ENERGY SAVING IN OFFICE BUILDINGS. A CASE STUDY IN ROME THROUGH THE USE OF DOE-2 AND OTHER SIMULATION TOOLS.

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ABSTRACT

A large office building has been the object of a detailed feasibility study in order to select the most effective actions for energy saving in space cooling. Actions concerning the modification of building envelope layout, including materials, shading devices, colours, and retrofit insulation have been tested together with a set of improvements of the lighting system and an extensive use of daylighting strategies. Building energy performances under the various retrofit hypotheses have been assessed by means of DOE-2.1E. Changes in consumption of both electricity and fuel have been evaluated through all year round simulation. The integration of daylighting with lighting controls was simulated using a specific software (LUMENMICRO) in combination with DOE-2. All the actions have been classified according to their economic, energy and environmental performances.

INTRODUCTION

In the framework of a work funded by UE (see acknowledgements), a detailed feasibility study about the implementation of some passive cooling and load control measures has been carried out in 1996. The case study was a large office building hosting the head office of the electric utility of Rome (ACEA), which co-funded the research. In the following, after a brief description of the building and its HVAC and electric appliances, all the retrofit measures will be described together with the simulation methods. In the last paragraph, main energy, environmental and economic results are discussed.

BUILDING ANALYSIS AND AUDIT

The ACEA offices are situated in a nine storey building with a total covered surface of about 30.000 m^2. It has been built at the end of the 50's, with a steel-concrete structure. About 50 % of the 18000 m^2 of facades surface is glazed. The majority of the glazings have a low thermal resistance and poor optical properties. This represents one of the most important problems on the way of improving the energy performances of the envelope. All the external walls typologies have been classified and translated in model input. The main block of the building has an horse-shoe shape with a circular closing element for the first three floors, facing south-east. Thermal zones (i.e. spaces with similar use, thermal loads and same air-conditioning system) have been described in the model according to the present situation of the building. With the support of ACEA engineers, we made a survey of the present HVAC system configuration and operating conditions.

During the survey office occupancy has been estimated taking into account the different use of spaces. In a medium/large office room the occupancy is on average of two people, which brings to a ratio of 15 m^2/capita. In service areas, corridors, stairs of the office blocks people density is the half, i.e. the Area vs. Person Ratio is the double. Time-schedules of people presence have been estimated by means of interviews to employees.

Electric appliances consumption is a major component of internal heat gains of the building. An energy audit of a typical floor has been performed. This floor has been assumed to be representative for an extrapolation of data for assessing loads and end-uses in other areas of the building. Unfortunately no metering could be performed. The energy audit consisted of compiling the list of electric appliances present in the examined area, taking note of their nominal power. Employees were interviewed about their mean behaviour during winter and summer regarding the use of lighting & office equipment. A time-schedule has been produced then for each category of appliances (lighting, computers, photocopiers, printers, fax, electric heaters). It reports the percentage of total installed power actually requested each hour of a day (*load factor)*. As for lighting in rooms different time schedules have been elaborated depending on season (summer & winter) and window orientation.

The space conditioning of the building, in winter and summer operation, is obtained via the combination of two different systems: an air treatment/distribution system and a water treatment/distribution system. As in many other buildings of the same size, the air conditioning task is performed by different plants. HVAC plants and distribution systems have been classified referring to the thermal zones subdivision. Also seasonal and daily regulation strategies of space conditioning have been investigated and described in the model by means of operation schedules.

Based on the data collected and the assumptions on time schedules the complete model of the building and plants has been set up and the present energy behaviour of the building has been simulated. For the Business as Usual case (BaU) the total yearly consumption of electric energy is 2,6 GWh. Fuel (gasoil) consumption is equal to 153956 litres/year. Specific total yearly electricity consumption is equal to 89 kWh/m^2-year, while primary energy for heating is 182,7 MJ/m^2-year. Electricity demand for air conditioning (excluding ventilation fans) amounts to 0,6 GWh/year (23% of total electricity consumption).

DESIGN CRITERIA TO REDUCE COOLING LOADS. METHODOLOGIES

The analysis of retrofit options focused to the following main goals:

- to reduce the solar gains through the building envelope
- to minimize internal gains mainly due to an inefficient lighting system

All the candidate measures have been tested from the point of view of energy and power demand through hourly simulations along a Test Reference Year. A special effort has been done about the exploitation of available daylighting. Most significant interventions rely on the adoption of: advanced glazings, lightshelves and control devices for artificial lighting. These actions have required the use of specific simulation tools in order to overcame some of the DOE-2 limitations. In particular daylighting issues have been studied in more detail by the use of LUMENMICRO simulation tool.

