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ENERGY RETROFIT OF RESIDENTIAL BUILDINGS IN HOT CLIMATE

Ilaria Falcone

Il Tutor
Prof. Enrico Sicignano

Il Coordinatore
Prof. Ciro Faella

Co-tutor
Prof. John Fernandez

Alla mia famiglia

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Acknowledgement

Three amazing years. This is the account of the journey just ended. The PhD experience has been important, intense and exciting. A training program in every possible way, both professionally and personally. Three years in which moments of overwhelming happiness, dark desolation, crazy freedom and passionate knowledge followed each other.

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I couldn’t be more happy and thankful.
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Introduction

Problem statement and research questions

The increasing demand for energy, resulting in cost growth and related environmental problems, led to an expanding 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 strategies of low-power 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 obtain a less power consumption. To solve this problem an integrated approach is essential.

Actually attempts to improve the energy performance in the residential sector mainly pay attention to new buildings. However, a decrease in energy consumption and greenhouse gas emissions will never occur if nothing is done to improve the existing energy devouring housing stock. The idea at the base of the research project was born from the need to analyze the "case of hot climate" separately, as the European directives and studies in this field cannot be fully adapted to the problem.

How to reduce energy consumption is a question studied for decades but since the problem was faced first in cold climates, where the cost for winter heating is the considerable one, the needs, the objectives, and consequently the means and results obtained do not fit well to the same problem handled in a different climatic situation. By changing the boundary conditions, the optimal solution may be different from that one analyzed up to now.

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 intervention should be carried out 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 production.

The more, attempts to improve the energy performance in the residential sector mainly pay attention to new buildings, “in literature, a large number of research papers report on cost-effective new low-energy buildings [1], on life cycle analysis of building materials and components[2] [3] and on the optimisation of energy related aspects, such as insulation measures, heating systems, photovoltaics a.o.[4]. Also, the combination of life cycle analysis and economic optimisation is used to create new energy-saving buildings. However, a decrease of the greenhouse gas emissions will not occur if no energy is saved through retrofit of the present housing stock”.[5]

Buildings can be defined the biggest energy consumer and CO_2 polluter, but hardly any other sector has such great prospects in energy saving as the building one.

This study aims at examining developments in the Mediterranean climate using an assessment tool that measures the energy performance of buildings in terms of sustainability.

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[1] W. Feist, Cost-efficient passive houses in Central-European Climate, 1998, http://www.passiv.de/.

[2] L. Canet, http://www.leidenuniv.nl/interfac/cml/lcanet/hp22.htm.

[3] R. Ries, A. Mahdavi, Integrated computational life cycle assessment of buildings, Journal of Computing in Civil Engineering 15 (1) (2001) pg. 59–66.

[4] F. Ali Mohamed, H. Hens, Reduction of the CO2 emissions due to space heating in the residential sector: efficiency of constructive measures, CO2 Project Electrabel – SPE, 2001, p. 85 (in Dutch).

[5] G. Verbeeck, H. Hens, Energy savings in retrofitted dwellings: economically viable?, Energy and buildings vol:37 issue:7 pages:747-754, Elsevier, January 2005

This study attempts to:

- Explain what is the meaning of “sustainability” in architecture now;
- analyse and understand buildings that have the greatest problems in terms of energy consumption, i.e. those belonging to social housing stocks, however so widely spread all over the country that replacement cannot be considered as a possible solution;
- model and assess building performance in the Mediterranean climate (south Italy);
- evaluate economic viability;
- establish guidelines for future sustainable retrofit actions.

Acting on the building envelope the energy upgrading of two buildings belonging to social housing has been simulated, one in Salerno, the other one in Pozzuoli, Napoli.

With the help of the software Ecotect and DesignBuilder the energy performance, on an annual base, has been modelled and assessed, in order to check the possible reduction in energy consumption for heating and cooling, and to control CO_2 emission level. The intention is to demonstrate that energy retrofit can be made without necessarily going through expensive technologies or ex-novo design, obtaining interesting results in terms of energy and environment, at a cost that can be recovered in a few years, making energy upgrading possible even on ordinary buildings and therefore desirable at a urban scale.

In each study case the analysis was conducted comparing consumption (annual) 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.

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.

Finally this thesis discusses economically feasible ways and means to choose between insulation measures, better glazing, shading systems and natural ventilation, in order to underline a logical hierarchy of energy-saving measures.

A decrease in energy consumption and greenhouse gas emissions will never occur if nothing is done to improve the existing energy devouring housing stock.

If we think that, depending on the available retrofit budget and the underlying 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, there is no reason to wait longer.

“From a policy point of view, the government can reduce these barriers by supporting the communication and information for decision makers namely consumers, investors and financial institutions.

A good example of this kind of promotion is given by advertising campaigns so called *Casa Clima* used by the government of the Italian province Alto Adige, or by information campaigns and subsidies applied to energy-efficient buildings in Switzerland, namely *Minergie* guidelines that combines efficiency and comfort”.[6]

Next to the financial support of governments, promotion and advertising campaigns, it’s necessary to educate or (re-educate) population to consumption control, pollutant production, respect for the environment, starting from small acts of everyday life.

However strategies of energy consumption reduction have to be associated with a wiser use of renewable sources.

Researches are now moving towards a multidisciplinary approach; in a city, in fact, it is possible to identify “homogeneous areas”, where existing buildings have the same date and are characterized, more or less,

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[6] S. Banfi, M. Farsi, M. Filippini, M. Jakob, Willingness to pay for energy-savings measures in residential building, Energy Economics Volume 32, Issue 1, pag. 129-136. January 2010.

by the same structural characteristics, therefore in good approximation by the same problems in terms of energy

An approach of this type, studied in detail in an Energy Plan that not only turns his attention to the residential sector but also to transport, lighting, exploitation of water resources and food production, should also integrate, in each macro areas, the identification of the most suitable renewable energy sources, the closest, available on site.

This could change effectively how to tackle the energy problem and contribute to improve urban resource efficiency and to provide pathways for the development of appropriate and effective sustainable technologies.

We need to change all this, we need to start it now.

Chapter I – Sustainability and Architecture

"Sustainability", a word so much used in the last years, maybe overused, does anybody really knows the meaning? Probably the meaning changed (and is still changing) a lot, as long as the problem grows. For this reason the first problem to me, was to define carefully and understand clearly what is the real meaning of this word.

As often happens recent researches and growth of knowledge about sustainable development have increased interest in sustainable development terminology. Therefore, it is easy to confuse the meaning of each term, or not fully understand it.

1.1 What is Sustainability?

Brutally "sustainability has been defined as the extent to which progress and development should meet the need of the present without compromising the ability of future generations to meet their own needs" [1]

Such a definition leaves plenty of room for interpretation of the readers. Therefore, probably, must be detailed and specified. To begin with, the term sustainability can be applied to many fields. In the following pages the acceptation in the architectural field will be

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[1] Steele J. Sustainable architecture: principles, paradigms, and case studies. New York: McGraw-Hill Inc, 1997.

specified, but in more general terms we refer to environmental sustainability, which represents an approach to problems of engineering that turns attention to the natural environment, its use and preservation.

In general, the difficulty in defining properly arises because:

1) the problem is huge, and it is not easy to define the boundaries clearly.
2) the magnitude of the problem leaves plenty of room for interpretation, from several points of view.

Sustainable development terminology embraces terms such as cleaner production, pollution prevention, pollution control, minimization of resource usage, eco-design and others. In my opinion at first can be useful to specify a little some main terms, as *sustainable development* should be supported by a common, unambiguous terminology applicable to real-world problems.

The following terms are “based upon usage within the United Nations Environment Programme (UNEP), the U.S. Environmental Protection Agency (EPA), the European Environmental Agency (EEA), the Organization for Economic Co-operation and Development (OECD), the Journal of Cleaner Production, and others.”[2]

“*Renewable resources* are available in a continually renewing manner, supplying materials and energy in more or less continuous ways. In other words, renewable resources do not rely on fossil fuels of which there are finite stocks”.[3]

“*Environmental accounting* is designed to bring environmental costs to the attention of the corporate stakeholders who may be able and motivated to identify ways of reducing or avoiding those costs while at

[2] Glavič P. Lukman R. Review of sustainability terms and their definitions, Journal of Cleaner Production, 2007.

[3] EEA (European Environmental Agency). Glossary. Available from: http://glossary.eea.eu.int/EEA_Glossary/>; 7 June 2004.

the same time improving environmental quality and profitability of the organization”.[4]

“*Eco-efficiency* is the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life cycle, to a level at least in line with the earth’s estimated carrying capacity. [5] [6] It is based on the concept of ‘‘doing more with less’’. [7]

Environmental approach “[..] is a concept-oriented term that encompasses pollution control, cleaner production, green chemistry, eco-design, life cycle assessment, waste minimization, and zero waste”.[8]

Eco-design or design for Environment “are understood as a product development process that takes into account the complete life cycle of a product and considers environmental aspects at all stages of a process, striving for products, which make the lowest possible environmental impact throughout the product’s life cycle” [9] [10]

A definition that gets wide acceptance of *life cycle assessment* (LCA) was provided by EPA[11] and EEA[12] as “the method/process for evaluating

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[4] US Environmental Protection Agency (EPA). Available from: <http:// ww.epa.gov/>; 1 June 2004.

[5] US Environmental Protection Agency (EPA). Available from: <http://www.es.epa.gov/cooperative/international/>; 2 June 2004.

[6] United Nation Environment Programme, Division of Technology, Industry, and Economics (UNEP DTIE). Cleaner production (CP) activities. Available from: <http://www.uneptie.org/>; 2 June 2004.

[7] Australian Government, Department of the Environment and Heritage. Available from: <http://www.deh.gov.au/industry/corporate/eecp/index. html>; 2 June 2004.

[8] Glavič P. Lukman R. Review of sustainability terms and their definitions, Journal of Cleaner Production, 2007.

[9] US Environmental Protection Agency (EPA). Available from: <http://www.es.epa.gov/cooperative/international/>; 2 June 2004.

[10] United Nation Environment Programme, Division of Technology, Industry, and Economics (UNEP DTIE). Cleaner production (CP) activities. Available from: <http://www.uneptie.org/>; 2 June 2004.

[11] US Environmental Protection Agency (EPA). Available from: <http://www.epa.gov/>; 1 June 2004.

[12] EEA (European Environmental Agency). Glossary. Available from: <http://glossary.eea.eu.int/EEA_Glossary/>; 7 June 2004.

the effects that a product has on the environment over the entire period of its life, thereby increasing resource use efficiency and decreasing liabilities”.

Finally numerous definitions of *Sustainable Development* are attainable but 1987 the World Commission on Environment and Development (i.e. Brundtland’s Commission) defined sustainable development as “[...] development that meets the needs of the present without compromising the ability of future generations to meet their own needs’’[13] and this is right now the most borne out definition.

It is crucial to fully understand the differences between these terms.

As previous said, all these definition can be easily applied to several fields, as both in architecture and in civil engineering, sustainability is increasingly becoming an object of study and discussion.

Even if, from one hand, environmental awareness is gaining a strong position in the social system of values, we cannot say yet that all sectors of human activity point to achieve sustainability.

It is still possible to “see” a sort of gap between what is economically convenient and what is needed.

This is because sustainable development is deeply related with many (probably too many) economic aspect of our lives. It’s not possible to face the problem of smart resource usage without bump into the prerogatives of the energy production sector, or face the energy-efficiency problem without bump into the priorities of the construction sector.

That’s why it comes natural to investigate what is the meaning of this term in the construction industry. What are the objectives of the future and what are the most plausible means to achieve the well known goals, for the Community to set out? Let’s try to answer to these questions.

[13] Brundtland G, Khalid M, Agnelli S, Al-Athel SA, Chidzero B, Fadika LM, et al. Our common future: the World commission on environment and development. Oxford: Oxford University Press; 1987.

1.2 Sustainability in Architecture

We can say that architecture has accompanied man since the dawn of time, manifesting, initially, simply as a necessity to create a shelter, a place where it was possible to feel safe and protected, and then over the centuries, has been specified more and more in a refined and complex system. Architecture has always been “[…] a response to tradition and culture of its time” which reflect “the pulse of society, environment action, life style of inhabitants and their aesthetic value as well as their building technology”[14].

Constantly in balance between pure necessity and the highest form of Art, architecture over the centuries has reflected more and better than any other human expression, times changes, tastes and situations. It has been a driving force for research and development, but at the same time has taken every possible technological innovation. It opened the way for new aesthetic expressions, and at the same time it has always translated the current taste. It is therefore a mirror and a window on society. Architecture, civil engineering, construction industry, merely reveal the state of society. This never changed, neither in recent years.

For some years now we are going through a period of major changes, first economic and social, to which were soon added the environmental ones. It is perhaps the first time in human history that we faced the need to "control" development, to anticipate its effects, and to limit damage. It is a novelty and a big challenge for men, who never before dealt with this type of problems. Therefore, it is very difficult to act not only on "common feeling", to make this kind of problems visible and understandable for everyone, but it is also very difficult to recognize which is the right direction to be taken.

“Today we face a great challenge for sustainability at the planetary scale brought about by the confluence of two global trends: the transition towards an increasingly urbanized world and global environmental

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[14] Amjad Almusaed, Biophilic and Bioclimatic Architecture: Analytical Therapy for the Next Generation of Passive Sustainable Architecture, Springer, London 2011

change. Since 1900, the proportion of the world's population that lives in urban areas has increased from 13 percent to more than half. Concomitant with these demographic changes, urban expansion and the demand for resources and energy from urban producers and consumers are transforming Earth's terrestrial ecosystem and with it, helping to drive the loss of habitat and species, changes in biogeochemistry, and modifying hydrological system".[15]

In fact "due to the rising number of environmental catastrophes, there was in increase of 40% between the years of 1990 to 2000 alone, when compared to economic damage sustained between 1950 and 1990. Without the implementation of effective measurements, further damage, which must therefore still be expected, cannot be contained. Companies across different industries have meanwhile come to realize that only a responsible handling of resources will lead to long-term success. Sustainable buildings that are both environmentally and resource-friendly enjoy an increasingly higher standing when compared to primarily economically oriented solutions"[16].

If at first climate changes, depletion of environmental resources, and increasing pollution, appeared to be distant concepts, almost abstract, now we have to deal already with past mistakes.

A change of direction is needed, we must do it now, and it is obvious to start from the sector that requires more in terms of energy consumption, which produces a lot of pollution, and that concerns all of us closely, the household one.

"European society is largely urban. It is estimated that approximately 80 per cent of the population live in cities and towns. The problem of urban areas varies enormously as some face the problem of rapid growth while others face those of economic decline while still others face both types of problems".[17]

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[15] K. Seto, D. Satterthwait, Interactions between urbanization and global environmental change, Current opinion in environmental sustainability, vol. 2 issue 3. pg 127-128. 2010

[16] M.Bauer, P.Mösle M.Schwarz, Green Building – Guidebook for Sustainable Architecture, Springer,2009 pg.10.

[17] B. Edwards, Sustainable Architecture, European directives and building design, Architectural Press, Oxford 1999.

Despite the transport sector and the industry's account for large shares of energy, the buildings account for about 40% of energy consumption in Europe. Even if sometimes sounds unbelievable lighting, heating, air conditioning systems and hot water in homes, workplaces and leisure facilities require more energy than transport or industry.

The reasons for this general increase are manifold, such as an increase in comfort habits, currently still pretty low energy costs, architectural trends like an increased fraction of glazed areas in buildings and last but not least slowly changing climate conditions.

This rising demand for cooling and air-conditioning in buildings involves unfavourable fossil fuel consumptions as well as upcoming stability problems in the electricity supply in Mediterranean countries, which in turn demands for costly upgrading of the grids to handle electricity peak power demand situations.

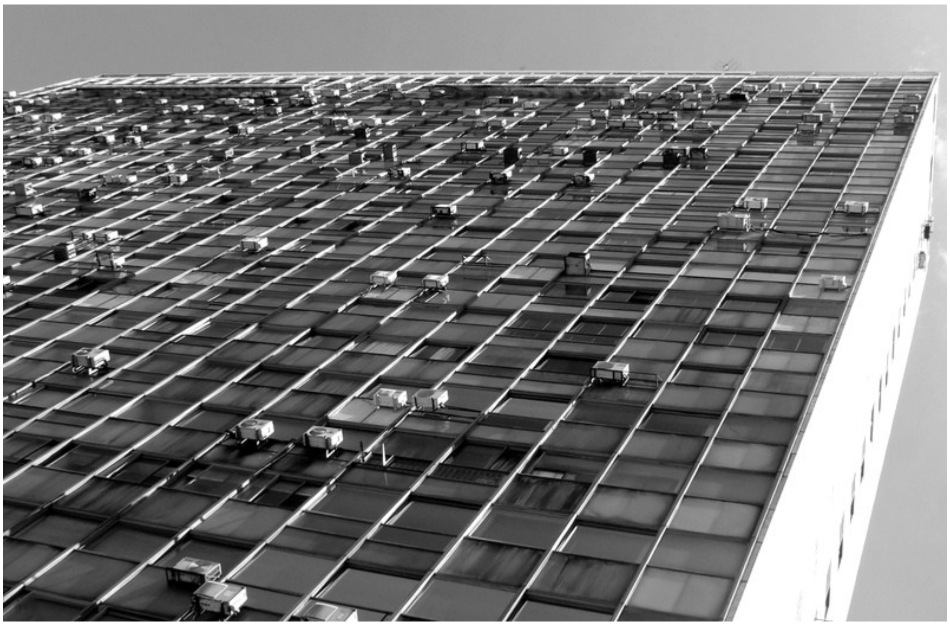

Fig.1.1: Palacio de la Ciudadela a Montevideo, Arch:Sichero 1958. Web site: http://www.skyscrapercity.com/

"In line with a sustainable development approach, it is critical for practitioners to create a healthy, sustainable built environment.[18] [19]

"Environmental protection and sustainable development are important areas of interest for the European Union.

Various directives and research funding programmes seek to improve the quality of life by ensuring that environmental matters are taken into account".[20]

The studies funded by the European Commission in recent years have shown that:

1. Two thirds of energy consumption in buildings in Europe comes from homes that require more and more energy, in tandem with the improvement of living standards, resulting from a greater use of air conditioning systems and heating systems.
2. From 30% to 50% of the energy used for lighting in offices, commercial buildings and leisure facilities could be spared.
3. Half of the increase in consumption of energy for air conditioners - which is forecast to double by 2020 - could be avoided facilities to comply with stricter standards.

Energy consumption in Italy is among the highest in Europe, as can be seen easily from the maps below.

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[18] Celik Z. Urban preservation as theme park: the case of Sogukcesme Street. In: Celik Z, Favro D, Ingersoll R, editors. Streets: critical perspectives on public space. Berkeley (CA): University of California Press, 1994:83–94.

[19] AboulNaga M, Amin M. Towards a healthy urban environment in hot-humid zones — information systems as an effective evaluation tool for urban conservation techniques. In: Proceedings of XXIV IAHS World Congress; Ankara, Turkey, 1996

[20] B. Edwards, Sustainable Architecture, European directives and building design, Architectural Press, Oxford 1999.

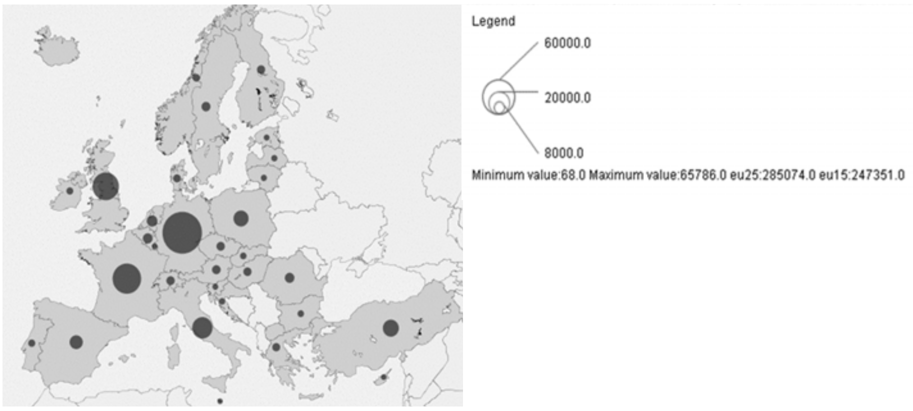

Fig.1. 2: Final energy consumption residential sector. Source data: Eurostat

But if on the one hand buildings have a key role to play, as they are one of the major sources of energy consumption, and development is one of the biggest factors changing the Environment of Europe, on the other it's true that construction is also second biggest industry in terms of people employed.

As buildings have a direct impact on the environment, both during the construction process and its use, appears clear how the residential sector has enormous potentialities that should be exploited to reduce consumption and pollution, but also careful and competent action are needed.

Buildings' construction is an activity with long-term effects, in which design decisions are able to move considerable amounts of resources, it is necessary to guide the architecture and technological research towards sustainable solutions.

The level of knowledge achieved in the field of technology already allows the construction of buildings to exploit the full potential of energy efficiency, and to take into account parameters such as position, orientation and building form, materials, insulation, system installation measures, all characteristics that can help in making a building more sustainable.

But, what are these issues that make a building sustainable? This is the important question.

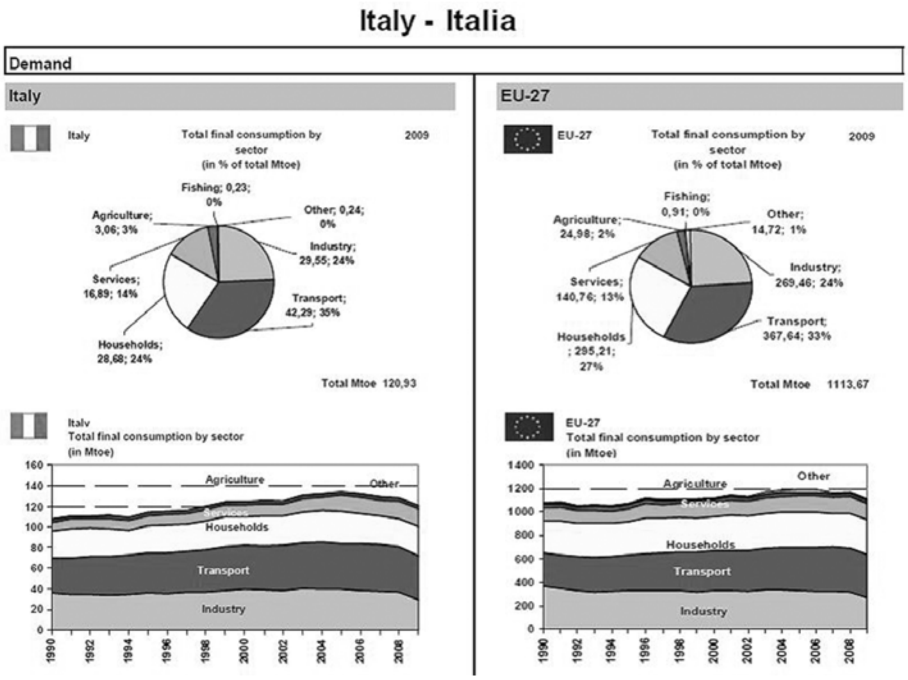

Fig.1. 3: Graphical comparative analysis of the Energy, between Italy and the 27 Member States of EU

Architecture is not just a “pretty” building; architecture find is highest expression studying and creating a good building in its environment.

Hence, site is also an important issue.

While a building inevitably consumes materials and energy resources, technology is available to use methods and materials that reduce a building’s environmental impacts, increase operating efficiency and durability.

“For environmentally responsible buildings, development practitioners must think in an integrated way. Literature on green buildings reveals a number of principles that can be synthesized in the creation of the built environment that is sustainable. According to one source, these are: land development, building design and construction, occupant considerations, life cycle assessment, volunteer incentives and marketing programs, facilitate reuse and remodelling, and final disposition of the structure.[21] These parameters and many more are essential for analysis, making them an important part of the design decision-making process".[22]

In 2050 population will reach 9 billion people, and each has the right to live a decent life. The architecture must help creating conditions so that this can happen. Architects and engineers are able to develop the foundations for a globally better and sustainable future.

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[21] Lobo C. Defining a sustainable building. In: Proceedings of 23rd National Passive Conference, ASES'98. Albuquerque (USA): American Solar Energy Society, 1998.
[22] AboulNaga M, Y. H. Elsheshtawy, Environmental sustainability assessment of buildings in hot climates: the case of the UAE. Renewable Energy, Vol 24, Issues 3-4, pag 553-563, Elsevier. November 2001.

Chapter II – Energy in Architecture

It is evident that the problem of sustainability in architecture can be approached from different points of view. Often the problem of energy consumption is analyzed with reference to the ex-novo design, but in this work the focus shifts to how to apply the principles of sustainability to existing buildings, that is, turns the attention to the issue of upgrading the energy efficiency and improving the performance of the building. Also the research field was restricted to residential buildings, investigating the performance of buildings in hot climates.

Even specifying the discussion a multidisciplinary approach will always be needed. To better define the subject is still necessary to understand the basic principles that make a building sustainable, explore the concept of climate responsive design, and then moving to how these concepts can be applied to the present case.

In addition, the European and Italian regulatory framework currently in force will be deepened.

2.1 Energy consumption in Europe and Italy in the domestic sector

“In Europe, 50% of material resources taken from nature are building-related, over 50% of national waste production comes from the building sector, and also 40% of energy consumption is building-related".[1] [2] The European Commission has defined a strategy necessary to achieve the goal of a competitive sustainable and safe energy for the European Countries, through a document that identifies priority actions for the next 10 years, by building an energy system more efficient, a market at competitive prices, energy supplies more secure, etc..

In addition, the International Energy Agency points out, in its report on the energetic perspectives, that the revolution hoped for a long time to respond to the issues related to climate change is actually a process already in progress.

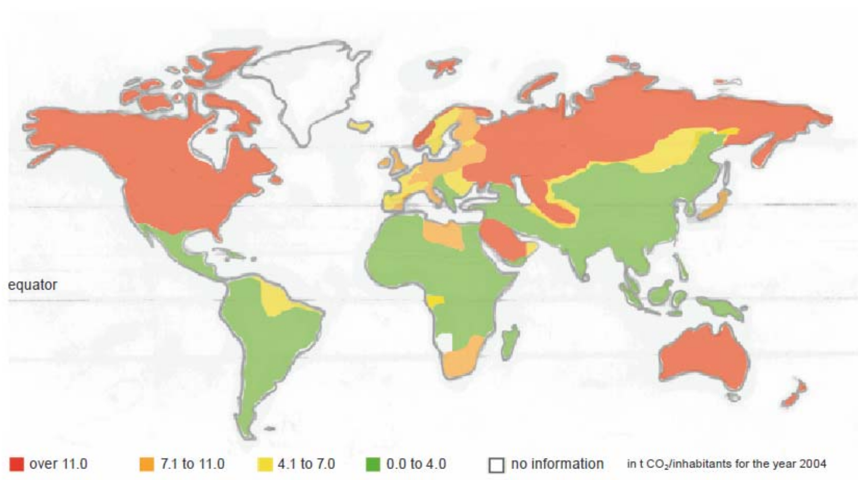


Fig. 2. 1: CO_2 Emissions Distribution levels per Capita, World Population, for the year 2004. M.Bauer, P.Mösle M.Schwarz, Green Building – Guidebook for Sustainable Architecture, Springer,2009 pg.13.

[1] Anink D, Boonstra C, Mak J. Handbook of sustainable building: an environmental preference method for selection of materials for use in construction and refurbishment. UK: James and James, 1996.

[2] AboulNaga M, Al-Sallal K, El Diasty R. The impact of city urban patterns on building energy consumption in hot climates: Al-Ain city as a case study. In: Proceedings of ISES Solar World Congress; Taejon, S. Korea, 1997:170–81.

A future of low carbon dioxide emissions is an effective solution to support both economic development and the international energy situation. In Italy, however, investment in low-carbon technology sector, despite a good growth rate, are unbalanced in favour of projects for power generation, while have almost zero shares for technological innovation. In our country it is necessary to identify policies and tools to enable a technology growth. The percentage composition of demand by source, confirms the specificity of Italy, in comparison with the average of the 27 countries of the European Union, concerning greater use of oil and gas, electricity import, small contribution of solid fuels 7% of primary energy consumption, and the non-use of nuclear power.

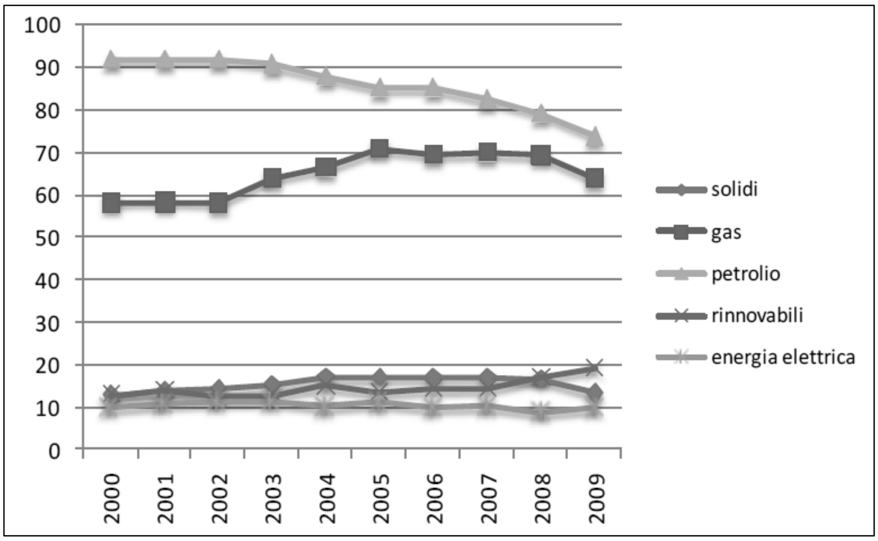


Fig. 2. 2: Energy consumption by source. Years 2000-2009. Source: ENEA based on MSE data.Years 2000-2009. ENEA, *"Rapporto Energia e Ambiente2009"*.

The *Rapporto Energia e Ambiente* 2009 by ENEA on energy consumption in end-use sectors of energy shows:

- a small but significant decline in consumption in the transport sector (-1.8%);

- a variation of opposite sign in the Civil sector (+3.5%) related to climate variability (gas +5%, electricity to +3%, and renewable +9%);
- a significant drop in consumption of "industry (-20%) in agreement with the sharp drop in industrial production (-13.3%).

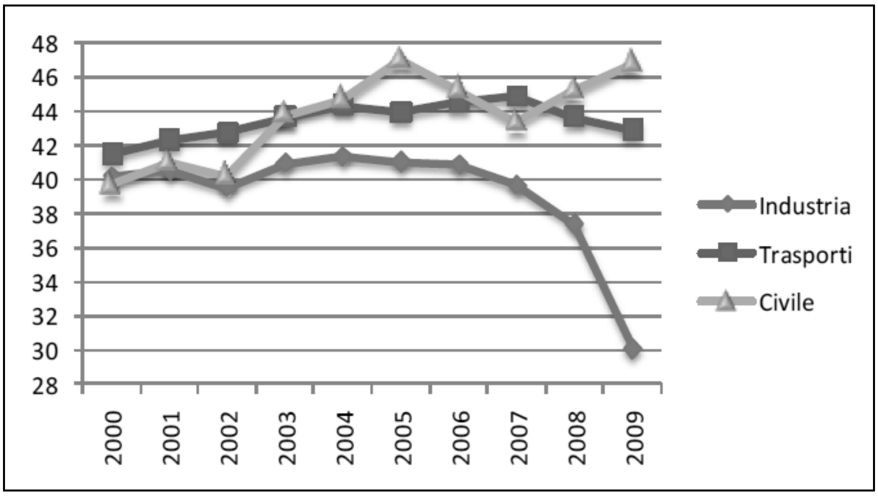


Fig. 2. 3: Final energy consumption by sector. Source: ENEA on MSE data. ENEA, *“Rapporto Energia e Ambiente2009”*.

As noted in the chart above, the domestic sector, unlike the others, in recent years has had a growing trend in terms of energy consumption. To act in the domestic sector is therefore important.

Furthermore, through simple measures, and the direct involvement of the population, it is possible to act on a large scale, a necessary condition to make the intervention effective. ENEA scenarios show how, in the domestic sector, a massive use of more efficient technologies will provide for reductions in fuel consumption by up to 12% already in the year 2020, about 4 Mtoe less than the evolving trend (according with the draft of the *Piano straordinario per l' Efficienza e il Risparmio Energetico*, of March 2010).

In the long run the reduction compared to the reference scenario may further increase, up to 29% (of the sector consumption) in 2050. These results are obtained primarily through efficiency improvement of the Italian high-tech sector for air conditioning (winter and summer) and production of hot water.

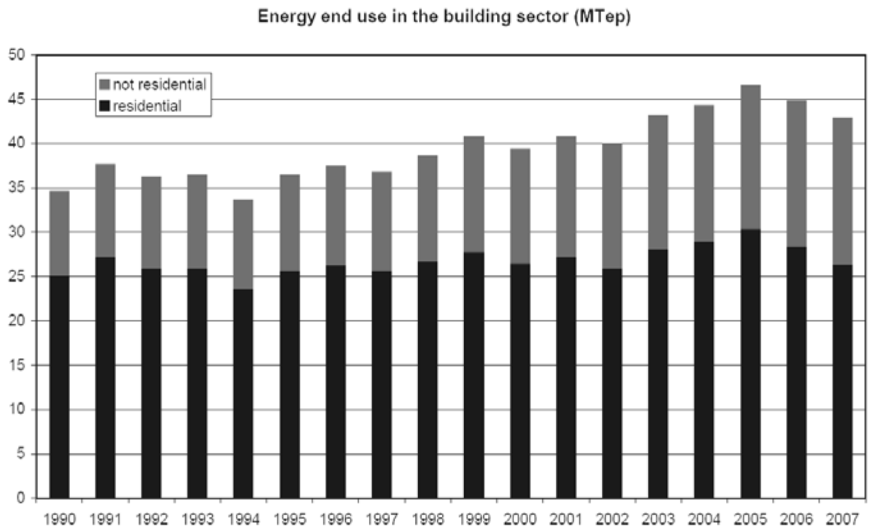


Fig. 2. 4: Energy end use in Italian buildings since 1990. Grey: non residential, black: residential. Source: M. Zinzi, G. Fasano, M. Citterio, Impact, compliance and control of legislation in Italy, ENEA, Brussel Sptember, 2009

Although in recent years progresses have been made in this direction, the scenarios show that there are still plenty of room for improvement.

For example greater use of high-efficiency condensing boilers, high-performance heat pumps and air conditioners, may guarantee to reduce consumption by about 3 Mtoe within 2020. Energy use for domestic hot water and kitchen use, are more or less the same, while electricity use is growing fast, (mainly because of the standard comfort that has been changing, and an increasing consumption of energy for summer cooling and dehumidification can be registered).

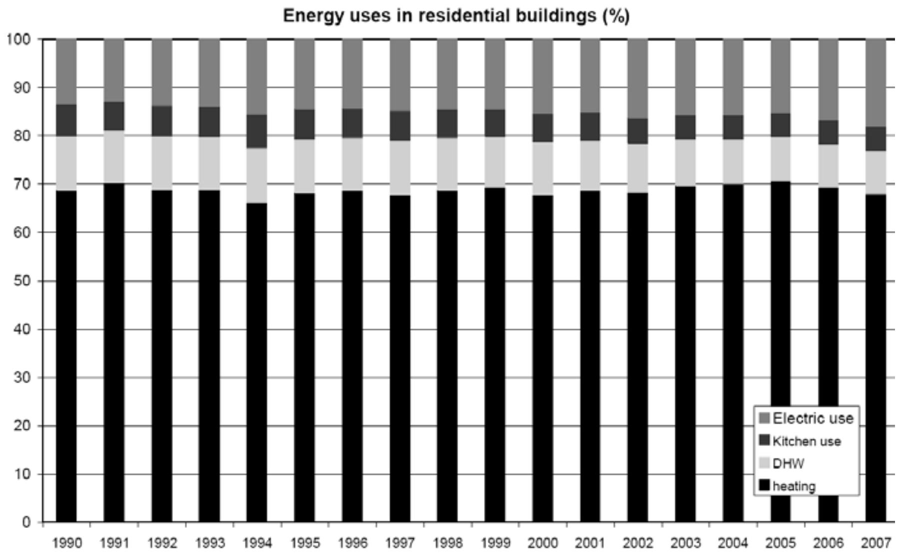
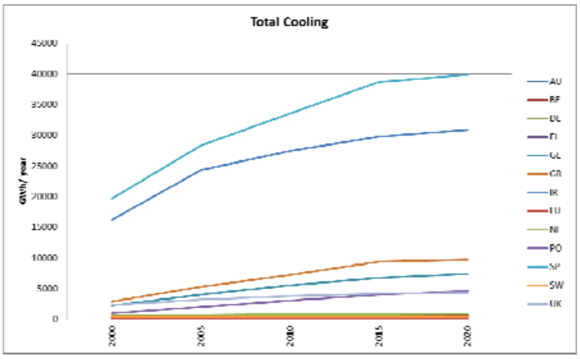


Fig. 2. 5 : Percentage Energy uses in residential sector per typology of Energy use. Source: Rapporto Energia e Ambiente ENEA 2008.

The lifestyle of western societies led to an increase in the consumption of primary energy needed to cool the buildings, with enormous impact on the environment. In particular, Mediterranean countries had a significant increase in energy consumption in summer due mainly to the use of air conditioners. In Europe, Italy is leading both for the number of square meters provided that in the growth forecasts, followed by Spain. According to studies EECCAC[3] demand for summer cooling will become up to four times higher by 2020. To deal with this question common to many European countries, the European Community in 2005 launched the "Keep Cool" programme with the aim of illustrating

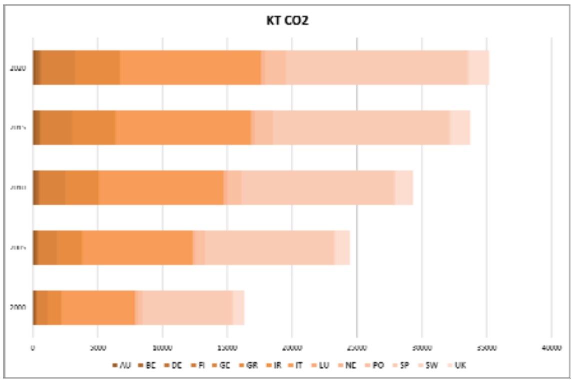
[3] J. Adnot et al., Energy Efficiency and Certification of Central Air Conditioners – Final report, 2003, p. 16.

the features and benefits of sustainable cooling systems, to propose regulatory changes and to encourage economic incentives.



Total Cooling - GWh/ year					
Country	Year				
	2000	2005	2010	2015	2020
AU	469	549	633	689	707
BE	274	422	559	681	708
DE	71	122	180	232	260
FI	206	210	229	242	246
FR	5010	8213	10954	13240	14071
GE	2286	4012	5542	6785	7415
GR	2909	5365	7269	9399	9734
IR	127	180	222	252	264
IT	16209	24336	27445	29795	30890
LU	11	18	23	27	29
NE	605	690	797	869	892
PO	1020	2049	3072	4039	4621
SP	19689	28333	33573	38719	39915
SW	391	378	403	421	425
UK	2359	3227	3826	4241	4401
Total	51636	78104	94727	109631	114578

Table 2. 1: Cooling only energy consumption by country and year.



KT CO_2					
Country	Year				
	2000	2005	2010	2015	2020
AU	164	192	221	241	248
BE	96	148	196	238	248
DE	25	43	63	81	91
FI	72	73	80	85	86
FR	1754	2874	3834	4634	4925
GE	800	1404	1940	2375	2595
GR	1018	1878	2544	3289	3407
IR	44	63	78	88	93
IT	5673	8518	9606	10428	10812
LU	4	6	8	9	10
NE	212	242	279	304	312
PO	357	717	1075	1414	1618
SP	6891	9916	11751	13552	13970
SW	137	132	141	148	149
UK	826	1129	1339	1484	1540
Total	18073	27335	33155	38370	40104

Table 2. 2: Numerical results about CO_2 emissions due to cooling in Europe.

While in the commercial sector the major saving's opportunities are offered by the improvement of energy management systems, in the residential sector, next to the update of heating/cooling systems, the crucial problem is the choice of a correct solution for the building envelope. That's why this research work analyses how act cleaver to reduce consumption, taking into account the boundary conditions, i.e climatic conditions and regulatory framework.

2.2 Regulatory Framework and trends in warm climate

In less than forty years environmental protection and sustainable development has become an important area of interest for the European Union. The gradual journey which has been undertaken can be summed up in ten key steps in the table below.

International milestones of environmental agreement or awareness	
Year	Event
1972	"The Limith to groth" Report
1972	Stockholm Conference on the Human Environment (UN)
1979	Berne Convention on Habitat Protecion (Council of Europe)
1979	Geneva Convention on Air Pollution (UN)
1980	World Coonservation strategy (IUCN)
1980	Global 2000 Report (USA)
1983	Helsinky Protocol on Air Quality
1983	Word Commission on Environment and Development (UN)
1987	Montreal Protocol on Substances that deplete the Ozone Layer (UN)
1987	Our Common Future (Brundtland Commission on behalf of the UN)
1990	Green Paper on the urban Environment
1992	Rio Summit Agreement (UN)
1992	Our Common Inheritance (UK)
1994	European Environment Agency established (EU)
1997	Kyoto conference on global warning
2007	Intergovernmental Panel on Climate Change (IPCC) publishes its fourth assessment, for which it wins the Nobel Peace Prize.
2009	Copenhagen Climate Change Conference

Fig. 2. 6 : International milestones of environmental agreement or awareness. BANHAM R., The architecture of the well-tempered environment, London : Architectural Press, 1984

To solve the problem of environmental impact of building several regulation and directives of interest to architects and engineers have been enacted, the two most important and recent, concerning energy consumption in buildings are:

- Directive 2002/91/EC: "The Directive concerns the residential sector and the tertiary sector (offices, public buildings, etc.). The scope of the provisions on certification does not, however, include some buildings, such as historic buildings, industrial sites, etc. It covers all aspects of energy efficiency in buildings in an attempt to establish a truly integrated approach. The Directive does not lay down measures on moveable equipment such as household appliances. Measures on labelling and mandatory minimum efficiency requirements have already been implemented or are envisaged in the Action Plan for Energy Efficiency".[4]
- On May 19 2010, the new Energy Performance of Buildings Directive (EPBD) was finally adopted as Directive 2010/31/EU. "It calls for increased national regulation for energy efficiency in new and renovated houses. It also includes the framework for national requirements for building systems, such as heating systems and larger ventilation systems. In July 2012, the new Directive shall be implemented, though many elements including the regulation of building systems only need to be implemented by January 2013 for public buildings and by July 2013 for all buildings."[5]

[4] From: http://europa.eu/legislation_summaries/other/l27042_en.htm "Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings".

[5] From http://www.inforse.dk/europe/eu_build-di.htm, Energy Performance of Buildings Directive (EPBD)

“The four key points of the Directive are:

- a common methodology for calculating the integrated energy performance of buildings;
- minimum standards on the energy performance of new buildings and existing buildings that are subject to major renovation;
- systems for the energy certification of new and existing buildings and, for public buildings, prominent display of this certification and other relevant information. Certificates must be less than five years old;
- regular inspection of boilers and central air-conditioning systems in buildings and in addition an assessment of heating installations in which the boilers are more than 15 years old.

