ENERGY RETROFIT OF RESIDENTIAL BUILDINGS IN HOT CLIMATE

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ABSTRACT

The topic of the research is to analyze the energetic efficiency of residential buildings in hot climates. The idea comes from the need to analyze the "case of hot climates" separately, as the European directives and all the studies so far undertaken in this area, too frequently not suit well to this case. Research begins with the evaluation of the energy performance of buildings (heating and cooling), analyzes the potential for energy retrofit, considers energy savings, economic feasibility and comfort improvements. With appropriate precautions and adopting new and more efficient materials and technologies, it's possible to significantly reduce the energy consumption of buildings, with an annual energy saving up to 44%.

1. Problem Statement

The increasing demand for energy, resulting in cost growth and related environmental problems, led to an increased interest in the design of energy-efficient buildings. In Mediterranean climate, warm and rather humid, it becomes of prime importance to be able to ensure a high indoor comfort. Buildings are built to protect people from adverse weather conditions, and to ensure a comfortable indoor environment. To achieve these goals a huge amount of energy is consumed in heating, ventilation, cooling or dehumidification. Many attempts have been made in order to use low-power strategies consumption. It is necessary however, to think of appropriate solutions in terms of shading and insulation in order to avoid excessive use of air-conditioning systems and reduce power consumption. To solve this problem an integrated approach is essential. This research focuses on energy upgrading of buildings, (belonging to social housing) in Salerno and Naples, acting on the building envelope, that is, proposing an improvement of materials and characteristics. This paper discusses economically feasible ways and means to choose between insulation measures, better glazing, shading systems and ventilation. Finally a hierarchy of energy-savings measures is deduced from the results. The intention is to demonstrate that an effective energy-retrofit can be done without necessarily going through expensive technologies or ex-novo designs, obtaining interesting results in terms of energy consumption and greenhouse gas emissions, at a cost that can be recovered in a few years, making retrofitting possible even on ordinary buildings and therefore desirable at a urban scale.

2. Strategies

The case of the warm climate needs to be analyzed separately, as the European directives and studies in the field cannot be fully adapted to the problem. In practice the cold climate strategy is "defensive", or rather of protection from cold, on the contrary an intervention in a hot climate needs more flexibility. Starting from a detailed analysis of the case study, in terms of macroclimate, microclimate, solutions and techniques used, a choice of the interventions that should be made, need to be taken, with the aim of reducing the risk of overheating in the summer, encouraging natural ventilation, maximizing the benefits of the solar gains during winter, in order to reduce annual energy consumption and CO_2 emissions. These objectives can be achieved with a bioclimatic approach. The "Climate Responsive Design" is part of an approach to design called "Ecological Sustainable Design (ESD)" based on an analysis of how the shape and structure of a building moderate the climate, in order to obtain a acceptable level of indoor comfort. The active principles of the "Climate Responsive Design" is the understanding of climatic parameters that can influence the process of planning/redevelopment, such as temperature, humidity, wind, light, vegetation, and everything that is related to geographical location. These principles can be applied , even if in a different ways, to retrofitting. We have therefore chosen the case studies in Campania, a region in the south of Italy, buildings belonging to social housing, and signed by designers known and appreciated, objectively valid in terms of design quality, but inevitably obsolete in terms of technological solutions, all these aspects made them particularly indicated for the study. Moreover, in each of the two cases the typology is repeated in the area with variable orientation, which allowed to analyze the effects of orientation on several units.

3. Methodology

The buildings analyzed are representative of the Italian building stock, built from 1950 up to 1980. The energy savings measures were applied by steps, analyzing as first intervention the thermal insulation through the cavity(case study 1) or outside the wall (case 2), the replacement of windows, then the use of a proper shading system and finally the integration of natural ventilation. For each item various options have been tested, choosing from time to time, the most advantageous.

Case Study 1- Quartiere Zevi Salerno

The first case study investigated is a residential building in Salerno, Quartiere INA CASA (social housing) by Bruno Zevi (1955/61). The site has 3 different types of buildings, the study was conducted on type A, at first, chosen for its particular shape. The building has a frame structure, a cavity wall (with an air-gap of 4 cm) and exposed bricks. The site inspection revealed a lack of uniformity in the condition of the neighbourhood. Not always planned maintenance has been carried out. Dwellings have no insulation, some still have single glazing and wooden windows frame, others standard double glazing, or veranda. Simulation was conducted using two software. The first one, Design Builder, is a software that allows to easily create a building model and lead the design of heating, cooling and annual simulation, obtaining a check of energy consumption, CO_2 production, lighting, analyzing the interior comfort, quickly testing different technical solutions by comparing efficiency and costs. Ecotect instead can perform more detailed analysis about energy performance climatic integration of buildings, and through tools for the creation and geometric import of models, it helps to contextualize geographically and characterize technologically the building, providing useful information and suggestions to identify the best design solution needed.

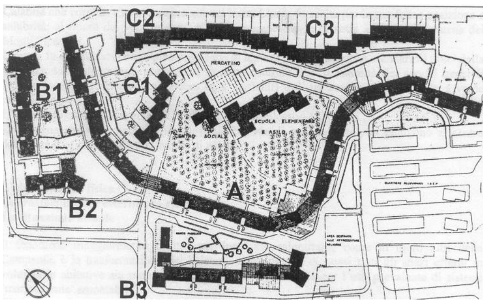


Fig. 1a: Quartiere Zevi- Pastena, Salerno1955/61. Site Plan

Fig. 1b Quartiere INA CASA Bruno Zevi in Salerno

Modelling

To make results generally good, but at the same time to simplify the analysis, the study was conducted on a virtual "slice" of the complex, schematizing the presence of the other units on both sides, with adjacent adiabatic blocks. The input data are related to technical solutions, materials, but also density (assumed to be equal to one person for each room) and activity (sedentary = 90 KW).

