cooling. Due to building destination, a careful investigation on internal loads has been made.

Building A has been partitioned into 5 homogeneous thermal zones: 3 zones for office spaces and 2 inter-zones unoccupied to account for the two technical sub-floors. Building B has been partitioned into 7 homogeneous zones, one for the basement and the others for each office floor. Thermal transmittance and internal specific heat capacity (ISO/DIS, 2005) of each envelope components are reported in Table 2. Internal loads are reported in Table 3.

Since the work is focused on the energy impact of envelope retrofit measure, the simplest HVAC system available has been chosen (an all air unit). Sensible heating and cooling energy are then derived form the resolution of the air heat balance. The air temperature set points and the continuous operating control types adopted are reported in Table 4.

The sensible and latent energy for ventilation has been determined off line assuming an isothermal air inflow and a humidity ratio such as to guarantee an indoor air relative humidity equal to 45% in winter, 55% in summer and 50% in intermediate seasons. The human water vapour production has been assumed equal to 60 g/h and the ventilation flow rate per person equal to 11 l/s per person (UNI 10339, 1995).

Hourly weather data referred to the location of Turin come from the International Weather for Energy Calculation database (IWEC weather files) developed by ASHRAE in 2001. To determine the annual energy thermal and electrical demand, an annual global efficiency of the thermal system equal to 0.8 and a mean annual COP equal to 3.5 were assumed. The annual cost for space conditioning is determined assuming a thermal energy cost equal to 0.05 €/kWh$_t$ and an electric energy cost equal to 0.10 €/kWh$_e$ as reported by building owner.

TABLE 2
Thermal transmittance and internal specific heat capacity of the envelope components of the buildings

BUILDING A			BUILDING B		
Component	U [W/m²K]	χ_i [kJ/m²K]	Component	U [W/m²K]	χ_i [kJ/m²K]
External wall n. 1	0.521	3.8	External wall	0.500	4.2
External wall n. 2	2.264	1.5	Window n. 1*	6.408	-
Window n. 1§	6.295	-	Window n. 2 ¤	5.927	-
Window n. 2 ¤	6.267	-	Internal wall n. 1	0.568	3.6
Internal wall n. 1	0.568	3.6	Internal wall n. 2	0.815	27.3
Internal wall n. 2	0.444	25.4	Internal wall n. 3	0.444	25.4
Plane roof	1.673	36.2	Plane roof	0.753	15.2
Internal ceiling	1.393	24.2	Internal ceiling	0.597	14.4
Internal floor	1.307	41.5	Internal floor	0.597	37.4

§ SHGC of the shaded construction 0.617, of the construction not shaded 0.859.
* SHGC of the shaded construction 0.618, of the construction not shaded 0.859.
¤ SHGC = 0.859.

TABLE 3
Internal loads

BUILDING A			BUILDING B		
Load	Value	Schedule	Load	Value	Schedule
Occupants (1.2 met, fraction radiant of 30%)	842 §	8:00 ÷ 13:00	Occupants (1.2 met, fraction radiant of 30%)	1187 ¤	8:00 ÷ 13:00
	421	13:00 ÷ 14:00		594	13:00 ÷ 14:00
	842	14:00 ÷ 18:00		1187	14:00 ÷ 18:00
Lights (fraction radiant of 37%)	20 W/m² *	8:00 ÷ 18:00	Lights (fraction radiant of 37%)	20 W/m² *	8:00 ÷ 18:00
Equipment	200 W/empl.	8:00 ÷ 18:00	Equipment	200 W/empl.	8:00 ÷ 18:00

§ The value corresponds to an occupancy area of 14 m²/employee.
¤ The value corresponds to an occupancy area of 10.8 m²/employee.
* Constant value referring to distribution areas (corridors, lobbies, equal to 14% of the floor area). In the office areas the value is reduced to 12 W/m² in winter and to 6 W/m² in summer.

TABLE 4
Control type and air temperature set point

From	To	Setpoint [°C]	Control type
10/15	3/15	21	Single heating set point
3/16	5/31	23	Single heating/cooling set point
6/1	8/31	26	Single cooling set point
9/1	10/14	23	Single heating/cooling set point

5. ENERGY AND ECONOMIC EVALUATION OF RETROFITTING MEASURES

To evaluate the performance of the building envelope, comparison between *ante* and *post operam* has been made not only in terms of primary energy demand and electric energy demand, but also in terms of ambient sensible heating/cooling energy excluding the contribution of the energy for ventilation.