The common calculation methodology should include all the aspects which determine energy efficiency and not just the quality of the building's insulation. This integrated approach should take account of aspects such as heating and cooling installations, lighting installations, the position and orientation of the building, heat recovery, etc. The minimum standards for buildings are calculated on the basis of the above methodology. The Member States are responsible for setting the minimum standards.”[6]

“The Directive forms part of the Community Initiatives on Climate Change (commitments under the Kyoto Protocol) and security of supply (the Green Paper on security of supply). Firstly, the Community is increasingly dependent on external energy sources and, secondly, greenhouse gas emissions are on the increase. The Community can have little influence on energy supply but can influence energy demand. One possible solution to both the above problems is to reduce energy consumption by improving energy efficiency.

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[6] From: http://europa.eu/legislation_summaries/other/l27042_en.htm “Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings”.

This Directive is a follow-up to the measures on boilers (92/42/EEC), construction products (89/106/EEC) and SAVE programme provisions on buildings. Though there is already a directive on the energy certification of buildings (Directive 93/76/EEC repealed by Directive 2006/23/32/EC), it was adopted in a different political context before the Kyoto agreement and the uncertainties with the security of energy supply in the Union. It does not have the same objectives as Directive 2002/91/EC. The latter is an additional instrument, proposing concrete action to fill any existing gaps."[7]

As energy consumption for buildings-related services accounts for approximately one third of total EU energy consumption, the Commission considers that, with initiatives in this area, significant energy savings can be achieved, thus helping to attain objectives on climate change and security of supply. Community-level measures must be framed in order to deal with such Community-level challenges.

Italy, as a country part of the European Community, transposes EU legislation. The implementation of the Energy Performance of Buildings Directive (EPDB) in Italy is a shared task between the State and the 21 Regions and Autonomous Provinces.

At the end of 2010, the revision process of the current legislation at the national level was completed (with the only exception being air conditioning inspections), and an initial group of 10 Regions implemented their transposition according to the national model and guidelines (generally adding more demanding elements than in national regulations) while the national rules still apply in the Regions that have not yet published their legislation.

Anyhow now certification is widespread in the building market, starting with the most active regions. The Ministry of Economic Development, in collaboration with the Ministry of Environment and the Ministry of Infrastructure are in charge of the regulation of energy conservation in building (ECB). A significant advancement in the national regulations was made in 2009, on 25th of July, with the new Ministerial Decree that adopted the National Guidelines on Energy

[7] http://europa.eu/legislation_summaries/other/l27042_en.htm

Certification of Buildings, guidelines that specify procedures, element of certification and performance classes which have legal value in all the Regions without a legislation of their own. Since that date all existing residential and non residential buildings need to be certified when they are sold, certification is compulsory also to gain access to most public incentives for energy efficiency, like 55% tax credit, the contribution allowed when performing energy audits, and the increase of the self-produced PV electricity premium tariff, (when at least 10% energy saving has been achieved).

Probably the most visible aspect of ECB is the Energy Performance Certificate, that assigns an energy performance label to buildings (residential and non-residential) classifying energy performance (kWh/m^2 or kWh/m^3 for non residential) on an efficiency scale ranging form A+ to G (poor efficiency).

The global energy performance is the sum of energy performance for heating (EPi) for domestic hot water (EPacs) for cooling (EPe) and artificial lighting (EPill):

$$EPgl = EPi + EPacs + EPe + EPill$$

Obviously the certificate gives also recommendations to the owners, trough a list of actions and implementation to obtain a better Energy performance, and pay back time. Heating classes are defined with reference to the minimum energy performance requirements.

About summer cooling, the thermal load of the new residential building has to respect the following maximum levels:

- For climatic zones A and B: 40 kWh/m^2 year.
- For climatic zones C through F: 30 kWh/m^2 year.

Summer performance quality can be evaluated in the certificate, on the basis of summer thermal load, so that classes of summer performance are obtained:

EP e, thermal load (kWh/m^2 year)	Evaluation	Performance quality
EP e, thermal load < 10	Optimal	I
EP e, thermal load < 20	Good	II
EP e, thermal load < 30	Medium	III
EP e, thermal load < 40	Sufficient	IV
EP e, thermal load > 40	Poor	V

Fig. 2. 7: Classes of summer performance.

Among the national incentives and subsidies, the tax credit programme (55% tax credit) has been considered a great success in terms of saved energy, induced investment and benefits, (the *Nuovo Decreto Sviluppo* provided for the extension of three years of tax deduction of 55% on energy retrofit of buildings, with some modifications such as the introduction of spending limits and the revised incentives as a function of the interventions). That's why on January 20th an extension of this decree has been proposed.

In the frame of the photovoltaic premium tariff and net metering system, an increase of up 30% of the tariff itself is available for buildings submitted to a renovation, leading to reduce consumption by at least 10% (the new *Decreto* also proposes a correction of tariffs on the production of electricity by solar panels, connected to degree-day of each climatic zones, in order to standardize the value of the incentive on the whole national territory).

The more, among the incentives for low energy buildings "a decree of march 2010 offers a public grant of 83 €/m^2 and for new residential buildings if the achieved Energy Performance is less than 30% and of 116 €/m^2 if the achieved Energy Performance is less than 50% of the minimum requirements in force. […] The EPBD requirement for new buildings and major renovations will certainly bring important energy savings in the near future, although new and renovated buildings only represent a small share of the entire building stock in Italy (about 1% per year of existing buildings).

Therefore, the impact of applying energy performance requirements in new and renovated buildings is obviously limited and will not lead, in useful time, to relevant reduction in energy consumption in the building sector. To achieve real energy savings in the building sector, significant incentives regarding the improvement of existing buildings are needed, and certification can play a fundamental role”[8].

2.3 Sustainable Building and energy upgrading

Building shall have to exercise functions of climate control and ensure comfortable indoor temperatures as much as possible during both winter and summer. This central role is played by the building envelope mainly, whose structure and whose materials are to be harmonized to avoid cold or overheating, even without recourse to expensive and complex technological systems. For this reason more and more often intelligent shells are the main goal in new projects.

Nevertheless it is important to extend the concept of sustainability and energy efficiency also to existing buildings, which represent the bulk of the Italian building stock. But how?

As previously said, legislative guidelines regard installation measures, renewable energy systems, new materials and technology in the construction sector. In this research heating/cooling systems have not been analyzed, so also the study of ways to intervene on a building and the analysis are limited to the field of technology and materials.

It’s possible to classify interventions as follow:

- thermal insulation
- replacement of windows
- shading systems
- ventilation

[8] M. Antinucci, G. Varalda, M. Macaluso, L. Marenco, “Implementation of the EPBD in Italy –Status in November 2010” Country Reports ofn EPBD implementation, June 2011.

Let's analyze briefly these "tools" one by one, starting from the first: insulation, the main intervention because it helps to protect from cold in winter.

The outer walls are usually the largest surface of the envelope and their importance increases with the height of the building. The thermal quality of the exterior walls exerts a strong influence on heat loss by conduction.

The thermal insulation can be obtained with several materials and techniques. A multi-layer structure requires the use of multiple layers of insulation, for which it's possible to use a variety of materials ranging from natural products such as cork, hemp, or wool, to extruded foams or panels. The choice of insulation depends on the area object of intervention and on the required characteristics such as resistance to pressure, moisture or fire. More generally, the characteristics that a thermal insulator for building must have are the following:

- durability, its characteristics must remain unchanged over time;
- ability to withstand thermal variation without structural changes;
- low permeability to water vapour;
- unassailable by bacteria and insects and rot;
- inertia to water and low water absorption;
- incombustible, or at least self-extinguishing;
- good mechanical strength to ensure the stay in position when subjected to loads pose and good compressive strength;
- no big sagging under the action of the weight and vibration;
- easy processing;

To ensure an ideal sequence of layers from a construction point of view, insulating material should be put on the outside of the perimeter walls, but in a retrofitting add a thermal insulation is subsequent, there are three different ways of acting:

- inside
- outside (thermal insulation coating, ventilated-wall system)
- inside the wall

Each technique has advantages and disadvantages, the advantages of insulation from the inside are listed below:

- it allows the maintenance, for existing buildings, of the external features;
- less expensive and more easily enforceable than insulation from the outside (no scaffolding, no need for external protection);

but on the other hand:

- does not eliminate a few thermal bridges (slab-wall connections, wall frame, wall-partition);
- results in a reduction of habitable volume;
- does not allow to exploit the thermal inertia of the wall;
- requires a careful analysis of humidity.

The isolation from the outside instead:

- eliminates thermal bridging related to the structure;
- is ideal when it is necessary to improve the external features of the building;
- ensures a proper hygrothermal behaviour of the wall;
- allows to increase the thermal inertia of the wall;
- do not cause discomfort to occupants during the assembly;

However, presents the following disadvantages:

- increased costs related to scaffolding and to the insulation protection needed;
- the need to protect the insulation from atmospheric agents;
- may present problems of durability of materials.

Often in new buildings walls are made of "sandwich" consisting of two walls in concrete or brick and an air gap interposed. Air has good insulating properties, but can be replaced with material with better ones. In existing buildings, a way to intervene consists in filling the air gap between the two layers of the wall, with foams or natural loose materials such as cork, vermiculite, clay pebbles etc..

MATERIALE	Densità (kg/m^3)	Conduttività utile di calcolo[3] a 20°C ($W/m^{-1}K^{-1}$)	Contenuto d'acqua al quale è riferita la conduttività (% di massa)	Assorbimento d'acqua per capillarità (% di volume)	Assorbimento d'acqua per Immersione (% di volume)
Fibre di vetro - materassini di feltro resinato - pannelli semirigidi - pannelli rigidi	 11÷16 16÷30 100	 0,053÷0,046 0,046÷0,038 0,038	1%	elevato	Elevato
Fibre minerali, di rocce feldspatiche o basaltiche	30÷125	0,038÷0,048	1%	elevato	Elevato
Legno - conglomerato di lana di legno e leganti inorganici - conglomerato di spaccato di legno e leganti inorganici, - pannelli di particelle di legno, pressati o estrusi - naturale duro o extraduro	 300÷500 400÷600 500÷700 800÷1000	 0,085÷0,11 0,12÷0,15 0,10÷0,17 0,14÷0,18	 15% 15% 10% 10%	elevato	Elevato
Polistirene espanso estruso - con pelle - senza pelle	 30÷35 30÷50	 0,035÷0,035 0,041÷0,034	1%÷2%	zero	0,2% in 29 giorni
Polistirene espanso, in lastre, - sinterizzato - stampato per termocompressione	 10÷30 20÷30	 0,052÷0,041 0,040÷0,039	1%÷2%	zero	3÷5% in 7 giorni
Poliuretano espanso - prodotto in lastre - ottenuto in situ	 25÷50 37	 0,034÷0,032 0,035	1%	elevato	Elevato
Sughero espanso	90÷200	0,043÷0,052	2%÷4%	12% in 3 giorni	20% in 3 giorni
Vetro cellulare	130÷180	0,055÷0,066	0%	nullo	Nullo
Materiali sfusi - polistirolo espanso in granuli - fibre di cellulosa - perlite espansa in granuli da 0,1 a 2,3 mm - vermiculite espansa in granuli da 1 a 12 mm - argilla espansa in granuli da 3 a 25 mm	 15 32 100 80÷120 280÷450	 0,054 0,058 0,066 0,077÷0,082 0,09÷0,12	 3% 15% 1% 1% 1%	 zero elevato modesto modesto elevato	 Modesto Elevato Elevato[4] Elevato 15% in 24 ore

Table 2. 3: Thermophysical and hygroscopic properties, at 20°C of some insulating materials.

The Insulation Handbook (by Richard T. Bynum Jr., A.I.A. McGraw-Hill) indicates several type of insulating systems:

- *loose-fill insulation*. "Loose-fill insulation materials (such as cellulose, fiberglass, mineral wool (rock wool and slag wool), vermiculite, perlite, wood shavings, and expanded polystyrene are distinguished from other insulation types by the size of the individual unit of material. Produced as shreds, granules, or nodules, loose-fill insulation products can either be poured or blown into place depending on the material or the construction application”. [9]

- *Blanket Insulation: batts and rolls*. “Blanket insulations are flexible, bound products made from mineral (glass, rock, and slag) or cotton fibers. They are available in widths suited to standard spacings of wall studs and attic or floor joists”. [10]

- *Sprayed-in-Place Insulation*: “are basically modified loose-fill products that are blown into wall cavities or attics. Cellulose, fiberglass, and rock wool are the most common materials used today. This method is similar to the exposed sprayed fireproofing systems commonly found on structural members in many commercial buildings”.[11]

- *Foamed-in-place insulation*. This “materials have become fairly popular in the commercial and residential building industry since the early 1970s. A plastic foam material consists of a gas phase dispersed in a solid plastic phase and derives its installed properties from both. The solid plastic component forms the matrix, whereas the gas phase is contained in voids or cells. Although specific processes vary, foamed-in-place insulations start as a liquid that is sprayed through a nozzle into wall, ceiling, and floor cavities”.[12]

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[9] Richard T. Bynum Jr., A.I.A. Insulation Handbook, McGraw-Hill, 2001.
[10] Ivi
[11] Ivi.
[12] Ivi.

Fig. 2. 8: Examples of : blanket insulation, loose-fill insulation, and foamed in place insulation.

But the vertical walls have other weak points, the presence of transparent components, windows. In the design of windows it's necessary to take into account several requirements, such as the use of daylight and the view out.

Transparent surfaces present, because of the material used, worse thermal property than the opaque components. The size and placement of glass surfaces can have substantial effects on heat losses. As for the other elements glass components may also differ in thermal characteristics, depending on climate zone, exposition and use.

Zona climatica	**strutture opache verticali**	**strutture opache orizzontali o inclinate**		**Chiusure apribili e assimilabili (**)**
		Coperture	Pavimenti (*)	
A	0,54	0,32	0,60	3,7
B	0,41	0,32	0,46	2,4
C	0,34	0,32	0,40	2,1
D	0,29	0,26	0,34	2,0
E	0,27	0,24	0,30	1,8
F	0,26	0,23	0,28	1,6

(*) Pavimenti verso locali non riscaldati o verso l'esterno

(**) Conformemente a quanto previsto all'articolo 4, comma 4, lettera c), del decreto Presidente della Repubblica 2 aprile 2009, n. 59, che fissa il valore massimo della trasmittanza (U) delle chiusure apribili e assimilabili, quali porte, finestre e vetrine anche se non apribili, comprensive degli infissi."

Fig. 2. 9: Reference values for thermal transmittance. D.M 26/01/2010

Several solutions are currently in use ranging from simple glass elements to highly developed ones in terms of isolation through the use of stratification of gas and glass. In temperate zones standard models are primarily used with double glazing and thermal break.

Directly related to the problem of transparent surfaces, is the use/reduction of solar radiation. This is an issue, that especially in temperate climate, is twofold, the glass surfaces in winter should allow the penetration of the almost horizontal sun rays, while during summer should protect from them to prevent overheating. The role of glass in this context is crucial, allowing thermal separation, the use of daylight and view of the outside; the more can act as a "heat-trap" thanks to its physical properties. The need to ensure adequate protection against excessive heat is becoming more urgent because e of global warming and increased climate comfort needs. There are many possibilities for optimizing thermal quality of transparent surfaces. For example modelling the facade of the building (as it's well known projections, recesses, corners etc... helps in "solar architecture") but also glass with solar control filter can be used, or windows in which the space between the pane is filled with reflective or absorbent materials (in each of these two cases, however, there is a high degree of reflection and a loss of neutrality in colour). Additionally, these systems have the disadvantage of reducing heat gain in winter.

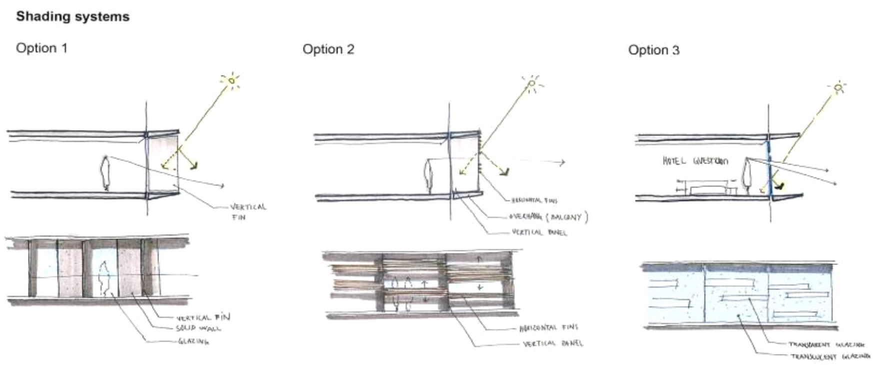

Fig. 2. 10: Different options in the design stage, Los Faros de Panama- Panama, Arup Associate

It is therefore preferable to use a system with greater flexibility; it is possible to distinguish between internal and external systems, usually external systems, for example venetian blinds, shade rolls, brise soleil, are those able to ensure the highest degree of protection, to which we can add the advantage of being able to open the windows. Alternatively it's possible to install wherever necessary, inside sunscreen.

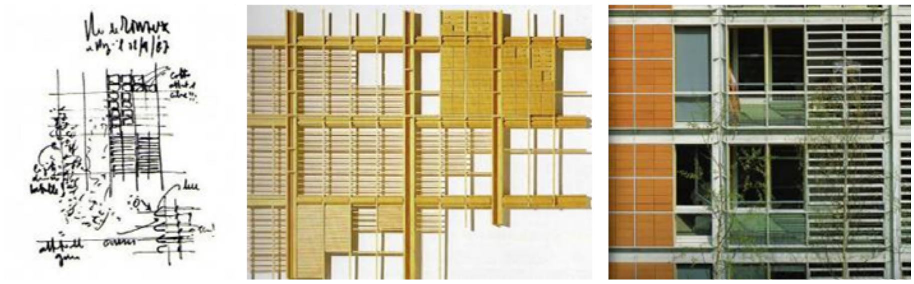

Fig. 2. 11**:** Sketch model and image of a shading system, Banca Popolare di Lodi – 1993-2001. Renzo Piano – *Giornale di Bordo* pg 205. Passigli Editori, Genova 2005.

Fig. 2. 12: Two examples of external shading devices: wood blinds and shade rolls. – from S. F.Brivio "Schermature solari e tende tecniche - Metodi e soluzioni di progetto, tipologie, risparmio energetico" Il Sole 24 Ore, 2010.

Finally a good indoor air quality requires a regular exchange of air, depending on the intended use and the number of occupants. But ventilation is also a fundamental tool to improve the interior comfort of buildings especially in hot climate. The winds acting on buildings are originated by the currents that are dependent on climatic conditions, topography, and the surrounding buildings and that require detailed analysis. Inflows of wind cause pressure conditions and suction near the buildings.

Fig. 2. 13: Grid to natural ventilation on windows and doors. From T. Contri “*Antoni Gaudì, l’Architetture – I protagonisti*” La Biblioteca di repubblica –l’Espresso Aprile 2007; pg 68.

As discovered in the 1950s studying human comfort, people felt about four degrees cooler in rapidly moving air than in still air because of the wind-chill effect. It's possible to create a wind chill, using ceiling fans, table fans, floor fans, and other circulating fans in occupied rooms.

Natural ventilation can be achieved (and at least partially controlled) through the adoption of specific tools such as the introduction of air supply openings in the external wall and the adoption of natural extraction devices (ventilators, chimneys, etc..).

The climates where ventilation is most desirable are the hot ones. Depending on the climate it is possible to suggest different behaviour:

- *Hot-dry climate* (North African or Middle Eastern) with cold nights and warm and dry days: it is desirable to ventilate rooms during the night and close windows during the day, to preserve the so accumulated freshness as long as possible.

- *Hot and humid climate* (subtropical) with very small temperature differences between night and day, it is preferable to have openings on all sides for maximum ventilation because it reduces the ambient humidity favouring evaporation and so cooling.

In the same way there are different ways of achieving natural ventilation. The main systems of cooling through natural ventilation are:

1. *Horizontal ventilation*. The air flow goes through one or more rooms, input and output air vents are located on opposite walls or adjacent but not coplanar, at the same height from the floor or at different heights to take advantage of the stack-effect;

2. *Vertical Ventilation*: input air vent is usually higher than the output one. The system consists of a vertical flow that goes from the input air vent to the room to be ventilated. The opening entry has to be windward.

3. *Single-sided ventilation* (with single opening or multiple openings): The fresh air is produced by one or more air vents located on the same exterior wall. The flow is intermittent and

dependent on changes in speed and wind direction. The total hourly flow rate is generally very low.

4. *Ventilation combined wind-stack effect*: In absence of wind, as at night, can be converted into a system of natural extraction of air creating a combined wind-stack effect.

5. *Hybrid ventilation* (wind air induction and assisted mechanical ventilation extraction).

So a simple way to cut air conditioning costs is to circulate cool night air with or without fans. Houses are solar collectors, which suck up solar heat all day.

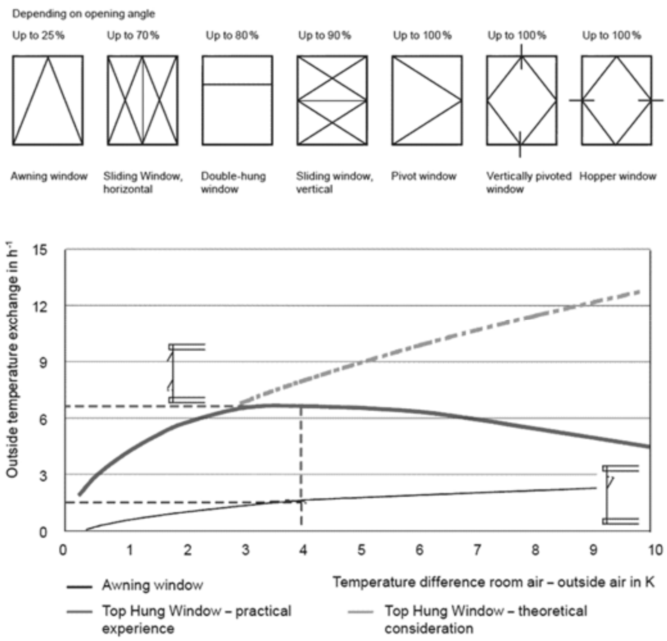

Fig. 2. 14: Relative air flow rate depending on window type and outside air exchange depending on temperature difference between indoor and outside air. M.Bauer, P.Mösle M.Schwarz, Green Building – Guidebook for Sustainable Architecture, Springer, 2009 pg.115.

Whole-house fans and window fans are used for flushing the home with cool night air. Passive ventilation works in mild summer weather: waiting until evening, when the outdoor air is cooler than the indoor air, and opening doors or windows helps to significantly reduce cooling costs. vicinity. “From an ecological point of view, a natural ventilation concept may make sense on account of the power savings for mechanical ventilation.

However, in case of high outside air exchange rates and low outside air temperatures, one needs to consider that huge airflow rates during natural ventilation will not be able to enter the room without draught.

Further, in case of extreme outside temperatures in winter, as well as in summer, there is considerable energy loss because heat recovery is not possible in case of natural ventilation. Hence, for these time periods, mechanical ventilation with efficient heat recovery is the method of choice”.[13]

2.4 Climate Responsive Design and retrofitting

EPIQR (energy performance, indoor environment quality and analysis of refurbishment cost) defines retrofit actions as those ones which upgrade and improve the building (or building element) to a higher standard than was originally planned for the apartment building.

Recently the main solution to gain the standards of comfort indoor has been the use of heating and cooling systems which led to the so called “universal climate”; it means that, whatever the climate outside, it is possible to have always the same climate condition indoor (about 25°C and 50% of humidity) almost everywhere, without concern for place.

But this way of design is absolutely improper from an energetic point of view, designers should respect the natural climate and should consider

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[13] M.Bauer, P.Mösle M.Schwarz, Green Building – Guidebook for Sustainable Architecture, Springer, 2009 pg.115

more the historically used strategies for environmental control, given a particular building function, design and context.

Thankfully in the last years we have witnessed an increase concern for environmental impacts of building and for the quality of internal environment, this has led to the raise of interest in "green buildings" and in climate responsive design.

In order not to have discomfort indoor, to reduce energy consumption, to minimize pollution, bioclimatic design should be considered.

Climate responsive design is part of an environmental approach to building development called ecological sustainable design (ESD), it is based on "the way buildings form and structure moderates the climates for human goods and well-being"[14]. The interaction between a building and the external environment depends mainly on the climate:

- cold climate requires a defensive strategy;
- buildings in warm climate, instead, have to filter the climate in a multitude of ways.

In order to optimize the relationship between the site, climate and building, climate responsive design requires both analytical and synthesis skills of the architects.

The main principle at the base of the climate responsive design is the understanding of the climate parameters which may be influential in the design process, id est: temperature, humidity, wind, vegetation, light, related to the geographical position.

As R. Hyde defines Climate Responsive Design in his book, it is possible to identify three main kind of condition:

- global condition (created by the dominant geographical features of land, sea, sun and air.);

[14] Hyde R., Climate Responsive Design- A study of building in moderate and hot humid climate,Spon Press, London UK 2000.

- local condition (dependent on dominant features of water, topography, vegetation and built environment);
- site condition and building context (interaction of local condition and the building).

The problem is that the weather is quite difficult to predict, so designers have to use a “patter”, a methodology, in order to design in an appropriate way.

First of all not all hot climates are equal, there are different “kind” of warm climate. The angle of incidence of the sun to the earth is particularly important because it rules the amount of solar radiation and so the temperature. There are a lot of different classifications for the warm weather, the first quantitative classification of world climates was presented by the German scientist Wladimir Köppen (1846–1940) in 1900. It has been available as world map updated 1954 and 1961 by Rudolf Geiger(1894–1981).

Köppen was trained as a plant physiologist and when he realised that plants are indicators for many climatic elements he constructed his effective classification on the basis of five vegetation groups determined by the French botanist De Candolle referring to the climate zones of the ancient Greeks. The five vegetation groups of Köppen distinguish between plants of the equatorial zone (A), the arid zone (B), the warm temperate zone (C), the snow zone (D) and the polar zone (E).

A second letter in the classification considers the precipitation (e.g. Df for snow and fully humid), a third letter the air temperature (e.g. Dfc for snow, fully humid with cool summer).

Although various authors published enhanced Köppen classifications or developed new classifications, the climate classification originally developed by Köppen (here referred to as Köppen-Geiger classification) is still the most frequently used climate classification. However the Köppen one is not the only useful classification.

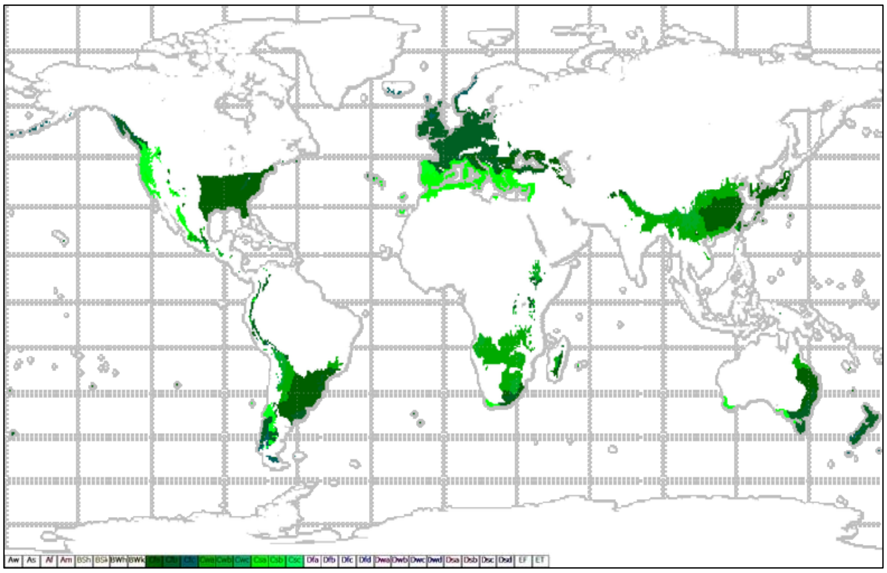

Fig. 2. 15: Koppen classification worldmap - GROUP C: Temperate/mesothermal climates.

Lippsmeier, for example, classifies climate by a wide range of factors and identifies main climate zones:

- subtropic;
- hot arid zone;
- savanna zones;
- monsoon zones;
- hot humid zones.

In addition he defines two other zones the mountainous and the maritime zone.

Another important classification is the one of Szokolay, more related with human comfort, in which four main climate are described:

- cool;
- moderate;
- hot dry;
- hot humid.

The last three are formed by the warm climate.

Whatever classification is followed, the first thing to do so, becomes to define and to understand, the nature of the warm climate, as the major difference between warm and cold climate is the amount of solar radiation that is received, consequently a classification by temperature and humidity is used and it is possible to identify three types of climate:

- hot humid;
- hot dry;
- moderate.

The classification defines the global climate parameters in which the building is located. But climate investigation involves the analysis of a wide collection of data in relation to the biological condition of human comfort in that area, so as suggested by Hyde, it is possible to identify three stages to be followed:

- *Stage 1*: information on seasonal and daily climatic data. It means to collect a wide range of data about the macroclimate. The important data are humidity and the dry-bulb temperature recorded a typical year. Minimum and maximum temperature on a monthly basis should be used.

- *Stage 2*: the bioclimatic chart. Check the bioclimatic chart related to the area of interest, then compare the chart with the data collected (stage1), in this way it is possible to assess climate in terms of days in which standard of comfort are granted, and days that not fit the “comfort zone”. This is a “zone”, that describes a set of temperatures and humidity at which it is thought humans feel comfortable. The problems become to extend the comfort zone.

- *Stage 3*: Climate modification strategies. For warm climate the temperature usually range above 20°C, but the real problem is humidity, which reduces the upper limit of acceptable temperatures to 22-23°C.

In order to establish which strategy is more efficient in one climate is important to compare data of the first stage with the data in the bioclimatic chart.

For example the *moderate climate* has characteristics of both the tropical region and the temperate one. The seasonal patter varies considerably with solar gain, rainfall and wind flow. In summer the land heat up, creating rising air and low pressure, in wind land cool down, the sea temperature act as a moderator (in winter it is warmer while in summer it is cooler).

The daily pattern is important too, and it varies with the season. Comparing the data with the bioclimatic chart can be seen that temperatures are in excess of the comfort zone for almost the 30% of the year, and also humidity is a problem. In these cases mass and air are the main strategies.

The *hot humid climate*, instead is the complete antithesis to the moderate climate, the main characteristic is the lack of seasonal variation.

The seasonal pattern is dominated by periods of high rainfall (named monsoon). Daily pattern, as usual, depends on season, in the dry season the clear and fine days are affected by thunderstorms, during the wet season there are long period of rain.

As can be easily understood, the main problem is humidity; climate is outside the comfort zone for a large period of the year, so strategies that reduce humidity and maximize airflow are desirable.

The *hot dry climate* is characterized by lack of humidity and seasonal changes in temperature both of which can be attributed to land mass effects, a cooling effect, during winter.

The lack of water makes the climate very severe. Rainfall is low, and is concentrated from December to March. The daily patter is similar most of the year. The lack of clouds, clear skies and lack of humidity means the sun is the main source of discomfort.

As it can be easily understood, these three cases need three different approaches. In fact the main difference from the cold climate is that in the warm one, buildings receive high level of solar radiation, so are in heat surplus for a large part of the year, but this is only one of the problems.

Connected with the higher temperature, is the problem of moisture, higher temperature allows the air to hold more moisture and have greater relative humidity.

Solar gain, rain water, air flow, moisture and condensation are the main struggle to be faced, but they present different characteristic depending on the different type of warm climate, so each case has to be treated as individually.

There are basic climate modification strategies that involve the use of airflow, shading, evaporative cooling and thermal mass, the following table summarize different cases and the main control strategies, in a very schematic way:

	PROBLEMS	TRANSPORTATION	MODE	CONTROL	DIRECTIONS
SOLAR GAIN	- discomfort - heat transfer - energy consumption	- conduction (major mode) - convection - radiation	- absorbing - reflecting - transmitting	opaque enclosure: [absorbed/reflected] transparent enclosure	SHADING SHADING ANALYSIS OF HEAT FLOW
RAIN WATER	- efflorescence - discoloration - mold growth - corrosion & decay	wind driven rain	- deflection - drainage - storage - exclusion	reduce the rainwater load accept rain water will penetrate provide drainage to remove it mass system: provide enough moisture to absorb all rainwater perfect barrier walls	controlling: siting, orientation, massing, of the building RAIN SCREEN applied to drained walls, with several layers to control rain LARGE QUANTITY OF MATERIAL REQUIRED: rubble, solid masonry etc.. MULTI LAYER ENCLOSURE, with a single layer with transmission
AIR FLOW	- energy consumption - condensation - mold & pollutants - health problems	forces driving: wind stack effect	control airflow control vapour transport thereby	ABS: Air Barrier System	1. Continuity 2. Strength and Durability 3. Stiffness 4. Impermeability
MOISTURE	- leakage of water & corrosion - freeze-thaw deterioration - biological growth, chemical deterioration - volume changes	function of: - wetting - storage - drying		Drying process: free liquid → drainage absorbed vapour → desorption capillary liquid → evaporation	DRAINAGE: removing great quantity in short time DIFFUSIVE DRYING: move vapour driven by vapour pressure AIR MOVEMENT: sometime caused by wintertime, stack-effect driven infiltration VENTILATION: useful especially in situation of solar heating
CONDENSATION	moisture mold growth health problems	cold-weather surface condensation warm-weather surface condensation	interior surface condensation interstitial condensation	diffusion control warm weather diffusion condensation vapour convective control	locating VAPOR RETARDENT LAYERS in the in the appropriate location EXPS: Extruded Polystyrene COMPARTMENTALIZING the enclosure to prevent cross flow DBZ: Dynamic Buffer Zone, strategy such as depressurization in winter and pressurization in summer etc..

Table 2. 4: Basic climate modification strategies and main control strategies

The problem becomes to “adapt” design objectives with what the climate factor made necessary. Even if it may sound simple, the application of all these strategies is not!

There are a lot of parameters that need to be taken into consideration.

The first ones are site and building context, it means that it’s necessary to understand the climate (micro and macroclimate) and the site potentiality, these led to the understanding of the building response to the climate (as it was in the vernacular architecture were climate, site and elements of the building generate the building form).

A strategy, which can be split in two levels, may be followed:

Level 1: relate the general building and the environmental control;
Level 2: analyse specific aspect of the building.

A really careful analysis of the site is important, the factors affected by the site are:

- temperatures, that can be modify by vegetation or topography;
- solar radiation, in fact shading from vegetation or other buildings can affect solar access to the building (= heating and light);
- airflow, modified by ground condition, with velocity growing with high, elevation and orientation are key factors;
- evaporative cooling, affected by topography and vegetation.

Another key aspect in the microclimate is the context, the rural one is represented by the prevalence of natural feature compared to the manmade, vegetation, proximity to ocean, sea, hills (that can provide shadows) are all aspects important in the design process, and are also aspects to consider in retrofitting actions.

In the suburban context, instead, the main issue can be the provision of airflow for ventilation, the higher density of the building, the less access to the building for the wind floe. In the urban context density of building is very high, this led to the so called *urban climate*, that has many different characteristic from the macroclimate of the area.

The fabric and spatial extent of urban context affects temperature, humidity, wind, and solar radiation, at the macroscale, but even at the microscale, land coverage, high of buildings, and orientation.

Microclimate produces the so called “microscale effects” for example the creation of shade in urban open spaces, provides the ideal environment for outside living, while the macroclimate produces “macroscale effects” one of the main effects is the so called “heat island” i.e. nocturnal elevation in temperatures as compared to the rural temperature.

The “island” extends both vertically and horizontally. To take advantage of the microclimate conditions careful considerations on orientation, airflow, environmental factor, is required, it means a careful site investigation.

Site investigation includes a collection of data on microclimate condition of the site, in order to use the data for an environmental analysis, and finally it led to conceive a climate responsive project. Looking carefully at traditional architecture all these aspect, or at least most of these, can be recognized in the wisdom of traditional construction practice.

Geographically, Italy lies in the temperate zone. Because of the considerable length of the peninsula, there is a variation between the climate of the north, so close to the centre of Europe, and that of the south, surrounded by the Mediterranean sea.

The weather conditions in a particular region will affect the life, and thus the architecture, which is in many cases a mirror of the needs and priorities of the life of people.

Traditional local architectures, also known as vernacular architectures, differentiated by latitude, are an example of harmonizing buildings with nature its features. This also applies to the architecture of the Mediterranean region, which, as said before, is characterized by very specific climatic conditions, presenting sometimes humid summers, not very cold winters but rainy, thanks to the strong mitigating effect of the sea. The Mediterranean traditional architecture evolved to produce buildings that would be in harmony with the harsh climates of its various regions.

To better understand the properties of modern building envelopes in the Mediterranean area is necessary, first, to analyse the properties of traditional enclosures. But which definitions can be given to the Mediterranean architecture? And which characteristics distinguish it?

Actually, building typologies are few and simple, as they have always complied with the territory according to simple paths of rationality and geometry. Architecture adapted to the uneven nature of the ground, repeating row houses in linear settlements along the sea coasts, or along main roads of the countryside, or expressed in isolated buildings that identify scenic viewpoints.

If you consider that the architectural culture has accepted the challenge of energy conservation as a driver of development and as a commitment to safeguarding the environment, we must not forget that Mediterranean architecture is, from this point of view, an effective model, tested for centuries to address these issues.

Fig. 2. 16: Trulli in Alberobello – Puglia (Italy) and a "dammuso" in Pantelleria (Italy)

In fact, traditional architectural solutions, thanks to the aforementioned climate, tended to maximize the use of energy contributions, both in terms of solar radiation and of natural ventilation provided by the external environment, and at the same time, to ensure proper shielding of windows.

"While the traditional Mediterranean residences provided shelter from extreme climatic conditions with various methods without consuming a lot of energy, the mechanization and the internationalisation caused the rejection of the tried methods and the lack of knowledge of building physics stripped the building structure from its basic operations and they left the building in the mercy of climate."[15]

Solar radiation has always been regarded by humans as a principal source of energy, enough to significantly influence the traditional building techniques.

The Mediterranean architecture has been characterized, during different historical periods, by solutions that had a relatively high number of openings, simple or complex, sometimes large, but always with shading systems. Due to the geometry of the openings, properly shielded, the sun could hardly penetrate and affect the interior surfaces for a major fraction of the day during summer.

With a proper dimensioning of the openings of two important objectives are achieved in the design of the traditional shells: the onset of natural ventilation and, simultaneously, the filtering of solar radiation.

Open or semi-open structures, such as terraces, loggias, balconies and porches, have helped to enrich the Mediterranean architecture and complete architecturally the traditional building.

But vernacular architecture in the Mediterranean climate has features far more extensive and complex, some basic points are:

- The location of the building and its orientation, chosen in such a way as to guarantee the ability to operate a natural cooling provided by the cross ventilation of rooms.
- The presence of massive walls capable of providing significant inertial characteristics of the building envelope.
- The use of building materials with low thermal conductivity that can reduce the total amount of energy transmitted through the outside walls
- The optimization of the size and location of openings through side walls and roof, both with regard to heat transfer and day light;

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[15] The Wisdom of Mediterranean Traditional Architecture versus Contemporary Architecture – The Energy Challenge. Despina K. Serghides. The Open Construction and Building Technology Journal, 2010,4, 29-38.

Men have gradually learned that many aspects participate in the operation and function of the thermal regulating mechanism such as: topography, construction it means morphology, materials and even the layout and use of internal spaces. Site was important too, the presence of vegetation, of water, or simply of other construction affects thermal performance of the building.

The more they learned that in hot regions ventilation is necessary for comfort and hygiene; even in warm summer days when the building interior is colder than the outdoor, that's why in traditional buildings a great deal of attention was given to ventilation especially to the pre-treatment of air.

Other architectural aspects and structural elements which exist in the old houses that reflect the traditional wisdom are solarium and the courtyard.

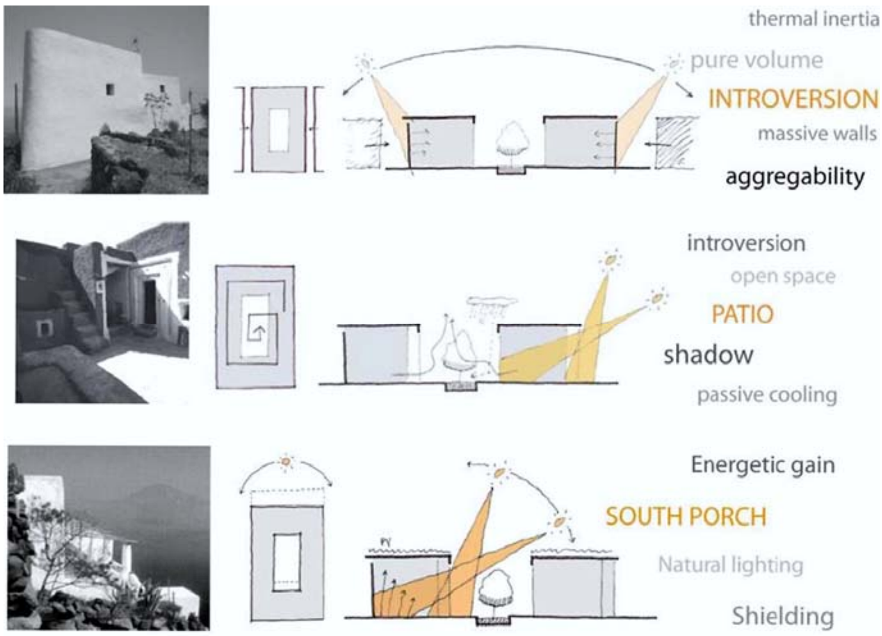

Fig. 2. 17: MED in Italy - The Sustainable Mediterranean House , *Tradizione Mediterranea, web site:* http://www.medinitaly.eu/it/progetto_mediterranea

"In the countries of Mediterranean and the regions with hot climates, in which the sun is desirable in the winter while in the summertime the cooling and ventilation is necessary, the solarium and the courtyard are indispensable solar features of houses, unique elements of local architecture.

Both components, although outdoor, open spaces of building, they are focal elements around which the various activities of all other spaces, are composed and synthesised whether the house is found in the plains or in the mountains, in the village or in the city.

They form the heart of the dwelling spatially, socially and environmentally.

They are important architectural characteristics and they show the instinctive approach of passive solar design and planning that contributed in the climatic configuration of the Mediterranean house.

Their form evolved naturally from the climatic conditions, the needs of the family and the social structure of community. Always adjoining each other they act upon as transit spaces and connect and unite the exterior with the internal building layout.

They are extensions of the house outwards and simultaneously extensions of the exterior spaces indoors."[16]

So we can say that the elements and architectural features, which are now the basis of a sustainable design, such as solar greenhouses, ventilated facades, or massive wall systems, are essentially applications derived from the study of compositional aspects of vernacular architecture and its characters.

Through a process of trial and error our predecessors have found ways to cope with the extremes of climate. The influence of western cultures is, however, all pervading.

The trend towards an internationalized style of building could result in a reduction in the traditional solutions, which have served several cultures well for many centuries.

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[16] The Wisdom of Mediterranean Traditional Architecture versus Contemporary Architecture – The Energy Challenge. Despina K. Serghides. The Open Construction and Building Technology Journal, 2010,4, 29-38.

Certainly, the architecture of the Mediterranean provides an interesting and alternative points of analysis and evaluation of construction technology comparing the criteria of simplicity with those of more advanced technology, those based on tradition with those addressed in the trial, makes valid the principles of insulation and thermal inertia, giving the designer a variety of solutions rational, reliable and effective in the long run.

It seems evident that, for a correct design of the building, it is not possible irrespective of an analysis of the climate and of evolutionary parameters of the buildings in that area.