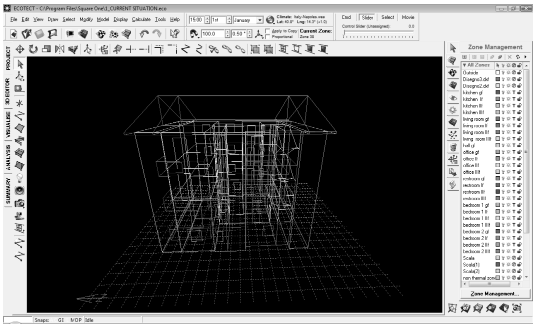


Fig. 2a: Model by the software Ecotect.

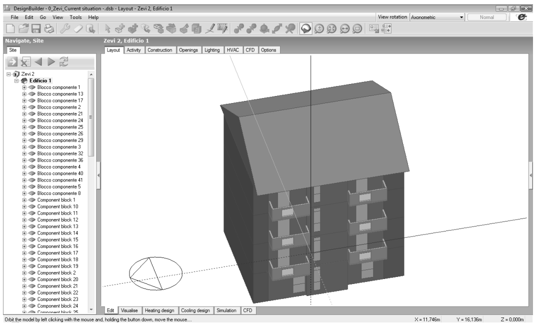


Fig. 2b: Model by the software DesignBuilder**.**

Initially, the block has been studied individually, it means without considering the presence of the context, i.e. of other buildings. The more to make clear the benefits of each intervention, the study was conducted comparing annual consumption of the building in the current situation indicated as "initial condition" (defined by the complete absence of upgrading solutions, that is considering the most disadvantageous situation of the entire complex, the absence of intervention) with those of the solution improved. However, in a second time was carried out a simulation of the performance of the building taking into account the presence of the surrounding blocks (for a total of about seventy) each schematically represented with an adiabatic block, only to verify that the results obtained, particularly from the analysis of ventilation, were not too far from the truth. And in fact the interaction with the surrounding buildings, probably due to the arrangement of blocks and open spaces, turned out to be negligible.

Insulation

Excluding the possibility of placing the insulation on the outside, to keep the exposed brick façade, only two possible ways remained:

1) use an insulating foam inside the internal cavity;
2) use an internal insulation, (although this one involves a loss of volume inside).

the presence of an air-gap of about 4 cm suggested the hypothesis of an internal insulation. It was analyzed the performance of different types of insulation, namely:

- Polystyrene foam, $0.034 < \lambda < 0.04$ [W/mK]
- Polyurethane foam, $0.025 < \lambda < 0{,}035$ [W/mK]
- Vermiculite, $0.05 < \lambda < 0.06$ [W/mK]
- Granular cork $0{,}040 < \lambda < 0{,}045$ [W/mK]

The most efficient insulation system from the standpoint of energy turned out to be the polyurethane foam, however it should be noted that the use of a natural material such as granular cork, can significantly reduce CO_2 emissions in the analysis of the life cycle of the building

Replacement of windows

The second step was to check the positive effects of the replacement of windows (in fact, not all the current owners have carried out this type of intervention over the years). However, having to intervene also in a feasible way from a financial point of view, the proposed solutions aim not only at efficiency but also at simplicity and economy. This is the reason why, an ordinary kind of window, with double clear glass and thermal break, was proposed. From the simulation it appears that the effect is the reduction of energy consumption (especially for heating in winter) up to 9%.

Use of a suitable shading system

The problem of introducing an effective shading system is anything but simple. Different types were studied in order to identify the one characterized by a fairly flexibility in order to reduce the unwanted summer solar gain, but to allow the filtering of winter sun and its beneficial effects, it is also important that the system does not represent an obstacle for natural ventilation. In order to facilitate ventilation, brise soleil were the most convenient. But a study and a design of the geometric characteristics was needed to maximize effectiveness, and also to keep the project affordable. For this purpose, several simulations were run by varying the distance between the plates, depth and angle. With the most effective of these combinations it's possible to get a reduction in energy consumption for cooling in summer up to 5%.

Education to natural ventilation

Natural ventilation is a practice far from innovative, its positive effects on interior comfort were known to the ancients. Practical, socio-cultural and technological reasons have sometimes gradually caused the abandon of this healthy practice, now reduced to a simple air-change, which while necessary for hygiene, is not positive as it could be to indoor environmental conditions. Ventilation can be mechanical or natural. We opted for the natural one that already provides, as we will see, a great benefit without extra expenses. Two cases were considered:

- Natural ventilation during the day (from 7:00 am to 11:30 am and from 6:00 pm to 8:00 pm)
- Natural ventilation during the night (from 7:00 pm to 6:30 am)

Often people do not like to leave windows open for reasons of safety and comfort, too much air in movement in fact (at a velocity of more than 1m/s causes discomfort). The architect Bruno Zevi planned for this building a window with a sliding "sopraluce" (sort of fanlight) and a "sottoluce", so we assumed (by associating a schedule) the opening of the upper one, so that the air circulates without disturbing the occupants.
The analysis shows a significant advantage due to ventilation at night. This is one of those good habits that would be wise to brush up (since it belong to the traditional culture)in order to limit energy consumption during summer.

3.1 First results

In percentage terms it's possible to find a reduction, during winter, of energy consumption for heating around 10% for insulation only, and 9% due to the replacement of windows.
It has been also obtained a reduction in consumption for summer cooling by 5% due to the use of a shading system and 12% thanks to nightly natural ventilation.
A combined solution of all interventions would lead to a reduction in terms of consumption (for winter heating and summer cooling) up to 31%.