In order to get the best out of advanced glazing we simulated with DOE-2 the effect of a number of glazing options on cooling and heating loads for each orientation of the facades of the ACEA building. To speed up the simulation and get rid of effects not connected with glazing itself, we considered a simplified building, composed of 3 floors with 6 rooms each and facade orientations as in the real ACEA building. The central rooms of each facade have the same floor and window size as a typical office module, and walls with very high thermal resistance in order to insulate them from the other rooms and facades influence. All frames are assumed to be made of aluminium with thermal break, since present frames made of aluminium without thermal break and with high air leakage have to be substituted anyway, due to their age and the discomfort they cause to users. So the reference case for glazing is assumed to be, as in the present situation, a clear single pane 3mm thick but mounted on a frame made in aluminium with thermal break instead of one without thermal break.

Starting from heating and cooling loads calculated with DOE-2 under different glazing choices, we calculated also electric energy required by the compression units in order to meet these loads, assuming a COP of 3,5, and a distribution efficiency of chilled water of 0,95. We didn't consider any possible reduction in energy for air distribution since the system is working at fixed air volume rates. Similarly, we calculated fuel energy consumption at the burner (burner efficiency 0,9, distribution efficiency 0,85). We then calculated primary energy consumption and CO_2 equivalent emissions for cooling and heating.

Glasses considered for simulation were:

- single pane clear glass (from DOE-2 library), on old aluminium frames without thermal break (that is the present situation or BaU);
- single pane clear glass (from DOE-2 library);
- single pane tinted (from DOE-2 library);
- single pane low-emissivity (from DOE-2 library);
- single pane selective;
- double pane clear glass, air filled, (from DOE-2 library);
- reflective+air+clear (from DOE-2 library);
- selective+air+clear (from DOE-2 library);
- selective+argon+clear (from the specifications of two different manufacturers);
- reflective+argon+low emissivity;
- reflective+argon+clear.

Based on the results of the simulations, we can comment that:

- as expected, in the base case the highest summer cooling loads are on facades WSW, SSE, SSW and highest winter heating loads are on NE, EN and NW.
- glazings achieving the highest reduction in primary energy consumption are double pane with one pane reflective or selective;
- reflective double glazings produce a large reduction in cooling loads, especially on facades facing S, W, and E, but they have visible transmittances (T_{vis}) between 0,17 and 0,28; the reduction in daylight availability is very high, and

use of artificial lighting increases accordingly; the windowed area is in this case not large enough to make attractive the use of these glazings;

- the three kinds of double pane selective glazing achieve a good all year-round reduction. The best one is also the one with better visible transmittance (T_{vis}=0,66).

When the values of T_{vis} for selective glasses are compared with the value (0,78) achievable with double pane clear glasses, we see that the reduction in the availability of daylighting can be relevant. Since from simulations with LUMENMICRO and measurements (see following paragraphs) we verified that interior illuminance is often much higher than required, a small reduction of daylighting can be accepted without a large penalty on artificial lighting consumption and at the same time reducing cooling loads (because of selectivity) and heating loads (because of low-emissivity in the infrared range and increased U-value) with respect to single pane clear. Moreover from preliminary calculations we saw that the higher price of the best selective is well counterbalanced by its performances. Even if best performances of selectives are achieved on WSW, SSE, and SSW facades they achieve good savings also on other facades. Double clear glazings anyway are an improvement with respect to single pane which is worth of consideration if there is a necessity to keep first costs as low as possible. The average reduction of primary energy consumption is only 1/3 of the savings achieved by selectives but with first costs which are also reduced of a factor 2,5÷3.

SIMULATIONS WITH LUMENMICRO FOR DAYLIGHTING ORIENTED ACTIONS

It is well known that the lightshelf is essentially a reflecting shelf which is located at an intermediate height of the window. It reduces the quantity of light reaching the area close to the window, while redirecting solar rays; it allows for a deeper penetration to the areas remote from the opening, making illuminance distribution inside the room more uniform and reducing, if correctly designed, the risks of glare.