"The selection of the appropriate design strategies, derived from a bioclimatic analysis, compatible with each other and other architectural aspects, could considerably reduce the cost of a building by minimizing, the mechanical means for cooling and heating".[17]

In particular the following chapters deal with the issue of sustainability, today absolutely primary, referring to those arrangements typical of Mediterranean houses (natural ventilation, thermal insulation, solar control) that should be re-considered in building practice to reduce energy consumption for heating and cooling, analysing before how the role has changed over the years and how we gradually abandoned the wise traditional design principles.

In the next chapter a brief history of the evolution of the building envelope will help in understanding which aspects of traditional architecture have been lost during the centuries, which others are still in use or can be easily restored.

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[17] M. Santamouris, "Natural cooling techniques", In: *Proceedings Conference workshop on Passive Cooling*, Ispra: Italy, 1990.

Chapter III – The building envelope

The traditional wisdom applied in the building design, related to thermal considerations, daylight, ventilation, and sun light usage, have been nowadays forgotten or abandoned and there are no signs in the new buildings to remind us the appreciative approach of the old. Buildings no longer act as climatic moderators to soften the unpleasant climatic extremes; architects and engineers are increasingly less able to handle traditional wisdom cleverly. On the contrary, the adoption of international styles aggravated adverse climatic conditions. Buildings have become enclosures for artificial environments, making increasingly necessary to use mechanical installations. How come? How has gradually evolved and what are the most in use façades today? In the paragraph below a short analysis of the façade system is presented, with the purpose to better understand how to act cleverly in the design stage or in a retrofitting study of a residential building.

3.1 The evolution of the building envelope: form and function

In recent years the need to create a good level of comfort indoor, guaranteed not only by mechanical air conditioning systems, but also by a passive or active use of atmospheric agent and renewable energy resources, has lead the scientific research attention to that element of separation between the outdoor and indoor environment: the building envelope.

As Richard Rush write in his book *The Building Systems Integration Handbook*, a building can be discretized in four main systems:

- Structure
- Envelope
- Mechanical
- Interior

In this categorization, "the envelope has to respond both to natural forces and human values. The natural forces include rain, snow, wind and sun. Human concerns include safety, security, and task success. The envelope provides protection by enclosure and by balancing internal and external environmental forces. To achieve protection it allows for careful control of penetrations. A symbol of the envelope might be a large bubble that would keep the weather out and the interior climate in."[1]

The building envelope, through a process of technological-architectural research and experimentation, has evolved from a protective barrier-element to a complex filter that optimizes the interactions between indoor and outdoor microenvironment.

The evolution it has undergone over the years has generated growth requirements, motivated by a significant increase in performance, complexity and by a range of products offered to the designers, and by the improvement of techniques and traditional materials.

Briefly the introduction of artificial and industrial materials (reinforced concrete and iron) and the social and cultural evolution processes, have led to the transformation of the masonry load-bearing component into the perimeter of the building, resulting in the progressive breaking down of functions in load bearing structure, protective film or “shell”, thermal and acoustic insulation etc...

It was the modern movement that brought back the idea of building wall from the “classical” conception that unifies structure and cladding,

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[1] Rush R. *The Building Systems Integration Handbook,* Architectural Press, February 1991.

to the diversification of a system, independent of external cladding and structural skeleton.

In modern architecture building envelope, that identifies the entire external “shelter” is divided into several functional layers and made with several materials and is increasingly being investigated in its relations with structure and systems.

The use of the term envelope, or "enclosure," refereed to architecture is fairly new and can be considered an evolution of the concept of “closure” that identified as separate units, vertical and horizontal exterior cladding. So the envelope gets rid of its historic role of defensive barrier from weather and is configured as a skin something regulates, in the broadest sense of the word, the communication with the outside.

It has become more and more a boundary dynamic layer, able to vary its performance as far as the external environmental conditions and the needs of those who live indoors change, and which can accommodate different kind of systems (heating, cooling, domestic hot water, etc...).

It’s clear how this different approach generated a radical change: from the idea of dissipative methodology we shift to conceive the envelope as a device capable of exploiting the natural resources in order to produce energy. The various components of the modern enclosure are now subject to constant technological evolution, both as individual elements and together they have to satisfy the increasing restrictions imposed by recent developments in the regulatory framework.

The current design of the building originate from the work of Reyner Banham who, already in 1969, introduced the concept of "well-tempered environment" and recognized to the envelope a key role in determining this condition. Analyzing the history of architecture Banham identifies three main "models of environmental control", each of which may be associated with a type of building envelope with specific characteristics.

The first model is *Conservative* and is characterized by a type of environmental control that uses large wall masses with few openings to reduce heat loss in cold climates and at the same time, to mitigate the effects of heating due to direct solar radiation in hot climates (or periods). “[…] the thick walls of a house in a hot climate will hold solar heat during the day, slowing down the rate at which the interior becomes hot, and then, after sunset, the radiation of that heat into the house will help to temper the sudden chill of evening. In more sophisticated forms that use glass as a filter to discriminate between light-energy, which is allowed to pass, and heat energy, whose passage is barred, similar effects of thermal storage are used in normal green-house, and the whole technique might well be termed the “Conservative” mode of environmental management, in honour of the “Conservative Wall” at Chatsworth, devised by the master-environmentalist Sir joseph Paxton, in 1846. The Conservative mode, which proverbially defines a house as four walls and a roof, is the ingrained norm of Europe culture”.[2] This mode suits mostly dry climates, hot or cold.

The second model, defined as *Selective*, it is particularly suitable for hot and humid climates and is characterized by general principles similar to the previous one, but "[…] operates to expel unwanted conditions from within and to admits desirable conditions from outside as an open window allows vitiated air to escape and fresh air to enter, and the glazing of that window admits light but not rain or wind”.[3] This mode predominates wherever humidity is a problem.

The third model, the *Regenerative solution*, characterizes the typical buildings of the American tradition without "massive" walls in which the environmental control is completely assigned to HVAC system, defined as "regenerative installations", while the envelope is seen only as a barrier that can limit the interaction between internal and external environment. “The importance of this developing regenerative tradition can be seen in the shifting centre of environmental invention as the century proceeded.”[4]

In the final part of his book Banham laid the foundations for an innovative vision of the building enclosure, designed not only as a nice image of the building, but as a complex multi-purpose system, a selective filter which, that in addition to separate two areas, is able to control and modulate the tangible and intangible interactions and exchanges between the internal and external environment, responding in a flexible way to the variability of environmental conditions, minimizing

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[2] Banham R., *The architecture of the well-tempered environment*, London : Architectural Press, 1984
[3] Banham R., The architecture of the well-tempered environment, London : Architectural Press, 1984
[4] Ivi.

heat loss in winter and limiting the rise in temperature during summer, with the consequent improvement of comfort and quality of life of the user. A building envelope can in fact be considered energy efficient if it's a dynamic interface, in continuous and active interaction with the external climate factors, and if it's able to activate under specific conditions, the metabolic exchange of energy necessary to respond to changes in environmental stimuli and to the needs of the occupants.

The development of an active envelope system must therefore be based on specific knowledge and depth of external climatic factors; parameters that define the level of environmental comfort and energy performance of materials and components of the building enclosure.

This study is now of primary importance because the correct design of the shelter allows the correct operation of the building.

"The envelope, or "enclosure," of a building or structure serves a variety of basic functions. As noted by Burnett and Straube [Dr. Eric Burnett, Dr. John Straube, Various Technical Papers and Publications] and others, the enclosure is a separation between the interior and exterior environment that experiences a variety of loadings, including, but not limited to, structural loadings, both static and dynamic, and heat, air, and moisture loads. The enclosure must then control these loads and support these loads. This includes both short-term and long-term loadings. The enclosure can also be used to carry or distribute some services within the building. In addition, the enclosure will have several aesthetic attributes, which can be summarized as finishes. […]

Burnett and Straube have defined four general building enclosure function categories. All enclosure elements have to provide the following functions:

- Support
- Control
- Finish (aesthetics)
- Distribution of Services (where required)

Support

Enclosures, including exterior wall systems, must be capable of withstanding all internal and external forces applied to them. The majority of these forces are structural loading. The loads include both static and dynamic loading including, but not limited to, dead load, live loads, wind loads, earthquake loads and possible blast loads. These loads have to be properly supported, resisted, and transferred.

Control

Enclosures, including wall systems, have to be able to control mass, energy, and particulate flows both within and across the system. These include, but are not limited to, heat, air, moisture, smoke, odor, fire, blast, birds, and insects.

Finish

The finish function at both the exterior and interior is the aesthetics of the finished surface, the visual, textural, and other aspects the designer wishes to convey with the visible elements of the system. Of the elements of an enclosure, wall systems typically have the largest consideration for finish.

Distribution

This function relates to the distribution of services through a building, both within a single element, and also through multiple elements”.[5]

Modern walls can also be exemplified by listing their functional requirements and needs. It’s possible to pick out at least thirteen distinct needs, some of which can apply to fenestration and the roof and a few also apply to below grade construction. Obviously almost each function has its own performance standards and methods of measurement, methods of testing for compliance, and acceptability criteria. The first (probably most obvious) function is the structural one, even when the

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[5] From: http://www.wbdg.org/design/env_wall.php “ Building Envelope Design Guide - Wall Systems” by Daniel J. Lemieux, AIA and Paul E. Totten, PE.

wall is not part of the load-bearing structure, has to support its own weight and transfer lateral loads to building frame. Then it’s mandatory to resist to water penetration, to excessive air infiltration and to condensation on interior surfaces.

As all the other part of the building the envelope has to accommodate differential movement (caused by moisture, seasonal or diurnal temperature variations, structural movement). From an energetic point of view it has to resist to thermal transfer through radiation, convection and conduction, but safety is another important aspect, it’s necessary to protect users from fire providing rated resistance to heat and smoke, and from the outside threats. Finally as always happen in the field of construction, designers have to deal with five essential principles: maintainability (allowing access to components for maintenance, restoration and replacement) constructability (providing adequate clearances, alignments and sequencing to allow integration of many components during construction using available components and attainable workmanship) obviously durability and aesthetics (keeping functionality and aesthetic characteristics for a long time) and finally economy, trying, as usual, to gain all of the above in the less expensive way possible.

Form and function of the building have undergone, over the time, substantial changes. If we want to chronicle and understand the evolution of the building enclosure it is necessary, first, to identify a starting point for the analysis.

We can say that the first “building envelope” that protected humans from the elements was probably a cave just because it was able to provide a certain privacy and security. But going ahead in time, when it is possible to identify the very first constructions, earliest envelopes were dome-shaped structures that combined wall and roof, that at an early stage, evolved in the two dominant forms, depending on climate and available materials: buildings with a timber frame and buildings with a masonry wall, the last one widespread in hot climate. It is easy to notice that, in every region and climates, the materials used were local, readily available, abundant and cheap. Especially heavier indigenous materials such as stone, rock and clay baked by the sun were used to provide more permanent accommodations.

Building envelope has continued till the beginning of the nineteen century, that means till the era of reinforced concrete technology, the with very little change in concept, use and even material.

Thinking about the wall, its basic performance requirements have remained the same from medieval times to “modern” days: protection of the interior from meteorological conditions and external elements, and security for its occupants, even if expectations have increased more and more depending on a society's structure and economy. Initially the wall was a single homogeneous material, stone or brick, exposed on the exterior and interior. Over the centuries wall has been modified to become more ornate, outside the rough stone becomes more regular in shape, thanks to a more precise cutting, and a refined aesthetic. Inside, the stone began to be refined thanks to the use of special plasters.

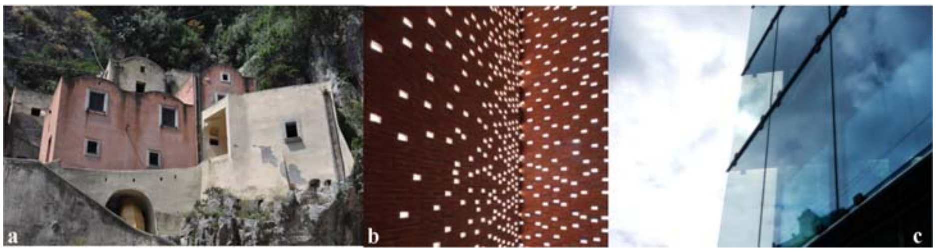

Fig.3. 1: a) Monazeni a Furore; b) Quartiere Generale della Hanson Building Product Ltd, Stewarby Regno Unito (I. Magliolica, Costruire in laterizio n 141, pg IC-XIV, Maggio Giugno 2011); vista del volume contenete la scala d’emergenza . c) Elsässertor Office and Cargo Building, Basel, Switzerland; Competition 1990 Herzog&DeMeuron,

Thanks to materials and technologies historic buildings accomplished many of the building envelope functions by default: thick, heavy masonry in fact is fireproof and good for insulation in both summer and winter, could guarantee an excellent acoustic performance, is reasonably able to resist to water penetration (acting also on the shape), to excessive air infiltration and to condensation on interior surfaces. However, comfort standards changed a lot, and by modern ones, the wall had fixed and limited performance capabilities.

“The big change in the concept of the wall—and the real beginning of today's concept of the building envelope—occurred with the invention of the steel, (and later, the reinforced concrete) frame in the nineteenth century. The exterior wall could become a screen against the elements and no longer be needed to support the floors and roof. However, for several decades steel frames were buried in masonry walls, and buildings continued to be designed in gothic or renaissance styles. The modern architectural revolution beginning in the early 20th century changed this and by mid-century the steel or concrete framed office building with its lightweight metal and glass curtain wall had become the new world-wide vernacular for larger commercial and institutional buildings".[6]

As soon as the wall lost its load-bearing function becoming a non-structural screen and no longer supported the upper floors and roof, some of the default beneficial aspects went lost, and new challenges started in order to reach better performances. At first research, and then industries have approached the problem of developing new insulating and fireproofing materials, air and moisture barriers and interior and exterior facings.

Since the improvement of the performance of the building envelope is a very active research area, in constant evolution, it is not easy to give an account of the current state of the art, nor does summarize the properties of modern shells in a few lines. However, it is possible to roughly outline the most common types of building shelter in use today:

- Cavity wall (offers many advantages over the other three types of exterior wall system. Typically include an exterior cladding element that is intended to either shed or absorb rainwater penetration, a drainage cavity, or air space, sometimes ventilated, an internal drainage layer that is intended to function as dividing line between the "wet" and "dry" zones, an insulating layer, which depending on the geographic region and climate, can be inside or outside.
- Barrier wall (an exterior wall system that relies principally upon the weather-tight integrity and resists rainwater penetration and/or

[6] From: http://www.wbdg.org/design/env_wall.php " Building Envelope Design Guide - Wall Systems" by Daniel J. Lemieux, AIA and Paul E. Totten, PE.

moisture ingress, such as precast concrete panels or metal plate exterior cladding etc...)

- Mass wall (less common in design and construction today mainly for economic reasons, it is a combination of wall thickness, with no air gap, but in common practice it is frequent to deal with this kind of wall when constructing an addition, or incorporating a portion of an existing building).

Building use, orientation, environmental exposure, overall response to the surrounding climate (micro and macro) need to be taken into account by the design team when it comes to choose or design a proper envelope.

The more materials and technologies evolve the more options designers have, in order to gain the best performance for a defined climate, and reduce energy consumption, especially if the economical aspect is not a problem.

Actually, this never happens, or almost never, and the majority of buildings in Italy (but also in the rest of the world) now are absolutely inappropriate from an energetic point of view, because of obsolescence or because they were built already in a very cheap way, (as it happens for many social housing complexes).

To better understand these problems it is important to know how building changed after the second world war, which were the common materials and technologies in Italy, especially those used in residential sector, how was their energetic performance and, as comfort parameters changed a lot, why they are so inappropriate now.

3.2 The building envelope from the 50's to modern age.

The form and function of present-day wall and façade constructions are the result of a long process of development, which is closely related to the history of humanity and as a consequence to development and changes in the construction criteria.

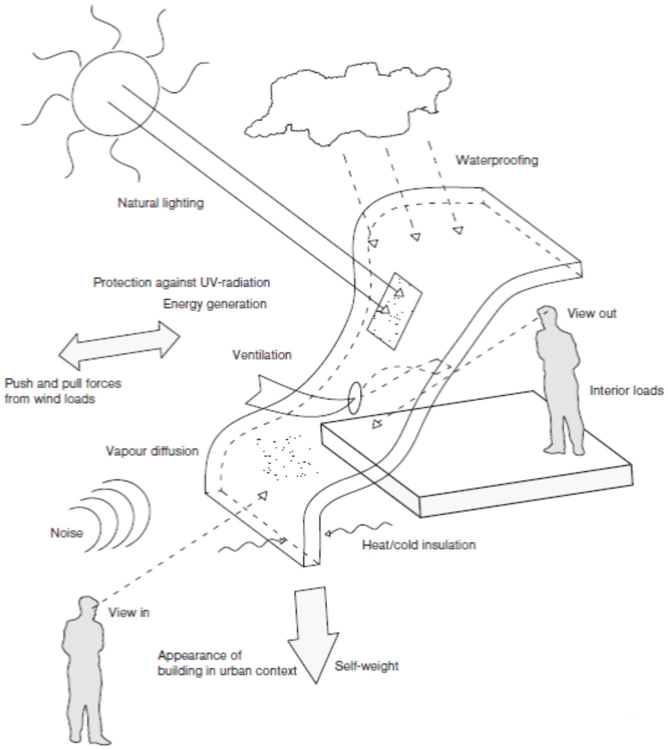

Fig.3. 2: Façade functions. “Façade” Knaack U., Klein T., Bilow M., 010 Publishers, Rotterdam 2008. pg 36

Façades always result not only from individual creative conceptions, but are designed for a specific place, context and architectural concept.

A modern facade today has to offer solution to many problems, even to those that in the traditional building practice, were usually solved by default, as said before, thanks to the characteristics of materials or to the construction techniques.

We can say that in the design of a modern façade have to be taken into account:

1. load transfer, different type of loads such as self-weight of the façade components, stress loads (caused by deflections of

components through changes in temperature or humidity), wind load (push and pull), eventually weight of snow and live loads e.g. a person/object colliding with the inside of the façade.

2. Thermal requirements (even if each user defines comfort differently, minimum requirements related to work environment or living space conditions are regulated by law).
3. Visual requirements (it means pay attention to the possibility to easily see the surroundings and receive a clear impression of the space from the inside) and obviously to enjoy natural light.
4. Hygienic requirements (to ensure hygienic comfort the air full of dust, gases, CO_2, odour substances, viruses and bacteria has to be adequately circulated).
5. Acoustic requirement (comfort level in a room is influenced by sounds transferred from the outside).

Paying attention, in the design process, to all the elements of the façade or to the means of building services components, all the required comfort levels described previously can be achieved. But how?

In order to simplify it is possible to make a classification of façades, depending on how the above problems are solved, "when dealing with the appearance and the structural design of façades, we may divide them up in two different approaches, into functional elements or into layered systems. In the former approach, each element will perform a particular task such as ventilation, lighting or the limitation of visual access. […] In a layered system, each function is performed by a different layer of the façade. The layers may be arranged so that the function can be performed at any point on the façade. Each function is performed via the layer in question to meet the relevant requirements".[7]

On the other hand we can classify façade depending on their flexibility and capacity to adapt to changing situations "depending on climatic conditions and the various life styles and dwelling styles that

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[7] Knaack U., Klein T., Bilow M., Auer T., Façade, Principles of Construction. Birkhäuser, Basel 2007.

grew out of them, two essentially different basic principles for the construction of the outer envelope of a dwelling place came into use: solid walls fixed to one particular spot and designed for permanence on the one hand, and more flexible, less permanent façades – typically represented by tents for mobile use – on the other".[8]

Based on the previous classification two different types of solid wall construction may currently be distinguished: warm façades, where the insulating layer is mounted directly on the outside or the inside of the façade construction, and cold façades where the insulating layer is separated from the climatic protection layer, by a layer of air.

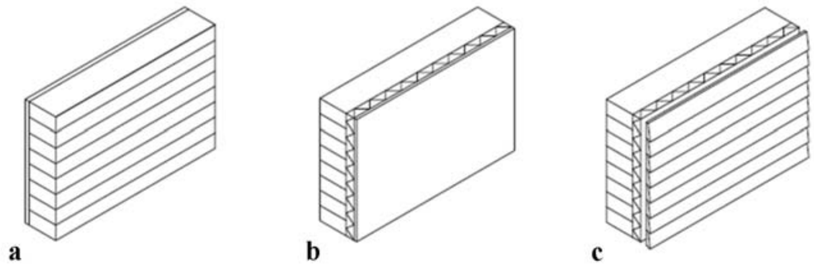

Fig.3. 3: a) Solid wall construction; b)Warm façade. c) Cold façade. From the book "Façade" Knaack U., Klein T., Bilow M., 010 Publishers, Rotterdam 2008. pg.14

In a parallel line of development some nomadic societies started to built a tent made of a supporting skeleton and an outer covering to keep out the elements in order to facilitate the transport, both the skeleton and the outer cover had to be as lightweight as possible, it was necessary to separate the functions of support and enclosure.

"The European predecessor of this building technique is half-timbered construction in which a timber skeleton is built and the spaces in between the timber elements are infilled in with different materials

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[8] Knaack U., Klein T., Bilow M., Auer T., Façade, Principles of Construction. Birkhäuser, Basel 2007.

according to the region".[9] This type of construction was the progenitor of the balloon frame solution.

The separation between structure and facade continued, driving the resolution of the wall into a loadbearing structure and façade (the bearing function is provided by columns, which are as far as possible enveloped into the interior of the building, while the façade leads an almost independent existence on the exterior).

Fig.3. 4: a) Siena Piazza del Campo (from http://www.fototeca.co.uk/siena.php). b) Half-timbered construction, Ancy Fr. c) Farnsworth House, Plano, Illinois, Ludwig Mies van der Rohe, 1950 (from http://ita.archinform.net/projekte/2096.htm)

Within the third type we can distinguish:

- Post-and-beam façade (as suggested by the name is made of storey-high posts, secured to the ceiling-floor and horizontal beams). In this category there are also post façade and beam façade using respectively only posts and only beams to transfer the loads with the aim to increase the degree of openness)
- Curtain wall (in which the elements of the façade hang from the front of the roof, it represents one of the previous type of modern façade, largely used by the modern movement;
- System façade (consists of fully prefabricated elements that simply have to be positioned and mounted in situ and are still

[9] Ivi

largely used in the present constructions thanks to the quality and rapid assembly).

When we look at the architectural façade solutions of early Modern Architecture, it becomes apparent that they were relevant in their time, but no longer fulfill today’s requirements.

A new trend suggest to use the external environment, instead of only struggling against it, trying to gain a positive impact on the comfort level of the occupants as well as on the energy consumption. This is what the adaptive (sometimes called intelligent) façades usually try to realize using sun light heat and ventilation. It means that buildings and façades should adapt to current weather conditions. Within this category we can find:

- Double façades (usually consist of three functional layers. Typically the exterior façade layer is made of single glazing separated from the interior glazing, which usually consists of double glazing);
- Second-skin façade (no compartmentalization of the space between the façade layers, the exterior façade contains a layer of air that envelops the entire building);
- Box-window façade (derived from the box window principle, consists of storey-high façade elements. The interior windows can be opened for ventilation into the gap between the two façade layers);
- Corridor façade (manages the airflow storey by storey, trying to prevent noise and interference from one room to another using vertical baffles);
- Shaft-box façade (box windows and shaft elements alternate. The last are used to favor air-changes thanks to a stack effect that ensures vertical motion);
- Alternating façade (single skin façades combined with double façades, simply adding another layer locally, in order to have more flexibility);

- Integrated façade (modular o hybrid, in which heating, cooling, ventilation as well as light-directing, shading, integration of artificial lighting can all be realized inside the façade).

Closely related is the problem of windows. First examples were single glazing and wood frame, and in some cases it's still possible to find some. Now insulated glazing or double glazing are widespread but there are more and more technical solution including smart materials. For example currently, research is underway for glass coatings as thermo-chromic layers that react to sunlight.

It goes without saying that great attention must be paid in designing a new façade as "a façade is the key element when observing a building from the exterior and has impact on the interior.

View, lighting, ventilation, user comfort, some building services and possibly loadbearing are all tasks the façade may need to address. Façades are an integral element of the entire building with direct relation to design, use, structure and building services. This has decisive impact on the entire design and construction process."[10]

But the same attention (or even more) must be paid in retrofitting cases, as the designers have to handle the same complex problems without all the freedom that a new design allows.

This is what usually happen acting on old buildings, both of artistic/historical value and simple residential building, obsolete, that are still in use, and will be in use for many years, but from an energetic point of view have huge problem.

It's easy to understand that social housing (especially old examples from the 60's and the 70's) because of the small budget used and of the short time often used to build, are the first that need to be upgraded. In the following paragraph materials and technologies used in social housing in Italy are presented.

[10] Knaack U., Klein T., Bilow M., Auer T., Façade, Principles of Construction. Birkhäuser, Basel 2007.

3.3 The building envelope in the INA experiences.

As seen in the previous paragraphs, the introduction and spread of iron before, and concrete then, gradually subverted the architecture of the twentieth century, introducing unimaginable possibilities in the past, giving great freedom of expression to designers all over the world.

Concrete in particular in Europe as in America fostered the creation and development of various “architectural currents” such as the organic represented, among the others, by Wright in the United States, but widely followed in Europe and beautifully interpreted by adherents as Alvar Alto. But Europe has been the cradle of another main current of these vibrant years for architecture, rationalism. This particular current found expression particularly in the field of housing, investigated by many distinguished figures such as the Swiss architect Le Corbusier.

The first half of the twentieth century was one of the most complex and troubled periods of human history. The newly Italy faces the new century full of hope and optimism, but as in many other states of Europe, the first World War, the emergence of a dictatorial regime, and finally the second devastating world war, left a country on its knees . Partially destroyed, depleted and confused.

These events were reflected equally present in architecture. In fact the construction sector more than any other had to face new serious complex problems, about the reconstruction of an entire country (economic, physical and social).

The term “reconstruction” took on different meanings at the time in the country, from the purely technical one to the ideological one, the latter derived from the climate of hope and expectation (perhaps necessary) that was present in much of the country. It was not just the reconstruction of facilities and infrastructures, but also a resumption of normal pre-war rate of development (or that hoped to be achieved before the World Wars).

The more, there was no clear image of the exact damages consequent the wars, which could have been the starting point to organize and plan the reconstruction. The agricultural sector was in trouble not only because of the damage and destruction, but also because of the lack of maintenance; in industries energy sources and raw materials were scarce.

The housing sector suffered extensive damage difficult to be quantified, but form the data provided by the Genio Civile, apparently 1.672.000 rooms were destroyed, 937.000 seriously damaged and slightly damaged more than three million, central Italy and the islands were the most damaged, followed from the north and south.

It seems clear that the reconstruction was a very complex issue, which included economic and social policy issues. The absence of a unified vision of the problem by the political class of that time, and then the absence not only of a general economic plan, but also of a firm and decisive economic policy, led the country to begin a not planned reconstruction.

So much so that when in 1948 Italy had to submit requests for U.S. aid of the Marshall Plan, it was not possible to present an organic development program, prompting criticism of the Americans to the lack of any programmed orientation of Italian politics.

A debate this complex on policy choices had a similar reflection, in going as in the results, in urban planning and in the construction sector. An opportunity for a comparison between the various positions was offered by the *Primo Convegno Nazionale per La Ricostruzione Edilizia* in Milan, held in December 1945, on initiative of the *dell'Associazione per la Casa* and of a group of scholars and technicians of CNR (Centro Nazionale delle Ricerche). Even in this case a unity of thought was not reached, the congress opinion separated into two distinct trends, a right-wing one, proponents of free enterprise, and a left-wing one, supporters of a reconstruction plan.

The economic aspect of the problem dragged a political and social content that was the true master of all dissents. However, the *Convegno* was an important event because for the first time it was possible to openly discuss the problem of houses and man, affirming the need to deal with new ideas and new methods.

From this moment in fact, and in the following years a major cultural ferment started, guided also by the birth of some journal like the newborn magazines *Metron* for example that claimed the concept of an essential planning, and by the reorganization of the profession with the Professional Registries, and by the update through bulletins and publications with appropriate techniques, such as the *Manuale dell'Architetto*.

This work, desired by the very active Zevi, was trying to fill a lack of technical information that would be dramatic especially during the reconstruction phase. The manual was published in 1946 and many young people worked on it, who, under the wise guidance of Mario Ridolfi, dealt with the general editorial phase, while appreciated technicians as Nervi and Piccinato, oversaw parts of their competence.

The manual was distributed in 25,000 copies for architects, engineers, surveyors, and was drafted on the model of American texts.

In 1947 also inaugurated the eighth *Triennale*, and again the central theme was that of the house. In those same years Parliament was debating a real program for the construction of housing, i.e., the piano INA-Casa, approved in February 1949, with the Law No. 43 *Progetto di legge per incrementare l'occupazione operaia, agevolando la costruzione di case per i lavoratori* also known as Legge Fanfani.

A project that not only had the precise purpose of starting reconstruction, then in serious crisis of production, but also to solve the problem of unemployment and of the construction of social housing for low-income families.

The speed of construction, made possible by the organizational structure of Ina-Casa, was extremely efficient and, when working at full performance, it produced about 2,800 units a week, with a weekly hand in of about housing 550 assignee families. In the first seven years of the program a total of 334 billion lire were invested for the construction of 147,000 homes.

At the end of the fourteen years of the plan 355,000 houses were completed. The Ina-Casa Plan opened a total of 20,000 yards, which led, as was the intent of legislators, to use a lot of labor in building: about 41,000 construction workers a year.

The possibility to begin the reconstruction immediately, however, poses a problem of "style". The world wars had suddenly stopped the development of the trends that elsewhere continued the growth unabated. The leading figures of the period were divided on the issue of the difficulty of giving continuity to the architecture. Bruno Zevi, became the spokesman of organic trend than the rational one, recognizing the first one in his book *Verso un'Architettura Organica*, as a tendency of concrete buildings, that leaves freedom and diversity to pragmatic architects, respecting individuality and allowing flexibility. Rogers and Giedion became spokesman for the reinterpretation of the principles of rationalism, invoking a "higher level" of functionalism, and a return to human scale.

Suggesting a move away from forms of the past, supporting a new concept of the Modern Movement as a triumph of form passed renewed, Zevi put emphasis on interior space.

Initially the INA-Casa project should have a life of seven years, but was later extended until 1963. However, it is possible to identify during all these years, some stages characterized by attention to different issues. Initially, the debate focused on planning, building and industrialization.

Firstly the idea of self-sufficient neighborhood spread, a large part of the newly formed residential complex placed in contiguity with the existing city or close to it, were planned and built.

The concept of “existence minimum” was not addressed at the individual level, but at the neighborhood level, not inventing new models of cities, but defining a set of elements of the house, from the internal ones to the external, by studying a good overlap of public and private spaces.

Housing characteristics such as size, quality, type and degree of finish, or aggregation of cells and buildings, spatial qualities of the cell and its relationship with the outside world, were all properties to be analyzed and decided.

In the early months of 1949 the Piano Fanfani intervened decisively to guide the strategies of the increasingly heated debate on the Italian post-war reconstruction. In previous years, in fact, the discussion about how to bridge the huge demand for housing had lead everyone to share the need to increase productivity, providing strong impetus to the progress of construction techniques.

The Piano Fanfani guided the reconstruction in a direction opposite to that of innovation and prefabrication in particular, identifying in the construction of houses for workers, before the goal of meeting the needs of housing, the means to increase employment.

For this reason it required, as a higher order need, a way to build houses in low-intensive mechanization and labor force. This fact led to the inhibition of any ambition of technological innovation, apart from the generic indication of favoring the “typization” of building elements.

Fig.3. 5: Fanfani visiting an INA Casa building, site. P. Di Biagi (a cura di), *La grande ricostruzione Il Piano INA-Casa e l’Italia degli anni ’50*, Donzelli Editore, Roma, 2001.

The preservation of the so-called “traditional” building technology is ratified in a precise way. But at what “tradition” it refers to? In the terminology of INA Casa the term traditional refers to a construction model different (and in some ways antithetical) from the generic international model of the modern building, based on the idea of a concrete skeleton and the dematerialization of the wall.

The building in INA Casa experience does not reflect even the nineteenth-century wall construction, because the extensive use of concrete changes the structural behavior of masonry.

Quite simply the method of construction used is that available in Italy after the war. This is a very well-defined building model with sufficient accuracy in the suggestions outlined on several occasions issued by the Gestione INA Casa, fully described in the *Capitolato Generale* and in detail prepared by the contracting authorities.

It is a system composed of a balanced combination of masonry and concrete elements, all made primarily on-site. Regarding the structural behavior of masonry elements and concrete elements it is necessary to distinguish between low houses and tall buildings. In buildings made of 2 or 3 stores, load-bearing walls is usually entrusted to brick or stone blocks although appears the innovative effect due to the capacity of the floors laterocementizi to perform the function of bracing, with the consequent possibility to alleviate the non-bearing walls .

In high buildings, towers or on a string, instead, the stability is assigned to a self-reinforced concrete skeleton. However even in these cases the conformation of the typical wall construction remains, as is also evident in the building by Bruno Zevi in Salerno.

All the rules of good wall construction are respected, with limited light, content changes, including small openings in the walls of the loggias backward.

Moreover, despite striking differences between the various geographical areas and between the first and subsequent works, the INA Casa constructions tends to be substantially homogeneous in character: it is basically a brick wall, however, subject to a progressive refinement due to the use of concrete elements. It is mostly a construction model apparently simple and ordinary, but actually derived from the long debate through which it has come to a perfect hybrid between traditional walls and reinforced concrete.

From a technological point of view the technique aforementioned, with reinforced concrete structure and masonry wall, was often accompanied by the practice of bring out the framework, designing as a module that regulates the façade. In fact, from a stylistic point of view the use of orthogonal free frame, which in the thirties was almost a manifesto of renewal of the Italian postwar reconstruction, becomes a clear sign of continuity.

The grid that often assumed the task of shading loggia or of architectural order was becoming the most common way to use chiaroscuro contrasts and effects of transparency, with perforated surfaces, concrete and glass parapets. In order to facilitate the task of contracting authorities and to give a more precise guidance to designers, the Gestione INA Casa produced a set of “files” sort of handbooks, that deserves attention for its practical relevance and its performative capacity.

Fig.3. 6: Covers of INA Casa handbooks volume 2 and 3

The INA Casa files had the intention of promoting the creation of settlements accompanying the process from concept to test, preparing indications of legislation to guide the design and construction without locking designers at indisputable, given patterns.

Through these papers, which make easily available the result of many studies conducted around the world, engineers and architects had at their disposal schemes and examples presented in a precise and clear form.

The suggestions made in the first issue distributed in October 1949, "*Suggerimenti norme e schemi per l'elaborazione e la presentazione dei progetti. Bandi dei concorsi* " dealt largely with the setting up of projects that had to be economically viable and the want to strike a balance between the different needs.

In the file are presented blueprints to show the possible distributive solutions, the patterns are grouped by the four building types allowed: multiple, continuous and isolated house, row house in one and two floor, habits and lifestyle.

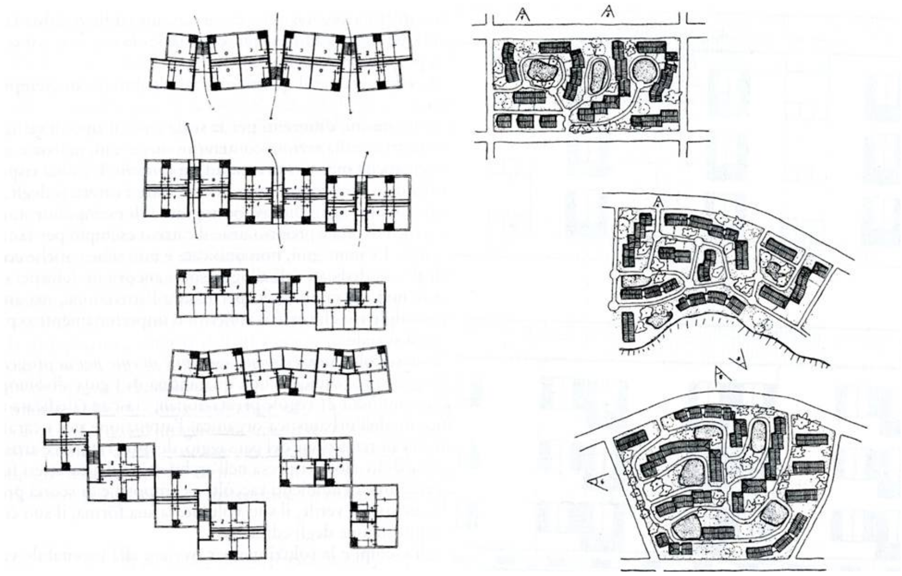

Fig.3. 7: Distributive solutions in "*Suggerimenti norme e schemi per l'elaborazione e la presentazione dei progetti. Bandi dei concorsi*".

The neighborhood are configured as a direct response to the need of simplicity and realism which invested, in the reconstruction climate, the Italian culture.

The attention to the "local problem" (habits, traditions, climate, local materials, handicrafts, craftsmen, construction systems, heating) had a significant effect on the range on techniques and materials of construction and on the masterplan.

In the second issue " *Suggerimenti norme e schemi per l'elaborazione e la presentazione dei progetti. Progetti tipo 195*0", there were 21 rules each devoted to a performance requirement for qualifying organic urbanism: the enhancement of the landscape, attention to the character of existing settlements, creation of environments and collected compounds.

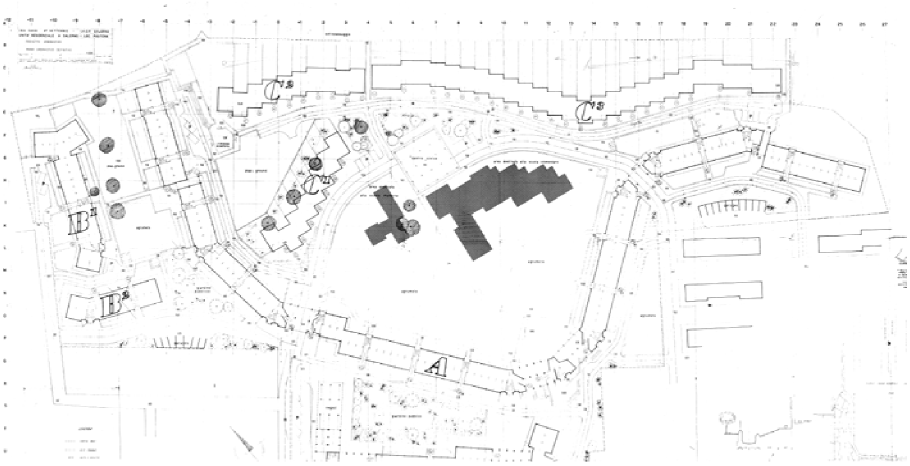

Fig.3. 8: Quartiere Pastena Masterplan, Bruno Zevi, Salerno.

Fig.3. 9: Quartiere Pastena, Bruno Zevi, Salerno

The third dossier "*Suggerimenti norme e schemi per l'elaborazione e la presentazione dei progetti. Guida per l'esame dei progetti delle costruzioni INA Casa da realizzare nel secondo settennio*"1956 , was also a regulatory budget, it was a back to talk about buildings, housing, headquarters and construction problems, explaining the strengths of previous recommendations and indicating the ones still problematic.

The fourth issue of 1957, *Norme per le costruzioni del secondo settennio estratte da delibere del comitato di attuazione del Piano e del consiglio Direttivo della Gestione INA Casa* " gave several suggestions from the design methods, to the choice of areas and interventions.

The third chapter also addresses the issue of urban standards design.

This last section lists the characteristics of housing, in terms of construction technology, materials used, and general references for systems.

If in the first septennium considerations about the most significant problems focused mainly on localization (ratio of new units to the existing city) on organizational problems (shape, space and distribution in relation to the construction of new parts of the city) and on qualitative problems, the tendency to design a self-contained and self-sufficient neighborhood was gradually replaced by a design planned by the development of *Piani di Zona*, in which it was possible to understand the will to overcome the artificial separation between urban design and architecture, meaning the house no longer as autonomous and independent entities, but as entities that need to integrate with the urban context, in order to achieve a wider residential space.

The *Piani di Zona*, often coincided with the development or revision of local masterplan by IACP (Istituto Autonomo Case Popolari) or municipalities. With the passing of the years, and the development of awareness and competence, the wild industrialization of the construction sector has been questioned in favor of a more realistic view of problems of growth and development and especially in favor of a better quality of life, gradually opting for a housing with limited number of plans, with medium density and abandoning systems of prefabrication and mass-binding.

The design specifications listed above, the small cost of the proposed solutions and banally technological knowledge which at the time, was inevitably smaller than now, make many complexes belonging to social housing, obsolete and inefficient from a technological point of view, although some are still architecturally valid and positive examples.

For this reason two case studies have been chosen which can be representatives of a very common situation in our country, for which action is urgent.

Chapter 4 – Case study I: Quartiere Pastena, *Bruno Zevi - Salerno*

In December 1945 took place in Milan the *Primo Convegno Nazionale per la ricostruzione edilizia,* in order to verify the status of the Italian building stock, assess needs and priorities of the sector, and identify problems and difficulties hindering the phase of reconstruction.

During the conference, as mentioned earlier, a rift arose between those who supported the need to plan the reconstruction and those who were against this kind of proposal. Among the participants, there was also Bruno Zevi, who in his speech said:

"*Vediamo anzitutto I punti principali del problema ricostruttivo urbanistico ed edilizio dell'Italia. Questi punti schematicamente espressi sono i seguenti:*

1. *La mancanza di un organo pianificatore, di un organo di governo che, di fronte all'emergenza edilizia, assuma i compiti e le responsabilità di coordinare tutti i vari poteri attinenti all'urbanistica e all'edilizia, e di tracciare un piano di ricostruzione organico su scala nazionale;*
2. *La mancanza di una legislazione urbanistica atta a risolvere i colossali problemi che confrontano la ricostruzione. […]*
3. *La necessità di affrontare la ricostruzione urbanistica ed edilizia in una situazione economica difficile […];*
4. *La carenza di materiali ed anche di mano d'opera organizzata e la conseguente necessità di economizzare al massimo.*

5. *La pressione dell'opinione pubblica che chiede a gran voce un riparo, la possibilità – sia pure minima – di sopravvivere biologicamente".* [1]

From his words we can clearly infer the rigor, honesty and courage of its ideas, ethics dedication and passion towards work. Coming from a Jewish family, he returned in 1944 in Italy, after being forced to leave the country in 1939 because of the racial laws. He graduated from Harvard with the respected but never loved Walter Gropious. In those years, Wright discovers and appreciates the organic architecture. He believed strongly in freedom of architecture as a mirror of a free society, open and creative. For this reason, even when he returned to Italy he placed side by side political and cultural activity.

For Zevi, speaking of and study architecture could not be separated from his being a man of action and his values as a citizen.

In the early years of the Italian reconstruction its contribution was overwhelming. More than in his numerous and fundamental writings, it is through his works that we can practically see the foresight of his thinking.

His urban and buildings design includes, among others, the railway station of Naples (1955-65); Quartiere Pastena in Salerno (1960), the project for the Garibaldi Bridge in Rome (1960), the library "Luigi Einaudi Dogliani (Cuneo); studies for new office buildings of Rome (1975), the plan of Benevento (1985-90), the refurbishment of railway areas of Florence.

In the following paragraphs there is a short introduction about the Quartiere Pastena in Salerno, the first case study of the hypothesis of energy retrofit carried on in this thesis.

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[1] Brunetti F., L'architettura in Italia negli anni della ricostruzione, Alinea Editrice, Firenze 1986.