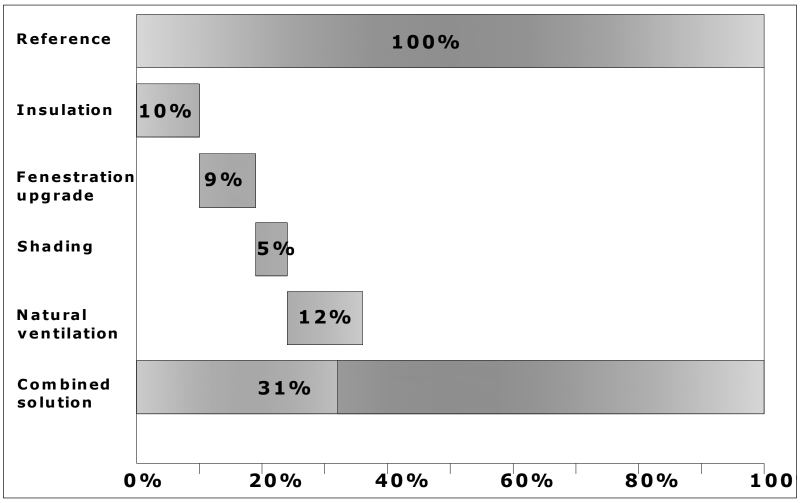


Fig. 3: Summary table of energy consumption percentage

3.2 Economic viability

It is of primary importance, in a retrofitting hypothesis, to correctly assess the costs of the intervention, that is, to quantify the economic feasibility and pay back time of the investment. Only if economically viable, these interventions can be proposed on a large scale. The input data to the analysis of the energy consumption are related to a simulation on an entire typical year, both for the building in current condition (i.e. without the proposed changes) and for the building energy-upgraded, and obviously the cost of the investment (estimated for each intervention (including costs for workmanship and safety, extracted from the Official Bulletin of the Campania Region, 2010 Edition, price list for public works or similar). Using the known formula:

$Ao = a\ (q^{n} - 1)\ /\ rq^{n}$

with:

Ao = investment cost

a = differential

q = 1 + r

r = interest rate deemed to be equal to 4%

n = number of years necessary to recover the investment

Taking into account an average value of the cost of energy of 0,15€/m^2 a pay back period of about 27 years was obtained that it's quite a long time. However, it was then assessed a "dynamic analysis", i.e. taking into account the rising cost of electricity and natural gas, in order to make the estimated payback time of the investment more plausible. So the first thing to do was to collect data about cost of electricity and natural gas for domestic use, identifying a trend for the next years.

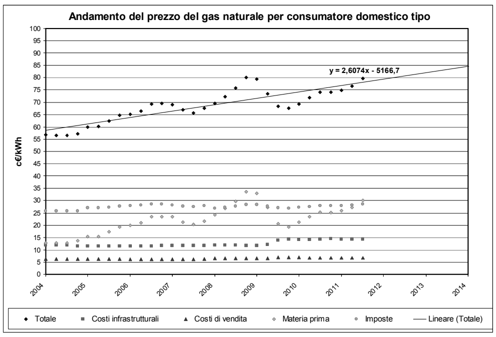


Fig. 4: Trend in the price of natural gas for domestic consumer.

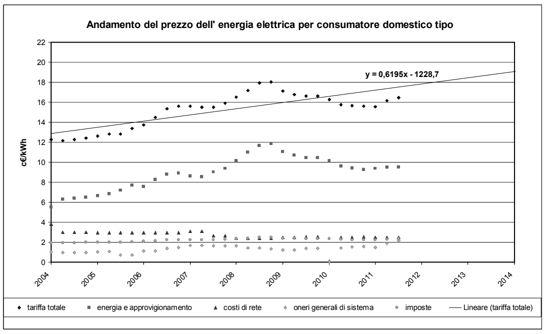
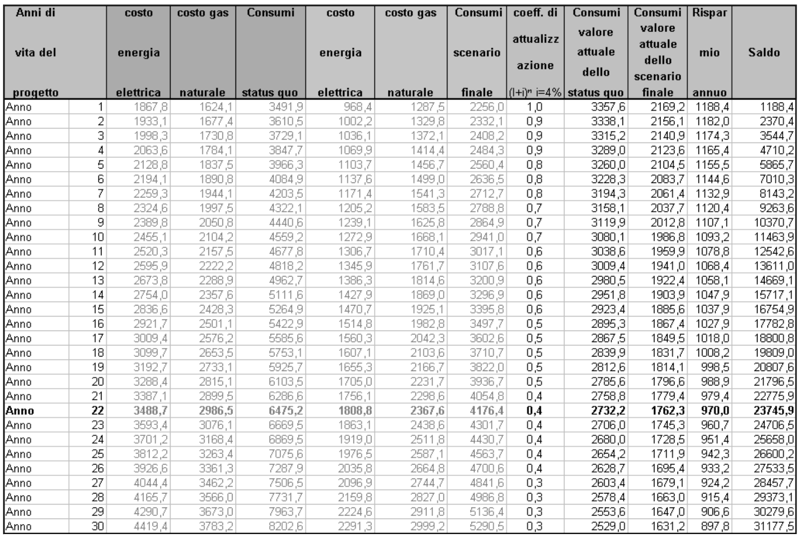


Fig. 5: Trend of electricity prices for domestic consumers.

Then we proceeded as before, assuming in addition to the growing trend identified.