Threshold angles and conditions for the design of an efficient lightshelf, in this situation are selected in order to shade the lower window in summer, redirect light, avoid glare.

A different configuration has been chosen for two groups of orientations:

- mainly South facing facades (orientations SSW, WSW and SE;
- mainly North facing facades (NE and NW).

The dimensions of the lightshelf are primarily determined by shading requirements. The reflectances of the lightshelf should be determined by the lighting demand at various times (of day and of year). Following the general criteria above, a simulation model has been set up taking into account the following issues:

- suitable modelling of the room modules;
- choice of the sample room (according to: floor height, orientation, geometry and materials);
- choice of the sample days of the year;
- number of hours to be simulated for each sample day.

The structure of the whole building is based on a module with size 4 x 6 x 3.10 m (figure 1); different room sizes, according to their use, are obtained by the single or multiple combination of the base module. Only for the orientation NW rooms have the length of 7 m. As shown in figure 1, the room geometry is characterised by the presence of internal obstructions, i.e. the central pillar, and by the fact that windows are slightly recessed from the external facade. For each relevant orientation and floor height the sample rooms have been chosen in order to represent the average conditions.

Sample days have been selected in order to represent homogeneous period of the year for what concerns climate and sky luminance conditions. It has been decided to simulate a winter and a summer day since these are the most critical situations, with maximum solar gains or very low external luminance values, in particular under overcast sky conditions.
As the DOE-2 simulation code does not allow for a complete simulation of complex optical devices like lightshelves are, numerical daylighting simulation has been carried on using a commercially available computer program, LUMENMICRO. Complex geometry, reflectances and transmittances of materials, as well as latitude, hour and date, may be simulated in a sufficiently accurate way.
Results of daylighting simulations with LUMENMICRO have been translated into several day schedules describing the hourly profile of power uses for artificial lighting according to:

- orientation of the room
- summer or winter situation
- clear or overcast sky conditions

All these schedules have been nested in typical weeks for each month of the year for each orientation. In a typical week the amount of clear or overcast sky days are proportional to the average values recorded for the month.
Modified time-schedules were then fed into DOE-2.

PROPOSED ACTIONS AND DETAILED FEASIBILITY STUDY. SIMULATION METHODS

From daylighting analysis and a review of retrofit options, a set of actions has been to be possibly implemented for ACEA building. The list of all actions is summarised in the following paragraphs. Words in italic capital letters are the nicknames of the actions. The methods followed for each simulation (including the code-words utilised in the Building Description Language of the DOE-2) are described in detail.

Surface albedo increase (*ALBEDO*)

This action consists in the change of surface properties of some external elements of the building.

In total 41% of envelope surface, which corresponds to the 63% of walls surfaces is assumed to be white painted. The code word SOLAR-ABSORPTION, describing the property of the selected external walls, has been set equal to 0,2.

Double pane clear glasses on all the facades (*DOUBLE CLEAR*)

In all office rooms double pane clear glasses (GLASS-TYPE-CODE = 2004) are installed on new aluminium frames with thermal break in all office rooms. In this simulation a value of the FRAME-CONDUCTANCE= 4,1 W/m^{2}K (excluding outside air film resistance) is applied compared to the present value of 10.7 W/m^{2}K. U-values are calculated hour by hour by the program depending on wind speeds. Another effect which has been considered is the reduction in air-infiltration. In case of renovation for a similar office in Rome, Italian codes state a frame allowing 0,46 volumes/hours of air changes.

Translucent louvers in all office windows (*LOUVERS*)

All office windows are equipped with translucent louvers. Main simulation parameters are: the probability of use of louvers (SUN-CTRL-PROB 0,9) and Shading Coefficient Multiplier (equal to 0,4).

Increased insulation of walls and roofs (*INSULATION*)

Pre-mounted panels of insulation material are installed in the portions of the wall located under the window sills. Panels are characterized by:
CONDUCTIVITY = 0.032 W/mK,
THICKNESS=0.04 m
DENSITY = 120 kg/m^3
SPECIFIC-HEAT= 800 J/kg K
Non paved roofs are retrofitted with an internal insulating layer defined as follows:
CONDUCTIVITY = 0.038 W/mK
THICKNESS=0.04 m
DENSITY = 100 kg/m^3
SPECIFIC-HEAT= 800 J/kg K

Overhangs on south facades (*AL OVERH*, *ACRYLIC OVERH*)

This action implies the installation of horizontal shading shelves on south facades of the building. The action is restricted to the office areas. In all the frames an element (1m wide and 1,9 m long) must be added. These shelves can be made of plastic (with a metallic structure) or aluminium foils. Simulation has been performed maintaining the existing frames and glasses.