4.1 Description

The experience of the first seven years of INA-Casa project in Salerno was of little importance for the limited interventions in the urban center. In second seven years with the extension of the law no.148 , however, major interventions were implemented, including the two units of Quartiere "De Gasperi" (designers P. Marconi, C. Agostini, M. Battaglini, G. Costadoni, R. Del Debbio - 1959) and Quartiere "Pastena" (designers B. Zevi, I. Ballets, M. Calandra, A. Di Carlo, L. Ronchi, L. Rubino).

These two realizations arise as a significant example of social housing for the urban setting, pretty well related and connected with the existing fabric, for the articulation of composition and for their autonomy in terms of social facilities and services.

The Quartiere Pastena, well known as Quartiere Zevi, by the name of its famous designer, stands on a flat area regular in shape, of approximately 5.5 hectares, adjacent to the Salerno-Reggio Calabria railway line that runs on embankment in the north-east of the lot.

The area was chosen for its strategic position and wholesomeness: protected from the marine winds, and contemporaneously protected in the north by the Picentini Mountains.

Fig.4. 1: Quartiere INA CASA- Bruno Zevi, Salerno - Pastena -1955/61

The entire project involved the construction of 216 flats with a total of 1280 rooms. The road pattern included two internal entry-ways that reach the center of the complex, consisting of three groups of buildings: A-B1, B2, B3-C1, C2, C3.

The work was completed with the planting of citrus fruits (lemons, oranges and mandarins) that are typical of Mediterranean vegetation located in the central area and close to the general services (nursery and primary school still exist today) and large space used as a public park.

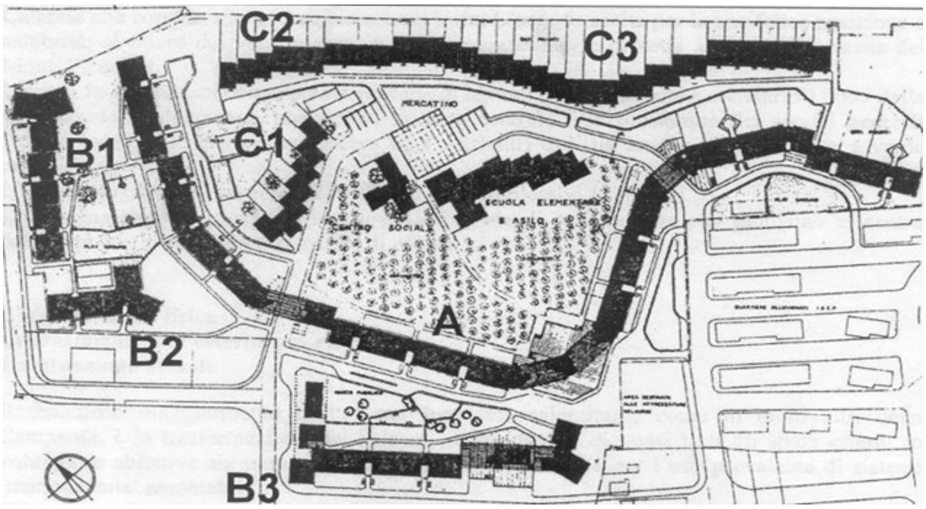


Fig.4. 2**:** Quartiere INA CASA- Bruno Zevi, Salerno - Pastena -1955/61- Site Plan

The building A is located in the central area and has a length of about 440 m, width of about 10.70 m and average height of 17 m (up to eaves).

The complex was designed to develop over four floors with a partial basement area and a ground floor that includes thirty-three apartments, while the upper floors include forty-two apartments.

Fig.4. 3: Building C duplex Quartiere Pastena, INA-Casa, Bruno Zevi - Salerno.

Fig.4. 4 Building A duplex Quartiere Pastena, INA-Casa, Bruno Zevi - Salerno

On the whole there are 159 rooms as follows:

- N° 2 flats of 3.5 rooms;
- N° 49 with 5 rooms;
- N° 102 with 6 rooms;
- N° 6 flats with 7 rooms.

The vertical connections are represented by 21 steps each of which serves two apartments per floor. The buildings are crossed by pedestrian and vehicular underpasses.

The balconies are made of concrete, railing is made with wrought iron and part of the lodges have brick facades parapet. The roof was made of reinforced concrete and covered with a slabs of asbestos "French style". Today no traces remain of them since were replaced by tiles, concrete eaves and metal drainpipe.

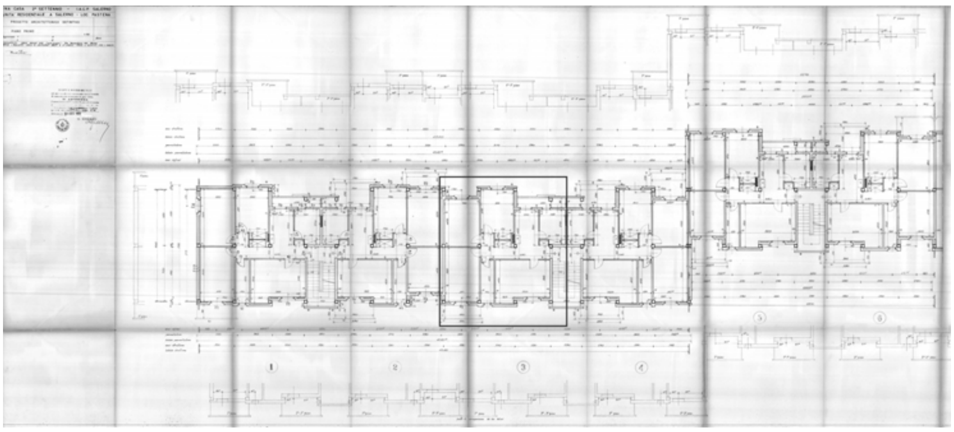


Fig.4. 5: Quartiere Ina-Casa, Bruno Zevi-design documents- First floor plan.

The building has a structural system consists of frames in one direction (the big one). The frames are made with flat and deep (or formed) beams, depending on their location inside the building.

As was common in the past, not all the beams are connected with the vertical elements in both directions, in one direction the connection between the pillars is entrusted only by the one-way floor. There is no information regarding the foundations, they should be, reflecting the knowledge of the time, made of isolated footings connected only overboard.

Pillars of the building A are square 30x30 cm, have constant dimension except in the arcade where, for aesthetic reasons, they have a hexagonal section. From what has emerged from the reports attached to the original design presented to the City of Salerno, the pillars have been calculated considering only the vertical loads.

The technical papers retrieved, were inaccurate, with no clear guidance on the disposition of armor.

The buildings indicated as B1, B2, B3, are "on a string", and have four floors. The buildings indicated as C1, C2, C3 are 41 single-family detached homes (for a total of 287 rooms), organized as follows:

- 5 simplex accommodations;
- 36 duplex accommodations.

The 36 duplex (approximately 106 square meters) have the living area downstairs and the bedroom on the first floor. Simplex and duplex accommodations are similar from a distributive point of view.

They have a private garden and a backyard.

Of particular interest in these buildings is the use of the brick facade, the development in the form of broken line and the alternating access of the stairwells in the building, which were once provided in the concave side, once in the convex one.

Among all the experiences of INA-Casa, the "Quartiere Pastena" in Salerno is one of the best, thanks to the original and very successful planimetric layout and the effort in the planning stage, both in the work as a whole and in details.

Fig.4. 6**:** Quartiere Pastena, INA-Casa, Bruno Zevi - Salerno.

The building has a frame structure and 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 neighborhood. Not always routine maintenance has been carried out.

Dwellings have no insulation, some still have single glazing and wooden windows frame, others standard double glazing, or veranda.

The whole building complex results to be interesting and qualitatively valuable, from an architectural point of view, but it is obviously obsolete from a technological point of view, for this reason it was chosen as the object of analysis.

The absence of gaps between different buildings on one side, and the pooling of houses on the other hand, have created a spatiality both internal and external, determined by the sequence of pages (as it was once the continuum of the ancient city), even more evident in comparison with the anonymous context of the rest of the city on the border.

4.2 Modeling

The Simulation was conducted using two software: 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 on the other hand can perform more detailed analysis about energy performance and 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 for a sustainable development of the project.

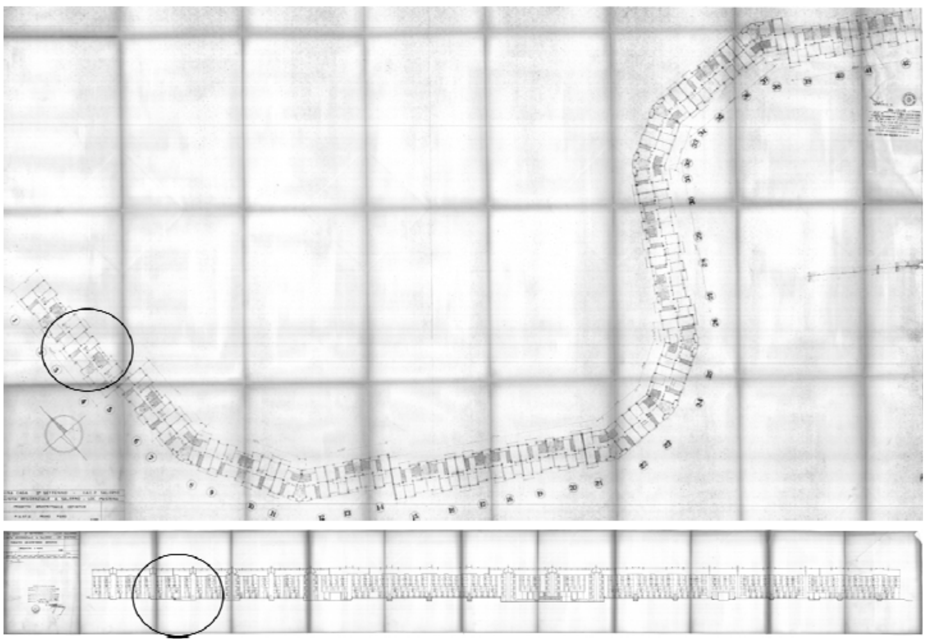


Fig.4. 7**:** Building A, Quartiere Pastena, Plan and front.

Bruno Zevi. 1955-1960

As mentioned before, there are different types of buildings built in the lot: A B C, among them all building A was chosen for the analysis, mainly because it allows, thanks to its serpentine shape, to change orientation and exposure, and check the results of simulation verifying the validity of hypothetical choices in several cases, with great simplicity.

Starting with DesignBuilder. the editing phase with this software is pretty easy; the first thing to do is to set the location. Setting the location will define not only the geographical location but also weather data for all buildings on the site.

All building simulation programs employ some means of representing local climatic conditions relative to the building models.

These software use a simple set of hourly temperature, humidity, wind speed and direction, atmospheric pressure and solar radiation or cloud cover data.

These data are often “typical” data derived from hourly observations at a specific location by the national weather service or meteorological office. Examples of these typical data include TMY2 (Typical Meteorological Year NREL 1995) and WYEC2 (ASHRAE 1997) in the United States and TRY (Test Reference Year CEC 1985) in Europe.

In the annex A (pg 267) weather data for Naples are reported, the data include basic location identifiers such as location name, data source, latitude, longitude, time zone, elevation, peak design, conditions, holidays, daylight saving period, typical and extreme period, ground temperature, period(s) covered by data and space for descriptive comments.

The time step data include dry bulb and dew point temperature, relative humidity, station pressure solar radiation (global, horizontal infrared, direct and diffuse) illuminance, wind direction speed, sky cover, and current weather.

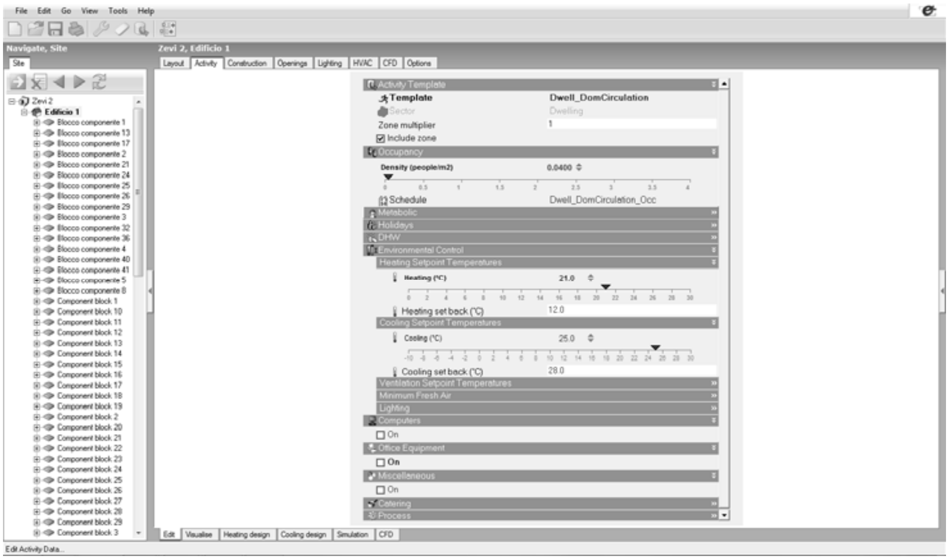


Fig.4. 8: DesignBuilder Software, Activity Template.

Actually even if the building object of analysis is located in Salerno, the main weather station, able to provide all these data is Napoli Capodichino; the two cities are near enough to assume the same weather conditions without committing a big mistake.

So adding the location all weather data and information related with legislative region (Italy in this case) and Energy Code/ Insulation Standard are updated.

Initially on the edit screen we simply have three axes, x y and the vertical z axe, the north indicator is automatically aligned with the y axe, but can be simply rotate setting a proper site orientation, and adjust for the building under study, that’s why it is very easy to test energy performance for different units.

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.

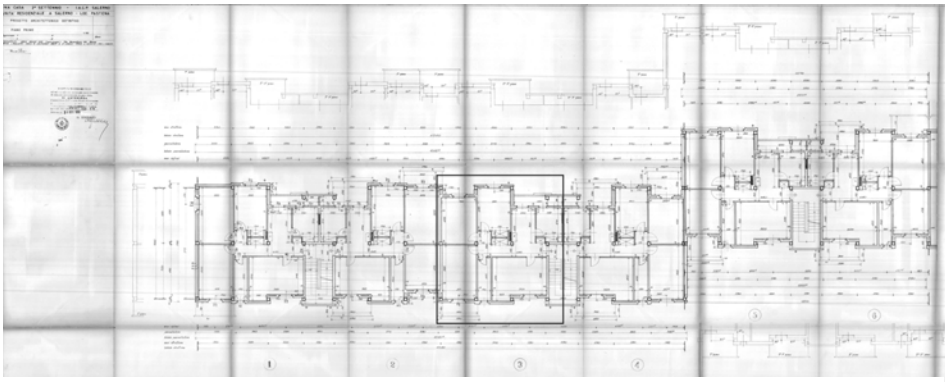


Fig.4. 9: Quartiere Pastena by Zevi, Building A, Plant, Salerno.

The software allows importing 2-D floor plans from DXF and bitmaps to help draw blocks and partitions.

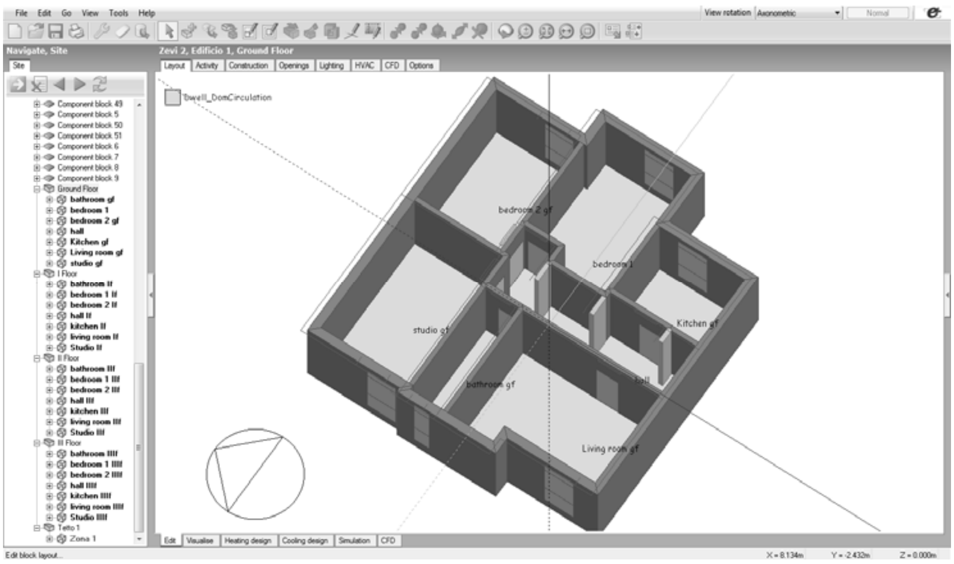


Fig.4. 10: DesignBuilder- Model of a slice of building A. Ground floor.

After drowing walls ad partitions, the software allows to associate different characteristics to every room, even in terms of use. With the "activity" button template, occupancy, metabolism of the occupants, information about environmental control and lighting can be assigned.

Properties assigned to each room are listed below:

Living room:

- Occupancy: density= 0.14 people/m^2
  Schedule: Compact, Dwell_DomCirculation_Occ,
  Fraction, Through: 31 Dec,
  For: Weekdays SummerDesignDay, Until: 07:00, 0,
  Until: 09:00, 0.1, Until: 18:00, 0,
  Until: 23:00, 0.05, Until: 24:00, 0,
  For: Weekends, Until: 09:00, 0,Until: 24:00, 0.05,
  For: Holidays, Until: 24:00, 0,
  For: WinterDesignDay AllOtherDays, Until: 24:00, 0;[2]
- Metabolic activity: light manual work= 180.0 (metabolic rate per person)
- Clothing: winter clothing (clo)= 1.00 summer clothing (clo) 0.50
- DHW (domestic hot water): comsuption rate (l/m^2-day) = 0.53
- Environmental control:
    - Heating Setpoint Temperatures: heating (°C)= 21.0 Heating set back (°C) = 12.0
    - Cooling Setpoit Temperature: cooling (°C) = 25.0 Cooling set back (°C) = 28 °C
    - Ventilation Setpoint Temperature

[2] Using the Compact Schedule definition all the features of the schedule components are accessed in a single command. Each Compact Schedule must cover all the days for a year and it must have values for all 24 hours and all values for all day types.
Each Compact Schedule must contain the elements Through (date), For (days), Interpolate (optional), Until (time of day) and Value. This field starts with 'For: ' and contains the applicable days. Multiple choices may be combined on the line. The field Until contains the ending time for the current days and day schedule being defined. Finally, the value field is the schedule value for the specified time interval. "0" means OFF o that the system is switched off during the specified period, otherwise "1" means ON.

Natural Ventilation cooling (°C): 22
Max in-out ΔT : -50

- Minimum Fresh air (l/s-person): 10.0
- Lighting, target illuminance (lux) : 150

- Computers: OFF,
- Office Equipment: OFF
- Lighting: OFF

In this first study case the energy performance has been calculated without taking into account the electricity consumption for lighting, as the bulding A is pretty big and the occupancy status rather variable, so lighting has considered to be too dependent on the users habits. In the second study case instead,where the occupancy status appears to be more homogeneous, lighting has been considered and a more detailed definition of occupancy/room and activity has been done.

Kitchen/ dining room:

- Occupancy: density= 0.4 people/m^2
  Schedule: Compact, Dwell_DomCirculation_Occ,
  Fraction, Through: 31 Dec,
  For: Weekdays SummerDesignDay, Until: 07:00, 0,
  Until: 09:00, 0.1, Until: 18:00, 0,
  Until: 23:00, 0.05, Until: 24:00, 0,
  For: Weekends, Until: 09:00, 0,Until: 24:00, 0.05,
  For: Holidays, Until: 24:00, 0,
  For: WinterDesignDay AllOtherDays, Until: 24:00, 0;
- Metabolic activity: eating/drinking= 110.0 (metabolic rate per person)
- Clothing: winter clothing (clo)= 1.00 summer clothing (clo) 0.50
- DHW (domestic hot water): comsuption rate (l/m^2-day) = 0.53
- Environmental control:
  - Heating Setpoint Temperatures: heating (°C)= 21.0 Heating set back (°C) = 12.0
  - Cooling Setpoit Temperature: cooling (°C) = 25.0 Cooling set back (°C) = 28 °C

  - Ventilation Setpoint Temperature
  - Natural Ventilation cooling (°C): 22
    Max in-out ΔT : -50
    - Minimum Fresh air (l/s-person): 10.0
    - Lighting, target illuminance (lux) : 100
- Computers: OFF
- Office Equipment: OFF

Studio:

- Occupancy: density= 0.1 people/m^2
  Schedule: Compact, Dwell_DomCirculation_Occ,
  Fraction, Through: 31 Dec,
  For: Weekdays SummerDesignDay, Until: 07:00, 0,
  Until: 09:00, 0.1, Until: 18:00, 0,
  Until: 23:00, 0.05, Until: 24:00, 0,
  For: Weekends, Until: 09:00, 0,Until: 24:00, 0.05,
  For: Holidays, Until: 24:00, 0,
  For: WinterDesignDay AllOtherDays, Until: 24:00, 0;
- Metabolic activity: light manual work= 180.0 (metabolic rate per person)
- Clothing: winter clothing (clo)= 1.00 summer clothing (clo) 0.50
- DHW (domestic hot water): comsuption rate (l/m^2-day) = 0.53
- Environmental control:
  - Heating Setpoint Temperatures: heating (°C)= 21.0 Heating set back (°C) = 12.0
  - Cooling Setpoit Temperature: cooling (°C) = 25.0 Cooling set back (°C) = 28 °C
  - Ventilation Setpoint Temperature
  - Natural Ventilation cooling (°C): 22
  - Max in-out ΔT : -50
  - Minimum Fresh air (l/s-person): 10.0
  - Lighting, target illuminance (lux) : 100
- Computers: ON
  Gains (W/m^2): 5.0
  Schedule: Compact, Dwell_DomCirculation_Equip,

Fraction, Through: 31 Dec,
For: Weekdays SummerDesignDay, Until: 07:00, 0.05,
Until: 09:00, 1, Until: 18:00, 0.05,
Until: 23:00, 1, Until: 24:00, 0.05,
For: Weekends, Until: 09:00, 0.05, Until: 24:00, 1,
For: Holidays, Until: 24:00, 0.05,
For: WinterDesignDay AllOtherDays, Until: 24:00, 0;

Radiant fraction: 2.0

- Office Equipment: OFF

Bedroom 1:

- Occupancy: density= 0.14 people/m^2
  Schedule: Compact, Dwell_DomCirculation_Occ,
  Fraction, Through: 31 Dec,
  For: Weekdays SummerDesignDay, Until: 07:00, 0,
  Until: 09:00, 0.1, Until: 18:00, 0,
  Until: 23:00, 0.05, Until: 24:00, 0,
  For: Weekends, Until: 09:00, 0,Until: 24:00, 0.05,
  For: Holidays, Until: 24:00, 0,
  For: WinterDesignDay AllOtherDays, Until: 24:00, 0
- Metabolic activity: Resting= 90 (metabolic rate per person)
- Clothing: winter clothing (clo)= 1.00 summer clothing (clo) 0.50
- DHW (domestic hot water): comsuption rate (l/m^2-day) = 0.53
- Environmental control:
  - Heating Setpoint Temperatures: heating (°C)= 21.0
    Heating set back (°C) = 12.0
  - Cooling Setpoit Temperature: cooling (°C) = 25.0
    Cooling set back (°C) = 28 °C
  - Ventilation Setpoint Temperature
    Natural Ventilation cooling (°C): 22
    Max in-out ΔT : -50
  - Minimum Fresh air (l/s-person): 10.0
  - Lighting, target illuminance (lux) : 100
- Computers: OFF
- Office Equipment: OFF

Bedroom 2:

- Occupancy: density= 0.14 people/m^2
  Schedule: Compact, Dwell_DomCirculation_Occ,
  Fraction, Through: 31 Dec,
  For: Weekdays SummerDesignDay, Until: 07:00, 0,
  Until: 09:00, 0.1, Until: 18:00, 0,
  Until: 23:00, 0.05, Until: 24:00, 0,
  For: Weekends, Until: 09:00, 0,Until: 24:00, 0.05,
  For: Holidays, Until: 24:00, 0,
  For: WinterDesignDay AllOtherDays, Until: 24:00, 0
- Metabolic activity: Resting= 90 (metabolic rate per person)
- Clothing: winter clothing (clo)= 1.00 summer clothing (clo) 0.50
- DHW (domestic hot water): comsuption rate (l/m^2-day) = 0.53
- Environmental control:
  - Heating Setpoint Temperatures: heating (°C)= 21.0
    Heating set back (°C) = 12.0
  - Cooling Setpoit Temperature: cooling (°C) = 25.0
    Cooling set back (°C) = 28 °C
  - Ventilation Setpoint Temperature
    Natural Ventilation cooling (°C): 22
    Max in-out ΔT : -50
  - Minimum Fresh air (l/s-person): 10.0
  - Lighting, target illuminance (lux) : 100
- Computers: OFF
- Office Equipment: OFF

Bathroom:

- Occupancy: density= 0.1 people/m^2
- Schedule:Compact, Dwell_DomCirculation_Occ,
  Fraction, Through: 31 Dec,
  For: Weekdays SummerDesignDay, Until: 07:00, 0,
  Until: 09:00, 0.1, Until: 18:00, 0,
  Until: 23:00, 0.05, Until: 24:00, 0,
  For: Weekends, Until: 09:00, 0, Until: 24:00, 0.05,
  For: Holidays, Until: 24:00, 0,
  For: WinterDesignDay AllOtherDays, Until: 24:00, 0;

- Metabolic activity: light manual work= 180 (metabolic rate per person)
- Clothing: winter clothing (clo)= 1.00 summer clothing (clo) 0.50
- DHW (domestic hot water): comsuption rate (l/m^2-day) = 0.53
- Environmental control:
  - Heating Setpoint Temperatures: heating (°C)= 21.0
    Heating set back (°C) = 12.0
  - Cooling Setpoit Temperature: cooling (°C) = 25.0
    Cooling set back (°C) = 28 °C
  - Ventilation Setpoint Temperature
    Natural Ventilation cooling (°C): 22
    Max in-out ΔT : -50
  - Minimum Fresh air (l/s-person): 10.0
  - Lighting, target illuminance (lux) : 100
- Computers: OFF
- Office Equipment: OFF
- Lighting: OFF

After completed the section "Activity" the programs allows to add information related to construction and materials. Walls, roof, ceilings and floors, doors etc…can be defined for the specific case.

First of all walls can be devided in external walls and internal walls or partitions. The Data detail dialogue window helps to configure the model detail. The "construction and glazing" model option controls the way construction templates are loaded in Model Data.

When the Floor/slab/ceiling representation model option is set to "Combined" the surface types and the constructions will be applied automatically according to the locations or orientation.
The properties of each are listed as follow:

- External Walls:
  Category: Walls, Region: Italy
  Number of layers: 4
  - Outermost layer: Brick –(brick work outer leaf)
    Source: CIBSE Guide A (2006)

Thickness (m): 0.01

Thermal properties
- Conductivity (W/mK): 0.840
- Specific heat (J/kgK) 800.0
- Density (kg/m^3) 1700.0

Surface properties
- Thermal absorptance: 0.900
- Solar absorptance: 0.700
- Visible absorptance : 0.700

- Layer 2: Air gap >= 25 mm

Thickness (not used in thermal calculations) (m): 0.040
Source: ISO/WD 6946
Thermal Resistence (R-value) (m^2K/W): 0.180

- Layer 3: Laterizio forato da 16 cm

Source: user defined
Thickness (m): 0.16

Thermal properties
- Conductivity (W/mK): 0.300
- Specific heat (J/kgK) 1930.0
- Density (kg/m^3) 800.0

Surface properties
- Thermal absorptance: 0.900
- Solar absorptance: 0.700
- Visible absorptance : 0.700

- Innemost layer: Plaster

Source: ISO 10456
Thickness (m): 0.0150

Thermal properties
- Conductivity (W/mK): 0.400
- Specific heat (J/kgK) 1000.0
- Density (kg/m^3) 1000.0

Surface properties
- Thermal absorptance: 0.900
- Solar absorptance: 0.500
- Visible absorptance : 0.500

- Internal Walls (partitions):
  Category: Walls; Region: Italy
  Number of layers: 3
  - Outermost layer: Plaster
    Source: ISO 10456
    Thickness (m): 0.025
    Thermal properties
    Conductivity (W/mK): 0.250
    Specific heat (J/kgK) 1000.0
    Density (kg/m^3) 900.0

    Surface properties
    Thermal absorptance: 0.900
    Solar absorptance: 0.500
    Visible absorptance: 0.500

  - Layer 2: Laterizio forato
    Thickness (m): 0.10
    Source: user defined
    Thermal Resistence (R-value) (m^{2}K/W): 0.150

  - Innemost layer: Plaster
    Source: ISO 10456
    Thickness (m): 0.0250
    Thermal properties
    Conductivity (W/mK): 0.400
    Specific heat (J/kgK) 1000.0
    Density (kg/m^3) 1000.0

    Surface properties
    Thermal absorptance: 0.900
    Solar absorptance: 0.500
    Visible absorptance : 0.500

- Roof : Pitched roof (unoccupied)[3]

Category: Roofs; Region: Italy
Number of layers: 3

- Outermost layer: Clay Tile (roofing)
  Thickness (m): 0.025
  Source: ISO 10456
  Thermal properties
  - Conductivity (W/mK): 1.00
  - Specific heat (J/kgK) 800.0
  - Density (kg/m^3) 2000.0

  Surface properties
  - Thermal absorptance: 0.900
  - Solar absorptance: 0.700
  - Visible absorptance : 0.700

- Layer 2: Insulation
  Source: ISO/WD 6946
  Thermal Resistence (R-value) (m2K/W): 0.150

- Innermost layer: Roofing Felt
  Thickness (m): 0.0050
  Thermal properties
  - Conductivity (W/mK): 0.190
  - Specific heat (J/kgK) 837.0
  - Density (kg/m^3) 960.0

  Surface properties
  - Thermal absorptance: 0.900
  - Solar absorptance: 0.800
  - Visible absorptance : 0.800

[3] As said before the roof has been recently replaced, that's why no hypothesis or replacement or retrofitting has been done about the roof, as appearsfairly improbable that other changes would be planned for the roof. For this reason the data reported in the text are relative to a standard floor, the first one, in order to consider only the heat losses with the adjacent flat, excluding the problem losses through the roof.

Unintentional infiltration rate can be set and is constant:
Airtightness (building): 0.07 ac/h
Airtightness (roof): 1.00 ac/h

Once defined materials and thermal properties of walls and roof, properties of windows has to be defined. As said in the previous paragraph the site inspection revealed a lack of uniformity in the condition of the neighbourhood, not all the current owners raplaced windows with new, and more efficient, ones.

In order to identify a state "zero" to which refer to start the analysis and also to make easily understandable 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.

Therefore, in the so called "initial condition" windows are the original one, single glaze, wood frame and no shading system, that in few cases can be still seen in situ. Glazing templates data are as follow:

- Glazong Template:
    - Single Glazng, clear, no shading devices.

      Thermal properties
      - Conductivity (W/mK): 0.90
      - Thickness (mm) 6.00

      Solar properties
      - Solar Trasmittance: 0.775
      - Outside Solar reflectance: 0.071
      - Inside Solar reflectance: 0.071

      Visible properties
      - Visible Trasmittance: 0.881
      - Outside visible reflectance: 0.080
      - Inside visible reflectance: 0.080

    - Painted wooden window frame

      Material: Painted Oak

	Thickness: 0.020
Thermal properties	Conductivity (W/mK): 0.190 Specific heat (J/kgK) 2390.0 Density (kg/m^3) 700.0
Surface properties	Thermal absorptance: 0.900 Solar absorptance: 0.500 Visible absorptance : 0.500

The last step is to define the HVAC: Heating, Ventilation and Air Conditioning.

First of all no mechanical ventilation was provided, the main goal of the research was to reduce the energy consumption (especially during summer) for this reason, the first resource used for summer cooling has been natural ventilation, assisted by the use of air conditioning to achieve an acceptable level of indoor comfort during the hottest hours of summer days. Following are features and operating modes of heating, cooling and DHW (Domestic Hot Water).

Natural ventilation (and its schedule) have been added only later.

- Heating:
  - Fuel: Natural Gas
  - CoP[4] (Coefficient of Performance): 0.650
  - Heating distribution loss (%): 5.0
  - Heating Type: Convective
  - Operation: Schedule
    From January to April and from October to December: ON
    Schedule: customized[5]
    From 7:30 to 8:30 ON
    From 8:30 to 12:00 OFF
    From 12:00 to 20:00 ON

[4] Heating/cooling system CoP is the whole seasonal coefficient of performance.
[5] Customized means that the profile is defined by a number of intervals, each if which can have a different value.

From 20:00 to 24:00 OFF

- Cooling:
  - Fuel: Electricity from Grid
  - CoP (Coefficient of Performance): 4.5
  - Supply air temperature (°C): 12.00
  - Supply air humidity ratio (g/g): 0.008
  - Operation: Schedule
    From June to September ON
    Schedule: customized
    From 12:00 to 18:00 ON
    From 18:00 to 12:00 OFF

- DHW:
  - Type: Instantaneous DHW only
  - CoP (Coefficient of Performance): 0.85
  - Delivery water temperature (°C): 65.00
  - Main supply temperature (°C): 10.0
  - Operation: Schedule
    From January to December ON
    Schedule: customized
    From 0:00 to 6:00 OFF
    From 6:00 to 10:00 ON
    From 10:00 to 12:00 OFF
    From 12:00 to 15:00 ON
    From 15:00 to 17:00 OFF
    From 17:00 to 23:00 ON

Default boundary conditions for CFD (Computation Fluid Dynamic, used for detailed analysis of occupant and pedestrian comfort, effectiveness of supply diffusers, and other applications requiring detailed analyse of air distribution) are listed below:

Inside surface temperature (internal surface) (°C): 20.00
Inside surface temperature (external surface) (°C): 20.00

Inside surface window temperature (°C): 10.00
Average zone air temperature (°C): 22.00
Incoming air temperature (°C): 20.00
Aperture position: top
Aperture size (% total opening area) : 20.0

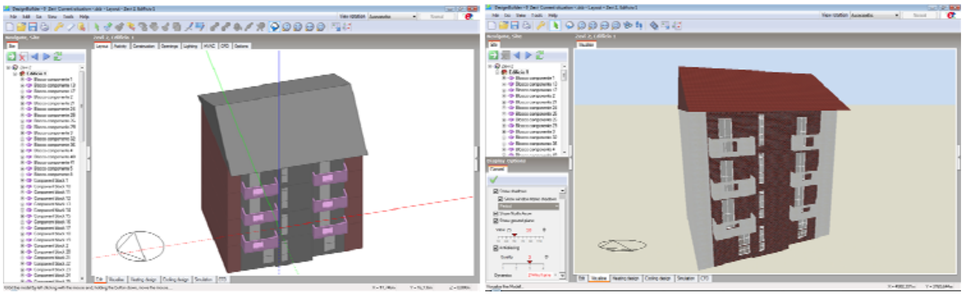


Fig.4. 11: DesignBuilder Layout (editing mode) and rendering. Case study I: Quartiere Pastena, Bruno Zevi. Salerno

The software DesignBuilder adapts to several Analysis Type: EnergyPlus, KLIMA Europa, DBSim. For the analysis, EnergyPlus was used because it is one of the most trusted and distributed.

EnergyPlus can run energy analysis and thermal load simulations. Based on a user's description of a building from the perspective of the building's physical make-up and associated mechanical and other systems, EnergyPlus calculates heating and cooling loads necessary to maintain thermal control set points, conditions throughout a secondary HVAC system and coil loads, and the energy consumption of primary plant equipment.

Model data can be configured to user’s requirement, for example it is possible to change “scope” switching from an analysis of the *whole building* to an in deep study of a *single zone*. Gains can be modeled with three different level of detail: *lumped* (all internal gains are lumped together into a single value), *early* (gains can be defined separately under various category i.e. equipment computers, process etc…) or *detailed* (gains are specified by defining each individual item of equipment in each zone).

Timing can be defined using two approaches: *typical workday* – where the schedule is defined by a start time, end time and seasonal variation – or *schedules* – where schedule can be either defined for each day of the week and each month of the year using daily Profiles or by using EnergyPlus Compact schedule.

HVAC (heating ventilation and air conditioning) can be defined as: *simple* – the heating/cooling system is modeled using basic algorithms and corresponding energy consumption is modeled as a post-process – or *compact* – the heating/cooling system are defined in DesignBuilder parametrically but modeled in detail in EnergyPlus.

Option for HVAC are *adequate* (the heating and cooling equipment can always meet demand and no autosizing is required), *manual* (the user is responsible for entering heating and cooling equipment size) *autosize* (the software always autosize heating and cooling equipment). Either natural ventilation can be scheduled or calculated.

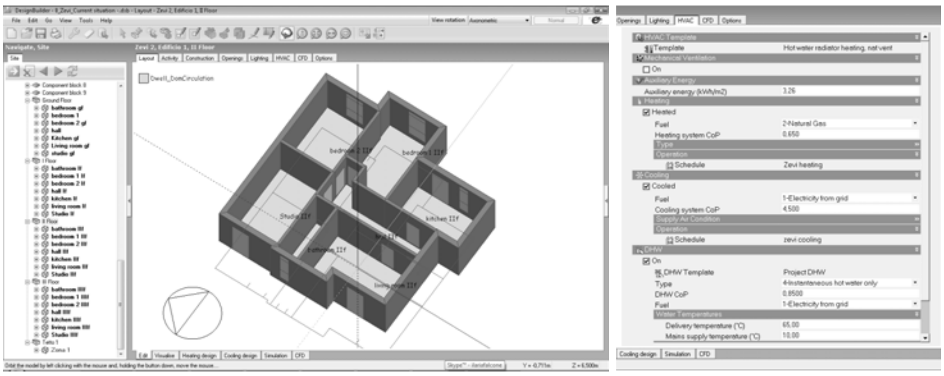


Fig.4. 12**:** HVAC definition - DesignBuilder

The software is able to runs four types of energy simulation:

1. Heating design simulation
2. Cooling design simulation

3. Simulation using hourly weather data (simply referred to as “simulation” in DesignBuilder documentation)
4. Daylighting

Heating design calculations are carried out to determine the size of heating equipment required to meet the coldest winter design weather conditions related to the site location. Calculations are carried out using steady-state. Heating design simulations using EnergyPlus have the following characteristics:

- Constant (Steady-state) external temperature is set to the winter design external temperature.
- Wind speed and direction are set to design values.
- Does not take into account solar gain.
- Does not take into account internal gains (lighting, equipment, occupancy etc…).
-

Moreover heated zones are heated constantly to achieve the heating temperature set point using a simple convective heating system, and as the calculations are based on a steady state analysis, which does not account for timing, schedules are not used in the heating design phase.

The simulation calculates heating capacities required to maintain the temperature set points in each zone and displays the total heat loss broken down as:

- Glazing
- Walls
- Partitions
- Solid floors
- Roofs
- External infiltration

- Internal natural ventilation (i.e. heat lost to other cooler adjacent spaces through windows, vents, doors, holes)

About Cooling design it is important to understand that calculations are carried out to determine the capacity of mechanical cooling equipment required to meet the hottest summer design weather conditions likely to be encountered at the site location and are traditionally carried out using periodic steady-state methods. Cooling design simulations have the following characteristics:

- The Periodic steady-state external temperatures are calculated using maximum and minimum design summer weather conditions.
- Does not take into account wind.
- Includes solar gains through windows and scheduled natural ventilation.
- Includes internal gains (from occupants, lighting and other equipment).
- Includes consideration of heat conduction and convection (between zones of different temperatures).
-

A true detailed building energy performance based on simulations using real weather data, can be achieved by running a simulation, that has the following characteristics:

- Weather data used comes from hourly weather data file.
- Includes consideration of heat conduction and convection between zones of different temperatures.
- Includes solar gain through windows.

- Includes one or more "warm-up" days to ensure correct distribution of heat in building thermal mass and the start of the simulation.[6]
- Eventually a simulation of HVAC can be done.

Finally it is possible to get a daylight simulation, to generate data on distribution of illuminance levels and daylight factors within each zone for one or more zones in the building. In this case data provided in the model are:

- Surface visible reflectance of the material on the innermost layer of constructions.
- Window glazing transmittance.
- Detailed geometry description
- Daylighting calculation options
- Site ground reflectance.

[6] Warm-up continues until temperatures/heat flows in each zone have converged. If convergence does not occur then simulation continues for the maximum number of days as specified in the calculation options.

4.3 Methodology

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 consumption (annual) 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 turned out to be negligible.

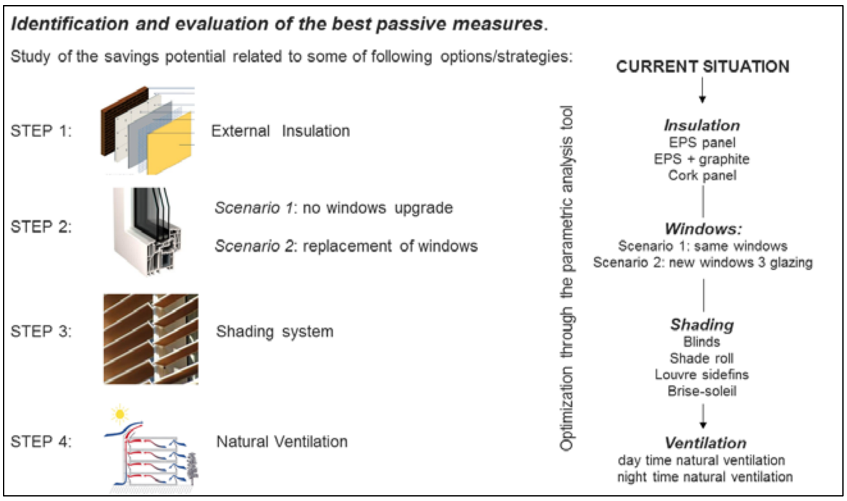


Fig.4. 13: Schematic diagram showing the subsequent steps procedure applied to the case study.

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.

4.3.1 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 life cycle analysis of the building.

The following graphs and tables show the beneficial effect of the use of thermal insulation in terms of energy savings.

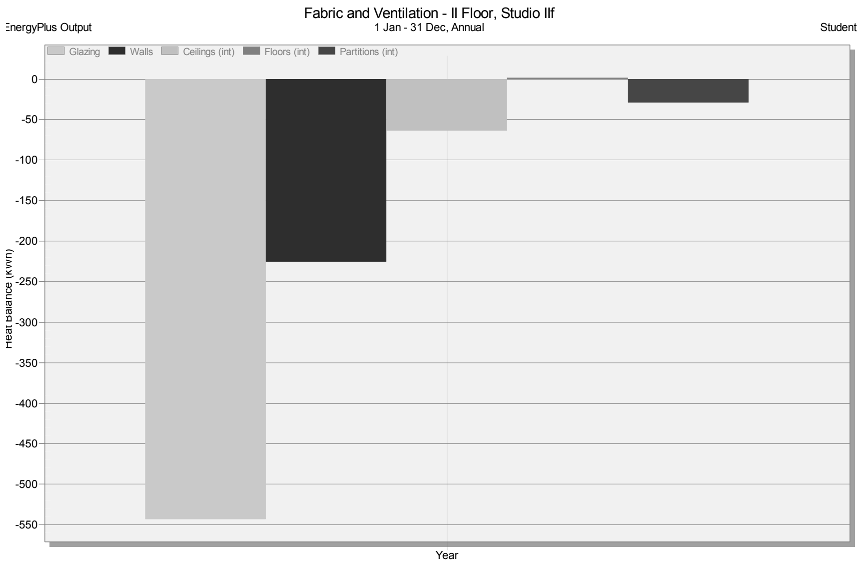


Fig.4. 14**:** Current situations, no insulating system. Heat Balance: -225,9 KWh.