Anni di vita del progetto		costo energia elettrica	costo gas naturale	Consumi status quo	costo energia elettrica	costo gas naturale	Consumi scenario finale	coeff. di attualizzazione $(1+i)^n$ i=4%	Consumi valore attuale dello status quo	Consumi valore attuale dello scenario finale	Risparmio annuo	Saldo
Anno	1	1867,8	1624,1	3491,9	968,4	1287,5	2256,0	1,0	3357,6	2169,2	1188,4	1188,4
Anno	2	1933,1	1677,4	3610,5	1002,2	1329,8	2332,1	0,9	3338,1	2156,1	1182,0	2370,4
Anno	3	1998,3	1730,8	3729,1	1036,1	1372,1	2408,2	0,9	3315,2	2140,9	1174,3	3544,7
Anno	4	2063,6	1784,1	3847,7	1069,9	1414,4	2484,3	0,9	3289,0	2123,6	1165,4	4710,2
Anno	5	2128,8	1837,5	3966,3	1103,7	1456,7	2560,4	0,8	3260,0	2104,5	1155,5	5865,7
Anno	6	2194,1	1890,8	4084,9	1137,6	1499,0	2636,5	0,8	3228,3	2083,7	1144,6	7010,3
Anno	7	2259,3	1944,1	4203,5	1171,4	1541,3	2712,7	0,8	3194,3	2061,4	1132,9	8143,2
Anno	8	2324,6	1997,5	4322,1	1205,2	1583,5	2788,8	0,7	3158,1	2037,7	1120,4	9263,6
Anno	9	2389,8	2050,8	4440,6	1239,1	1625,8	2864,9	0,7	3119,9	2012,8	1107,1	10370,7
Anno	10	2455,1	2104,2	4559,2	1272,9	1668,1	2941,0	0,7	3080,1	1986,8	1093,2	11463,9
Anno	11	2520,3	2157,5	4677,8	1306,7	1710,4	3017,1	0,6	3038,6	1959,9	1078,8	12542,6
Anno	12	2595,9	2222,2	4818,2	1345,9	1761,7	3107,6	0,6	3009,4	1941,0	1068,4	13611,0
Anno	13	2673,8	2288,9	4962,7	1386,3	1814,6	3200,9	0,6	2980,5	1922,4	1058,1	14669,1
Anno	14	2754,0	2357,6	5111,6	1427,9	1869,0	3296,9	0,6	2951,8	1903,9	1047,9	15717,1
Anno	15	2836,6	2428,3	5264,9	1470,7	1925,1	3395,8	0,6	2923,4	1885,6	1037,9	16754,9
Anno	16	2921,7	2501,1	5422,9	1514,8	1982,8	3497,7	0,5	2895,3	1867,4	1027,9	17782,8
Anno	17	3009,4	2576,2	5585,6	1560,3	2042,3	3602,6	0,5	2867,5	1849,5	1018,0	18800,8
Anno	18	3099,7	2653,5	5753,1	1607,1	2103,6	3710,7	0,5	2839,9	1831,7	1008,2	19809,0
Anno	19	3192,7	2733,1	5925,7	1655,3	2166,7	3822,0	0,5	2812,6	1814,1	998,5	20807,6
Anno	20	3288,4	2815,1	6103,5	1705,0	2231,7	3936,7	0,5	2785,6	1796,6	988,9	21796,5
Anno	21	3387,1	2899,5	6286,6	1756,1	2298,6	4054,8	0,4	2758,8	1779,4	979,4	22775,9
Anno	**22**	**3488,7**	**2986,5**	**6475,2**	**1808,8**	**2367,6**	**4176,4**	**0,4**	**2732,2**	**1762,3**	**970,0**	**23745,9**
Anno	23	3593,4	3076,1	6669,5	1863,1	2438,6	4301,7	0,4	2706,0	1745,3	960,7	24706,5
Anno	24	3701,2	3168,4	6869,5	1919,0	2511,8	4430,7	0,4	2680,0	1728,5	951,4	25658,0
Anno	25	3812,2	3263,4	7075,6	1976,5	2587,1	4563,7	0,4	2654,2	1711,9	942,3	26600,2
Anno	26	3926,6	3361,3	7287,9	2035,8	2664,8	4700,6	0,4	2628,7	1695,4	933,2	27533,5
Anno	27	4044,4	3462,2	7506,5	2096,9	2744,7	4841,6	0,3	2603,4	1679,1	924,2	28457,7
Anno	28	4165,7	3566,0	7731,7	2159,8	2827,0	4986,8	0,3	2578,4	1663,0	915,4	29373,1
Anno	29	4290,7	3673,0	7963,7	2224,6	2911,8	5136,4	0,3	2553,6	1647,0	906,6	30279,6
Anno	30	4419,4	3783,2	8202,6	2291,3	2999,2	5290,5	0,3	2529,0	1631,2	897,8	31177,5

Fig. 6: Pay back time of the investment. Approximately 22 years. i=4%

In this case the pay back time is about 22 years, all in all comparable with other similar interventions (such as a photovoltaic system).

We have to say that this kind of estimation, from a practical point of view, is "inadequate", because it does not take into account the bonus, in terms of value, that the property acquires once upgraded. Recent studies[1] show that a green property gains (compared to a similar but energy-inefficient) up to 13% more value when sold. If a new green building increases the value of 13% is reasonable to think that, in principle, an old property upgraded purchases at least 5-6 %. Starting from an approximate estimation of the value of the property, conducted using the guidelines of the"Osservatorio del Mercato Immobiliare (OMI)", a flat of about 87/108 m^2 as the property studied, is approximately € 230,000, the "bonus" can be considered equal to 11000 €. Considering that the cost of the investment is about € 6000 (for each flat) it follows that the investment would be recovered in theory immediately if the flat is sold.

The more, this type of intervention, especially when applied at a urban scale, not only produces substantial savings in monetary terms, but, perhaps even more significant savings in terms of CO_2 released into the atmosphere and the fundamental conservation of exhaustible fossil fuels.

3. 3 Estimate reduction of CO_2 emissions

The software used allows to predict the CO_2 emission levels produced by the selected building. The analysis was conducted as previously, comparing to the current state of the building and the final hypothesis (retrofitted). In this way it's possible to compare and understand the reduction of emissions.

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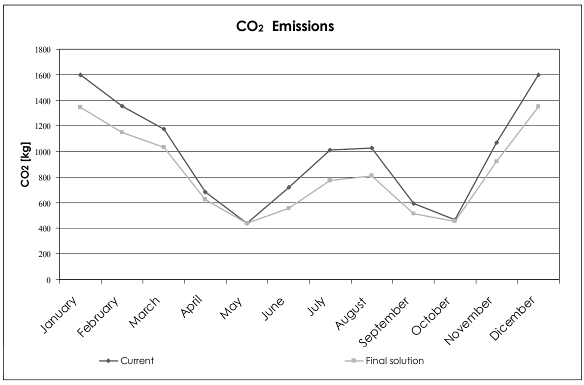
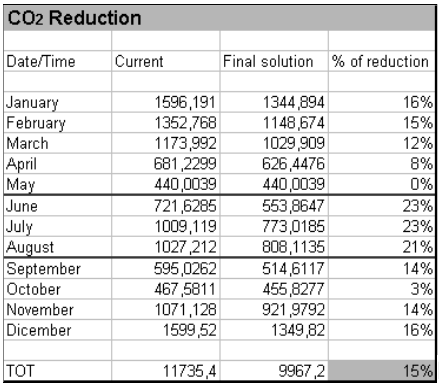
[1] *Sustainability and the Dynamics of Green Buildings, P. Eichholtz, N. Kok, J. Quigley-Ricsrisearch October 2010.*