Double pane selective glasses on all the facades (*SELECTIVE*)

Selective glasses are installed in all windows of office rooms. Simulations have been performed assuming that new aluminium frames (with thermal break) are adopted. Properties of selective glass, as specified by the Italian producer, are:
SHADING-COEF=0.39
GLASS-CONDUCTANCE= 1.14
VIS-TRANS=0.66.
As can be noted the value of luminous efficiency of the glass (K_e= T_{vis}/ SC) is particularly high (1.69).
Time schedules for office artificial lighting have been modified accordingly to the reduced T_{vis} value.

Mix of actions concerning building envelope (*MIX-ENV*)

This action implies the contemporary application of: *ALBEDO*, *DOUBLE CLEAR*, *OVERH (Acrylic)*, *INSULATION*.

Variable Speed Drives for water pumps (*VSD*)

Circulation pumps equipped with inverters for controlling the speed of motors are utilized for the water distribution system (CIRCULATION-PUMPS=VARIABLE-SPEED).

Medium efficiency renovation of fluorescent lighting system (*LIGHTS1A*).

High efficiency fixtures provided with efficient fluorescent lamps (26 mm diameter type) powered by electronic ballast have been adopted. In particular the ratio LIGHTING/AREA for offices is reduced to 10,4 W/m^2 (in BaU this value is equal to 21,9 W/m^2), while in corridors and other service areas the value is 7,8 W/m^2 (compared to 14,8 W/m^2 in BaU).

High efficiency renovation of fluorescent lighting system (*LIGHTS1B*)

Same renovation as in *LIGHTS1A* is adopted for corridors. A more advantageous renovation for room lighting systems is assumed. This action highly reduces the installed power (LIGHTING/AREA ratio drops from 21,9 W/m² to 8,1 W/m²) still providing adequate illuminance levels.

Renovation as in *LIGHTS1A* and installation of occupancy sensors (*LIGHTS2A*)

The effect of occupancy sensors on consumption for lighting in rooms, if *LIGHTS1A* is assumed, has been assessed. Ceiling mounted PIR (Passive Infra-Red) occupancy sensors have been considered (Swiss manufacturer). An average reduction of consumption of 10% during morning and 20% during afternoon has been estimated. New LIGHTING-SCHEDULEs for office rooms have been set accordingly.

Renovation as in *LIGHTS1B* and installation of occupancy sensors (*LIGHTS2B*)

Same installation as in *LIGHTS1B* scenario with the addition occupancy sensors (see previous paragraph for details) is considered. Also in this case new LIGHTING-SCHEDULEs have been set.

Replacement of office equipment according to EPA standards (*EQUIP-EPA*)

This action does not decrease installed power, but modifies EQUIPMENT_SCHEDULEs shortening full-usage hours (that is consumption) of appliances according to EPA standards about stand-by operating mode. I.e. for the computers we assume a reduction of consumption ranging from 8% to 40% depending on time of the day.

Replacement of office equipment according to Swiss stand-by target values (*EQUIP-CH*)

EQUIPMENT_SCHEDULEs have been modified in order to implement Swiss standards which are more restrictive than EPA ones.

Integration of daylighting and efficient artificial lighting (*DAYL.A*)

This scenario is the combination of different individual actions:

- installation of lightshelves on prevailing south facades
- installation of high efficiency lamps and fixtures as in scenario *LIGHTS1B*
- installation of dimmers in rooms provided with lightshelves
- installation of double clear glasses on every facade.

The evaluation of shading and daylighting effects on artificial lighting and HVAC loads is the priority objective of this scenario.

As previously described lighting time-schedules have been set according to the results of daylighting simulations with LUMENMICRO.