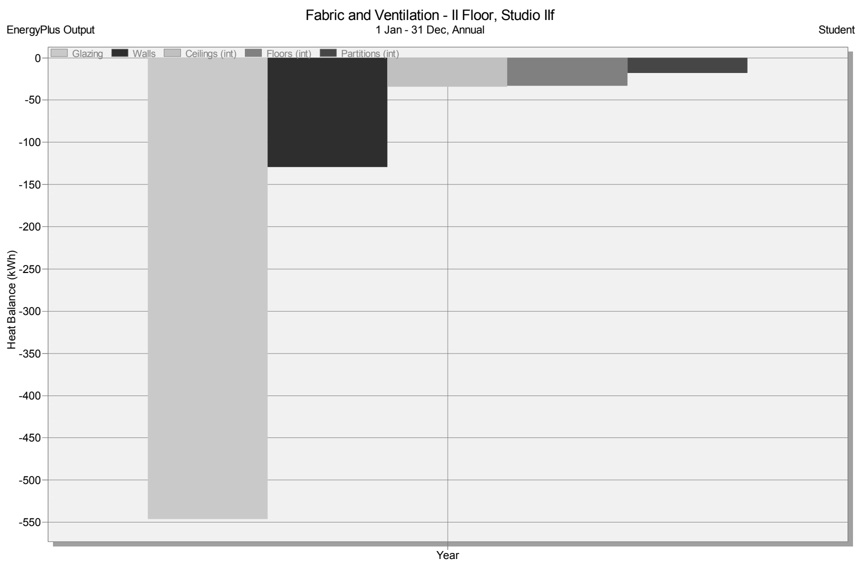


Fig.4. 15: ESP Expanded Polystyrene insulating system. The thermal conductivity varies between 0.034 and 0.04 W/mK . Heat Balance: -129,8 KWh.

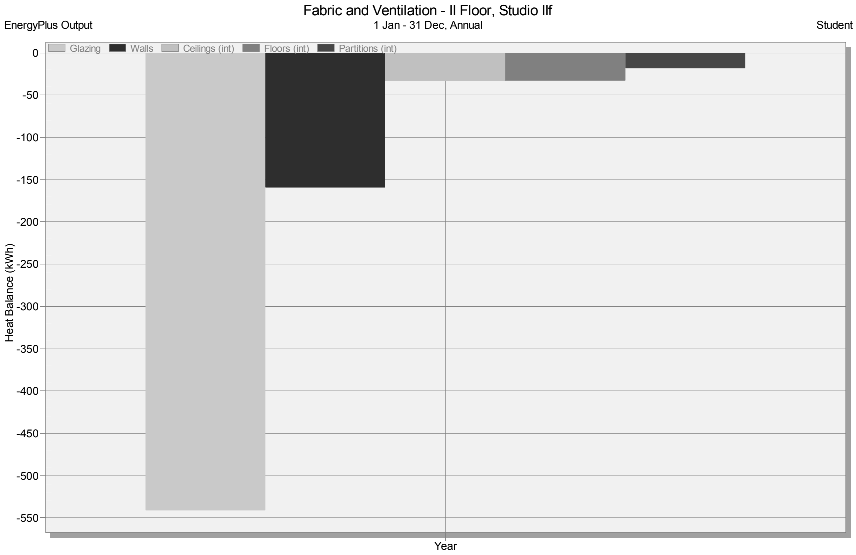


Fig.4. 16: Vermiculite: The thermal conductivity varies between 0.05 and 0.06 W/mK . Heat Balance: -159,6 KWh.

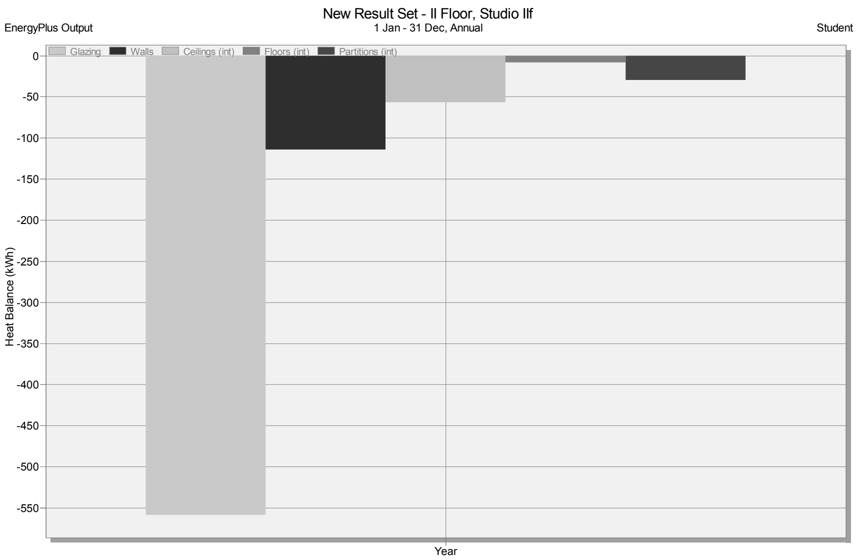


Fig.4. 17: Polyurethane Foam: The thermal conductivity varies between 0.025 and 0.035 W/mK . Heat Balance: -113,9 KWh

Figure 4.11-4.12- 4.13 and 4.14 show a comparison between the graphs representing the sum of heat gains to the zone from external wall inner surfaces (fabric and ventilation).

Current Situation					
Building	Block	Zone	Temperatura operante (°C)	Perdita di calore in regime stazionario (kW)	Potenza di progetto ((kW)
Edificio 1	Ground Floor	bedroom 1	19.36	0.78	1.18
Edificio 1	Ground Floor	Living room gf	19.6	0.83	1.24
Edificio 1	Ground Floor	hall	20.39	0.36	0.54
Edificio 1	Ground Floor	Kitchen gf	19.35	0.5	0.76
Edificio 1	Ground Floor	bathroom gf	19.88	0.29	0.44
Edificio 1	Ground Floor	studio gf	19.76	0.69	1.03
Edificio 1	Ground Floor	bedroom 2 gf	19.65	0.62	0.92
Edificio 1	I Floor	bedroom 1 If	19.41	0.79	1.18
Edificio 1	I Floor	living room If	19.54	0.76	1.13
Edificio 1	I Floor	hall If	20.38	0.35	0.52
Edificio 1	I Floor	kitchen If	19.23	0.75	1.12
Edificio 1	I Floor	bathroom If	19.85	0.27	0.41
Edificio 1	I Floor	Studio If	19.76	0.66	1
Edificio 1	I Floor	bedroom 2 If	19.7	0.63	0.95
Edificio 1	II Floor	bedroom 1 IIf	19.39	0.79	1.19
Edificio 1	II Floor	living room IIf	19.51	0.77	1.15
Edificio 1	II Floor	hall IIf	20.38	0.35	0.52
Edificio 1	II Floor	kitchen IIf	19.2	0.76	1.14
Edificio 1	II Floor	bathroom IIf	19.83	0.28	0.42
Edificio 1	II Floor	Studio IIf	19.74	0.67	1.01
Edificio 1	II Floor	bedroom 2 IIf	19.68	0.64	0.96
Edificio 1	III Floor	bedroom 1 IIIf	19.3	0.84	1.25
Edificio 1	III Floor	living room IIIf	19.41	0.81	1.22
Edificio 1	III Floor	hall IIIf	20.27	0.39	0.58
Edificio 1	III Floor	kitchen IIIf	19.11	0.79	1.19
Edificio 1	III Floor	bathroom IIIf	19.74	0.3	0.44
Edificio 1	III Floor	Studio IIIf	19.63	0.72	1.08
Edificio 1	III Floor	bedroom 2 IIIf	19.58	0.68	1.02
Edificio 1	Tetto 1	Zona 1	0.02	0	0
		TOT		17.07	25.59

Table 4. 1: Summary of heating design, initial situation, defined as "current".

The table above (and the followings that include also a comparison between the different insulating system and the initial status without insulation) shows the summary of comfort temperature, steady state heat loss and design heating capacity:

- Comfort temperature - The average value of the internal air and radiant temperatures;

- Steady-state heat loss - heat delivered to maintain the internal heating design temperature.

- Design capacity - is the steady-state heat loss multiplied by the design margin to give the design heating capacity of the equipment.

EPS Expanded Polystirene					
Edificio	Blocco	Zona	Temperatura operante (°C)	Perdita di calore in regime stazionario (kW)	Potenza di progetto ((kW)
Edificio 1	Ground Floor	bedroom 1	19.68	0.66	0.98
Edificio 1	Ground Floor	Living room gf	19.7	0.79	1.18
Edificio 1	Ground Floor	hall	20.45	0.34	0.51
Edificio 1	Ground Floor	Kitchen gf	19.58	0.45	0.67
Edificio 1	Ground Floor	bathroom gf	20.02	0.26	0.39
Edificio 1	Ground Floor	studio gf	19.93	0.62	0.93
Edificio 1	Ground Floor	bedroom 2 gf	19.84	0.55	0.83
Edificio 1	I Floor	bedroom 1 lf	19.74	0.66	0.99
Edificio 1	I Floor	living room lf	19.79	0.65	0.97
Edificio 1	I Floor	hall lf	20.47	0.32	0.48
Edificio 1	I Floor	kitchen lf	19.47	0.66	0.99
Edificio 1	I Floor	bathroom lf	20.01	0.24	0.37
Edificio 1	I Floor	Studio lf	19.93	0.6	0.9
Edificio 1	I Floor	bedroom 2 lf	19.89	0.56	0.85
Edificio 1	II Floor	bedroom 1 IIf	19.72	0.66	1
Edificio 1	II Floor	living room IIf	19.78	0.65	0.98
Edificio 1	II Floor	hall IIf	20.47	0.32	0.48
Edificio 1	II Floor	kitchen IIf	19.44	0.67	1.01
Edificio 1	II Floor	bathroom IIf	19.99	0.25	0.37
Edificio 1	II Floor	Studio IIf	19.9	0.61	0.91
Edificio 1	II Floor	bedroom 2 IIf	19.87	0.57	0.86
Edificio 1	III Floor	bedroom 1 IIIf	19.61	0.71	1.06
Edificio 1	III Floor	living room IIIf	19.67	0.7	1.05
Edificio 1	III Floor	hall IIIf	20.35	0.36	0.54
Edificio 1	III Floor	kitchen IIIf	19.34	0.71	1.06
Edificio 1	III Floor	bathroom IIIf	19.9	0.27	0.4
Edificio 1	III Floor	Studio IIIf	19.78	0.66	0.99
Edificio 1	III Floor	bedroom 2 IIIf	19.76	0.61	0.92
Edificio 1	Tetto 1	Zona 1	0.03	0	0
		TOT		15.11	22.67

Comparison Current situation- EPS							
Edificio	Blocco	Zona	Temperatura operante (°C)	Perdita di calore in regime stazionario (kW)	Potenza di progetto ((kW)	riduzione in % delle perdite di calore	riduzione in % della potenza di progetto
Edificio 1	Ground Floor	bedroom 1	0.32	0.12	0.2	15%	17%
Edificio 1	Ground Floor	Living room gf	0.1	0.04	0.06	5%	5%
Edificio 1	Ground Floor	hall	0.06	0.02	0.03	6%	6%
Edificio 1	Ground Floor	Kitchen gf	0.23	0.05	0.09	10%	12%
Edificio 1	Ground Floor	bathroom gf	0.14	0.03	0.05	10%	11%
Edificio 1	Ground Floor	studio gf	0.17	0.07	0.1	10%	10%
Edificio 1	Ground Floor	bedroom 2 gf	0.19	0.07	0.09	11%	10%
Edificio 1	I Floor	bedroom 1 lf	0.33	0.13	0.19	16%	16%
Edificio 1	I Floor	living room lf	0.25	0.11	0.16	14%	14%
Edificio 1	I Floor	hall lf	0.09	0.03	0.04	9%	8%
Edificio 1	I Floor	kitchen lf	0.24	0.09	0.13	12%	12%
Edificio 1	I Floor	bathroom lf	0.16	0.03	0.04	11%	10%
Edificio 1	I Floor	Studio lf	0.17	0.06	0.1	9%	10%
Edificio 1	I Floor	bedroom 2 lf	0.19	0.07	0.1	11%	11%
Edificio 1	II Floor	bedroom 1 IIf	0.33	0.13	0.19	16%	16%
Edificio 1	II Floor	living room IIf	0.27	0.12	0.17	16%	15%
Edificio 1	II Floor	hall IIf	0.09	0.03	0.04	9%	8%
Edificio 1	II Floor	kitchen IIf	0.24	0.09	0.13	12%	11%
Edificio 1	II Floor	bathroom IIf	0.16	0.03	0.05	11%	12%
Edificio 1	II Floor	Studio IIf	0.16	0.06	0.1	9%	10%
Edificio 1	II Floor	bedroom 2 IIf	0.19	0.07	0.1	11%	10%
Edificio 1	III Floor	bedroom 1 IIIf	0.31	0.13	0.19	15%	15%
Edificio 1	III Floor	living room IIIf	0.26	0.11	0.17	14%	14%
Edificio 1	III Floor	hall IIIf	0.08	0.03	0.04	8%	7%
Edificio 1	III Floor	kitchen IIIf	0.23	0.08	0.13	10%	11%
Edificio 1	III Floor	bathroom IIIf	0.16	0.03	0.04	10%	9%
Edificio 1	III Floor	Studio IIIf	0.15	0.06	0.09	8%	8%
Edificio 1	III Floor	bedroom 2 IIIf	0.18	0.07	0.1	10%	10%
Edificio 1	Tetto 1	Zona 1	0.01	0	0		
Edificio 1				1.96	2.92	11%	11%

Table 4. 2 : Summary of heating design using EPS, expanding polystyrene, as thermal insulation, and comparison with the current situation. Reduction of design heating capacity in percentage: 11%.

Polyuretan spray (ICYNENE)					
Edificio	Blocco	Zona	Temperatura operante (°C)	Perdita di calore in regime stazionario (kW)	Potenza di progetto ((kW)
Edificio 1	Ground Floor	bedroom 1	19.75	0.63	0.95
Edificio 1	Ground Floor	Living room gf	19.62	0.83	1.24
Edificio 1	Ground Floor	hall	20.46	0.34	0.51
Edificio 1	Ground Floor	Kitchen gf	19.62	0.44	0.65
Edificio 1	Ground Floor	bathroom gf	20.04	0.26	0.39
Edificio 1	Ground Floor	studio gf	19.96	0.61	0.92
Edificio 1	Ground Floor	bedroom 2 gf	19.88	0.54	0.81
Edificio 1	I Floor	bedroom 1 If	19.8	0.63	0.95
Edificio 1	I Floor	living room If	19.83	0.63	0.95
Edificio 1	I Floor	hall If	20.49	0.32	0.48
Edificio 1	I Floor	kitchen If	19.52	0.64	0.97
Edificio 1	I Floor	bathroom If	20.04	0.24	0.36
Edificio 1	I Floor	Studio If	19.96	0.59	0.88
Edificio 1	I Floor	bedroom 2 If	19.93	0.55	0.83
Edificio 1	II Floor	bedroom 1 IIf	19.78	0.64	0.96
Edificio 1	II Floor	living room IIf	19.84	0.63	0.95
Edificio 1	II Floor	hall IIf	20.49	0.32	0.48
Edificio 1	II Floor	kitchen IIf	19.49	0.65	0.98
Edificio 1	II Floor	bathroom IIf	20.03	0.24	0.36
Edificio 1	II Floor	Studio IIf	19.94	0.6	0.9
Edificio 1	II Floor	bedroom 2 IIf	19.91	0.56	0.84
Edificio 1	III Floor	bedroom 1 IIIf	19.67	0.69	1.03
Edificio 1	III Floor	living room IIIf	19.72	0.68	1.02
Edificio 1	III Floor	hall IIIf	20.37	0.36	0.54
Edificio 1	III Floor	kitchen IIIf	19.39	0.69	1.04
Edificio 1	III Floor	bathroom IIIf	19.93	0.26	0.39
Edificio 1	III Floor	Studio IIIf	19.81	0.65	0.97
Edificio 1	III Floor	bedroom 2 IIIf	19.79	0.6	0.9
Edificio 1	Tetto 1	Zona 1	0.04	0	0
		TOT		14.82	22.25

Current situation- Icynene							
Edificio	Blocco	Zone	Temperatura operante (°C)	Perdita di calore in regime stazionario (kW)	Potenza di progetto (kW)	heat losses reduction in %	riduzione in % della potenza di progetto
Edificio 1	Ground Floor	bedroom 1	0.39	0.15	0.23	19%	19%
Edificio 1	Ground Floor	Living room gf	0.02	0	0	0%	0%
Edificio 1	Ground Floor	hall	0.07	0.02	0.03	6%	6%
Edificio 1	Ground Floor	Kitchen gf	0.27	0.06	0.11	12%	14%
Edificio 1	Ground Floor	bathroom gf	0.16	0.03	0.05	10%	11%
Edificio 1	Ground Floor	studio gf	0.2	0.08	0.11	12%	11%
Edificio 1	Ground Floor	bedroom 2 gf	0.23	0.08	0.11	13%	12%
Edificio 1	I Floor	bedroom 1 If	0.39	0.16	0.23	20%	19%
Edificio 1	I Floor	living room If	0.29	0.13	0.18	17%	16%
Edificio 1	I Floor	hall If	0.11	0.03	0.04	9%	8%
Edificio 1	I Floor	kitchen If	0.29	0.11	0.15	15%	13%
Edificio 1	I Floor	bathroom If	0.19	0.03	0.05	11%	12%
Edificio 1	I Floor	Studio If	0.2	0.07	0.12	11%	12%
Edificio 1	I Floor	bedroom 2 If	0.23	0.08	0.12	13%	13%
Edificio 1	II Floor	bedroom 1 IIf	0.39	0.15	0.23	19%	19%
Edificio 1	II Floor	living room IIf	0.33	0.14	0.2	18%	17%
Edificio 1	II Floor	hall IIf	0.11	0.03	0.04	9%	8%
Edificio 1	II Floor	kitchen IIf	0.29	0.11	0.16	14%	14%
Edificio 1	II Floor	bathroom IIf	0.2	0.04	0.06	14%	14%
Edificio 1	II Floor	Studio IIf	0.2	0.07	0.11	10%	11%
Edificio 1	II Floor	bedroom 2 IIf	0.23	0.08	0.12	13%	13%
Edificio 1	III Floor	bedroom 1 IIIf	0.37	0.15	0.22	18%	18%
Edificio 1	III Floor	living room IIIf	0.31	0.13	0.2	16%	16%
Edificio 1	III Floor	hall IIIf	0.1	0.03	0.04	8%	7%
Edificio 1	III Floor	kitchen IIIf	0.28	0.1	0.15	13%	13%
Edificio 1	III Floor	bathroom IIIf	0.19	0.04	0.05	13%	11%
Edificio 1	III Floor	Studio IIIf	0.18	0.07	0.11	10%	10%
Edificio 1	III Floor	bedroom 2 IIIf	0.21	0.08	0.12	12%	12%
Edificio 1	Tetto 1	Zona 1	0.02				
Edificio 1	TOT			2.25	3.34	**13%**	**13%**

Table 4. 3**:** Summary of heating design using Polyurethane foam as thermal insulation, and comparison with the current situation. Reduction of design heating capacity in percentage: 13%.

Vermiculite					
Edificio	Blocco	Zona	Temperatura operante (°C)	Perdita di calore in regime stazionario (kW)	Potenza di progetto ((kW)
Edificio 1	Ground Floor	bedroom 1	19.56	0.7	1.05
Edificio 1	Ground Floor	Living room gf	19.64	0.81	1.22
Edificio 1	Ground Floor	hall	20.43	0.35	0.52
Edificio 1	Ground Floor	Kitchen gf	19.49	0.47	0.7
Edificio 1	Ground Floor	bathroom gf	19.97	0.27	0.41
Edificio 1	Ground Floor	studio gf	19.87	0.65	0.97
Edificio 1	Ground Floor	bedroom 2 gf	19.77	0.58	0.86
Edificio 1	I Floor	bedroom 1 If	19.62	0.7	1.05
Edificio 1	I Floor	living room If	19.69	0.69	1.03
Edificio 1	I Floor	hall If	20.44	0.33	0.5
Edificio 1	I Floor	kitchen If	19.38	0.69	1.04
Edificio 1	I Floor	bathroom If	19.95	0.26	0.38
Edificio 1	I Floor	Studio If	19.87	0.62	0.93
Edificio 1	I Floor	bedroom 2 If	19.82	0.59	0.88
Edificio 1	II Floor	bedroom 1 IIf	19.6	0.71	1.07
Edificio 1	II Floor	living room IIf	19.68	0.69	1.04
Edificio 1	II Floor	hall IIf	20.44	0.33	0.5
Edificio 1	II Floor	kitchen IIf	19.35	0.7	1.05
Edificio 1	II Floor	bathroom IIf	19.93	0.26	0.39
Edificio 1	II Floor	Studio IIf	19.84	0.63	0.95
Edificio 1	II Floor	bedroom 2 IIf	19.8	0.6	0.89
Edificio 1	III Floor	bedroom 1 IIIf	19.5	0.75	1.13
Edificio 1	III Floor	living room IIIf	19.58	0.74	1.11
Edificio 1	III Floor	hall IIIf	20.32	0.37	0.56
Edificio 1	III Floor	kitchen IIIf	19.26	0.74	1.11
Edificio 1	III Floor	bathroom IIIf	19.84	0.28	0.42
Edificio 1	III Floor	Studio IIIf	19.73	0.68	1.02
Edificio 1	III Floor	bedroom 2 IIIf	19.69	0.64	0.96
Edificio 1	Tetto 1	Zona 1	0.02	0	0
		TOT		15.83	23.74

CONFRONTO	Current situation-Vermiculite						
Edificio	Blocco	Zone	Temperatura operante (°C)	Perdita di calore in regime stazionario (kW)	Potenza di progetto (kW)	heat losses reduction in %	riduzione in % della potenza di progetto
Edificio 1	Ground Floor	bedroom 1	0.2	0.08	0.13	10%	11%
Edificio 1	Ground Floor	Living room gf	0.04	0.02	0.02	2%	2%
Edificio 1	Ground Floor	hall	0.04	0.01	0.02	3%	4%
Edificio 1	Ground Floor	Kitchen gf	0.14	0.03	0.06	6%	8%
Edificio 1	Ground Floor	bathroom gf	0.09	0.02	0.03	7%	7%
Edificio 1	Ground Floor	studio gf	0.11	0.04	0.06	6%	6%
Edificio 1	Ground Floor	bedroom 2 gf	0.12	0.04	0.06	6%	7%
Edificio 1	I Floor	bedroom 1 If	0.21	0.09	0.13	11%	11%
Edificio 1	I Floor	living room If	0.15	0.07	0.1	9%	9%
Edificio 1	I Floor	hall If	0.06	0.02	0.02	6%	4%
Edificio 1	I Floor	kitchen If	0.15	0.06	0.08	8%	7%
Edificio 1	I Floor	bathroom If	0.1	0.01	0.03	4%	7%
Edificio 1	I Floor	Studio If	0.11	0.04	0.07	6%	7%
Edificio 1	I Floor	bedroom 2 If	0.12	0.04	0.07	6%	7%
Edificio 1	II Floor	bedroom 1 IIf	0.21	0.08	0.12	10%	10%
Edificio 1	II Floor	living room IIf	0.17	0.08	0.11	10%	10%
Edificio 1	II Floor	hall IIf	0.06	0.02	0.02	6%	4%
Edificio 1	II Floor	kitchen IIf	0.15	0.06	0.09	8%	8%
Edificio 1	II Floor	bathroom IIf	0.1	0.02	0.03	7%	7%
Edificio 1	II Floor	Studio IIf	0.1	0.04	0.06	6%	6%
Edificio 1	II Floor	bedroom 2 IIf	0.12	0.04	0.07	6%	7%
Edificio 1	III Floor	bedroom 1 IIIf	0.2	0.09	0.12	11%	10%
Edificio 1	III Floor	living room IIIf	0.17	0.07	0.11	9%	9%
Edificio 1	III Floor	hall IIIf	0.05	0.02	0.02	5%	3%
Edificio 1	III Floor	kitchen IIIf	0.15	0.05	0.08	6%	7%
Edificio 1	III Floor	bathroom IIIf	0.1	0.02	0.02	7%	5%
Edificio 1	III Floor	Studio IIIf	0.1	0.04	0.06	6%	6%
Edificio 1	III Floor	bedroom 2 IIIf	0.11	0.04	0.06	6%	6%
Edificio 1	Tetto 1	Zona 1	0	0			
Edificio 1	TOT			1.24	1.85	7%	7%

Table 4. 4: Summary of heating design using vermiculite as thermal insulation, and comparison with the current situation. Reduction of design heating capacity in percentage: 7 %.

It must be said that filling the cavity wall using foam like the Polyurethane one is anything but simple. It must be done by a professional team. The outer layer has to be checked to avoid the risk of bowing outwards, because of the pressure from the expanding foam.

Then a more “sustainable” solution has been analyzed, i.e. a material with a materials with a renewable matrix - or we should say “ecological” material – granular cork , to check the efficiency of a more “green” action.

The "materials with a renewable matrix" are those insulating materials made from plant fibers mainly from agriculture, regenerable by nature. For example, hemp fiber, kenaf, coir, flax, jute, maize, cork, or from waste products like flakes of recycled paper or wood fiber, analyzing the life cycle during the production phase, they emit a quantity of CO_2 in the atmosphere equal to or slightly less than that required in the growth phase. They can be used as a mixed composition (85% renewable sources fiber and the residual percentage of polyester backing fiber) or totally made of renewable fiber.

The cork insulation can also be used in wet environments as it is waterproof and its characteristics remain unchanged without perishing early.

It comes in form of irregular granules with different particle sizes. It is obtained from a particular treatment of crushing and grinding of corky bark. The granules obtained are freed from the dross and porous wood with a treatment of dust collection, and finally selected to further eliminate any residual organic substances.

The natural cork granules so obtained can be used dissolved or mixed with other materials.

Properties

Granulometry: mm 5/10
Density: kg/m3 65/75
thermal conductivity (at 10 °C):
λ = 0,045 W/m K
Risk of putrefy: no
Aging stability: unlimited

Fig.4. 18: Granular Cork- Thermal properties.

As previously done for other insulation materials it was hypothesized to fill the wall cavity of 3.5 cm, with granulated cork. A simulated design of the heating system was done and then results were compared with the initial situation and with the results of other insulating materials.

With an expected consumption saving of 9% for heating the granular cork appears to be better than the vermiculite.

Granular Cork					
Building	Block	Zone	Comfort Temperature (°C)	Steady-State Heat Loss (kW)	Design Capacity (kW)
Edificio 1	Ground Floor	bedroom 1	19.62	0.68	1.02
Edificio 1	Ground Floor	Living room gf	19.67	0.8	1.2
Edificio 1	Ground Floor	hall	20.44	0.34	0.52
Edificio 1	Ground Floor	Kitchen gf	19.54	0.46	0.68
Edificio 1	Ground Floor	bathroom gf	19.99	0.27	0.4
Edificio 1	Ground Floor	studio gf	19.9	0.63	0.95
Edificio 1	Ground Floor	bedroom 2 gf	19.81	0.56	0.85
Edificio 1	I Floor	bedroom 1 If	19.68	0.68	1.02
Edificio 1	I Floor	living room If	19.75	0.67	1
Edificio 1	I Floor	hall If	20.46	0.33	0.49
Edificio 1	I Floor	kitchen If	19.43	0.68	1.01
Edificio 1	I Floor	bathroom If	19.98	0.25	0.37
Edificio 1	I Floor	Studio If	19.9	0.61	0.92
Edificio 1	I Floor	bedroom 2 If	19.86	0.58	0.86
Edificio 1	II Floor	bedroom 1 IIf	19.66	0.69	1.03
Edificio 1	II Floor	living room IIf	19.73	0.67	1.01
Edificio 1	II Floor	hall IIf	20.46	0.33	0.49
Edificio 1	II Floor	kitchen IIf	19.4	0.69	1.03
Edificio 1	II Floor	bathroom IIf	19.96	0.25	0.38
Edificio 1	II Floor	Studio IIf	19.87	0.62	0.93
Edificio 1	II Floor	bedroom 2 IIf	19.84	0.58	0.88
Edificio 1	III Floor	bedroom 1 IIIf	19.55	0.73	1.1
Edificio 1	III Floor	living room IIIf	19.63	0.72	1.08
Edificio 1	III Floor	hall IIIf	20.33	0.37	0.55
Edificio 1	III Floor	kitchen IIIf	19.3	0.72	1.08
Edificio 1	III Floor	bathroom IIIf	19.87	0.27	0.41
Edificio 1	III Floor	Studio IIIf	19.76	0.67	1
Edificio 1	III Floor	bedroom 2 IIIf	19.73	0.62	0.94
Edificio 1	Tetto 1	Zona 1	0.03	0	0
		TOT	555.15	15.47	23.2

CONFRONTO	Current situation-Granular Cork						
Edificio	Blocco	Zone	Temperatura operante (°C)	Perdita di calore in regime stazionario (kW)	Potenza di progetto (kW)	heat losses reduction in %	riduzione in % della potenza di progetto
Edificio 1	Ground Floor	bedroom 1	0.26	0.1	0.16	13%	14%
Edificio 1	Ground Floor	Living room gf	0.07	0.03	0.04	4%	3%
Edificio 1	Ground Floor	hall	0.05	0.02	0.02	6%	4%
Edificio 1	Ground Floor	Kitchen gf	0.19	0.04	0.08	8%	11%
Edificio 1	Ground Floor	bathroom gf	0.11	0.02	0.04	7%	9%
Edificio 1	Ground Floor	studio gf	0.14	0.06	0.08	9%	8%
Edificio 1	Ground Floor	bedroom 2 gf	0.16	0.06	0.07	10%	8%
Edificio 1	I Floor	bedroom 1 If	0.27	0.11	0.16	14%	14%
Edificio 1	I Floor	living room If	0.21	0.09	0.13	12%	12%
Edificio 1	I Floor	hall If	0.08	0.02	0.03	6%	6%
Edificio 1	I Floor	kitchen If	0.2	0.07	0.11	9%	10%
Edificio 1	I Floor	bathroom If	0.13	0.02	0.04	7%	10%
Edificio 1	I Floor	Studio If	0.14	0.05	0.08	8%	8%
Edificio 1	I Floor	bedroom 2 If	0.16	0.05	0.09	8%	9%
Edificio 1	II Floor	bedroom 1 IIf	0.27	0.1	0.16	13%	13%
Edificio 1	II Floor	living room IIf	0.22	0.1	0.14	13%	12%
Edificio 1	II Floor	hall IIf	0.08	0.02	0.03	6%	6%
Edificio 1	II Floor	kitchen IIf	0.2	0.07	0.11	9%	10%
Edificio 1	II Floor	bathroom IIf	0.13	0.03	0.04	11%	10%
Edificio 1	II Floor	Studio IIf	0.13	0.05	0.08	7%	8%
Edificio 1	II Floor	bedroom 2 IIf	0.16	0.06	0.08	9%	8%
Edificio 1	III Floor	bedroom 1 IIIf	0.25	0.11	0.15	13%	12%
Edificio 1	III Floor	living room IIIf	0.22	0.09	0.14	11%	11%
Edificio 1	III Floor	hall IIIf	0.06	0.02	0.03	5%	5%
Edificio 1	III Floor	kitchen IIIf	0.19	0.07	0.11	9%	9%
Edificio 1	III Floor	bathroom IIIf	0.13	0.03	0.03	10%	7%
Edificio 1	III Floor	Studio IIIf	0.13	0.05	0.08	7%	7%
Edificio 1	III Floor	bedroom 2 IIIf	0.15	0.06	0.08	9%	8%
Edificio 1	Tetto 1	Zona 1	0.01	0			
Edificio 1	TOT			1.6	2.39	9%	9%

Table 4. 5: Summary of heating design using granular cork as thermal insulation, and comparison with the current situation. Reduction of design heating capacity in percentage: 9 %.

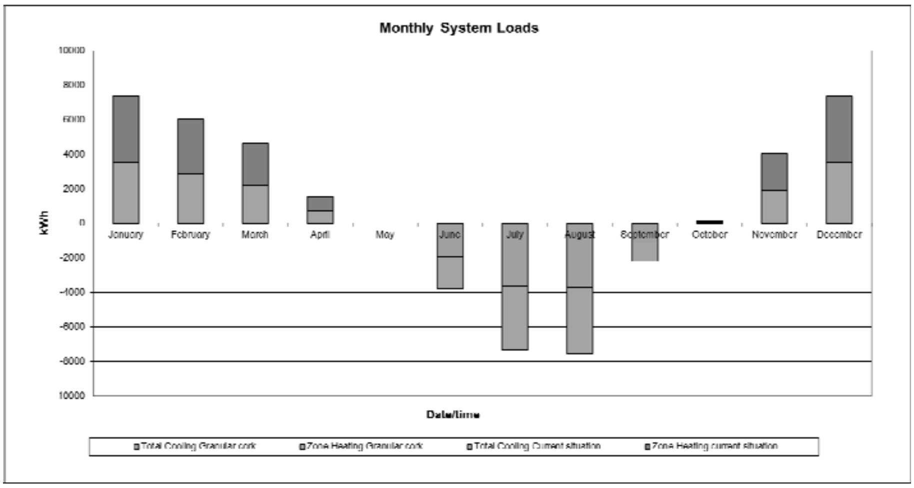


Fig.4. 19: Monthly System loads. Comparison between granular cork and no insulation, heating and cooling , annual based simulation.

MONTHLY SYSTEM LOADS Granular Cork			
Date/Time	Sensible Cooling kWh	Total Cooling Granular cork kWh	Zone Heating Granular cork kWh
January	0	0	3531
February	0	0	2860
March	0	0	2180
April	0	0	705
May	0	0	0
June	-1549	-1909	0
July	-2782	-3619	0
August	-2774	-3710	0
September	-774	-1100	0
October	0	0	66
November	0	0	1916
December	0	0	3527

MONTHLY SYSTEM LOADS current situation			
Date/Time	Sensible Cooling kWh	Total Cooling Current situation kWh	Zone Heating current situation kWh
January	0	0	3869
February	0	0	3151
March	0	0	2436
April	0	0	835
May	0	0	0
June	-1534	-1891	0
July	-2868	-3724	0
August	-2886	-3847	0
September	-741	-1070	0
October	0	0	92
November	0	0	2130
December	0	0	3852

Table 4. 6: Monthly System loads. Comparison between granular cork and no insulation situation, heating and cooling .Annual based simulation.

Finally a simulation for an entire year was conducted, to assess the effect of insulation during summer; in fact insulating cork and / or wood fiber are particularly suitable for thermal insulation thanks to the good heat storage capacity. It’s important to add to that the advantage of using an environmentally friendly material that is 100% biodegradable and with a very low level of CO_2 emissions throughout the life cycle.

ENERGY CONSUMPTION CURRENT SITUATION				
Date/Time	Total Cooling	Zone Heating	TOT	
Annual	kWh	kWh	kWh	
Building	-10532.49	16365.99	26898	67
II floor	-2747.15	4119.5	6867	69

ENERGY CONSUMPTION 1_Zevi + isolante plyurethane FOAM (ICYNENE)								
Date/Time	Total Cooling	Zone Heating	TOT		Reduction cooling	Reduction heating	TOT Reduction	TOT Reduction/m2
Annual	kWh	kWh	kWh		%	%	%	%
Building	-10245.89	14073.31	24319	61	3%	14%	**10%**	10%
II floor	-2676.32	3497.65	6174	62	3%	15%	**10%**	10%

ENERGY CONSUMPTION 2_Zevi + isolante plystirene FOAM (ESP)								
Date/Time	Total Cooling	Zone Heating	TOT		Reduction cooling	Reduction heating	TOT Reduction	TOT Reduction/m2
Annual	kWh	kWh	kWh		%	%	%	%
Building	-10315.21	14505.29	24821	62	2%	11%	8%	8%
II floor	-2690.79	3618.26	6309	63	2%	12%	8%	8%

ENERGY CONSUMPTION 3bis_Zevi +CORK								
Date/Time	Total Cooling	Zone Heating	TOT		Reduction cooling	Reduction heating	TOT Reduction	TOT Reduction/m2
Annual	kWh	kWh	kWh		%	%	%	%
Building	-10350.7	14785.65	25136	63	2%	10%	7%	7%
II floor	-2699.48	3692.25	6392	64	2%	10%	7%	7%

ENERGY CONSUMPTION 3_Zevi + vermiculite								
Date/Time	Total Cooling	Zone Heating	TOT		Reduction cooling	Reduction heating	TOT Reduction	TOT Reduction/m2
Annual	kWh	kWh	kWh		%	%	%	%
Building	-10395.81	15160.3	25556	64	1%	7%	5%	5%
II floor	-2710.6	3791.08	6502	65	1%	8%	5%	5%

Table 4.7: Comparison, in terms of energy consumption/m^2, between different insulating systems. Annual based insulation.

Table 4.7 shows the results of a heating design simulation trying all the four insulating system in order to check heat losses reduction/ m^2 in percentage. From an energetic point of view polyurethane foam seems to work better for this case.

4.3.2 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).

From the site inspection it was clear that there is a very inhomogeneous situation, every owner did autonomous maintenance intervention, and sometime it is still possible to see the old original windows with wood frame and single glazing.

Fig.4. 20: As can be seen from the picture, each owner did autonomous maintenance interventions, there is no homogeneity. Quartiere Pastena , Bruno Zevi Salerno.

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.

New Windows (double glaze /thermal break)					
Edificio	Blocco	Zona	Temperatura operante (°C)	Perdita di calore in regime stazionario (kW)	Potenza di progetto ((kW)
Edificio 1	Ground Floor	bedroom 1	19.95	0.54	0.82
Edificio 1	Ground Floor	Living room gf	19.85	0.71	1.06
Edificio 1	Ground Floor	hall	20.53	0.32	0.47
Edificio 1	Ground Floor	Kitchen gf	19.91	0.35	0.53
Edificio 1	Ground Floor	bathroom gf	20.23	0.22	0.32
Edificio 1	Ground Floor	studio gf	20.17	0.52	0.78
Edificio 1	Ground Floor	bedroom 2 gf	20.11	0.45	0.68
Edificio 1	I Floor	bedroom 1 lf	20.01	0.54	0.81
Edificio 1	I Floor	living room lf	20.05	0.54	0.82
Edificio 1	I Floor	hall lf	20.57	0.3	0.44
Edificio 1	I Floor	kitchen lf	19.86	0.52	0.78
Edificio 1	I Floor	bathroom lf	20.25	0.19	0.29
Edificio 1	I Floor	Studio lf	20.2	0.5	0.74
Edificio 1	I Floor	bedroom 2 lf	20.17	0.46	0.69
Edificio 1	II Floor	bedroom 1 llf	20	0.54	0.82
Edificio 1	II Floor	living room llf	20.06	0.54	0.82
Edificio 1	II Floor	hall llf	20.57	0.3	0.44
Edificio 1	II Floor	kitchen llf	19.84	0.52	0.79
Edificio 1	II Floor	bathroom llf	20.24	0.2	0.29
Edificio 1	II Floor	Studio llf	20.18	0.5	0.75
Edificio 1	II Floor	bedroom 2 llf	20.15	0.46	0.7
Edificio 1	III Floor	bedroom 1 lllf	19.88	0.59	0.88
Edificio 1	III Floor	living room lllf	19.94	0.59	0.88
Edificio 1	III Floor	hall lllf	20.44	0.34	0.5
Edificio 1	III Floor	kitchen lllf	19.73	0.56	0.84
Edificio 1	III Floor	bathroom lllf	20.14	0.21	0.32
Edificio 1	III Floor	Studio lllf	20.05	0.55	0.83
Edificio 1	III Floor	bedroom 2 lllf	20.03	0.51	0.76
Edificio 1	Tetto 1	Zona 1	0.05	0	0

Current situation- Isolante (Polyuretan Foam) + Nuovi infissi							
Edificio	Blocco	Zone	Temperatura operante (°C)	Perdita di calore in regime stazionario (kW)	Potenza di progetto (kW)	heat losses reduction in %	riduzione in % della potenza di progetto
Edificio 1	Ground Floor	bedroom 1	0.59	0.24	0.36	31%	31%
Edificio 1	Ground Floor	Living room gf	0.25	0.12	0.18	14%	15%
Edificio 1	Ground Floor	hall	0.14	0.04	0.07	11%	13%
Edificio 1	Ground Floor	Kitchen gf	0.56	0.15	0.23	30%	30%
Edificio 1	Ground Floor	bathroom gf	0.35	0.07	0.12	24%	27%
Edificio 1	Ground Floor	studio gf	0.41	0.17	0.25	25%	24%
Edificio 1	Ground Floor	bedroom 2 gf	0.46	0.17	0.24	27%	26%
Edificio 1	I Floor	bedroom 1 lf	0.6	0.25	0.37	32%	31%
Edificio 1	I Floor	living room lf	0.51	0.22	0.31	29%	27%
Edificio 1	I Floor	hall lf	0.19	0.05	0.08	14%	15%
Edificio 1	I Floor	kitchen lf	0.63	0.23	0.34	31%	30%
Edificio 1	I Floor	bathroom lf	0.4	0.08	0.12	30%	29%
Edificio 1	I Floor	Studio lf	0.44	0.16	0.26	24%	26%
Edificio 1	I Floor	bedroom 2 lf	0.47	0.17	0.26	27%	27%
Edificio 1	II Floor	bedroom 1 llf	0.61	0.25	0.37	32%	31%
Edificio 1	II Floor	living room llf	0.55	0.23	0.33	30%	29%
Edificio 1	II Floor	hall llf	0.19	0.05	0.08	14%	15%
Edificio 1	II Floor	kitchen llf	0.64	0.24	0.35	32%	31%
Edificio 1	II Floor	bathroom llf	0.41	0.08	0.13	29%	31%
Edificio 1	II Floor	Studio llf	0.44	0.17	0.26	25%	26%
Edificio 1	II Floor	bedroom 2 llf	0.47	0.18	0.26	28%	27%
Edificio 1	III Floor	bedroom 1 lllf	0.58	0.25	0.37	30%	30%
Edificio 1	III Floor	living room lllf	0.53	0.22	0.34	27%	28%
Edificio 1	III Floor	hall lllf	0.17	0.05	0.08	13%	14%
Edificio 1	III Floor	kitchen lllf	0.62	0.23	0.35	29%	29%
Edificio 1	III Floor	bathroom lllf	0.4	0.09	0.12	30%	27%
Edificio 1	III Floor	Studio lllf	0.42	0.17	0.25	24%	23%
Edificio 1	III Floor	bedroom 2 lllf	0.45	0.17	0.26	25%	25%
Edificio 1	Tetto 1	Zona 1	0.03	0	0		

Table 4. 8: Summary of heating design using polyurethane foam as thermal insulation (that resulted to be the best one) and new, more efficient windows, with thermal break and double glazing. On the right comparison with the current situation. Reduction of design heating capacity in percentage: up to 9 %.