The differences between the sensible heating and cooling energy assessed for the retrofitted configurations and the reference configuration are shown in Figure 2. It is possible to see that all the design alternatives reduce the ambient heating energy (approx 38 kWh/m^2 for building A and 46 kWh/m^2 for building B): all the solutions provide, more or less, the same performance. On the contrary, as far as cooling energy is concerned, reductions depend on design alternatives selected. One of them for example leads to a small increase of the cooling energy (solution 1-a). Even the most performing design (solution 3-b) cannot reduce the cooling energy amount of more than 10÷11 kWh/m^2.

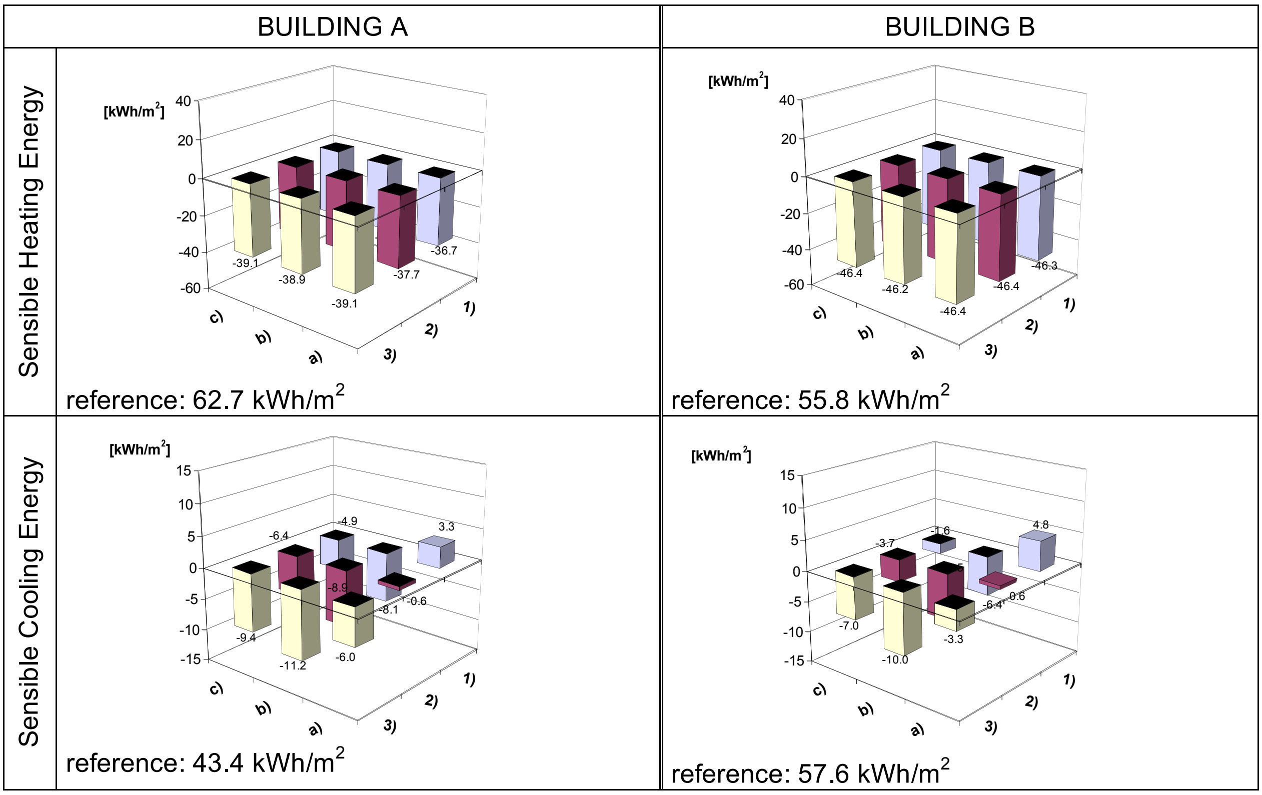


Figure 2: Differences between the sensible heating and cooling energy divided by floor space assessed for the retrofitted configurations and for the buildings as built.

However, in order to have a more realistic evaluation of the design alternatives, also the energy demand for ventilation has to be considered. Annual primary thermal energy, electric energy consumption and cost for conditioning of each building are reported in Table 5 for each design alternative. The percentage reduction in the cost is also reported. The influence of the ventilation on the total load is greater in building B than in building A, due to the smaller occupancy rate (m^2/employee, see Table 3). This results in a thermal energy demand comparable between the two buildings.