a



CO2 Reduction			
Date/Time	Current	Final solution	% of reduction
January	1596,191	1344,894	16%
February	1352,768	1148,674	15%
March	1173,992	1029,909	12%
April	681,2299	626,4476	8%
May	440,0039	440,0039	0%
June	721,6285	553,8647	23%
July	1009,119	773,0185	23%
August	1027,212	808,1135	21%
September	595,0262	514,6117	14%
October	467,5811	455,8277	3%
November	1071,128	921,9792	14%
Dicember	1599,52	1349,82	16%
TOT	11735,4	9967,2	15%

b

Fig. 7a: CO2 Emissions, annual simulation

Fig. 7b: CO2 Emissions, percentage of reduction.

The graph shows a reduction in annual CO_2 emissions (relative to energy consumption for heating and cooling) with an average of 15%, reaching a maximum of 23% just during the summer months, or in relation to energy consumption for cooling. This result emphasizes the enormous importance of sunscreens and ventilation in a hot climate.

Case Study 2- Quartiere INA-Olivetti Pozzuoli (NA)

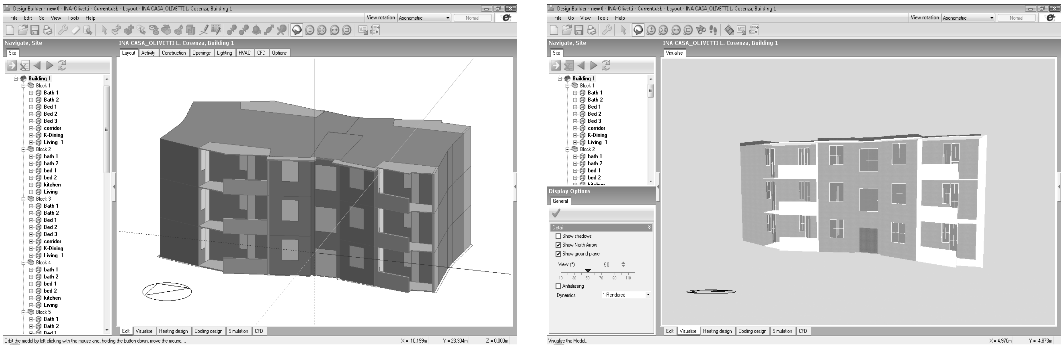
Quartiere INA-Olivetti is a residential complex built for the employees of Olivetti in Pozzuoli, close to the Anfiteatro Flavio and the factory. They were built through time and as different batches. The buildings have three floors and their typology changes in the different batches a bit, reflecting the evolution of the design through time. Some have the typical Neapolitan courtyard, centre of community life, surrounded by the buildings connected by open stairways.

Fig. 8 a,b,c: L. Cosenza_Quartiere residenziale INA-Olivetti, Pozzuoli, 1952-1963 (NA)

Modeling

Also for the Ina-Olivetti quarter, the procedure was exactly the same, it means for subsequent steps:

- Insulation (EPS panels, panels of EPS improved with graphite, cork boards)
- Replacement of windows (low emissivity triple glazing)
- Shading (blinds, shade-roll, sidefins louvre, brise-soleil)
- Natural ventilation (night and day)



Orbit the model by left clicking with the mouse and, holding the button down, move the mouse....
X = -10,199m Y = 23,304m Z = 0,000m

☐ Show shadows
☑ Show North Arrow
☑ Show ground plane
View (°) 50
☐ Antialiasing
Dynamics 1-Rendered

Visualise the Model...
X = 4,970m Y = -4,873m

Fig. 9: Model By the software DesignBuilder

In the district Ina-Olivetti, it was possible to model an entire building, as it is quite small. Each building consists of a stairwell that serves two units per floor, a larger one of about 115 m^2 and a smaller one of about 70 m^2. Apart from a few differences all buildings have the same characteristics, which allows to control the performance of the various buildings by simply changing the orientation in the software.

Insulation

The main difference with the previous case was that, since there are no exposed brick, it was possible to opt for the use of an external insulation (coating insulation or in italian “a cappotto”), it is realized by using rigid insulation boards on the exterior of the wall sheathing with a plaster appearance exterior skin. This kind of insulation system is much more efficient as it helps to solve also the problem of thermal bridges.

Different options were tested: EPS panels, EPS improved with graphite, cork boards. Unlike the previous case study, in which the thickness of the insulation was fixed since it corresponded to the size of the air-gap inside the wall, in this case it was necessary to calculate the thickness for each type of panel. The procedure consists in assuming initially the use of a panel (such as expanded polystyrene EPS) 10 cm thick. Dividing the thickness of the panel for_the Coefficient of Thermal Conductivity λ of the panel chosen (thermal insulation coating “Fassa” type with λ = 0.034 W/mK) we obtain the thermal resistance R= 2.35 m^2k/W. To take into account also the thermal resistance given by two layers of air that inevitably will be created during the installation of the panel, a fixed value equal to 0.17 m^2k/W is considered. Thermal transmittance U from thermal resistance can be expressed as: $U = 1/R$ which is the starting point to get to know if the panel size is appropriate or not. We obtain as a result of the simple and unique insulating panel 0.32 W/m^2K and we can say that the EPS-100 with thickness of 10 cm is appropriate and complies with the provisions of the new decree on energy efficiency in buildings (D.M 26-01-2010, U<0,34 W/m^2K, as Naples is in zone C).
So we obtained the following thicknesses:

EPS: λ = 0.034 W/mK, thickness: 10 cm
EPS + graphite: λ = 0.031 W/mK, thickness: 9 cm
Cork: λ = 0.040 W/mK, thickness: 11 cm

As before we proceeded with a schematic model of the building under study, and a simulation of the annual consumption for heating and cooling, from time to time compared with the corresponding value of the "status quo" or current situation, without any changes, aiming at improving energy performance of the building