Integration of daylighting and efficient artificial lighting (*DAYL.B*)

This action differs from the previous one since:

- instead of dimmers, occupancy sensors are installed in the whole building
- selective glasses are present in the North facing windows
- the office equipment complies with the *EQUIP-CH* standards

SIMULATION RESULTS. DISCUSSION

Actions have been evaluated according to a set of performance parameters. They are:

- Cost of Conserved electric Energy (CCeE), to be compared with a purchase price typical of the service sector of 0,092-0,102 ECU/kWh (without or with penalties for low power factor and harmonics pollution);
- Net Present Value of the action over lifetime (NPV) to be compared with an annual energy bill of 438 kECU in Base Case;
- present value of investment (investment in year zero + actualized replacement expenditures);
- total annual energy bill (electric energy charge + power demand charge + fuel expences);
- simple Payback Time (PT);
- percentage savings in electricity consumption for cooling;
- percentage change in total electricity and fuel consumption;
- percentage primary energy savings;
- percentage CO_2 emissions reduction.

All economic parameters have been calculalated assuming a 8% real interest rate. Table 1 shows the results of simulations.

Five actions show a CCeE definitely higher than the purchase price of a kWh for a customer of the size of ACEA building. They are *INSULATION*, Aluminium and Acrylic *OVERHangs*, *LOUVERS*, and *ALBEDO* increase. The same actions, obviously, show a negative value of the NPV. They will therefore be discarded based on economic considerations, even if they achieve in some cases interesting savings in electricity consumption for cooling (around 10% or more for albedo and overhangs, more than 20% for louvers). Anyway their impact on primary energy and CO_2 emissions is low (0,5÷4%).

The installation of double pane clear glasses (*DOUBLE CLEAR*) shows a negative value of the CCeE. This is due to the fact that every year the reduction in costs for fuel and power is higher than annual capital costs. Its effects on cooling energy are very limited (3%). Its impact is obviously more important on winter energy needs, and overall primary energy reduction is 5%.

A combination of Acrylic overhangs (not cost effective *per se*, but achieving a 10% reduction in cooling energy consumption) and double clear (cheap, but with small effect on cooling demand) achieves a good value of CCeE (0,040 ECU/kWh), a PT of 9,7 years and a 13% reduction in cooling energy consumption. Both electricity and fuel consumption are reduced with respect to base case. This combination is also likely to reduce to a certain extent some acute discomfort situations due to high temperatures reached by existing single pane glasses when directly exposed to sunshine. For this scenario (*OVERH.&DOUBLE*) primary energy savings are in the order of 5%.

The combination of actions concerning the envelope layout (*MIX-ENV*) has the second best score in cutting down electricity consumption for cooling (-27%). This action results at the limit of cost effectiveness (CCeE = 0,101 ECU/kWh). It achieves a reduction in both fuel and electricity consumption, and a primary energy reduction of 9%.

Frequency inverters to drive water pumps at variable speed (*VSD*) both in summer (chilled water) and in winter (hot water), appear to be a low investment with a good CCeE (0,028 ECU/kWh). Savings in cooling electricity are around 6%, but the impact on total primary energy consumption is low (1,6%). PT is less than 5 years.

The two scenarios of replacement of office equipment with high efficiency equipment show the lowest CCeE (0,015 ECU/kWh), since we assume a gradual substitution with high performance machines only when there is a need for replacement. Especially the Swiss standards scenario is a very cost effective option, but as for the other actions above, when considered alone the impact on cooling energy (-2,4%) and total primary energy (-4,3%) is limited. The reduction in power demand charge (from 90 to 66 kECU/y) is worth of interest.

The substitution of single pane glazings with double pane selective ones on all the facades (*SELECTIVE*), is one of the actions with highest impact on cooling energy requirements (-22,5%), and achieves the highest reduction in fuel consumption (-26,5%). The increase of electric consumption for lighting is low, since we chose a glass with high K_e (T_{vis} = 66%, K_e = 1,69) and very low heat transfer coefficient (U = 1,2 W/m^2 K). In spite of a relatively high initial investment (440 kECU, comparable to annual total energy bill), it achieves an interesting cost of conserved energy (0,066 ECU/kWh), and a PT of 11 years, more than reasonable when compared to a lifetime of 40 years. Primary energy savings are around 7%.