Taking into account the energy required for ventilation, reductions in energy demand due to an upgrade of the façade are, obviously, much smaller than reductions in ambient sensible energy.

In order to evaluate the economical feasibility of the proposed retrofits, the following procedure has been used. Assuming a PBP of 40 years and an annual interest rate of 5.62 % (values commonly adopted by the building owner to determine its investments) the maximum allowable cost (per unit surface) of the façade for each solution was calculated (last column of Table 5). As a result, it emerged that all these costs were much lower than currently market costs relative to the design alternative, ranging between 300 €/m^2 (solution 1-a) and 400 €/m^2 (solution 3-c). Market costs, comprehensive of laying, have been determined assuming a module of 1.2x3.5m and takes into account the discount due to a supply equal to the façade area.

TABLE 5
Annual thermal primary energy and electric energy consumption, cost for conditioning, divided by floor space; percentage cost reduction for each building. Cost per façade square meter that lead to a 40 year PBP of the façade renovation investment (last column).

	BUILDING A				BUILDING B				A+B
Config.	Thermal energy	Electric energy	Cost	Cost reduction	Thermal energy	Electric energy	Cost	Cost reduction	Façade cost §
	[kWh$_t$/m^2]	[kWh$_e$/m^2]	[€/m^2]	[%]	[kWh$_t$/m^2]	[kWh$_e$/m^2]	[€/m^2]	[%]	[€/m^2]
As built	157.5	18.5	9.82		158.5	23.6	10.41		
1-a	112.4	19.4	7.63	– 22	101.0	24.9	7.67	– 26	98
1-b	113.2	16.1	7.33	– 25	101.8	21.8	7.37	– 29	109
1-c	112.4	17.0	7.41	– 25	101.8	23.2	7.50	– 28	105
2-a	110.7	18.2	7.44	– 24	101.0	23.8	7.54	– 28	104
2-b	111.5	15.8	7.22	– 26	101.0	21.4	7.31	– 30	112
2-c	110.7	16.6	7.29	– 26	101.0	22.5	7.42	– 29	109
3-a	109.0	16.7	7.20	– 27	101.0	22.7	7.42	– 29	111
3-b	109.0	15.2	7.06	– 28	101.0	20.7	7.22	– 31	117
3-c	109.0	15.7	7.10	– 28	101.0	21.6	7.31	– 30	115

§ Cost per façade square meter.

6. CONCLUSIONS

The energy and the economic feasibility of the renovation of a data elaboration centre façade has been evaluated by means of dynamic simulations. The performed analysis shows that just the envelope retrofitting is not an effective solution as far as energy and economy savings are concerned. However, apart from the reduction of the energy demand, other benefits must be considered in the façade renovation. These are:

- a reduction of maintenance expenses due to the abandonment of the present façade, whose condition can no more guarantee airtight, watertight and operation of solar shadings;
- an increase in the indoor environment comfort conditions (thermal, visual and acoustical) – especially an increase of the floor area in comfort condition;
- the image benefit that a renovation of the façade can lead to the building owner.

7. ACKNOWLEDGEMENTS

This work was carried out within the national research program “Energy and comfort assessment of responsive building elements” co-funded by the Italian Ministry for Universities and Research (PRIN 2005).

8. REFERENCES

Crawley, D.B., Lawrie, L., Pedersen, C. et al. (2001). EnergyPlus: creating a new-generation building energy simulation program. *Energy and Buildings* **33:4**, 319-331.

Flourentzou, F., Roulet, C.A. (2002). Elaboration of retrofit scenarios, *Energy and Buildings* **34:2**, 185-192.

ISO/DIS (2005), Thermal performance of building components. Dynamic thermal characteristics. ISO/DIS 13786.

Kaklauskas, A., Kazimieras Zavadskas, E., Raslanas, S., et al. (2006). Selection of low-e windows in retrofit of public buildings by applying multiple critweria method COPRAS: A Lithuanian case. *Energy and Buildings* **38:5**, 454-462

UNI (1995), Impianti aeraulici ai fini di benessere. Generalità, classificazione e requisiti, UNI 10339, 14.

Vosilla, A. (2006). Criteri e strumenti per l’ottimizzazione della schermatura solare ai fini del risparmio energetico e della qualità ambientale. Ph.D Thesis, Dipartimento di Energetica, Politecnico di Torino.