Replacement of windows

Unlike the previous case, in the Ina-Olivetti quarter, the quality of the buildings is a bit higher due to the maintenance that the owners have carried out over the years. However, many things have changed since the original project, such as window frames. The original windows were made of iron and with a single layer of glass, very obsolete. The site inspection revealed that in the whole lot only one original frame remained. Therefore was decided to proceed with the analysis of two different scenarios:

- Scenario1: to assume the replacement and upgrading of windows with a low-emissive type, with thermal break, three layers of glass and two layer of gas (=air). This type has a U<1 W/m^{2}k much lower than the value indicated by the standard DM 26-01-2010, where U = 2.1 W/m^{2}k in the climate zone C.
- Scenario 2: Since almost all the buildings have windows with double glass that therefore should already meet the standards, to continue with the analysis, leaving windows unchanged, and moving directly to the study of a proper shading system.

It was noted that a low-emissivity window (rarely used in hot climate) can further reduce energy losses during the winter season. Little or nothing is however the advantage during summer except for an exiguous reduction of solar gains. Considered the high cost of this intervention (such windows still have a rather high cost on the market) and that, in percentage terms, with low-emissivity windows there is a reduction (only on consumption for winter heating) by about 10%, with the economic feasibility analysis performed later, a very long pay-back period is observed.
The intervention appears to be of little advantage or at least not enough to be considered on a building that has already many years.
Therefore the research continued with scenario 2, by studying in detail the most appropriate shading system.

Use of a suitable shading system

As before, also in this second case study the simulation was conducted assuming the alternative use of different sunscreens, namely:

- blinds
- venetian
- shade rolls
- sidefins (of 70 and 75 cm)
- brise soleil (0° or 36° to the horizontal)

An operating program was associated at blinds, venetian and shade rolls and with, specifically openings from 11:30 am to 6:00 pm.
Brise soleil, as done before, was tested adjusting size and geometry, in order to allow the protection from the sun during summer and the access of sunlight in winter. The most effective solution appears to be the use of shade rolls, brise soleil and sidefins do not seem to be particularly effective, probably because of the considerable depth of the balcony.

This is confirmed by the fact that no buildings of the lot preserved the original brise soleil, which points out that none of the people considered appropriate to replace the old one.

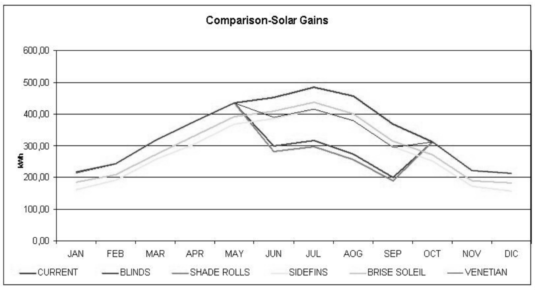


Fig. 10: Solar gain through windows. Comparison of the effectiveness of the different sunscreen.

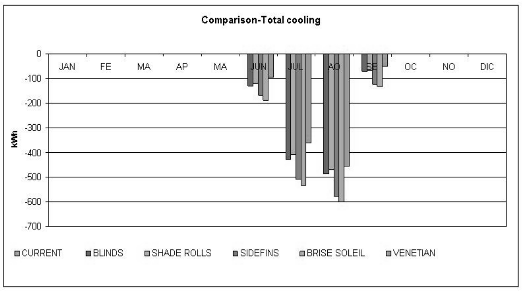


Fig. 11: Total Cooling in kWh using different shading systems.

Education to natural ventilation

Again, natural ventilation was tested, that already provides as we'll see in the results, a great benefit without extra expenses. Two cases were analyzed:

- Natural ventilation during the day (from 7:00 to 11:30 and from 18.00 to 20:00)
- Natural ventilation during the night (from 19:00 to 6:30)

As before the interaction of the shading system chosen with natural ventilation, was observed in order to optimize both. The system that still seems to be most effective is shade roll, because it disappears completely when not in use (i.e. during the hours when the sun is low or at night), thus favouring ventilation at the most.
Below is a brief report the values obtained in tables and graphics in a final summary.

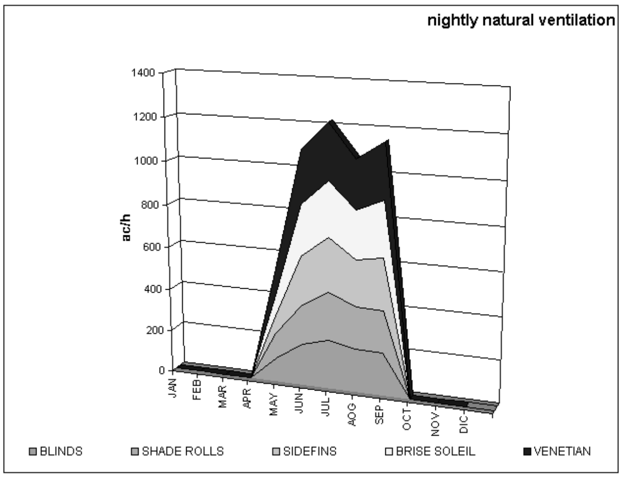
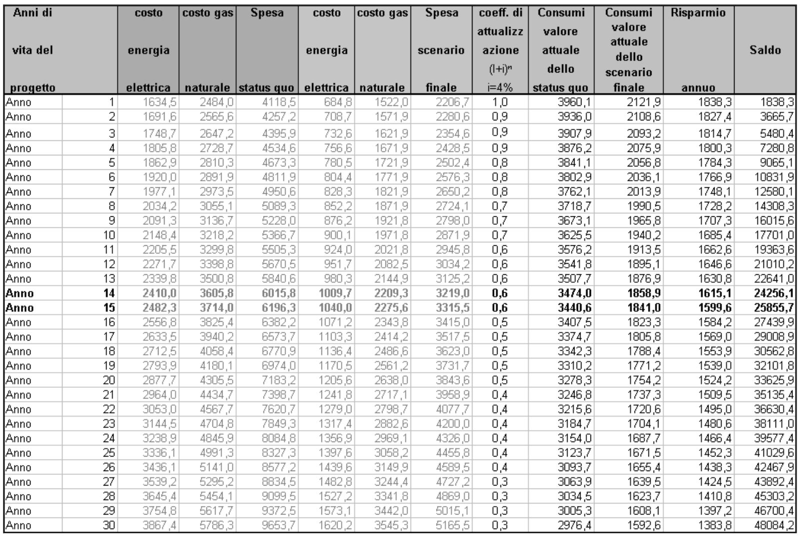


Fig. 12: percentage of natural ventilation, with different sunscreen. [ac/h]

3.4 Economic viability

The upgrading-package proposed in this second case study is quite expensive, starting with the insulation solution, with a price range from 40 up to 80 €/m^2 to which is added a 5% for the labor costs, and 1% for security costs.