The four lighting retrofit scenarios are actually among the best six as for total electric consumption and primary energy savings. Lighting retrofits are important components also of the two lowest energy scenarios (*DAYL.A and DAYL.B*). Primary energy savings for these 6 scenarios range from 18% (*LIGHTS1A*) to 35% (*DAYL.B*). CCeE ranges from 0,054 (*LIGHTS1B*) to 0,089 ECU/kWh (*LIGHTS2A*), and PT from 7,2 (*LIGHTS1B*) to 10,9 years (*DAYL.A*). Payback Times of this order might appear high, but we should consider that for lifetimes in the order of 30 years, a PT of 9 years corresponds to an internal rate of return of about 11% (real).

Particularly interesting in this group are *LIGHTS1B* and *LIGHTS2B*. The latter makes also use of infrared occupancy sensors. They produce reductions in total electric energy of 25÷30%, but also an increase of about 10% in fuel consumption for space heating.

Out of this couple, *LIGTHS1B* shows the lowest PT (7,2 vs. 8,7 years), lowest CCeE (0,054 vs. 0,071 ECU/kWh), and the highest NPV. Scenario 1B has the highest PT of all the 19 scenarios considered and 2B is the third best. In the case of *LIGHTS1B*, primary energy savings are about 20%, and reduction in electric energy for cooling is 5%. 2B scores respectively -24% and -6%.
In conclusion these two scenarios should have a high priority if a medium level investment (between 100 and 150% of annual energy expenditures) is planned.

If a higher initial investment is feasible, then *DAYL.B* will achieve a number of goals. Primary energy savings are as high as 35%, electric power demand is cut down to one half, total electric energy is reduced by more than 40%, electric energy for cooling by 34%. This requires an investment nearly equal to three times the annual total energy bill, but gets fairly good economic performances: CCeE is 0,075, simple PT is 10 years, and net present value is the second best, even if not high in absolute value (around 50% of annual total energy bill).

In case of the construction of a new building, a comprehensive scenario like *DAYL.B*, would increase its cost effectiveness due to the sensible reduction in size and power of air conditioning plant and distribution equipment.

CONCLUSIONS

By means of a well tested and powerful software as DOE-2, a set of actions for achieving energy savings in a large office building have been assessed. In order to verify the convenience of the use of lightshelves, and due to the limitations of DOE-2, an additional set of input data about daylighting has been obtained with LUMENMICRO. With a carefull selection of representative conditions (orientation, sample days, floor location,...) the complexity of the simulation has been kept limited, while allowing at the same time a relatively accurate estimate of the effects of lightshelves in the specific design configuration
Good economic results have been assessed for several retrofit actions in the studied building, allowing electricity saving up to 42% and fuel saving up to 26,5%.

In comparing the different actions, we should keep in mind that according to our audits a high share of electric energy consumption in ACEA building is due to area lighting (45%) and office equipment (16%). Even important reductions in cooling loads, then, will not imply high percentage savings compared to total electric and primary energy consumption.
When dealing with a new building at the design stage, or a new air conditioning plant, much more options would be available and incremental investments for the same action would generally be lower.
The building under study is representative of a typology relatively diffused in Rome. Hence the results obtained, which show the economic attractiverness of certain envelope and lighting technologies not only in new constructions but also in retrofits, claim for an extension of the research to verify the feasibility of wide implementation of the most promising options.