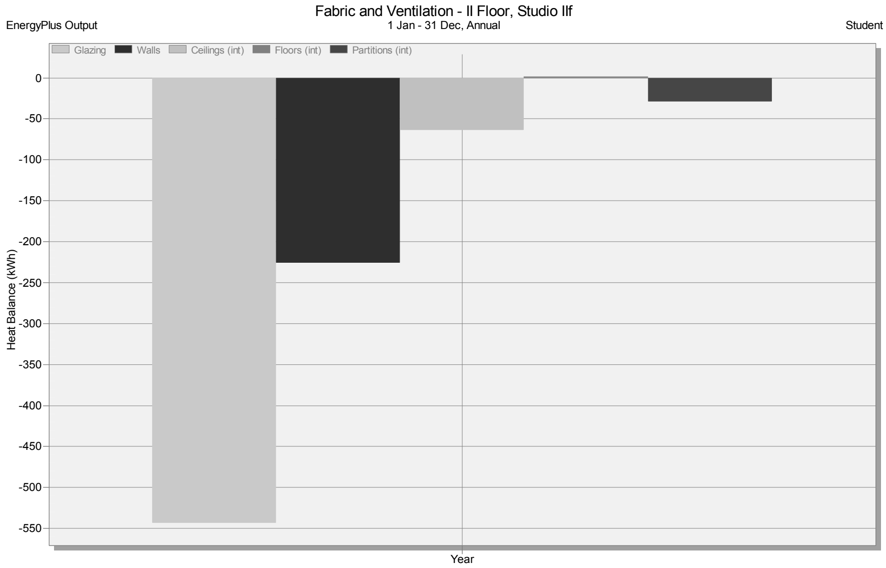


Fig.4. 21: Fabric and Ventilation ;single glazing, clear, no shading. Wood frame. Heat Balance through glazing: -543,5 KWh

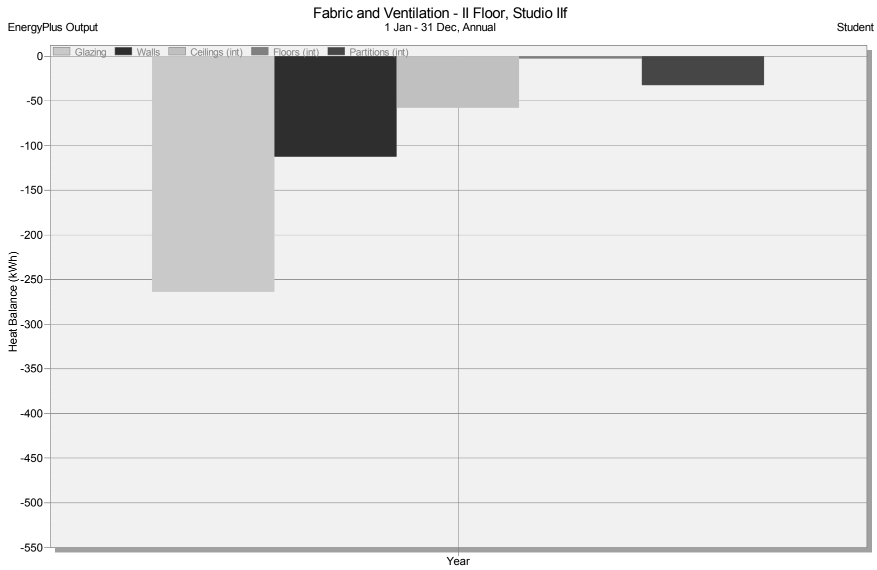


Fig.4. 22: Double glazing, clear, no shading. Heat Balance through glazing: -264,1 KWh

ENERGY CONSUMPTION 4_Zevi + isolante plyurethane (ICYNENE)+ nuovi infissi									
Date/Time	Total Cooling	Zone Heating	TOT		Reduction cooling	Reduction heating	TOT Reductio	TOT Reduction/m2	partial reductio/m2
	kWh	kWh	kWh		%	%	%	%	%
Annual	-9123,459	12935,98	22059	55	13%	21%	18%	18%	9%
II floor	-2396,93	3195,67	5593	56	13%	22%	19%	19%	9%

Table 4. 9: Energy consumption with new windows and percentage of reduction.

From the simulation it appears that the effect is the reduction of energy consumption (especially for heating in winter) up to 19% (in terms of percentage of reduction of kWh/m^2).

4.3.3 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.

The more, it is also important that the system does not represent an obstacle for natural ventilation. Several shading devices have been tested during a simulation based on an entire typical year, shade rolls, side fins, brise soleil, changing material (and consequently thermal and visual property) geometry and position.

Properties of each shading device are listed below:

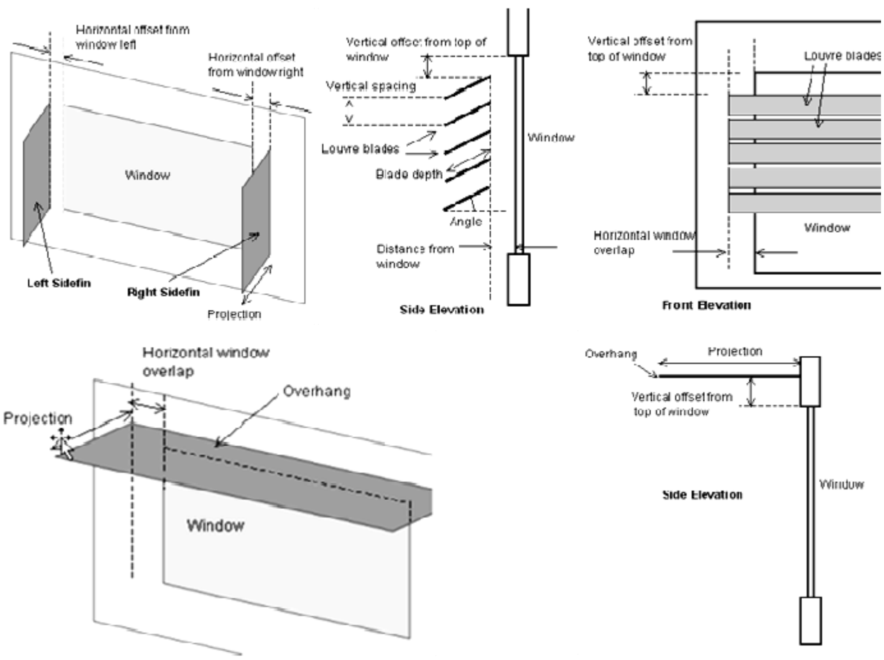


Fig.4. 23: DesignBuilder editing layout for shading devices.

- *Shade rolls (Window shading device)*:
  Light opaque and assumed perfectly diffusing-position outside,
  Thickness (m): 0.003
  Conductivity (W/mK): 0.100
  Solar trasmittance:0.050
  Solar reflectance: 0.500
  Visible trasmittance:0.500
  Visible reflectance : 0.500
  Long-wave emissivity :0.900
  Lonw-wave trasmittance : 0.00
  Shade-to-glass distance (m) : 0.050
  Control type: schedule
  Schedule:
    From January to April: OFF
    From May to September:
      From 0:00 to 10:30 OFF
      From 10:30 to 19:00 ON
      From 19:00 to 24:00 OFF
    From October to December: OFF

- *Louvre Side fins (local shading device)*:
  Blade material: Pine 20% moist
  Geometry:

  Left
  - Projection (m) 1.00
  - Horizontal offset from window left (m): 0.00
  - Top overlap (m): 0.00
  - Bottom overlap (m): -1.00

  Right
  - Projection (m) 1.00
  - Horizontal offset from window left (m): 0.00
  - Top overlap (m): 0.00
  - Bottom overlap (m): -1.00

- *Brise soleil (Window shading device_Slatted blind-schedule)*:
  Slat data:

Blind to glass distance (m): 1.00
Slat Orientation: horizontal
Slat width (m): 0.200
Slat separation: 0.200
Slat Angle (°)[7]: 50.0
Minimum slat angle (°): 0
Maximum slat angle (°): 180
Slat conductivity (W/mK): 0.130
Slat beam solar transmittance: 0.000
Slat beam solar reflectance: 0.500 (front and back side)
Slat diffuse solar transmittance: 0.000
Slat diffuse solar reflectance: 0.500 (front and back side)
Slat beam visible transmittance: 0.500
Slat beam visible reflectance: 0.500 (front and back side)
Slat diffuse visible transmittance: 0.000
Slat diffuse visible reflectance: 0.500 (front and back side)
Long-wave emissivity: 0.900
Long-wave transmittance: 0.00
Shade-to-glass distance (m): 0.050
Control type: schedule
Schedule:
From January to April: OFF
From May to September:
From 0:00 to 10:30 OFF
From 10:30 to 19:00 ON
From 19:00 to 24:00 OFF
From October to December: OFF

- *Brise soleil (Local shading device_louvres)*:
  Blade material: Pine 20% moist
  Blade geometry:
  Number of blades: 7

[7] The slat angle is the angle between the glazing outward normal to the slat outward normal. A slat angle of 0° sets slats to be vertical, while an angle of 90° sets them to be horizontal.

Vertical spacing (m): 0.200
Angle (°): 50.00
Distance from window (m): 1.350
Blade depth (m): 0.200
Vertical offset from window top (m): 0.00
Horizontal window overlap (m): 0.700

This kind of analysis is strongly related with the inner comfort. The simulations on the entire can generate extensive data on environmental conditions within the building and resultant occupant comfort levels. For this reason the results about the most effective shading system are expressed (in the following tab and graph) in terms of comfort. The output includes information about:

- Internal air temperature (calculated average temperature of the air)
- Internal radiant temperature (the average Mean Radiant Temperature (MRT) of the zone, calculated assuming that the person is in the center of the zone.
- Internal operative temperature (the mean of the internal air and radiant temperatures)
- Discomfort hrs summer clothing (the time when the combination of zone humidity ratio and operative temperature is not in the ASHRAE 55-2004 summer clothes region shown in fig……).
- Discomfort hrs winter clothing (the time when the combination of zone humidity ratio and operative temperature is not in the ASHRAE 55-2004 winter clothes region shown in fig……).
- Discomfort hrs all clothing (the time when the combination of zone humidity ratio and operative temperature is not in the ASHRAE 55-2004 summer or winter clothes region).

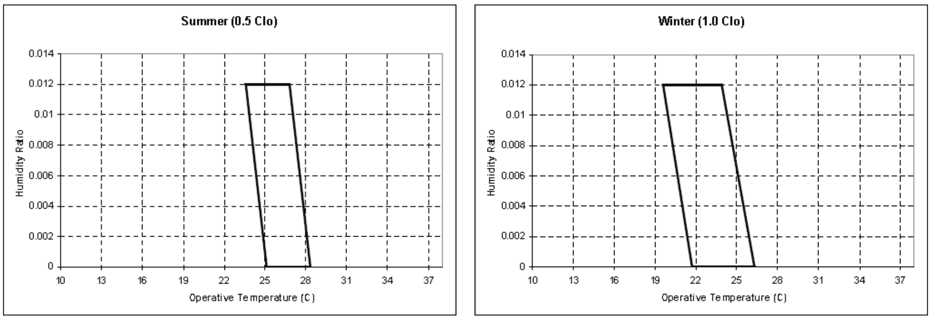


Fig.4. 24: ASHRAE Standard 55-200. The region shows a comfortable balance of humidity ratio and operative temperature. For summer, the 0.5 Clo level is used and, for winter, the 1.0 Clo level is used.

COMFORT MONTHLY	**Air Temperature** [°C]				**Radiant Temperature** [°C]				**Operative Temperature** [°C]				**Discomfort hrs** (all clothing)			
Date/Time	Insulation + new windows	Shade roll	Louvre Sidefins	Brise soleil	Insulation + new windows	Shade roll	Louvre Sidefins	Brise soleil	Insulation + new windows	Shade roll	Louvre Sidefins	Brise soleil	Insulation + new windows	Shade roll	Louvre Sidefins	Brise soleil
Maggio	24.48849	24.2504	23.98534	23.54037	25.16716	24.91388	24.6178	24.12263	24.82783	24.58214	24.30157	23.8315	88.92138	78.22913	74.82639	70.39109
Giugno	25.68736	25.59022	25.5172	25.32592	26.64061	26.49573	26.38133	26.10819	26.16399	26.04298	25.94927	25.71706	118.9714	112.775	107.9662	101.2812
Luglio	26.55316	26.48363	26.44167	26.29962	27.66153	27.53813	27.45975	27.2421	27.10734	27.01088	26.95071	26.77086	220.7456	216.9365	215.3796	205.0211
Agosto	26.58435	26.52505	26.48381	26.37187	27.6455	27.53967	27.4586	27.28389	27.11492	27.03236	26.97121	26.82788	217.7442	215.2825	213.0596	209.1903
Settembre	25.05582	24.99897	24.89875	24.83887	25.76195	25.68525	25.52891	25.4476	25.40888	25.34211	25.21383	25.14323	152.8804	154.7338	159.3652	162.3029
SUMMER	78.82487	78.5989	78.44268	77.99741	81.94764	81.57353	81.29968	80.63418	80.38625	80.08622	79.87119	79.3158	557.4612	544.994	536.4054	515.4926

Table 4. 10 Comparison between different solutions, shade roll, louvre sidefins, brise soleil. Monthly Comfort

COMFORT MONTHLY	% of reduction Air Temperature			% of reduction Radiant Temperature			% of reduction Operative Temperature			% of increase comfort hours		
Date/Time	Shade roll	Louvre Sidefins	Brise soleil	Shade roll	Louvre Sidefins	Brise soleil	Shade roll	Louvre Sidefins	Brise soleil	Shade roll	Louvre Sidefins	Brise soleil
Maggio	1.0%	2.1%	3.9%	1.0%	2.2%	4.2%	1.0%	2.1%	4.0%	12.0%	15.9%	20.8%
Giugno	0.4%	0.7%	1.4%	0.5%	1.0%	2.0%	0.5%	0.8%	1.7%	5.2%	9.3%	14.9%
Luglio	0.3%	0.4%	1.0%	0.4%	0.7%	1.5%	0.4%	0.6%	1.2%	1.7%	2.4%	7.1%
Agosto	0.2%	0.4%	0.8%	0.4%	0.7%	1.3%	0.3%	0.5%	1.1%	1.1%	2.2%	3.9%
Settembre	0.2%	0.6%	0.9%	0.3%	0.9%	1.2%	0.3%	0.8%	1.0%	-1.2%	-4.2%	-6.2%
SUMMER	0.3%	0.5%	1.0%	0.5%	0.8%	1.6%	0.4%	0.6%	1.3%	2.2%	3.8%	7.5%

Table 4. 11 Comparison between different solutions, shade roll, louvre sidefins, brise soleil. Monthly Comfort, in percentage terms..

	Solar Gains Exterior Windows						
Date/Time	NO shading system	Shade roll	% of reduction	Sidefins	% of reduction	Brise soleil	% of reduction
	kWh	kWh		kWh		kWh	
May	769,2513	526,2914	32%	496,4412	35%	458,8059	40%
June	792,9539	535,7697	32%	505,4641	36%	459,8913	42%
July	869,1572	588,5966	32%	559,0431	36%	510,5846	41%
August	783,0732	534,3948	32%	502,9335	36%	463,7374	41%
September	567,3254	391,5243	31%	356,2343	37%	343,2374	39%

Table 4. 12: Percentage of reduction of solar gains[8] during summer.

	Zone sensible Cooling						
Date/Time	NO shading system	Shade roll	% of reduction	Sidefins	% of reduction	Brise soleil	% of reduction
	kWh	kWh		kWh		kWh	
January	0	0	-	0	-	0	-
February	0	0	-	0	-	0	-
March	0	0	-	0	-	0	-
April	0	0	-	0	-	0	-
May	0	0	-	0	-	0	-
June	-399,9985	-319,7834	20%	-297,0413	26%	-259,9603	35%
July	-747,9993	-581,4127	22%	-556,868	26%	-515,8041	31%
August	-752,6876	-587,9684	22%	-561,8162	25%	-526,9605	30%
September	-195,246	-168,0789	14%	-143,7845	26%	-135,0968	31%
October	0	0	-	0	-	0	-
November	0	0	-	0	-	0	-
Dicember	0	0	-	0	-	0	-

Table 4. 13: Zone Sensible Cooling[9] (kWh) related to each shading device**.**

[8] Solar Gains Exterior Windows - (used to be called 'Transmitted solar gains'). Short-wave solar radiation transmission through all external windows.

[9] Zone Sensible Cooling - is the sensible cooling effect on the zone of any air introduced into the zone through the HVAC system. It includes any 'free cooling' due to introduction of relatively cool outside air and the heating effect of any fans present

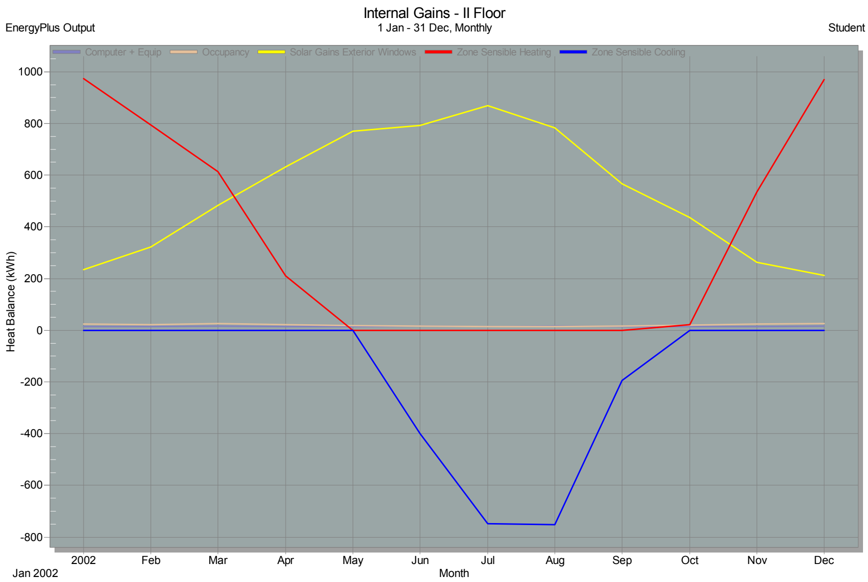


Fig.4. 25: :Internal Gains, II floor – no shading system [current situation(red= zone sensible heating, blue=zone sensible cooling, yellow=solar gains, pink=occupancy, violet=computer and equipment, light blue=general lighting)].

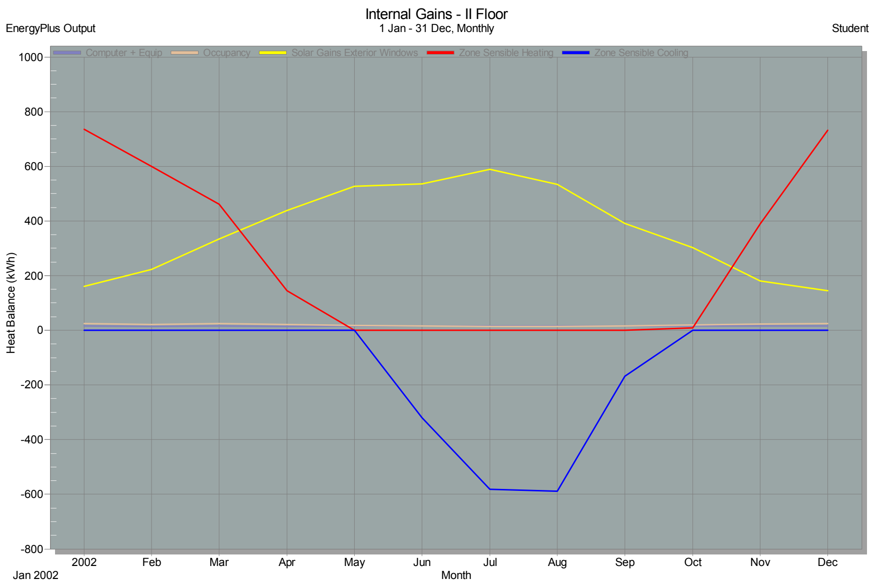


Fig.4. 26: Monthly internal Gains, II floor – shade rolls.

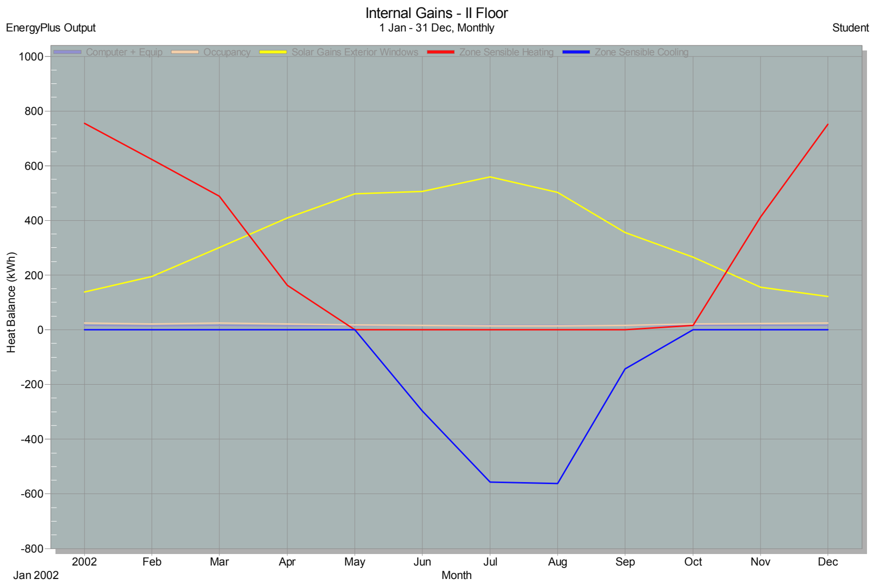


Fig.4. 27**:** Monthly internal gains, II floor – Louvre Sidefins.

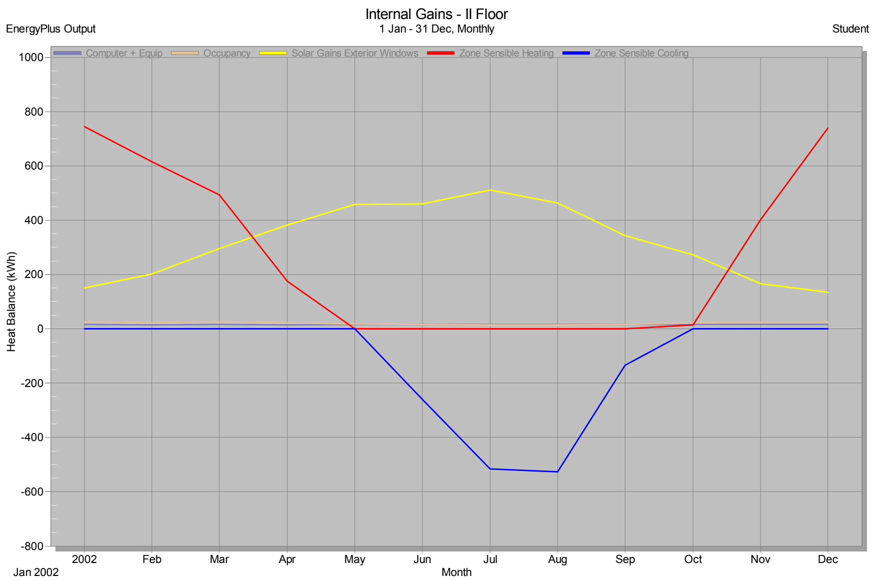
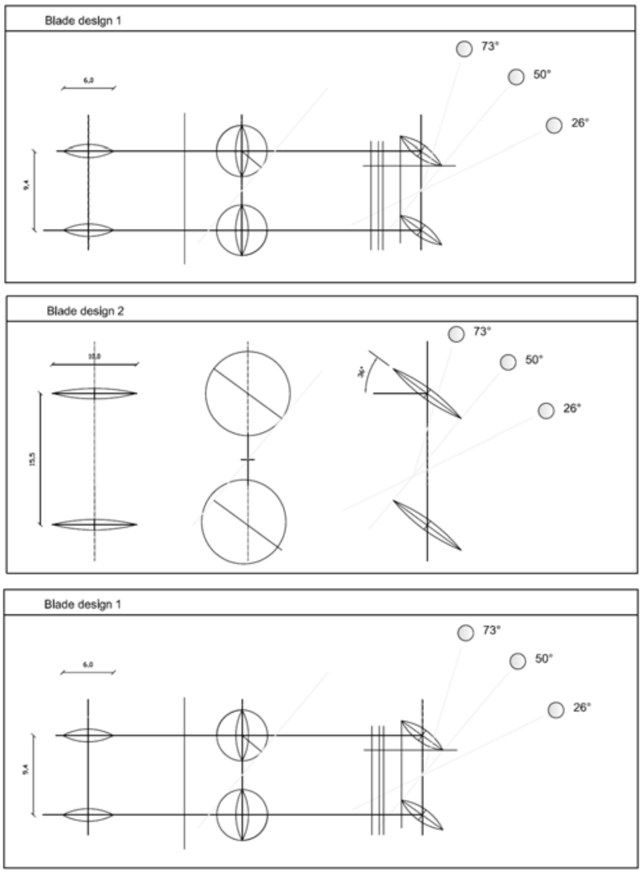


Fig.4. 28: Monthly internal gains, II floor – Brise soleil.

However, the simulation allowed us to observe how the geometry of a non-automatic system is essential for a proper optimization of the shading device.

For this reason an in depth study and design of the geometric characteristics of the shading system was carried out, this time designing a more complete system. The main aim of using a brise soleil in fact is that of reducing solar gains in summer in order to avoid overheating, but to allow the access of sunlight during the winter to take advantage of the favorable free solar gain.



Height of the sun on the horizon:

Winter solstice:
90 - (L+23,5)

Summer solstice:
90- (L-23,5)

Equinox: 90 - L

Fig.4. 29: Study of the geometric properties of the blade.

There have been several attempts to design the brise soleil, adjusting the size, distance and materials of the blades (varying the distance between the plates, depth and angle) to maximize effectiveness, and also to keep the project affordable, that's why an adjustable systems fully automated was not considered as a possible solution

BLADE DESIGN						
d_1	senα	x_1	d_2	n	α	α (radianti)
5	0.642788	3.21	7.78	19	0	0
6	0.642788	3.86	9.33	16	0	0
8	0.642788	5.14	12.45	12	0	0
10	0.642788	6.43	15.56	9	36	0.628319
12	0.642788	7.71	18.67	8	/	/
14	0.642788	9.00	21.78	7	/	/

Table 4. 14: Study of the geometric properties of the blade: depth, distance, angle.

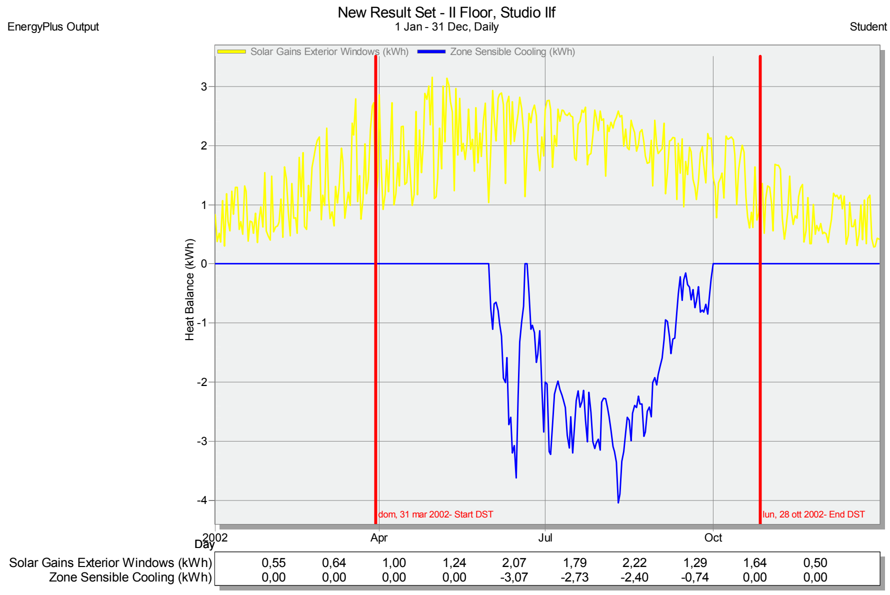


Fig.4. 30: Sensible Cooling and solar gains, simulation on a daily base, studio II floor. Brise soleil 5/ 7.8 angle: 0°

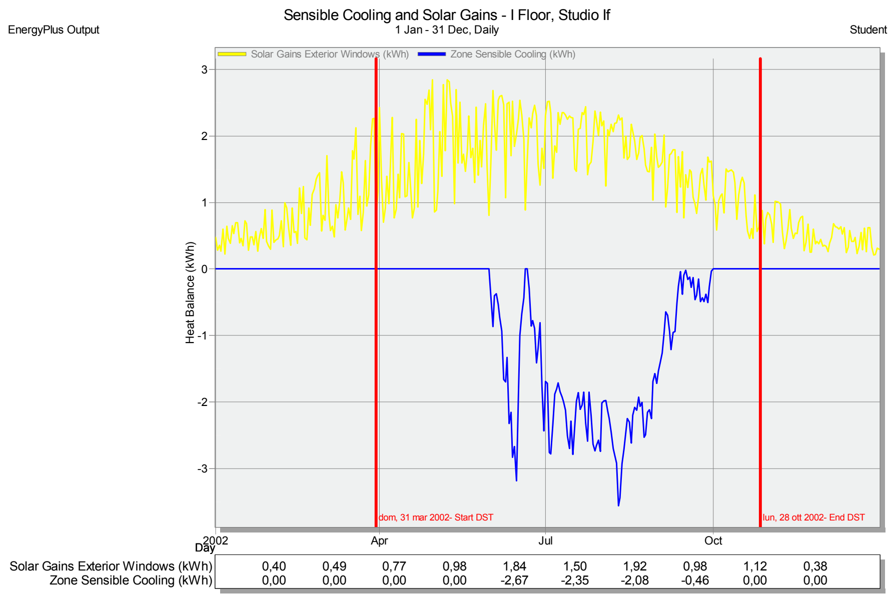


Fig.4. 31: Sensible Cooling and solar gains, simulation on a daily base, studio II floor. Brise soleil 6/9 angle: 0°

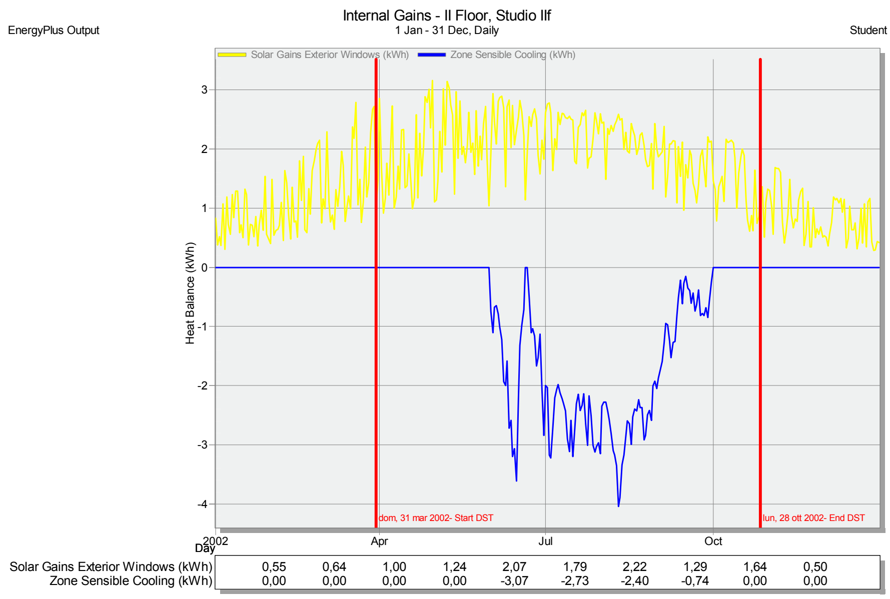


Fig.4. 32: Sensible Cooling and solar gains, simulation on a daily base, studio II floor. Brise soleil 8/12 angle: 0°

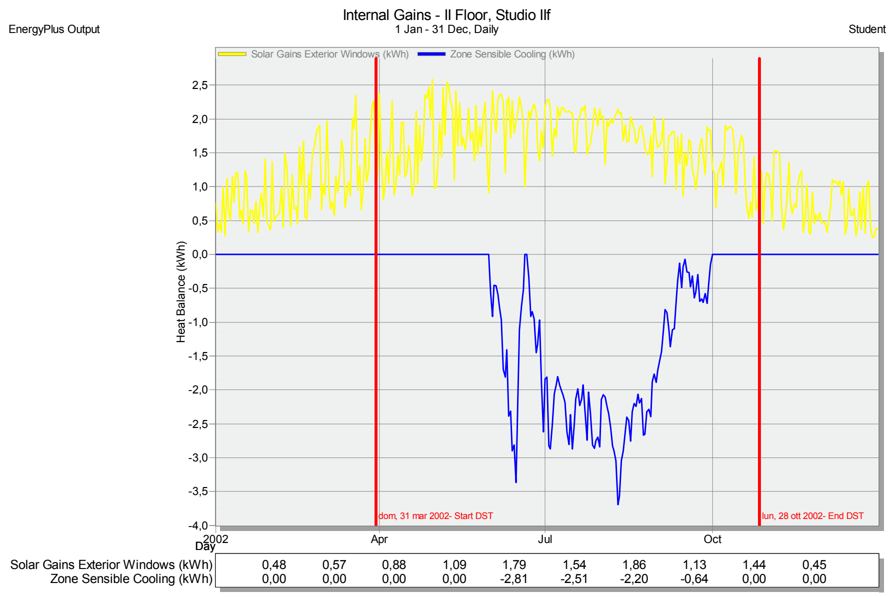


Fig.4. 33: Sensible Cooling and solar gains, simulation on a daily base, studio II floor. Brise soleil 10/9 angle: 36°

Comparing the energy used for cooling in the “current” situation with that used in an upgraded hypothesis (whit polyurethane foam, new windows and brise soleil) it’s possible to get a reduction in energy consumption for cooling in summer up to 25% (for the whole building, 24% if we consider the single flat).

The shading system contribution in the energy consumption reduction is up to 6%.

ENERGY CONSUMPTION 4_Zevi + isolante plyurethane (ICYNENE)+ nuovi infissi+Shade rolls

Date/Time	Total Cooling	Zone Heating	TOT		Reduction cooling	Reduction heating	TOT Reduction
	kWh	kWh	kWh		%	%	%
Annual	-8560,059	12658,45	21219	53	19%	23%	21%
II floor	-2271,71	3128,78	5400	54	17%	24%	21%

ENERGY CONSUMPTION 4_Zevi + isolante plyurethane (ICYNENE)+ nuovi infissi+louvre sidefins

Date/Time	Total Cooling	Zone Heating	TOT		Reduction cooling	Reduction heating	TOT Reduction
	kWh	kWh	kWh		%	%	%
Annual	-8129,523	13284,97	21414	54	23%	19%	20%
II floor	-2151,64	3272,91	5425	54	22%	21%	21%

ENERGY CONSUMPTION 4_Zevi + isolante plyurethane (ICYNENE)+ nuovi infissi+brise soleil 8-12

Date/Time	Total Cooling	Zone Heating	TOT		Reduction cooling	Reduction heating	TOT Reduction
	kWh	kWh	kWh		%	%	%
Annual	-8223,102	12810,64	21034	53	22%	22%	22%
II floor	-2166,71	3165,48	5332	53	21%	23%	22%

ENERGY CONSUMPTION 4_Zevi + isolante plyurethane (ICYNENE)+ nuovi infissi+brise soleil 6-9

Date/Time	Total Cooling	Zone Heating	TOT		Reduction cooling	Reduction heating	TOT Reduction	TOT Reduction/m2	partial reductio/m2
	kWh	kWh	kWh		%	%	%	%	%
Annual	-7870,969	12965,45	20836	52	25%	21%	23%	23%	6%
II floor	-2079,94	3201,97	5282	53	24%	22%	23%	23%	6%

Table 4. 15: Reduction in percentage in terms of energy consumption/m^2, between the shading devices studied. Annual simulation.

4.3.4 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.

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.

In the image below Fig. 4.26 it is possible to see the different type of windows that architect Bruno Zevi draw for this project. Windows indicated as D has been drawn for building A, while version D* was for building C. The architect planned for this building a window with a "sopraluce" (sort of fanlight) and a "sottoluce" both sliding. As the two models have the same size and shape, it is possible to think to replace D with D* in building A too, assuming (by associating a schedule) the opening of the upper one, so that the air circulates without disturbing the occupants.

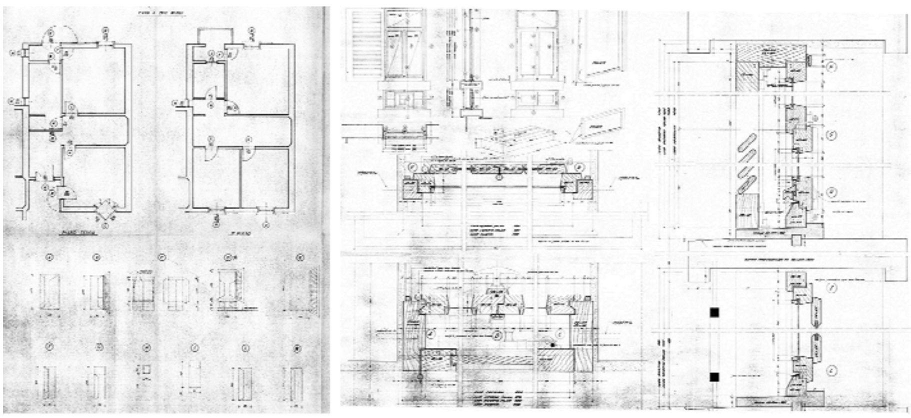


Fig.4. 34: Windows technical drawings by Bruno Zevi. Windows indicated as D was (and is) drawn for building A, while version D* was for building C.

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)

Date/Time	CURRENT		SHADE ROLL		SIDEFINS		BRISE SOLEIL 6/9		BRISE SOLEIL 36°	
	Solar Gains Exterior kWh	Zone Total Cooling kWh	Solar Gains Exterior kWh	Zone Total Cooling kWh	Solar Gains Exterior kWh	Zone Total Cooling kWh	Solar Gains Exterior Windows kWh	Zone Total Cooling kWh	Solar Gains Exterior kWh	Zone Total Cooling kWh
JAN	38,49	0,0	25,58581	0	13,84223	0	23,74845	0	21,7811	0
FEB	52,09	0,0	35,08616	0	20,48568	0	32,07844	0	28,55917	0
MAR	78,41	0,0	52,48588	0	35,73305	0	45,75083	0	39,59782	0
APR	100,51	0,0	66,51133	0	50,9139	0	56,28834	0	47,65486	0
MAY	123,38	0,0	78,82249	0	63,57565	0	65,40274	0	55,25617	0
JUN	138,01	-88,5	85,90851	-38,1042	70,49745	-31,6655	70,08427	-30,8622	58,84596	-26,7462
JUL	142,60	-162,4	89,18842	-91,8122	74,17158	-82,6837	72,95135	-81,9184	61,34886	-75,54917
AOG	126,97	-167,4	81,47085	-103,428	65,38042	-92,7808	66,83796	-93,6735	56,34978	-87,18449
SEP	92,29	-49,5	61,55602	-16,6489	43,47588	-9,50924	52,68497	-24,275	45,28774	-10,16113
OCT	70,03	0,0	47,18887	0	28,88154	0	42,65157	0	37,7799	0
NOV	44,03	0,0	29,44228	0	16,17684	0	27,18472	0	24,64661	0
DIC	35,75	0,0	23,8118	0	12,34713	0	22,16293	0	20,35932	0
ANNUAL	1042,56	-467,81	677,06	-249,99	495,48	-216,64	577,83	-230,73	497,47	-199,64

Table 4. 16: Solar gains [kWh] and zone total cooling [kWh], comparison between different shading systems.

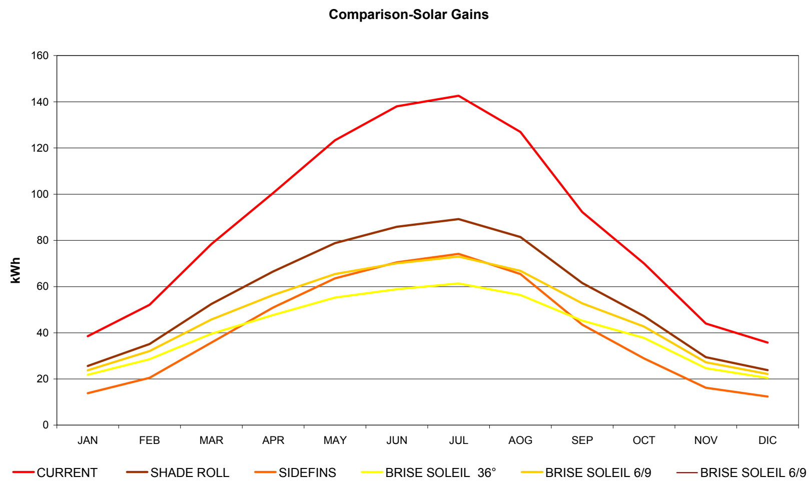


Fig.4. 27: Solar gains [kWh]

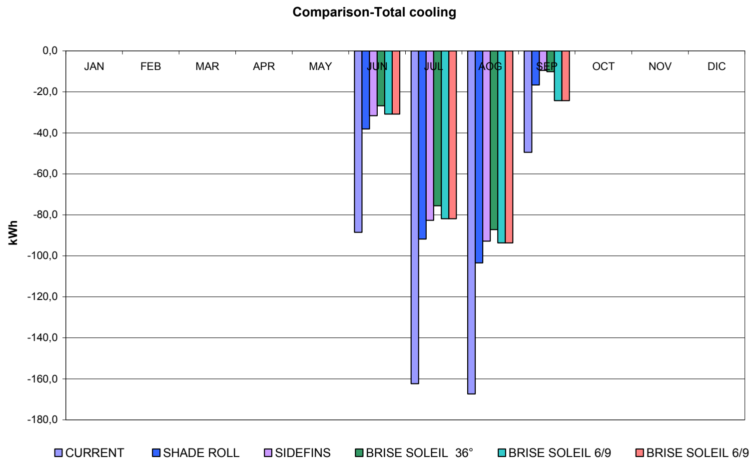


Fig.4. 35: Zone total cooling[10] [kWh]

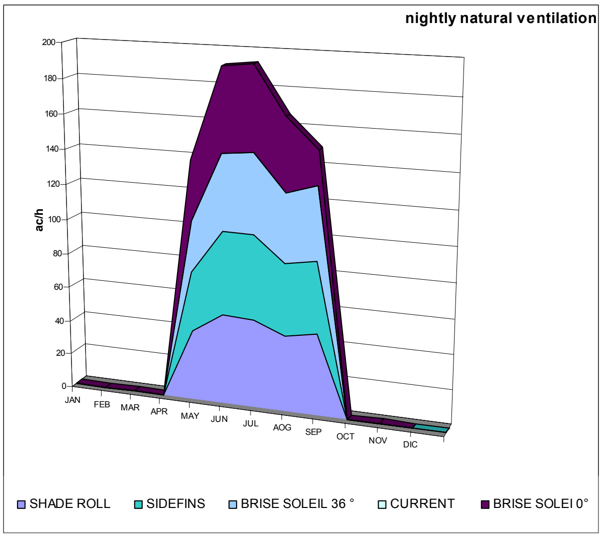


Fig.4. 36: Nightly natural ventilation, [ac/h].

[10]Total Cooling is the rate at which total energy (sensible and latent) is removed from the mixed outside and return air stream in order to bring the mixed air stream to the specified temperature and humidity ratio of the supply air stream.