As previously explained the improvement of the windows turned out to be a very ineffective intervention in relation to its cost. About shading systems must be said that, as before, they do not represent the highest cost item, because it was intentionally chosen a simple products, not automatic.
Finally ventilation, that being natural and not mechanical, as no cost item, it's just a good habit, the only expense is the time to acquire it.
Even in this case an analysis as before, even dynamic type, was conducted. The results are reported in the following tables:



Anni di vita del progetto		costo energia elettrica	costo gas naturale	Spesa status quo	costo energia elettrica	costo gas naturale	Spesa scenario finale	coeff. di attualizzazione $(1+i)^n$ i=4%	Consumi valore attuale dello status quo	Consumi valore attuale dello scenario finale	Risparmio annuo	Saldo
Anno	1	1634,5	2484,0	4118,5	684,8	1522,0	2206,7	1,0	3960,1	2121,9	1838,3	1838,3
Anno	2	1691,6	2565,6	4257,2	708,7	1571,9	2280,6	0,9	3936,0	2108,6	1827,4	3665,7
Anno	3	1748,7	2647,2	4395,9	732,6	1621,9	2354,6	0,9	3907,9	2093,2	1814,7	5480,4
Anno	4	1805,8	2728,7	4534,6	756,6	1671,9	2428,5	0,9	3876,2	2075,9	1800,3	7280,8
Anno	5	1862,9	2810,3	4673,3	780,5	1721,9	2502,4	0,8	3841,1	2056,8	1784,3	9065,1
Anno	6	1920,0	2891,9	4811,9	804,4	1771,9	2576,3	0,8	3802,9	2036,1	1766,9	10831,9
Anno	7	1977,1	2973,5	4950,6	828,3	1821,9	2650,2	0,8	3762,1	2013,9	1748,1	12580,1
Anno	8	2034,2	3055,1	5089,3	852,2	1871,9	2724,1	0,7	3718,7	1990,5	1728,2	14308,3
Anno	9	2091,3	3136,7	5228,0	876,2	1921,8	2798,0	0,7	3673,1	1965,8	1707,3	16015,6
Anno	10	2148,4	3218,2	5366,7	900,1	1971,8	2871,9	0,7	3625,5	1940,2	1685,4	17701,0
Anno	11	2205,5	3299,8	5505,3	924,0	2021,8	2945,8	0,6	3576,2	1913,5	1662,6	19363,6
Anno	12	2271,7	3398,8	5670,5	951,7	2082,5	3034,2	0,6	3541,8	1895,1	1646,6	21010,2
Anno	13	2339,8	3500,8	5840,6	980,3	2144,9	3125,2	0,6	3507,7	1876,9	1630,8	22641,0
Anno	**14**	**2410,0**	**3605,8**	**6015,8**	**1009,7**	**2209,3**	**3219,0**	**0,6**	**3474,0**	**1858,9**	**1615,1**	**24256,1**
Anno	**15**	**2482,3**	**3714,0**	**6196,3**	**1040,0**	**2275,6**	**3315,5**	**0,6**	**3440,6**	**1841,0**	**1599,6**	**25855,7**
Anno	16	2556,8	3825,4	6382,2	1071,2	2343,8	3415,0	0,5	3407,5	1823,3	1584,2	27439,9
Anno	17	2633,5	3940,2	6573,7	1103,3	2414,2	3517,5	0,5	3374,7	1805,8	1569,0	29008,9
Anno	18	2712,5	4058,4	6770,9	1136,4	2486,6	3623,0	0,5	3342,3	1788,4	1553,9	30562,8
Anno	19	2793,9	4180,1	6974,0	1170,5	2561,2	3731,7	0,5	3310,2	1771,2	1539,0	32101,8
Anno	20	2877,7	4305,5	7183,2	1205,6	2638,0	3843,6	0,5	3278,3	1754,2	1524,2	33625,9
Anno	21	2964,0	4434,7	7398,7	1241,8	2717,1	3958,9	0,4	3246,8	1737,3	1509,5	35135,4
Anno	22	3053,0	4567,7	7620,7	1279,0	2798,7	4077,7	0,4	3215,6	1720,6	1495,0	36630,4
Anno	23	3144,5	4704,8	7849,3	1317,4	2882,6	4200,0	0,4	3184,7	1704,1	1480,6	38111,0
Anno	24	3238,9	4845,9	8084,8	1356,9	2969,1	4326,0	0,4	3154,0	1687,7	1466,4	39577,4
Anno	25	3336,1	4991,3	8327,3	1397,6	3058,2	4455,8	0,4	3123,7	1671,5	1452,3	41029,6
Anno	26	3436,1	5141,0	8577,2	1439,6	3149,9	4589,5	0,4	3093,7	1655,4	1438,3	42467,9
Anno	27	3539,2	5295,2	8834,5	1482,8	3244,4	4727,2	0,3	3063,9	1639,5	1424,5	43892,4
Anno	28	3645,4	5454,1	9099,5	1527,2	3341,8	4869,0	0,3	3034,5	1623,7	1410,8	45303,2
Anno	29	3754,8	5617,7	9372,5	1573,1	3442,0	5015,1	0,3	3005,3	1608,1	1397,2	46700,4
Anno	30	3867,4	5786,3	9653,7	1620,2	3545,3	5165,5	0,3	2976,4	1592,6	1383,8	48084,2

Fig. 11: Pay back time of the investment. Approximately 14-15 years. i=4%

The pay back period is 15 years, definitely a reasonable one. As done before it's possible to quantify the bonus value that the building gains thanks to the retrofit. Again starting from an approximate estimation of the value of the property, conducted using the guidelines of the"Osservatorio del Mercato Immobiliare (OMI)", a residential building in the area object of the study in Pozzuoli has a range of value from 1900 to 2900 €/m^2. A flat of about 115 m^2 as the property studied, is approximately € 280,000, the bonus can be considered equal to 14000 €. Considering that the cost of the investment is about € 5000-6000 (for each flat) it follows that the investment would be recovered, in theory, immediately if the flat is sold, and the retrofitting turns out to be a profitable investment.