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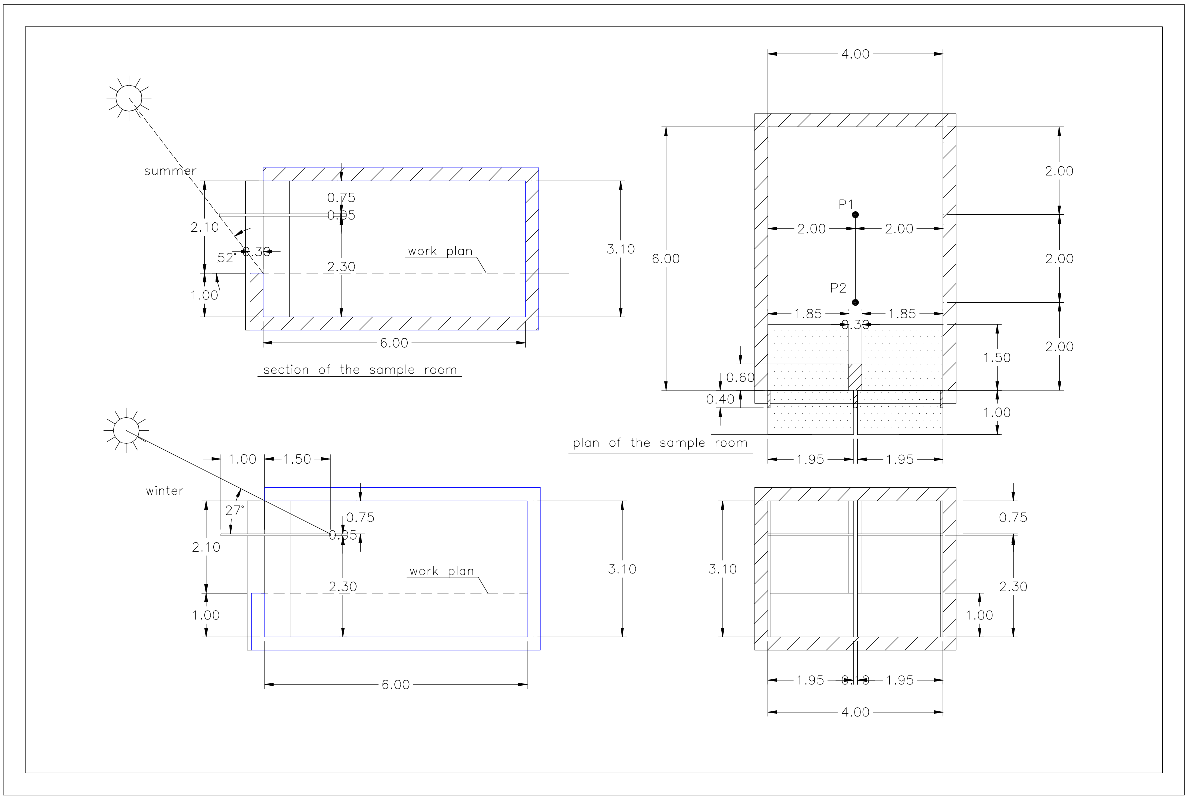

Figure 1. Section, plan and prospect of the sample room

Name	total electricity saving [%]	cooling electricity saving [%]	fuel saving [%]	primary energy saving [%]	CO_2 emissions reduction [%]	Total energy bill [kECU/y]	Present value of invest [kECU]	CCeE [ECU/kWh]	Life cycle Net Present Value [kECU]	Simple Payback [y]
BaU	-	-	-	-		438	-	-		-
Albedo	2,8	12,6	-8,4	0,7	0,5	420	32	0,1541	-44	∞
Double clear	1,3	3,0	21,7	5,0	5,5	387	169	-0,3747	192	5,6
Al Overh.	2,2	10,2	-5,5	0,8	0,6	416	205	0,4127	-183	111,4
Acrylic Overh.	2,2	10,2	-5,5	0,8	0,6	416	54	0,1537	-357	29,4
Overh. & Double	3,3	13,2	11,2	4,7	4,9	394	223	0,0400	65	9,2
Insulation	0,3	0,8	6,9	1,5	1,7	410	145	0,6232	-54	18,0
Selective	2,4	22,5	26,5	6,8	7,3	379	441	0,0658	20	11,4
Louvers	4,7	20,6	-2,1	3,5	3,3	405	221	0,2025	-115	17,9
Mix-Env	6,7	26,9	17,4	8,7	8,9	379	390	0,1009	0	10
VSD	1,6	5,6	1,9	1,6	1,7	411	31	0,0275	23	4,9
Lights 1a	23,6	4,1	-8,0	17,9	17,1	356	630	0,0762	110	9,4
Lights 1b	25,9	4,7	-9,4	19,5	18,7	351	526	0,0542	286	7,2
Lights 2a	30,1	4,9	-9,8	22,9	22,0	340	860	0,0886	32	10,7
Lights 2b	31,9	5,9	-10,9	24,2	23,2	335	757	0,0707	200	8,7
Equip-CH	5,7	2,4	-2,1	4,3	4,1	402	0	0,0148	46	0,0
Equip-EPA	3,8	1,7	-1,4	2,8	2,7	407	0	0,0152	30	0,0
Dayl. A	30,8	19,8	5,0	26,1	25,5	318	1093	0,0811	108	10,9
Dayl. B	41,9	34,2	5,7	35,4	34,6	287	1302	0,0748	229	10,1

Table 1. Main results of simulations for ACEA building.