	CURRENT	SHADE ROLL	SIDEFINS	BRISE SOLEI 0°	BRISE SOLEIL 36 °
Date/Time	Nat Vent + Infiltration ac/h	Nat Vent + Infiltration ac/h	Nat Vent + Infiltration ac/h	Nat Vent + Infiltration	Nat Vent + Infiltration ac/h
JAN	0	0	0	0	0
FEB	0	0	0	0	0
MAR	0	0	0	0	0
APR	0	0	0	0	0
MAY	0	-40,78	-34,22	-34,26	-29,14
JUN	0	-51,86	-48,00	-47,34	-43,63
JUL	0	-50,84	-48,66	-47,95	-45,73
AOG	0	-43,59	-41,53	-41,25	-39,54
SEP	0	-47,16	-41,27	-19,07	-41,81
OCT	0	0	0	0	0
NOV	0	0	0	0	0
DIC	0	0	0	0	0
ANNUAL	0	-234,24	-213,69	-189,87	-199,86

Table 4. 17: natural ventilation ac/h

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

ENERGY CONSUMPTION 4_Zevi + isolante plyurethane (ICYNENE)+ nuovi infissi+Shade roll+NV

Date/Time	Total Cooling	Zone Heating	TOT		Reduction cooling	Reduction heating	TOT Reduction	TOT Reduction/m2	partial reductio/m2
	kWh	kWh	kWh		%	%	%	%	%
Annual	-5942,83	12653,9	18597	46	44%	23%	31%	31%	12%
II floor	-1554,18	3131,72	4686	47	43%	24%	32%	32%	13%

ENERGY CONSUMPTION 4_Zevi + isolante plyurethane (ICYNENE)+ nuovi infissi+louvre sidefins+NV

Date/Time	Total Cooling	Zone Heating	TOT		Reduction cooling	Reduction heating	TOT Reduction	TOT Reduction/m2	partial reductio/m2
	kWh	kWh	kWh		%	%	%	%	%
Annual	-5646,05	13281,04	18927	47	46%	19%	30%	30%	12%
II floor	-1474,09	3276,33	4750	48	46%	20%	31%	31%	12%

Table 4. 18: Energy consumptionand nigthly natural ventilation – comparison between different shading systems, total cooling, zone heating, and % of reduction

ENERGY CONSUMPTION 4_Zevi + isolante plyurethane (ICYNENE)+ nuovi infissi+brise soleil 6-9+NV									
Date/Time	Total Cooling	Zone Heating	TOT		Reduction cooling	Reduction heating	TOT Reduction	TOT Reduction/m2	partial reductio/m2
	kWh	kWh	kWh		%	%	%	%	%
Annual	-5911,77	12816,47	18728	47	44%	22%	30%	30%	10%
II floor	-1543,31	3170,18	4713	47	44%	23%	31%	31%	11%

ENERGY CONSUMPTION 4_Zevi + isolante plyurethane (ICYNENE)+ nuovi infissi+brise soleil 36° +NV									
Date/Time	Total Cooling	Zone Heating	TOT		Reduction cooling	Reduction heating	TOT Reduction	TOT Reduction/m2	partial reductio/m2
	kWh	kWh	kWh		%	%	%	%	%
Annual	-5460,81	12974,47	18435	46	48%	21%	31%	31%	**12%**
II floor	-1425,01	3206,96	4632	46	48%	22%	33%	**33%**	**13%**

Table 4. 19: Energy consumption and nigthly natural ventilation – comparison between different shading systems, total cooling, zone heating, and % of reduction.

In terms of % of reduction of energy consumption, at the end of the analysis the best shading device appears to be brise soleil with an angle to the horizontal of 36° and a blade depth of 10 cm. This final solution allows to reduce energy consumption, comparing the same hypothesis without natural ventilation, of an extra 12%.

4.3.5 Urban environnement influence on natural ventilation potential

The meteorological models give the wind, temperature and sky cover on a fictitious surface at, usually, 10 m above the ground level on a grid of about several kilometers. In order to be used for estimating the natural ventilation air-flow due to wind pressure and stack effect, these values need to be changed as a function of the urban environment.

Air-flow in street canyons has much lower values as compared with the undisturbed wind. Lower wind velocity means reduced wind pressure on the building facade and less effective cross ventilation. Reduced wind velocity, urban heat island, noise and pollution, are considered to be important barriers to natural ventilation application in urban environment.

To test the effect of natural ventilation has been shaped the area around the building under study for a total of about seventy buildings..

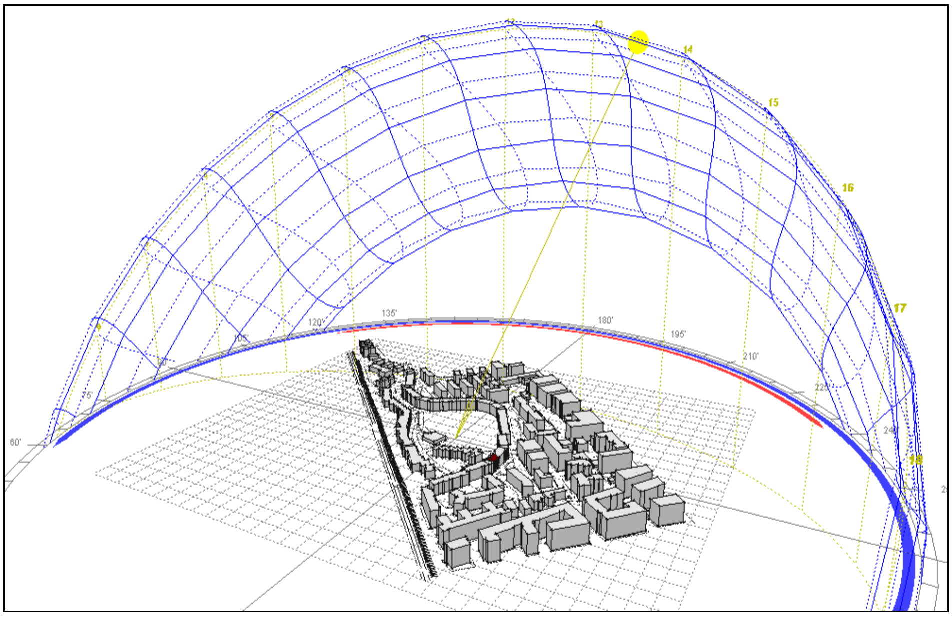


Fig.4. 37: Analysis of urban environnement influence on natural ventilation potential

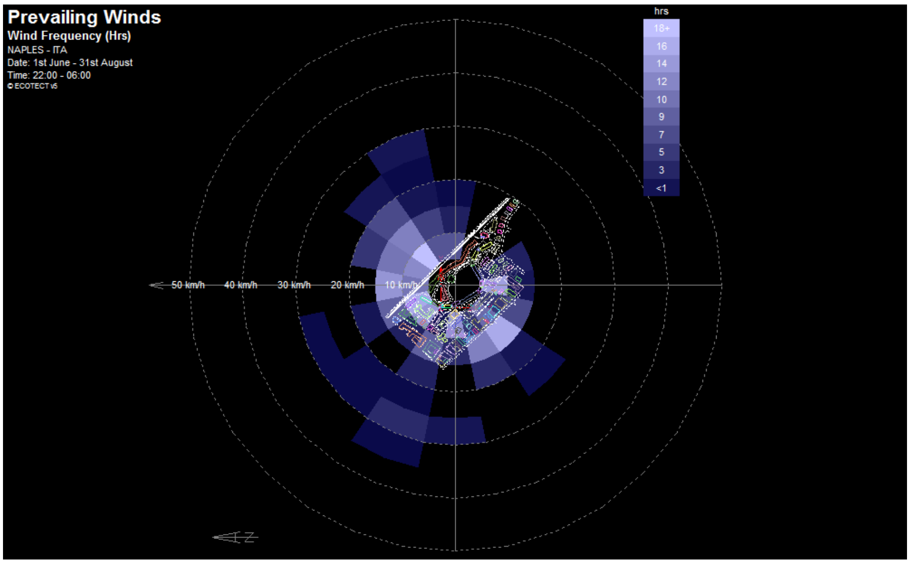


Fig.4. 38: Graph representing the prevailing winds in the region object of the analysis. Ecotect.

Each building, however, was modeled as adiabatic block since the purpose was just to verify the interaction with the prevailing breeze and any reduction in the beneficial effects of ventilation The image above Fig. 4.30 simultaneously displays speed, direction and frequency. Wind speed is shown by the distance of each block from the graph center whilst frequency is indicated using colored shading.

Such a graph allows determining information such as where the best breezes generally come from, how hot or cold they are and the major direction of driving rains.

The software ECOTEC helps us more than Design Builder in checking the natural ventilation potential, if we consider the building, surrounded by other buildings. As previously done with the software Design Builder, Ecotect allows to add a schedule of opening hours for the upper windows,

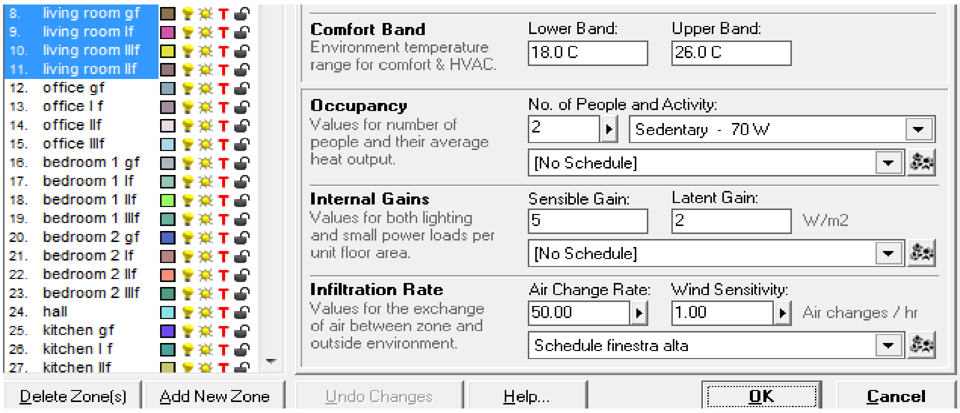


Fig.4. 39**:** Input Data infiltration rate - Ecotect

Values for the exchange of air between zone and outside environment:

- Air Change Rate:
- Cross Ventilated 50.00 air change/hour
- Wind Sensitivity: very sensitive 1.00 ach

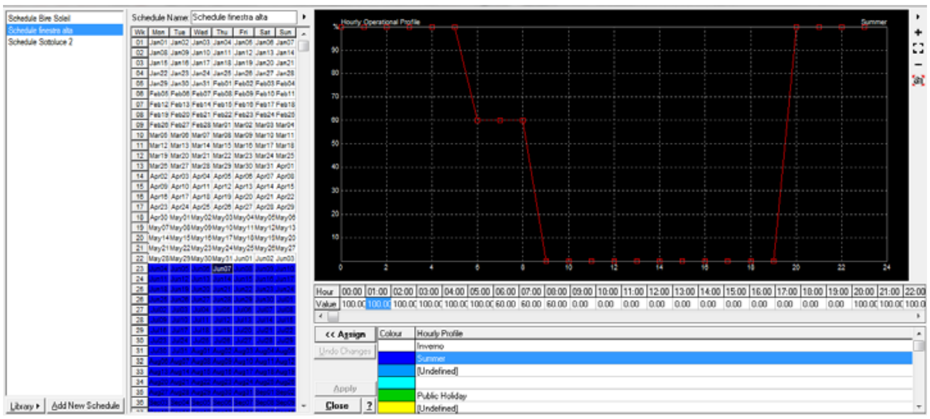


Fig.4. 40: Schedule of opening hours of the upper windows

This energy performance simulation of the building, that takes into account the presence of the surrounding blocks (for a total of about seventy) each schematically represented with an adiabatic block, has been useful to verify that natural ventilation is not particularly affected by the presence of other buildings, probably thanks to the special shape of block A, and to the distance (sometimes considerable) to other buildings.

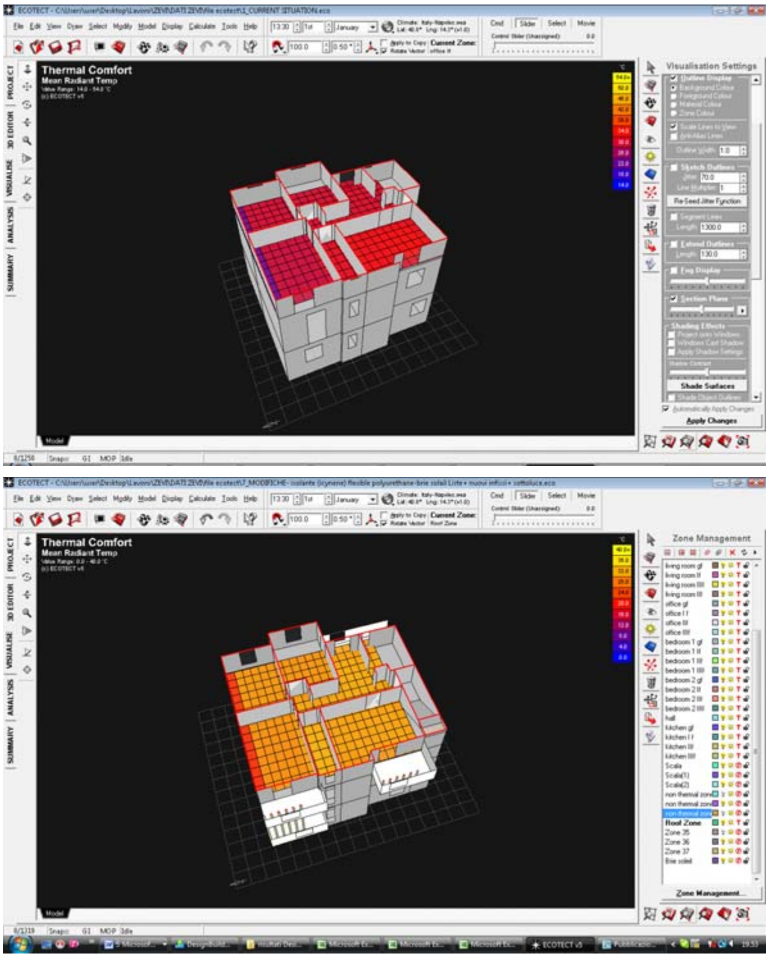


Fig.4. 41: Thermal Analysis Ecotect radiant temperature., comparison between current situation and final situation with Polyurethan foam, new windows, brise soleil and natural ventilation.

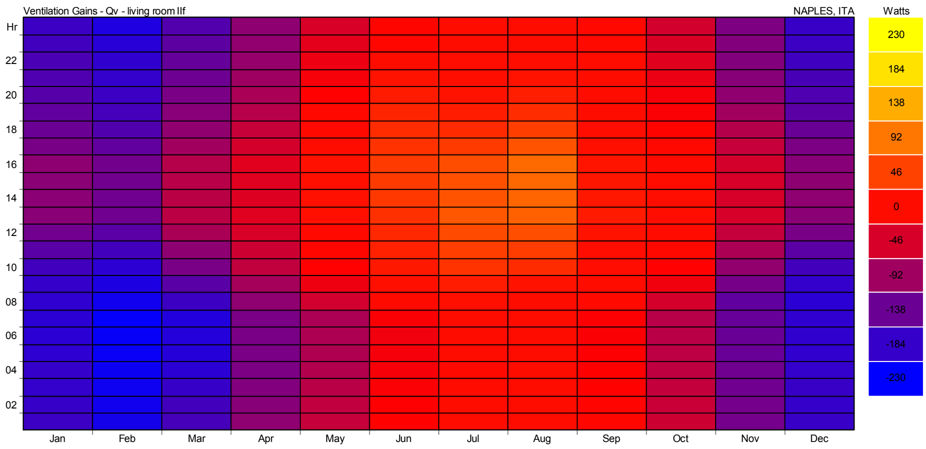


Fig.4. 42:Thermal Anlisys- Ventilation gains Qv, living room second floor, (monthly average shown as loads)

The thermal analysis shows the contribution of ventilation and infiltration gains it means, the heat flow due to the exchange of air between inside and outside. This includes infiltration, due to leakage through gaps and porous material as well as ventilation through openings.

ANNUAL LOADS TABLE
Ventilation Gains - Qv
living room IIf - Monthly Averages

HOUR	JAN (Wh)	FEB (Wh)	MAR (Wh)	APR (Wh)	MAY (Wh)	JUN (Wh)	JUL (Wh)	AUG (Wh)	SEP (Wh)	OCT (Wh)	NOV (Wh)	DEC (Wh)
0	-179	-212	-170	-107	-60	-9	0	0	-5	-54	-130	-182
1	-183	-215	-173	-114	-65	-11	-1	0	-7	-58	-130	-184
2	-185	-218	-182	-119	-71	-14	-1	0	-9	-62	-133	-182
3	-184	-219	-193	-122	-77	-17	-3	0	-10	-66	-134	-185
4	-190	-222	-197	-125	-80	-19	0	0	-12	-68	-140	-188
5	-193	-224	-199	-126	-81	-22	0	0	-14	-71	-139	-188
6	-193	-226	-200	-125	-83	-15	0	0	-13	-72	-141	-189
7	-189	-216	-178	-108	-50	-2	2	0	-3	-47	-147	-193
8	-184	-204	-153	-88	-25	2	13	5	0	-22	-127	-186
9	-173	-192	-126	-64	-10	10	33	27	0	-10	-104	-172
10	-153	-172	-108	-53	-6	18	43	42	1	-3	-82	-151
11	-131	-153	-84	-44	-3	24	53	56	5	-1	-62	-127
12	-112	-134	-69	-37	3	31	63	73	12	0	-45	-111
13	-110	-132	-70	-39	4	37	61	77	10	0	-45	-108
14	-111	-131	-72	-37	2	40	58	78	8	0	-45	-109
15	-109	-131	-74	-37	4	39	56	81	7	-2	-48	-113
16	-126	-146	-91	-48	0	33	39	61	2	-4	-61	-122
17	-138	-160	-106	-60	-3	27	25	43	1	-8	-75	-139
18	-146	-171	-113	-74	-4	20	14	27	0	-14	-91	-152
19	-156	-179	-125	-84	-10	13	5	16	0	-18	-106	-162
20	-162	-186	-136	-94	-18	6	1	5	0	-26	-113	-168
21	-166	-189	-142	-102	-26	0	1	1	-1	-36	-118	-175
22	-174	-196	-150	-105	-33	-4	0	0	-2	-43	-118	-179
23	-179	-204	-159	-108	-44	-6	0	0	-3	-49	-121	-182

Fig.4. 43: Ventilation gains Qv, living room second floor, (monthly average shown as loads).

So as said before, the interaction with the surrounding buildings turned out to be negligible.

4.4 Economic feasibility

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 payback 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)[11].

CASO STUDIO 1: ZEVI		
Perimeter	1050	m
High	12.5	m
Totale	13125	mq
Singolo blocco	313	mq
wall gap	16	mc
Glazing surface	65	mq
brise soleil	22.4	mq
Flat wall gap	4	mc
Flat glazing	16	mq
Flat brise soleil	5.6	mq

Table 4. 20: Geometric input data, virtual slice of the building.

[11] Some not found in the Official Bulletin of the Campania Region are taken from Prezzario delle opera edili del piemonte, while brise soleil cost is taken from Prezzario Regionale dei Lavori Pubblici of Sardegna.

Investment cost			€/m²	% labor costs	% security costs	building	single flat
Insulation total expese							
03.P01.E01.030	**vermiculite** (λ=0,057 100 kg/cm³)	m³	194,03	30	1	3972	993
E.10.70.30	**ESP Polistirene** (λ=0,040 15 kg/cm³)	m²	7,91	33,1	0,85	3290	823
E.10.70.30	**Poliuretano** (λ=0,035 3 3 kg/cm³)	m²	9,33	28,32	0,72	3744	936
03.P09.H13	**Sughero** (λ=0,045 65/75 kg/cm³)	m³	120	30	1	2456	614
Replacement (of windows)							
E 18.30.30	window (< 3 m²)	m²	256	6,7	0,08	17768	4500
R 02. 110.10	replacement	m²	7,84	73,21	2,21	559	150
	tot					18327	4650
E.21.20.40	painting	m²	4,91	65,58	1,68	2566	642
shading system							
01 01.P 13.E00	veneziane e tende	m²	30	5		706	200,0
A.0072.0001.0003	Brise soleil	m²	44,46	5		1680	420,0
TOT [€]						**10074**	**5856**

Table 4. 21: Investment costs

Using the well 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 (average between cost of electricity and natural gas) of 0,15 €/m^2 it is possible to obtain the following tables (for the entire building and the single flat).

Anni di vita del progetto		Consumi status quo	Consumi scenario finale	coeff. di attualizzazione $(l+i)^n$ i=4%	Consumi valore attuale dello status quo	Consumi valore attuale dello scenario finale	Risparmio annuo	Saldo
Anno	1	4304	2950	0,9615	4138	2836	1302	1302
Anno	2	4304	2950	0,9246	3979	2727	1252	2554
Anno	3	4304	2950	0,8890	3826	2622	1204	3758
Anno	4	4304	2950	0,8548	3679	2521	1158	4915
Anno	5	4304	2950	0,8219	3537	2424	1113	6028
Anno	6	4304	2950	0,7903	3401	2331	1070	7098
Anno	7	4304	2950	0,7599	3271	2241	1029	8127
Anno	8	4304	2950	0,7307	3145	2155	989	9117
Anno	9	4304	2950	0,7026	3024	2072	951	10068
Anno	10	4304	2950	0,6756	2907	1993	915	10983
Anno	11	4304	2950	0,6496	2796	1916	880	11863
Anno	12	4304	2950	0,6246	2688	1842	846	12708
Anno	13	4304	2950	0,6006	2585	1771	813	13522
Anno	14	4304	2950	0,5775	2485	1703	782	14304
Anno	15	4304	2950	0,5553	2390	1638	752	15056
Anno	16	4304	2950	0,5339	2298	1575	723	15779
Anno	17	4304	2950	0,5134	2209	1514	695	16474
Anno	18	4304	2950	0,4936	2124	1456	668	17142
Anno	19	4304	2950	0,4746	2043	1400	643	17785
Anno	20	4304	2950	0,4564	1964	1346	618	18403
Anno	21	4304	2950	0,4388	1889	1294	594	18997
Anno	22	4304	2950	0,4220	1816	1245	571	19568
Anno	23	4304	2950	0,4057	1746	1197	549	20118
Anno	24	4304	2950	0,3901	1679	1151	528	20646
Anno	25	4304	2950	0,3751	1614	1106	508	21154
Anno	26	4304	2950	0,3607	1552	1064	488	21642
Anno	27	4304	2950	0,3468	1493	1023	470	22112
Anno	28	4304	2950	0,3335	1435	984	452	22564
Anno	29	4304	2950	0,3207	1380	946	434	22998
Anno	30	4304	2950	0,3083	1327	909	417	23415
Anno	**31**	**4304**	**2950**	**0,2965**	**1276**	**874**	**401**	**23817**
Anno	**32**	**4304**	**2950**	**0,2851**	**1227**	**841**	**386**	**24203**
Anno	33	4304	2950	0,2741	1180	808	371	24574
Anno	34	4304	2950	0,2636	1134	777	357	24931

Table 4. 22: Economic viability of the upgrading investment. Whole building. Payback time estimated: 33 years.

Anni di vita del progetto		Consumi status quo	Consumi scenario finale	coeff. di attualizzazione (l+i)^n i=4%	Consumi valore attuale dello status quo	Consumi valore attuale dello scenario finale	Risparmio annuo	Saldo
Anno	1	4304	2970	0,9615	4138	2855	1283	1283
Anno	2	4304	2970	0,9246	3979	2746	1234	2516
Anno	3	4304	2970	0,8890	3826	2640	1186	3702
Anno	4	4304	2970	0,8548	3679	2538	1140	4843
Anno	5	4304	2970	0,8219	3537	2441	1097	5939
Anno	6	4304	2970	0,7903	3401	2347	1054	6994
Anno	7	4304	2970	0,7599	3271	2257	1014	8008
Anno	8	4304	2970	0,7307	3145	2170	975	8983
Anno	9	4304	2970	0,7026	3024	2086	937	9920
Anno	10	4304	2970	0,6756	2907	2006	901	10821
Anno	11	4304	2970	0,6496	2796	1929	867	11688
Anno	12	4304	2970	0,6246	2688	1855	833	12521
Anno	13	4304	2970	0,6006	2585	1783	801	13322
Anno	14	4304	2970	0,5775	2485	1715	770	14093
Anno	15	4304	2970	0,5553	2390	1649	741	14834
Anno	16	4304	2970	0,5339	2298	1585	712	15546
Anno	17	4304	2970	0,5134	2209	1525	685	16231
Anno	18	4304	2970	0,4936	2124	1466	659	16890
Anno	19	4304	2970	0,4746	2043	1409	633	17523
Anno	20	4304	2970	0,4564	1964	1355	609	18132
Anno	21	4304	2970	0,4388	1889	1303	585	18717
Anno	22	4304	2970	0,4220	1816	1253	563	19280
Anno	23	4304	2970	0,4057	1746	1205	541	19821
Anno	24	4304	2970	0,3901	1679	1159	520	20342
Anno	25	4304	2970	0,3751	1614	1114	500	20842
Anno	26	4304	2970	0,3607	1552	1071	481	21324
Anno	27	4304	2970	0,3468	1493	1030	463	21786
Anno	28	4304	2970	0,3335	1435	990	445	22231
Anno	29	4304	2970	0,3207	1380	952	428	22659
Anno	30	4304	2970	0,3083	1327	916	411	23070
Anno	31	4304	2970	0,2965	1276	880	396	23466
Anno	**32**	**4304**	**2970**	**0,2851**	**1227**	**847**	**380**	**23846**
Anno	**33**	**4304**	**2970**	**0,2741**	**1180**	**814**	**366**	**24212**
Anno	34	4304	2970	0,2636	1134	783	352	24564

Table 4. 23: Economic viability of the upgrading investment. Single flat. Payback time estimated: 33 years.

A payback period of about 33 years has been obtained if we consider the investment for the whole building, and 29 for the single flat (i.e. single user) that it's a pretty 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.

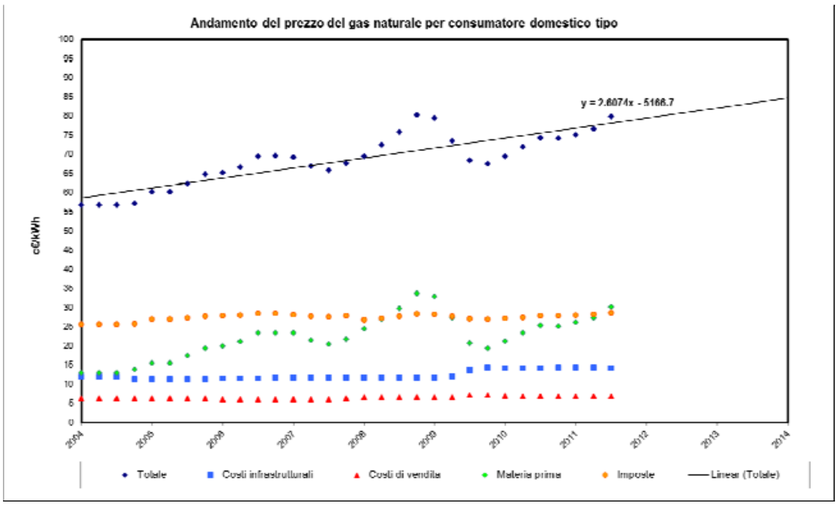


Fig.4. 44: Trend in the price of natural gas for domestic consumer.

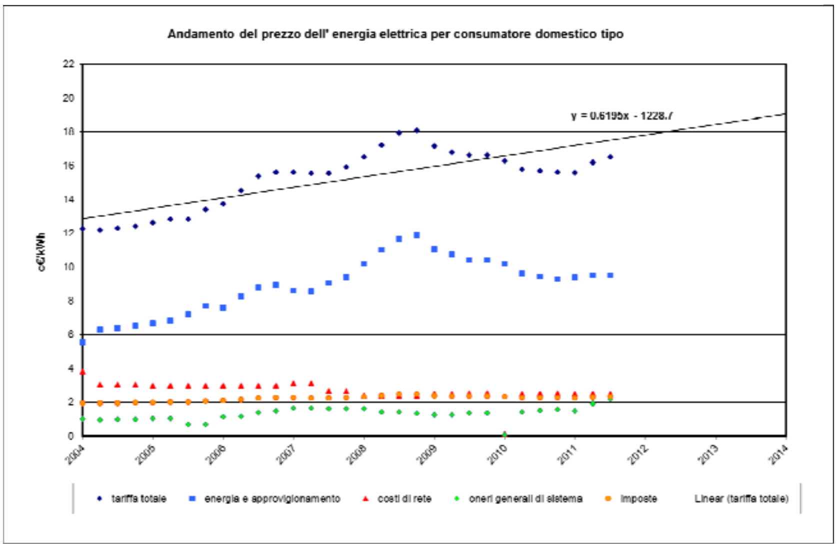


Fig.4. 45: Trend of electricity prices for domestic consumers.

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 attualizz azione $(I+i)^n$ i=4%	Consumi status quo	Consumi 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

Table 4. 24: Payback time of the investment, whole building, approximately 22 years.

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 $(l+i)^n$ i=4%	Consumi status quo	Consumi scenario finale	Risparmio annuo	Saldo
Anno	1	487,2	408,8	896,0	252,71	318,25	571	0,9615	862	549	313	313
Anno	2	504,2	422,2	926,4	261,54	328,70	590	0,9246	857	546	311	623
Anno	3	521,2	435,7	956,9	270,37	339,15	610	0,8890	851	542	309	932
Anno	4	538,2	449,1	987,3	279,20	349,60	629	0,8548	844	537	306	1239
Anno	5	555,3	462,5	1017,8	288,02	360,06	648	0,8219	837	533	304	1542
Anno	6	572,3	475,9	1048,2	296,85	370,51	667	0,7903	828	527	301	1843
Anno	7	589,3	489,4	1078,7	305,68	380,96	687	0,7599	820	522	298	2141
Anno	8	606,3	502,8	1109,1	314,51	391,41	706	0,7307	810	516	295	2436
Anno	9	623,3	516,2	1139,5	323,33	401,86	725	0,7026	801	510	291	2727
Anno	10	640,3	529,6	1170,0	332,16	412,32	744	0,6756	790	503	287	3015
Anno	11	657,4	543,1	1200,4	340,99	422,77	764	0,6496	780	496	284	3298
Anno	12	677,1	559,4	1236,4	351,22	435,45	787	0,6246	772	491	281	3579
Anno	13	697,4	576,1	1273,5	361,76	448,52	810	0,6006	765	487	278	3857
Anno	14	718,3	593,4	1311,7	372,61	461,97	835	0,5775	758	482	276	4133
Anno	15	739,9	611,2	1351,1	383,79	475,83	860	0,5553	750	477	273	4406
Anno	16	762,1	629,6	1391,6	395,30	490,10	885	0,5339	743	473	270	4676
Anno	17	784,9	648,5	1433,4	407,16	504,81	912	0,5134	736	468	268	4944
Anno	18	808,5	667,9	1476,4	419,38	519,95	939	0,4936	729	464	265	5209
Anno	19	832,7	687,9	1520,7	431,96	535,55	968	0,4746	722	459	263	5471
Anno	20	857,7	708,6	1566,3	444,92	551,62	997	0,4564	715	455	260	5731
Anno	**21**	**883,4**	**729,8**	**1613,3**	**458,26**	**568,17**	**1026**	**0,4388**	**708**	**450**	**258**	**5989**
Anno	22	909,9	751,7	1661,7	472,01	585,21	1057	0,4220	701	446	255	6244
Anno	23	937,2	774,3	1711,5	486,17	602,77	1089	0,4057	694	442	253	6497
Anno	24	965,4	797,5	1762,9	500,76	620,85	1122	0,3901	688	438	250	6747
Anno	25	994,3	821,4	1815,8	515,78	639,48	1155	0,3751	681	433	248	6995

Table 4. 25: Payback time of the investment, single flat, approximately 21 years.

Then we proceeded as before, assuming in addition to the growing trend identified. In this case the payback time is about 22 years for the building and 21 for the single flat, 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[12] 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 €.

Tipologia	Stato conservativo	Valore Mercato (€/mq)		Superficie (L/N)	Valori Locazione (€/mq x mese)		Superficie (L/N)
		Min	Max		Min	Max	
Abitazioni civili	NORMALE	2800	3200	L	7,2	8,2	L
Abitazioni di tipo economico	NORMALE	1900	2750	L	4,9	6,9	L
Autorimesse	NORMALE	990	1400	L	4,7	6,4	L
Box	NORMALE	1250	1600	L	5,5	7,4	L
Ville e Villini	NORMALE	2300	3400	L	6,1	8,8	L

Fig. 4. 1: Risultato interrogazione: Anno 2010 - Semestre 2

Provincia: Salerno, Comune: Salerno, Fascia/zona: Periferica/Torrione alto, Lungomare Colombo Vie Del Pezzo,Trento, Posidonia (Lato Est). Codice di zona: D3 Microzona catastale n.: 5 - Tipologia prevalente: Abitazioni di tipo economico - Destinazione: Residenziale

[12] P. Eichholtz and N. Kok, J. Quigley, *Doing well by doing good? An analysis of the financial performance of green office buildings in the USA*, March 2009.

So if we want to make a more complete economic analysis we must take into account the added value of the property. Bearing in mind that this is not a new building, it is not possible to apply the increase in value by 25% because the initial situation is clearly different, but surely it is reasonable to expect an increase in the value of at least a half, i.e. of 10-13%.

Present value of the property in square meters: 2300 € /m²
Flat surface: 87/108 m
flat value: € 200,000
adjustment costs: ~ € 24,000
"bonus value "of green flat: 10% € ⟶ 20000

This value must therefore be subtracted from the initial cost of the investment, it follows that the investment would be recovered in theory
In less than 4 years 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.

4.5 Reduction of CO_2 emissions

The software used allows predicting the CO_2 emission levels produced by the selected building. CO_2 emissions are calculated in DesignBuilder by multiplying fuel consumption by the kg CO_2 per kWh conversion factor for that fuel. Conversion factors can be made specific to the region (previously defined).

A legislative region in DesignBuilder is typically a whole country or a region, province or state within a country which has its own building control powers, it contains information on local energy codes/building regulations and carbon dioxide emission factors are provided for a range of fuels. So in the modeling phase Italy has been chosen as legislative region, and the mandatory Energy Code that for Italy ids provided by Eurima.[13]

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[13] Energy code data is used within DesignBuilder to indicate the mandatory energy performance of the building components and/or the whole building. Energy Code for Italy is provided by Eurima, sector: domestic/non domestic. Specific mandatory maximum U-values through the individual components (walls, windows, roofs etc..) are also provided and listed below:
Envelope component heat losses:

- maximum U-Values (exposed Elements)
  Wall (W/m^{2}K): 0.580
  Flat roof (W/m^{2}K): 1.000
  Pitched roof (W/m^{2}K): 1.000
  Roofspace floor (W/m^{2}K): 1.000
  Floor (W/m^{2}K): 0.900
  Sold floor to ground (W/m^{2}K): 0.900
  Window (W/m^{2}K): 5.200
  Rooflight (W/m^{2}K): 5.200
  Personnel doors(W/m^{2}K): 2.200
  Personnel doors(W/m^{2}K): 2.200
  High usage entrance doors (W/m^{2}K): 2.200
- maximum U-Values (semi-exposed Elements):
  Window (W/m^{2}K): 5.200
  Wall (W/m^{2}K): 0.580
  Floor (W/m^{2}K): 0.900

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.

CO_2 Reduction							
Date/Time	Current	Cork	Polyurethane	Windows	Shading System	Final solution	% of reduction
January	1596.191	1494.87	1448.044	1365.758	1351.673	1344.894	16%
February	1352.768	1265.309	1225.96	1158.61	1154.398	1148.674	15%
March	1173.992	1097.192	1063.023	1020.409	1037.495	1029.909	12%
April	681.2299	642.1949	625.3816	612.4889	637.2368	626.4476	8%
May	440.0039	440.0039	440.0039	440.0039	440.0039	440.0039	0%
June	721.6285	724.373	725.1535	689.3846	638.1383	553.8647	23%
July	1009.119	993.1819	985.1841	927.1922	868.7065	773.0185	23%
August	1027.212	1006.352	995.7255	940.6215	887.7563	808.1135	21%
September	595.0262	601.4055	603.2952	581.3012	553.2416	514.6117	14%
October	467.5811	459.8485	456.7	454.2036	457.5298	455.8277	3%
November	1071.128	1006.892	978.2404	930.2734	927.4926	921.9792	14%
Dicember	1599.52	1502.001	1457.256	1371.662	1356.424	1349.82	16%
TOT	11735.4	11233.6	11004.0	10491.9	10310.1	9967.2	15%

Table 4. 40: The table shows the monthly emission of CO_2 for each upgrading step and the percentage of reduction that can be achieved with the final solution

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Whole envelope heat loss (sets a limit of the rate of heat transfer through the overall building envelope. The limit is typically set as an average U-value for the overall building envelope):
Airthightness:
Max air permeability ($m^3/hr/m^2$ 50 Pa): 10.00

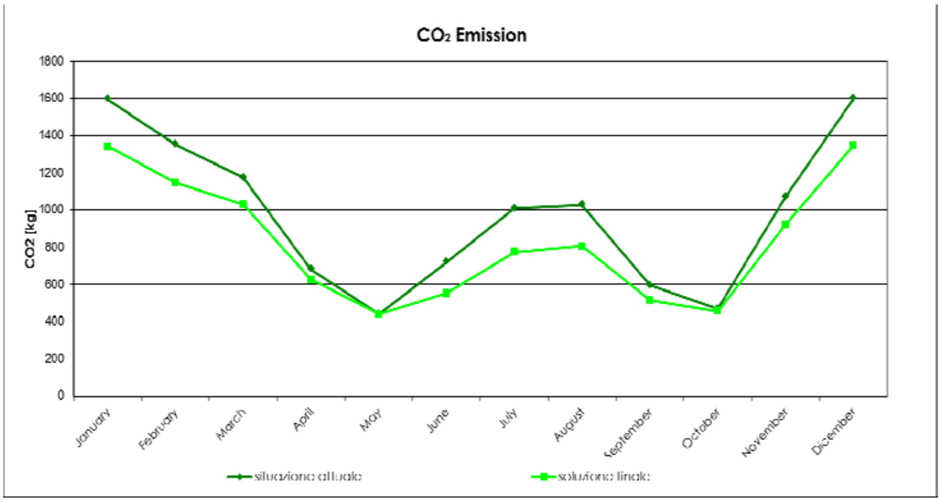


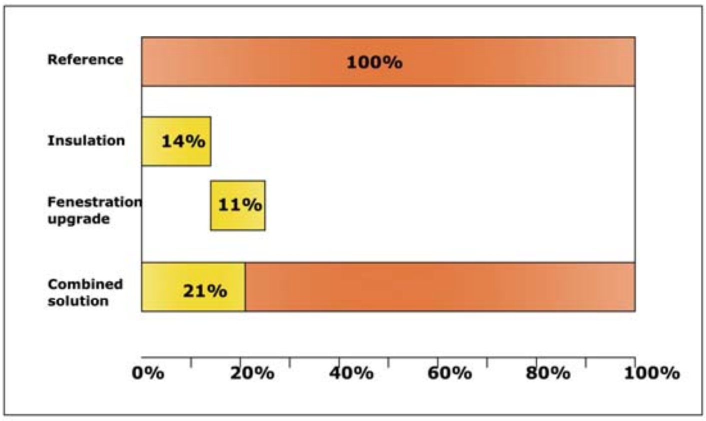
Fig.4. 46: CO_2 Emissions, annual simulation .

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.

4.6 Summary

Thanks to the simulated upgrade of the building envelope, analyzed on an entire typical year simulation, a reduction in percentage terms for the winter heating consumption by 14% due to the use of thermal insulation has been observed, and a reduction of 12% due to the replacement of windows.

HEATING CONSUMPTION- KWh/m²
Building



HEATING CONSUMPTION- KWh/m²
Single flat II floor

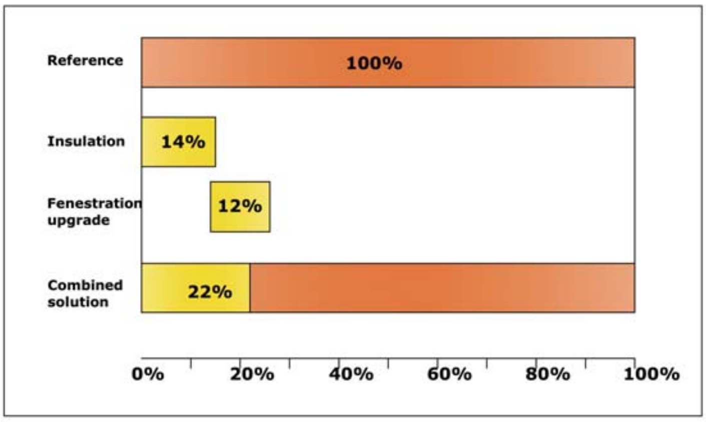
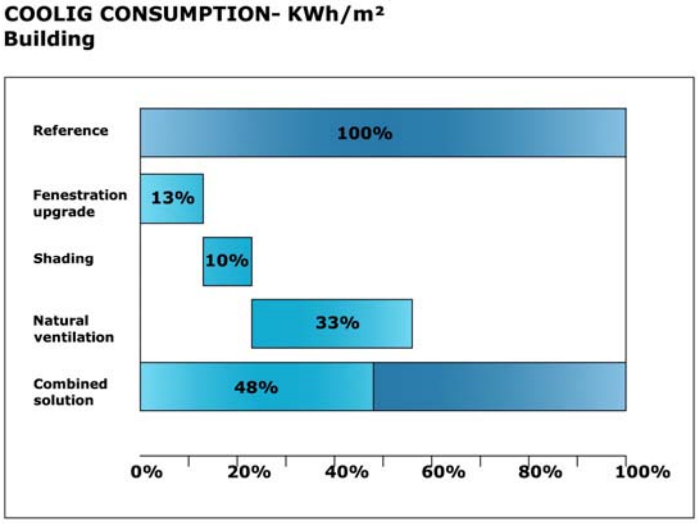


Table 4. 26: Reduction in heating consumption for each step analyzed, in percentage.



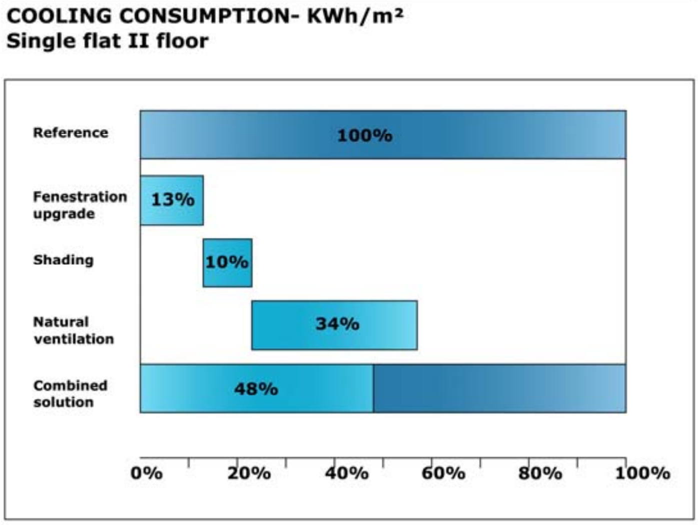
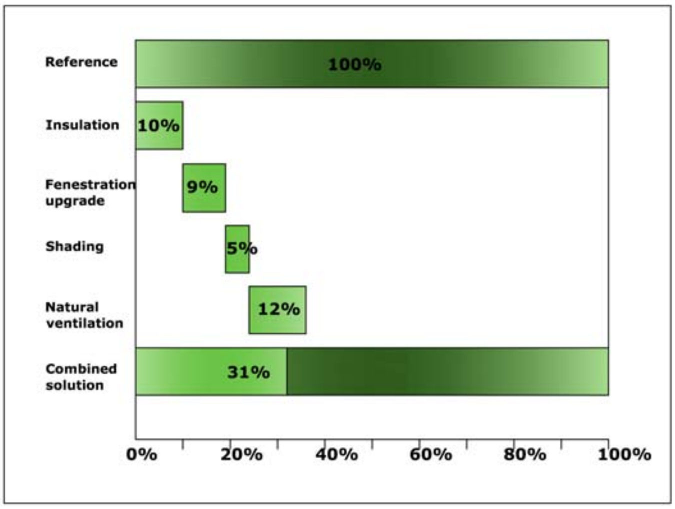


Table 4. 27: Reduction in cooling consumption for each step analyzed, in percentage

It has also obtained a reduction in consumption for summer cooling by 10% due to the use of a properly designed solar device and 12% due to natural ventilation at night. A combined solution of all interventions would lead to a reduction in terms of consumption (on winter heating and summer cooling) by 48%.