3.5 Estimate reduction of CO_2 emissions

The program, as mentioned above, provides an estimate of CO_2 emissions and even in this case, it's important to emphasize how the proposed measures are effective in reducing emissions, especially during the summer months. To support the importance of these measures in countries with hot climate.

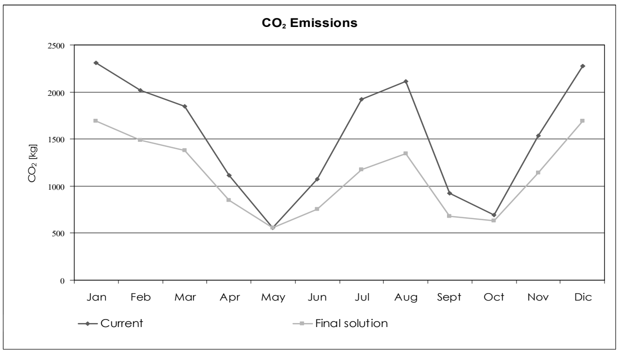
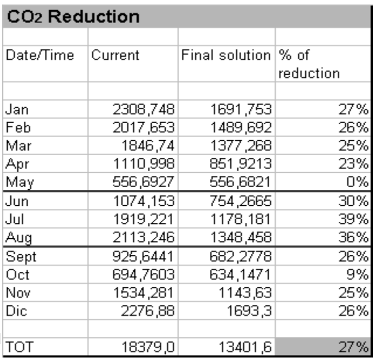


Fig.12a**:** CO2 Emissions, annual simulation



CO2 Reduction

Date/Time	Current	Final solution	% of reduction
Jan	2308,748	1691,753	27%
Feb	2017,653	1489,692	26%
Mar	1846,74	1377,268	25%
Apr	1110,998	851,9213	23%
May	556,6927	556,6821	0%
Jun	1074,153	754,2665	30%
Jul	1919,221	1178,181	39%
Aug	2113,246	1348,458	36%
Sept	925,6441	682,2778	26%
Oct	694,7603	634,1471	9%
Nov	1534,281	1143,63	25%
Dic	2276,88	1693,3	26%
TOT	18379,0	13401,6	27%

Fig. 14b: CO2 Emissions, percentage of reduction.

4. First results

In percentage terms it's possible to find a reduction, during winter, of energy consumption for heating around 29% for insulation only, and 12% due to the use of a shading system It has been also obtained a reduction in consumption for summer cooling by 11% thanks to nightly natural ventilation.

A combined solution of all interventions would lead to a reduction in terms of consumption (on winter heating and summer cooling) by 44%. The scenario 1 showed a reduction of about 10% due to the replacement of windows with a low –emission type

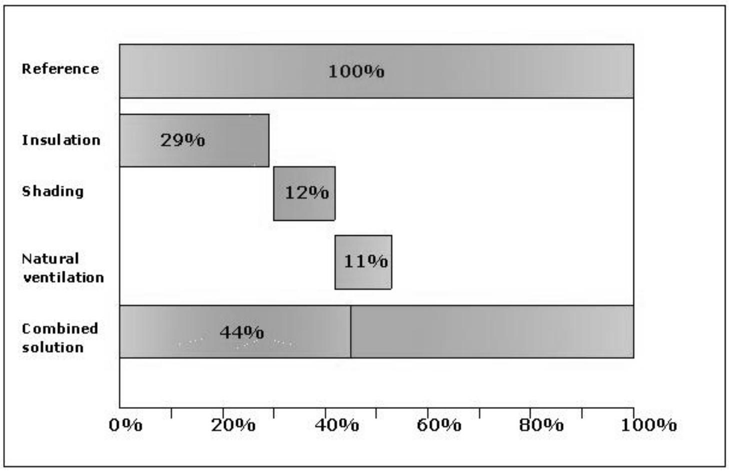


Fig. 15: Summary table of energy consumption, in percentage

5. Conclusions

The methodology proposed in this research, is strongly linked to the concept of energy efficiency and indoor comfort, and arises from the acknowledgment of the important role that sustainability has been in these years.

The main scope is to equip the building, selecting appropriate morphological and constructive choices, whit an enclosure capable of balancing the winter need of collection and storage of solar heat indoor, and the summer one of protection from unwanted solar radiation and dissipation of excessive heat. The study therefore shows that:

- Depending on the available retrofit budget and the other motivation (limited investment, economic benefit at long term) the implementation of the energy saving measures can be spread over time, as most of the measures can be applied independently from each other.
- The thermal insulation of the wall has a primary role in a hot climate too.
- replacement of the window frames and some type of insulation of the façade are the most expensive measures to be taken.
- In warm weather the consumption for cooling system is not negligible, also burdensome, if not more in some cases, than the heating one.
- It is therefore essential to pay attention to the choice of an appropriate shading system, though simple.
- It is of primary importance, always in order to curb energy consumption during summer, to re-educate people to the practice of natural ventilation, preferably at night.
- The costs for retrofitting investment like the one described, choosing the best solution appropriately, can be recovered within at least two decade, a very reasonable time.
- Finally, by putting into effect the choices described above, it's possible to greatly reduce the emission of greenhouse gases, especially during summer, reaching monthly reductions up to 39%.

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