ENERGY CONSUMPTION- KWh/m²
Building



ENERGY CONSUMPTION- KWh/m²
Single flat II floor

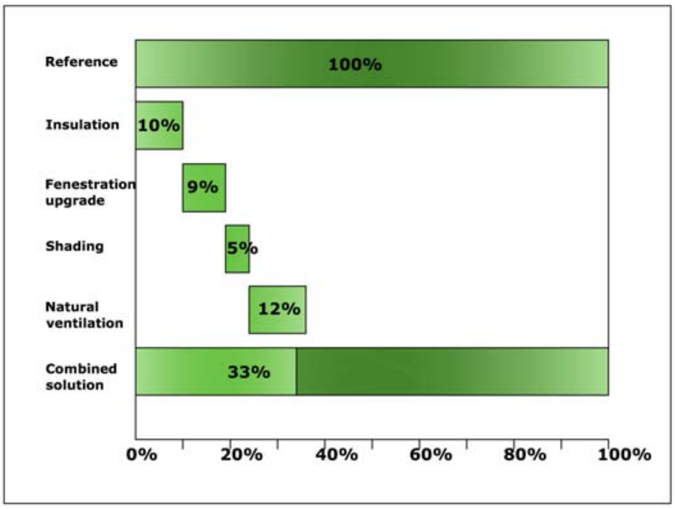


Table 4. 28: Reduction in energy consumption for each step analyzed, in percentage

Chapter V – Case study 2: Quartiere INA-Olivetti, Pozzuoli (NA)

As mentioned in the previous chapter the devastation caused by the second world war and the centuries-old plague of the shortage of housing, imposed in the critical consciences the theme of a "home for all" as a crucial issue for a reconstruction based on ethical values, even before the technical ones.

After the war Luigi Cosenza extend its research on housing to the field social housing.

It is known, moreover, that in those years, the architectural culture was able to provide the most convincing evidence of urban design just in the field of social housing, and Cosenza, like few others, chose the social and the rational design as objectives of his work.

In 1932 Adriano Olivetti, after an apprenticeship in his father's factory and a *voyage d'instruction* in the United States to learn about the industrial reality of a country on the cutting-edge, was back to Ivrea, with the aim to transform the semi-traditional typewriter factory of his family in a modern industry with a mechanical production line, starting an enterprise policy that could lead to the rational development not only of factories, but also of comfortable and decent working-class neighborhoods, with after-work activity center and other facilities (cafeterias, kindergartens, schools, etc..) and modern branches all over the world.

The objective achieved by Adriano Olivetti throughout his life as a business man and modern designer, of promoting the creation of a community where working space and living space were in tune, became reality when Luigi Cosenza was entrusted in 1951 for the design of an industrial complex in southern Italy.

The acquaintance between Cosenza and Olivetti was born probably in the late thirties, with the publication of some works of the architect in Casabella a magazine around which orbited the first generation of Italian rationalist architects, works that were appreciated by Olivetti. The interest in architecture by the businessman led him to become, until his death in 1960, one of the more enlightened patrons of architecture of the twentieth century.

The urban vision of Cosenza, already in embryo in the studio of a master plan for the Campania region, remained at a preliminary stage, was based on willingness to recommend the appropriate way to deal with a detailed analysis of the problems to be solved" generally identified in the "chase away the misery "and try to "create happiness" through action against outdated mentality, ignorance, selfishness and speculation.

And in fact in a few years the pursuit of happiness for mankind, especially for the factory workers and residents of the houses built in Pozzuoli, led to, in some sense, a shift in the interests of the Neapolitan architect, from the original preference for the villas to the most complex urban and social issues.

In this field of research the collaboration with Adriano Olivetti was strengthened.

In Pozzuoli there was in these years a successful combination between Olivetti businessman "*sempre un passo avanti, ma molti passi avanti rispetto ai contesti in cui operò*"[1] and an engineer-architect who was always been a pioneer with respect to the architectural and cultural context in which we had, not without difficulty, to work.

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[1] C. de Seta, Una storia su cui ritornare, prefazione a R. Astarita, Gli architetti di Olivetti.., cit. pg. 9.

5.1 Description

Luigi Cosenza is the most representative member of the Neapolitan School that during the last half-century has made a significant contribution to Italian architecture.

Luigi Cosenza graduated in engineering from Polytechnic of Naples, his first work was, in 1929, the fish market, a monumental structure with large flat surfaces and long, narrow openings dominated by a large barrel vault. The project of the building was studied together with the reorganization of via Marina. During the Thirties he wrote for the architectural reviews Casabella and Domus and started collaboration with Bernard Rudofsky, a Wiener architect who had worked with Mendelsohn and other European architects.

During this decade he studied the single-family houses, designing villa Oro and villa Savarese on the hill of Posillipo, connecting his work to the Mediterranean architecture of the Gulf of Naples and the Rationalist stream of contemporary architecture. After the Second World War, the project of the Termini Railway station in Rome (1947) and the "circolo della Stampa" in Naples, underlined his rationalist calling. His goals were not limited to the design phase of a single building, but were related with those economic and social aspects that influence the life of a city.

In fact the architectonical design during these years went with the urban planning, the cultural commitment went with the political one, and despite of the tumultuous growth of the city of Naples, he was able to build several plan like his proposals for the destroyed areas in the Masterplan of Naples, the Reconstruction Plan of Torre Annunziata, the Reconstruction Plan of via Marina, the Detail Plan of Fuorigrotta and Bagnoli. He presented the "grid" for Naples at the CIAM congress of Bergamo in 1949, in which the Reconstruction Plan of the city was mainly described under the economic and financial point of view.

From 1948 to 1958 he was Professor of Architecture Composition and Building Design at the Faculty of Engineering of Naples.

Unusual, compared with the common practice in south Italy, was the collaboration between Adriano Olivetti and Luigi Cosenza, the architect in fact was entrusted in 1951 to build a factory near Pozzuoli, and a neighborhood for the workers (widened from 1958 to 1959), with the collaboration of Marcello Nizzoli. During the second half of the fifties he designed and built the Politecnico of Napoli, the elementary school of Resina, near Ercolano, the post office in Torre Annunziata. From 1959 to 1965 he addressed planning, seen as the great hope of rational development of the territory.

He made the plans of Torre Annunziata, Ercolano, Campi Flegrei, Aversano, with a special care for the various aspects of social growth: unemployment, building industrialization, housing, leisure time, transportations, but at this point, in contrast with the University, he left the Faculty of Engineering, the INU (Istituto Nazionale di Urbanistica) and several project and construction site, tired and upset, because of the impossibility to balance between architecture and urbanism, without being able to control economic variables.

After this traumatic setback, the creative process re-started with the help of Giancarlo Cosenza, he completed some pavilion for the Olivetti, laboratories for the Polytechnic, the Landys&Gyr factory in Salerno, and in 1974 he designed the enlargement of the Galleria Nazionale di Arte Moderna in Rome, started in 1965. He died in 1984.

"Quartiere INA-Olivetti" is a residential housing 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.

Fig. 5. 1: Quartiere INA_Olivetti, Pozzuoli (NA). Aerial photography and Plan

Fig. 5. 2: Quartiere INA-Olivetti, Pozzuoli (NA). Old aerial photos and inauguration in 1956. (From the book “Luigi Cosenza oggi, 1905-2005” A. Buccaro, G. Mainini, CLEAN, Napoli 2006.

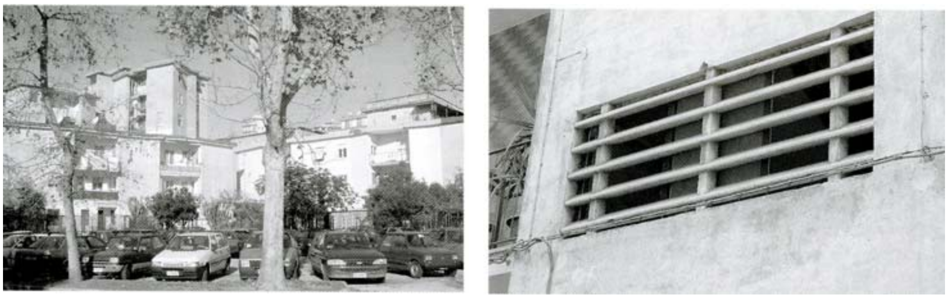

Fig. 5. 3: Inner court and concrete shading system (from P .G Bardelli,: L'architettura INA Casa (1949-1963): aspetti e problemi di conservazione e recupero, Gangemi Editori 2003).

The buildings have three floors and their typology changes in the different batches a bit, reflecting the evolution of the design through time.

The one studied belongs to the first (and maybe most intersting) batch. The one built between 1952 and 1956, year of the inauguration (Fig. 5.1).

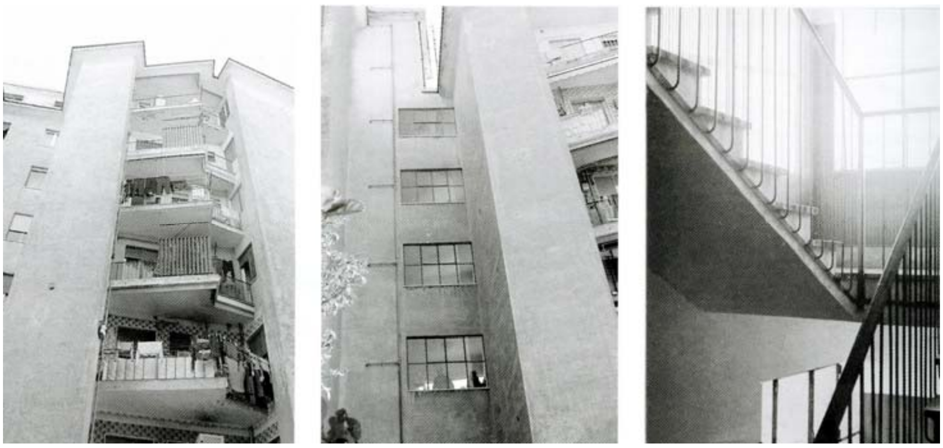

Fig. 5. 4: Shading system and staircase (from P .G Bardelli,: L'architettura INA Casa (1949-1963): aspetti e problemi di conservazione e recupero, Gangemi Editori 2003).

Still quite original for the shape of the building and the studies conducted by the author about circulation, the housing conplex is, as for Zevi before, obsolete in terms of tecnologies, but of good quality in terms of architectural spaces.

Some buildings have the typical neapolitan courtyard, centre of community life, surrounded by the buildings connected by open stairways.

5.2 Modeling

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: concrete frame structure and tuff walls. Even in this case the site inspection revealed a lack of uniformity in the condition of the neighborhood.

Fig. 5. 5: Quartiere INA-Olivetti, Pozzuoli (NA). Today

Dwellings have no insulation, few have single glazing and one still the single glazing and steel frame designed by Cosenza. Few others standard double glazing, but the general condition is better then the one in Salerno.

Fig. 5. 6: Quartiere INA-Olivetti, Pozzuoli (NA). Today. Tuff walls under the plaster

The position of the housing complex, with a magnificent view of the bay and the Anfiteatro Flavio, the proximity to the city center, and the original and nice arrangement scheme of the buildings clinging to the hill, make this a very interesting housing complex.

As before it was necessary to model (in a very simple and schematic way) the building. Again the first thing to do is to set the location. Setting the location will defines the geographical location and weather data for all buildings on this site.

The main weather station, able to provide all these data is Napoli Capodichino; Pozzuoli and Naples are near enough (less than 20 km) to assume the same weather conditions without committing a big mistake.

Adding the location, all weather data and information related with legislative region (Italy in this case) and Energy Code/Insulation Standard are updated.

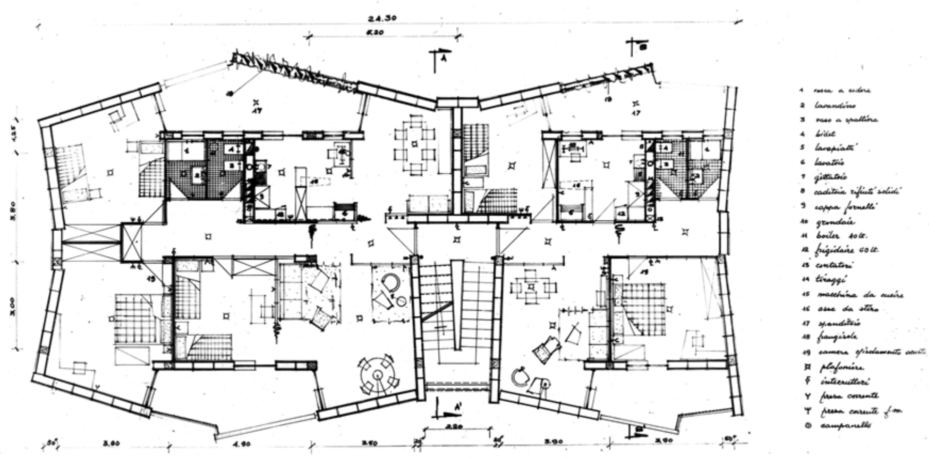

Fig. 5. 7: Quartiere INA-Olivetti, Pozzuoli, by Luigi Cosenza. Plan of a typical floor. (from the book: "Luigi Cosenza oggi, 1905-2005" A. Buccaro, G. Mainini, CLEAN, Napoli 2006).

In INA-Olivetti neighborhood the building type is different, it is no longer an "on a string" kind of building, but we have separate blocks.

Even in this case however the block is repeated several times in the site (with very few changes), so as before, it is possible to model just one, and then check the result for the other simply changing the orientation in the site panel

The software allows to import 2-D floor plans from DXF and bitmaps to help drawing blocks and partitions.

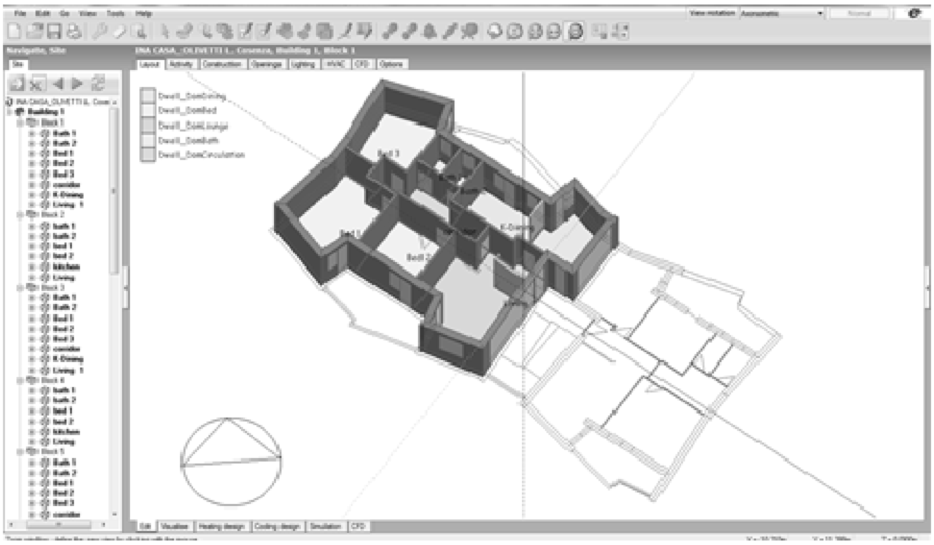

Fig. 5. 8:DesignBuilder-Ina-Olivetti, Standard Building. First floor.

After drowing walls ad partitions, again it's necessary to associate different characteristics to every room, both in terms of "usage" and materials. With the "activity" button template, occupancy, metabolism of the occupants, information about environmental control and lighting can be assigned.

Properties assigned to each room are listed below (bigger unit of about $115m^2$):

Living room:

- Occupancy: density= 0.02 people/m^2
  Schedule: Compact,[2]

[2] Using the Compact Schedule definition all the features of the schedule components are accessed in a single command. Each Compact Schedule must cover all the days for a year and it must have values for all 24 hours and all values for all day types.

Dwell_DomLounge_Occ,
Fraction, Through: 31 Dec,
For: Weekdays SummerDesignDay, Until: 18:00, 0,
Until: 22:00, 0.75, Until: 23:00, 0.5, Until: 24:00, 0,
For: Weekends, Until: 10:00, 0,
Until: 17:00, 0.1, Until: 18:00, 0.25,
Until: 23:00, 0.75, Until: 24:00, 0.5,
For: Holidays, Until: 24:00, 0,
For: WinterDesignDay AllOtherDays,
Until: 24:00, 0;

- Metabolic activity: eating/drinking= 110.0 (metabolic rate per person)
- Clothing: winter clothing (clo)= 1.00 summer clothing (clo) 0.50
- DHW (domestic hot water): comsuption rate (l/m^2-day) = 0.53
- Environmental control:
    - Heating Setpoint Temperatures: heating (°C)= 21.0
      Heating set back (°C) = 12.0
    - Cooling Setpoit Temperature: cooling (°C) = 25.0
      Cooling set back (°C) = 28 °C
    - Ventilation Setpoint Temperature
      Natural Ventilation cooling (°C): 22
      Max in-out ΔT : -50
    - Minimum Fresh air (l/s-person): 10.0
    - Lighting, target illuminance (lux) : 150
- Office Equipment: ON, Gains (W/m2) : 5.0
  Radiant fraction: 0.2
- Lighting: (template = Italy) ON[3]
  Lighting energy (W/m^2-100 lux) = 3.40

Each Compact Schedule must contain the elements Through (date), For (days), Interpolate (optional), Until (time of day) and Value. This field starts with 'For: ' and contains the applicable days. Multiple choices may be combined on the line. The field Until contains the ending time for the current days and day schedule being defined. Finally, the value field is the schedule value for the specified time interval. "0" means OFF o that the system is switched off during the specified period, otherwise "1" means ON.

[3] In this case the contribution of lighting has been considered.

Schedule: Compact, Dwell_DomLounge_Light,
Fraction, Through: 31 Dec,
For: Weekdays SummerDesignDay,
Until: 18:00, 0, Until: 23:00, 1, Until: 24:00, 0,
For: Weekends, Until: 10:00, 0, Until: 24:00, 1,
For: Holidays, Until: 24:00, 0,
For: WinterDesignDay AllOtherDays, Until: 24:00, 0;

- Luminaire Type: suspended
- Radiant fraction: 0.42
- Visible fraction: 0.18
- Lighting contol ON (linear type)
- Maximun allowable glare index: 22.0

Kitchen/ dining room:

- Occupancy: density= 0.02 people/m^2
- Schedule:Compact, Dwell_DomDining_Occ,
  Fraction, Through: 31 Dec,
  For: Weekdays SummerDesignDay, Until: 07:00, 0,
  Until: 09:00, 0.5, Until: 18:00, 0,
  Until: 20:00, 0.5, Until: 24:00, 0,
  For: Weekends, Until: 09:00, 0,
  Until: 11:00, 0.5 Until: 13:00, 0,
  Until: 14:00, 0.5, Until: 18:00, 0,
  Until: 21:00, 0.5, Until: 24:00, 0,
  For: Holidays, Until: 24:00, 0,
  For: WinterDesignDay AllOtherDays, Until: 24:00, 0;
- Metabolic activity: eating/drinking= 110.0 (metabolic rate per person)
- Clothing: winter clothing (clo)= 1.00 summer clothing (clo) 0.50
- DHW (domestic hot water): comsuption rate (l/m^2-day) = 0.53
- Environmental control:
  - Heating Setpoint Temperatures: heating (°C)= 21.0
    Heating set back (°C) = 12.0
  - Cooling Setpoit Temperature: cooling (°C) = 25.0
    Cooling set back (°C) = 28 °C
  - Ventilation Setpoint Temperature
    Natural Ventilation cooling (°C): 22

Max in-out ΔT : -50
- Minimum Fresh air (l/s-person): 10.0
- Lighting, target illuminance (lux) : 150

- Computers: OFF
- Office Equipment: OFF
- Lighting: (template = Italy) ON

Lighting energy (W/m^2-100 lux) = 3.4
Schedule:Compact, Dwell_DomDining_Light,,
Fraction, Through: 31 Dec,
For: Weekdays SummerDesignDay,
For: Weekdays SummerDesignDay,
Until: 07:00, 0, Until: 09:00, 1, Until: 18:00, 0,
Until: 20:00, 1, Until: 24:00, 0,
For: Weekends, Until: 09:00, 0, Until: 11:00, 1,
Until: 13:00, 0, Until: 14:00, 1, Until: 18:00, 0,
Until: 21:00, 1, Until: 24:00, 0,
For: Holidays, Until: 24:00, 0,
For: WinterDesignDay AllOtherDays, Until: 24:00, 0;

- Luminaire Type: suspended
- Radiant fraction: 0.42
- Visible fraction: 0.18
- Lighting contol ON (linear type)
- Maximun allowable glare index: 22.0

Corridor:

- Occupancy: density= 0.02 people/m^2
- Schedule:Compact, Dwell_DomCirculation_Occ,
  Fraction, Through: 31 Dec,
  For: Weekdays SummerDesignDay, Until: 07:00, 0,
  Until: 09:00, 0.1, Until: 18:00, 0,
  Until: 23:00, 0.05, Until: 24:00, 0,
  For: Weekends, Until: 09:00, 0, Until: 24:00, 0.05,
  For: Holidays, Until: 24:00, 0,
  For: WinterDesignDay AllOtherDays, Until: 24:00, 0;
- Metabolic activity: Walking about= 180.0 (metabolic rate per person)
- Clothing: winter clothing (clo)= 1.00 summer clothing (clo) 0.50
- DHW (domestic hot water): comsuption rate (l/m^2-day) = 0.53

- Environmental control:
  - Heating Setpoint Temperatures: heating (°C)= 21.0
    Heating set back (°C) = 12.0
  - Cooling Setpoit Temperature: cooling (°C) = 25.0
    Cooling set back (°C) = 28 °C
  - Ventilation Setpoint Temperature
    Natural Ventilation cooling (°C): 22
    Max in-out ΔT : -50
  - Minimum Fresh air (l/s-person): 10.0
  - Lighting, target illuminance (lux) : 150
- Computers: OFF
- Office Equipment: OFF
- Lighting: (template = Italy) ON
  Lighting energy (W/m^2-100 lux) = 3.4
  Schedule:Compact, Dwell_DomCirculation_Light,
  Fraction, Through: 31 Dec,
  For: Weekdays SummerDesignDay, Until: 07:00, 0.05,
  Until: 09:00, 1, Until: 18:00, 0.05,
  Until: 23:00, 1, Until: 24:00, 0.05,
  For: Weekends, Until: 09:00, 0.05, Until: 24:00, 1,
  For: Holidays, Until: 24:00, 0.05,
  For: WinterDesignDay AllOtherDays, Until: 24:00, 0;
  - Luminaire Type: suspended
  - Radiant fraction: 0.42
  - Visible fraction: 0.18
  - Lighting contol ON (linear type)
  - Maximun allowable glare index: 22.0

Bed 1:

- Occupancy: density= 0.02 people/m^2
- Schedule:Compact, Dwell_DomBed_Occ,
  Fraction, Through: 31 Dec,
  For: Weekdays SummerDesignDay, Until: 07:00, 1,
  Until: 09:00, 0.5, Until: 21:00, 0, Until: 22:00, 0.25,
  Until: 23:00, 0.5, Until: 24:00, 1,
  For: Weekends, Until: 08:00, 1,

Until: 09:00, 0.5, Until: 11:00, 0.25,
Until: 21:00, 0, Until: 22:00, 0.25,
Until: 23:00, 0.5, Until: 24:00, 1,
For: Holidays, Until: 24:00, 0,
For: WinterDesignDay AllOtherDays, Until: 24:00, 0;

- Metabolic activity: Resting= 90 (metabolic rate per person)
- Clothing: winter clothing (clo)= 1.00 summer clothing (clo) 0.50
- DHW (domestic hot water): comsuption rate (l/m^2-day) = 0.53
- Environmental control:
  - Heating Setpoint Temperatures: heating (°C)= 21.0
    Heating set back (°C) = 12.0
  - Cooling Setpoit Temperature: cooling (°C) = 25.0
    Cooling set back (°C) = 28 °C
  - Ventilation Setpoint Temperature
    Natural Ventilation cooling (°C): 22
    Max in-out ΔT : -50
  - Minimum Fresh air (l/s-person): 10.0
  - Lighting, target illuminance (lux) : 150
- Computers: OFF
- Office Equipment: OFF
- Lighting: (template = Italy) ON
  Lighting energy (W/m^2-100 lux) = 3.4
  Schedule:Compact, Dwell_DomBed_Light,
  Fraction, Through: 31 Dec,
  For: Weekdays SummerDesignDay, Until: 07:00, 0,
  Until: 09:00, 1, Until: 18:00, 0,
  Until: 23:00, 1, Until: 24:00, 0,
  For: Weekends, Until: 07:00, 0,
  Until: 09:00, 1, Until: 18:00, 0,
  Until: 23:00, 1, Until: 24:00, 0,
  For: Holidays, Until: 24:00, 0,
  For: WinterDesignDay AllOtherDays, Until: 24:00, 0;
  - Luminaire Type: suspended
  - Radiant fraction: 0.42
  - Visible fraction: 0.18
  - Lighting contol ON (linear type)
  - Maximun allowable glare index: 22.0

Bed 2:

- Occupancy: density= 0.02 people/m^2
- Schedule:Compact, Dwell_DomBed_Occ,
  Fraction, Through: 31 Dec,
  For: Weekdays SummerDesignDay, Until: 07:00, 1,
  Until: 09:00, 0.5, Until: 21:00, 0, Until: 22:00, 0.25,
  Until: 23:00, 0.5, Until: 24:00, 1,
  For: Weekends, Until: 08:00, 1,
  Until: 09:00, 0.5, Until: 11:00, 0.25,
  Until: 21:00, 0, Until: 22:00, 0.25,
  Until: 23:00, 0.5, Until: 24:00, 1,
  For: Holidays, Until: 24:00, 0,
- Metabolic activity: Resting= 90 (metabolic rate per person)
- Clothing: winter clothing (clo)= 1.00 summer clothing (clo) 0.50
- DHW (domestic hot water): comsuption rate (l/m^2-day) = 0.53
- Environmental control:
  - Heating Setpoint Temperatures: heating (°C)= 21.0
    Heating set back (°C) = 12.0
  - Cooling Setpoit Temperature: cooling (°C) = 25.0
    Cooling set back (°C) = 28 °C
  - Ventilation Setpoint Temperature
    Natural Ventilation cooling (°C): 22
    Max in-out ΔT : -50
  - Minimum Fresh air (l/s-person): 10.0
  - Lighting, target illuminance (lux) : 150
- Computers: OFF
- Office Equipment: OFF
- Lighting: (template = Italy) ON
  Lighting energy (W/m^2-100 lux) = 3.4
  Schedule:Compact, Dwell_DomBed_Light,
  Fraction, Through: 31 Dec,
  For: Weekdays SummerDesignDay, Until: 07:00, 0,
  Until: 09:00, 1, Until: 18:00, 0,
  Until: 23:00, 1, Until: 24:00, 0,
  For: Weekends, Until: 07:00, 0,
  Until: 09:00, 1, Until: 18:00, 0,
  Until: 23:00, 1, Until: 24:00, 0,

For: Holidays, Until: 24:00, 0,
For: WinterDesignDay AllOtherDays, Until: 24:00, 0;

- Luminaire Type: suspended
- Radiant fraction: 0.42
- Visible fraction: 0.18
- Lighting contol ON (linear type)
- Maximun allowable glare index: 22.0

Bed 3:

- Occupancy: density= 0.02 people/m^2
- Schedule:Compact, Dwell_DomBed_Occ,
  Fraction, Through: 31 Dec,
  For: Weekdays SummerDesignDay, Until: 07:00, 1,
  Until: 09:00, 0.5, Until: 21:00, 0, Until: 22:00, 0.25,
  Until: 23:00, 0.5, Until: 24:00, 1,
  For: Weekends, Until: 08:00, 1,
  Until: 09:00, 0.5, Until: 11:00, 0.25,
  Until: 21:00, 0, Until: 22:00, 0.25,
  Until: 23:00, 0.5, Until: 24:00, 1,
  For: Holidays, Until: 24:00, 0,
- Metabolic activity: Resting= 90 (metabolic rate per person)
- Clothing: winter clothing (clo)= 1.00 summer clothing (clo) 0.50
- DHW (domestic hot water): comsuption rate (l/m^2-day) = 0.53
- Environmental control:
  - Heating Setpoint Temperatures: heating (°C)= 21.0
    Heating set back (°C) = 12.0
  - Cooling Setpoit Temperature: cooling (°C) = 25.0
    Cooling set back (°C) = 28 °C
  - Ventilation Setpoint Temperature
    Natural Ventilation cooling (°C): 22
    Max in-out ΔT : -50
  - Minimum Fresh air (l/s-person): 10.0
  - Lighting, target illuminance (lux) : 150
- Computers: OFF
- Office Equipment: OFF
- Lighting: (template = Italy) ON

Lighting energy (W/m^2-100 lux) = 3.4
Schedule:Compact, Dwell_DomBed_Light,
Fraction, Through: 31 Dec,
For: Weekdays SummerDesignDay, Until: 07:00, 0,
Until: 09:00, 1, Until: 18:00, 0,
Until: 23:00, 1, Until: 24:00, 0,
For: Weekends, Until: 07:00, 0,
Until: 09:00, 1, Until: 18:00, 0,
Until: 23:00, 1, Until: 24:00, 0,
For: Holidays, Until: 24:00, 0,
For: WinterDesignDay AllOtherDays, Until: 24:00, 0;

- Luminaire Type: suspended
- Radiant fraction: 0.42
- Visible fraction: 0.18
- Lighting contol ON (linear type)
- Maximun allowable glare index: 22.0

Bathroom 1:

- Occupancy: density= 0.02 people/m^2
- Schedule:Compact, Dwell_DomCirculation_Occ,
  Fraction, Through: 31 Dec,
  For: Weekdays SummerDesignDay, Until: 07:00, 0,
  Until: 09:00, 0.1, Until: 18:00, 0,
  Until: 23:00, 0.05, Until: 24:00, 0,
  For: Weekends, Until: 09:00, 0, Until: 24:00, 0.05,
  For: Holidays, Until: 24:00, 0,
  For: WinterDesignDay AllOtherDays, Until: 24:00, 0;
- Metabolic activity: light manual work= 90 (metabolic rate per person)
- Clothing: winter clothing (clo)= 1.00 summer clothing (clo) 0.50
- DHW (domestic hot water): comsuption rate (l/m^2-day) = 0.53
- Environmental control:
  - Heating Setpoint Temperatures: heating (°C)= 21.0
    Heating set back (°C) = 12.0
  - Cooling Setpoit Temperature: cooling (°C) = 25.0
    Cooling set back (°C) = 28 °C
  - Ventilation Setpoint Temperature
    Natural Ventilation cooling (°C): 22

Max in-out ΔT : -50
- Minimum Fresh air (l/s-person): 10.0
- Lighting, target illuminance (lux) : 150

- Computers: OFF
- Office Equipment: OFF
- Lighting: (template = Italy) ON

  Lighting energy (W/m^2-100 lux) = 3.4
  Schedule:Compact, Dwell_DomBath_Light,
  Fraction, Through: 31 Dec,
  For: Weekdays SummerDesignDay,Until: 07:00, 0,
  Until: 09:00, 1, Until: 19:00, 0,
  Until: 22:00, 1, Until: 24:00, 0,
  For: Weekends, Until: 09:00, 0,
  Until: 11:00, 1, Until: 19:00, 0,
  Until: 21:00, 1, Until: 24:00, 0,
  For: Holidays, Until: 24:00, 0,
  For: WinterDesignDay AllOtherDays, Until: 24:00, 0;
  - Luminaire Type: suspended
  - Radiant fraction: 0.42
  - Visible fraction: 0.18
  - Lighting contol ON (linear type)
  - Maximun allowable glare index: 22.0

Bathroom 2:

- Occupancy: density= 0.04 people/m^2
- Schedule:Compact, Dwell_DomCirculation_Occ,
  Fraction, Through: 31 Dec,
  For: Weekdays SummerDesignDay, Until: 07:00, 0,
  Until: 09:00, 0.1, Until: 18:00, 0,
  Until: 23:00, 0.05, Until: 24:00, 0,
  For: Weekends, Until: 09:00, 0, Until: 24:00, 0.05,
  For: Holidays, Until: 24:00, 0,
  For: WinterDesignDay AllOtherDays, Until: 24:00, 0;
- Metabolic activity: light manual work= 90 (metabolic rate per person)

- Clothing: winter clothing (clo)= 1.00 summer clothing (clo) 0.50
- DHW (domestic hot water): comsuption rate (l/m^2-day) = 0.53
- Environmental control:
  - Heating Setpoint Temperatures: heating (°C)= 21.0
    Heating set back (°C) = 12.0
  - Cooling Setpoit Temperature: cooling (°C) = 25.0
    Cooling set back (°C) = 28 °C
  - Ventilation Setpoint Temperature
    Natural Ventilation cooling (°C): 22
    Max in-out ΔT : -50
  - Minimum Fresh air (l/s-person): 10.0
  - Lighting, target illuminance (lux) : 150
- Computers: OFF
- Office Equipment: OFF
- Lighting: (template = Italy) ON
  Lighting energy (W/m^2-100 lux) = 3.4
  Schedule:Compact, Dwell_DomBath_Light,
  Fraction, Through: 31 Dec,
  For: Weekdays SummerDesignDay,Until: 07:00, 0,
  Until: 09:00, 1, Until: 19:00, 0,
  Until: 22:00, 1, Until: 24:00, 0,
  For: Weekends, Until: 09:00, 0,
  Until: 11:00, 1, Until: 19:00, 0,
  Until: 21:00, 1, Until: 24:00, 0,
  For: Holidays, Until: 24:00, 0,
  For: WinterDesignDay AllOtherDays, Until: 24:00, 0;
  - Luminaire Type: suspended
  - Radiant fraction: 0.42
  - Visible fraction: 0.18
  - Lighting contol ON (linear type)
  - Maximun allowable glare index: 22.0

Properties assigned to each room of the smaller unit (of about 78m^2) are listed in the following pages:

Living room:

- Occupancy: density= 0.02 people/m^2
  Schedule: Compact,
  Dwell_DomLounge_Occ,
  Fraction, Through: 31 Dec,
  For: Weekdays SummerDesignDay, Until: 18:00, 0,
  Until: 22:00, 0.75, Until: 23:00, 0.5, Until: 24:00, 0,
  For: Weekends, Until: 10:00, 0,
  Until: 17:00, 0.1, Until: 18:00, 0.25,
  Until: 23:00, 0.75, Until: 24:00, 0.5,
  For: Holidays, Until: 24:00, 0,
  For: WinterDesignDay AllOtherDays,
  Until: 24:00, 0;
- Metabolic activity: eating/drinking= 110.0 (metabolic rate per person)
- Clothing: winter clothing (clo)= 1.00 summer clothing (clo) 0.50
- DHW (domestic hot water): comsuption rate (l/m^2-day) = 0.53
- Environmental control:
  - Heating Setpoint Temperatures: heating (°C)= 21.0
    Heating set back (°C) = 12.0
  - Cooling Setpoit Temperature: cooling (°C) = 25.0
    Cooling set back (°C) = 28 °C
  - Ventilation Setpoint Temperature
    Natural Ventilation cooling (°C): 22
    Max in-out ΔT : -50
  - Minimum Fresh air (l/s-person): 10.0
  - Lighting, target illuminance (lux) : 150
- Office Equipment: ON, Gains (W/m2) : 5.0
  Radiant fraction: 0.2
- Lighting: (template = Italy) ON[4]
  Lighting energy (W/m^2-100 lux) = 3.40
  Schedule: Compact, Dwell_DomLounge_Light,
  Fraction, Through: 31 Dec,
  For: Weekdays SummerDesignDay,

[4] In this case the contribution of lighting has been considered.

Until: 18:00, 0, Until: 23:00, 1, Until: 24:00, 0,
For: Weekends, Until: 10:00, 0, Until: 24:00, 1,
For: Holidays, Until: 24:00, 0,
For: WinterDesignDay AllOtherDays, Until: 24:00, 0;

- Luminaire Type: suspended
- Radiant fraction: 0.42
- Visible fraction: 0.18
- Lighting contol ON (linear type)
- Maximun allowable glare index: 22.0

Kitchen/ dining room:

- Occupancy: density= 0.02 people/m^2
- Schedule:Compact, Dwell_DomDining_Occ,
  Fraction, Through: 31 Dec,
  For: Weekdays SummerDesignDay, Until: 07:00, 0,
  Until: 09:00, 0.5, Until: 18:00, 0,
  Until: 20:00, 0.5, Until: 24:00, 0,
  For: Weekends, Until: 09:00, 0,
  Until: 11:00, 0.5 Until: 13:00, 0,
  Until: 14:00, 0.5, Until: 18:00, 0,
  Until: 21:00, 0.5, Until: 24:00, 0,
  For: Holidays, Until: 24:00, 0,
  For: WinterDesignDay AllOtherDays, Until: 24:00, 0;
- Metabolic activity: eating/drinking= 110.0 (metabolic rate per person)
- Clothing: winter clothing (clo)= 1.00 summer clothing (clo) 0.50
- DHW (domestic hot water): comsuption rate (l/m^2-day) = 0.53
- Environmental control:
  - Heating Setpoint Temperatures: heating (°C)= 21.0
    Heating set back (°C) = 12.0
  - Cooling Setpoit Temperature: cooling (°C) = 25.0
    Cooling set back (°C) = 28 °C
  - Ventilation Setpoint Temperature
    Natural Ventilation cooling (°C): 22
    Max in-out ΔT : -50
  - Minimum Fresh air (l/s-person): 10.0
  - Lighting, target illuminance (lux) : 150

- Computers: OFF
- Office Equipment: OFF
- Lighting: (template = Italy) ON
  Lighting energy (W/m^2-100 lux) = 3.4
  Schedule:Compact, Dwell_DomDining_Light,,
  Fraction, Through: 31 Dec,
  For: Weekdays SummerDesignDay,
  For: Weekdays SummerDesignDay,
  Until: 07:00, 0, Until: 09:00, 1, Until: 18:00, 0,
  Until: 20:00, 1, Until: 24:00, 0,
  For: Weekends, Until: 09:00, 0, Until: 11:00, 1,
  Until: 13:00, 0, Until: 14:00, 1, Until: 18:00, 0,
  Until: 21:00, 1, Until: 24:00, 0,
  For: Holidays, Until: 24:00, 0,
  For: WinterDesignDay AllOtherDays, Until: 24:00, 0;
  - Luminaire Type: suspended
  - Radiant fraction: 0.42
  - Visible fraction: 0.18
  - Lighting contol ON (linear type)
  - Maximun allowable glare index: 22.0

Bed 1:

- Occupancy: density= 0.02 people/m^2
- Schedule:Compact, Dwell_DomBed_Occ,
  Fraction, Through: 31 Dec,
  For: Weekdays SummerDesignDay, Until: 07:00, 1,
  Until: 09:00, 0.5, Until: 21:00, 0, Until: 22:00, 0.25,
  Until: 23:00, 0.5, Until: 24:00, 1,
  For: Weekends, Until: 08:00, 1,
  Until: 09:00, 0.5, Until: 11:00, 0.25,
  Until: 21:00, 0, Until: 22:00, 0.25,
  Until: 23:00, 0.5, Until: 24:00, 1,
  For: Holidays, Until: 24:00, 0,
  For: WinterDesignDay AllOtherDays, Until: 24:00, 0;
- Metabolic activity: Resting= 90 (metabolic rate per person)
- Clothing: winter clothing (clo)= 1.00 summer clothing (clo) 0.50
- DHW (domestic hot water): comsuption rate (l/m^2-day) = 0.53

- Environmental control:
  - Heating Setpoint Temperatures: heating (°C)= 21.0
    Heating set back (°C) = 12.0
  - Cooling Setpoit Temperature: cooling (°C) = 25.0
    Cooling set back (°C) = 28 °C
  - Ventilation Setpoint Temperature
    Natural Ventilation cooling (°C): 22
    Max in-out ΔT : -50
  - Minimum Fresh air (l/s-person): 10.0
  - Lighting, target illuminance (lux) : 150
- Computers: OFF
- Office Equipment: OFF
- Lighting: (template = Italy) ON

  Lighting energy (W/m^2-100 lux) = 3.4
  Schedule:Compact, Dwell_DomBed_Light,
  Fraction, Through: 31 Dec,
  For: Weekdays SummerDesignDay, Until: 07:00, 0,
  Until: 09:00, 1, Until: 18:00, 0,
  Until: 23:00, 1, Until: 24:00, 0,
  For: Weekends, Until: 07:00, 0,
  Until: 09:00, 1, Until: 18:00, 0,
  Until: 23:00, 1, Until: 24:00, 0,
  For: Holidays, Until: 24:00, 0,
  For: WinterDesignDay AllOtherDays, Until: 24:00, 0;
  - Luminaire Type: suspended
  - Radiant fraction: 0.42
  - Visible fraction: 0.18
  - Lighting contol ON (linear type)
  - Maximun allowable glare index: 22.0

Bed 2:

- Occupancy: density= 0.02 people/m^2
- Schedule:Compact, Dwell_DomBed_Occ,
  Fraction, Through: 31 Dec,
  For: Weekdays SummerDesignDay, Until: 07:00, 1,
  Until: 09:00, 0.5, Until: 21:00, 0, Until: 22:00, 0.25,
  Until: 23:00, 0.5, Until: 24:00, 1,

For: Weekends, Until: 08:00, 1,
Until: 09:00, 0.5, Until: 11:00, 0.25,
Until: 21:00, 0, Until: 22:00, 0.25,
Until: 23:00, 0.5, Until: 24:00, 1,
For: Holidays, Until: 24:00, 0,

- Metabolic activity: Resting= 90 (metabolic rate per person)
- Clothing: winter clothing (clo)= 1.00 summer clothing (clo) 0.50
- DHW (domestic hot water): comsuption rate (l/m^2-day) = 0.53
- Environmental control:
  - Heating Setpoint Temperatures: heating (°C)= 21.0
    Heating set back (°C) = 12.0
  - Cooling Setpoit Temperature: cooling (°C) = 25.0
    Cooling set back (°C) = 28 °C
  - Ventilation Setpoint Temperature
    Natural Ventilation cooling (°C): 22
    Max in-out ΔT : -50
  - Minimum Fresh air (l/s-person): 10.0
  - Lighting, target illuminance (lux) : 150
- Computers: OFF
- Office Equipment: OFF
- Lighting: (template = Italy) ON

  Lighting energy (W/m^2-100 lux) = 3.4
  Schedule:Compact, Dwell_DomBed_Light,
  Fraction, Through: 31 Dec,
  For: Weekdays SummerDesignDay, Until: 07:00, 0,
  Until: 09:00, 1, Until: 18:00, 0,
  Until: 23:00, 1, Until: 24:00, 0,
  For: Weekends, Until: 07:00, 0,
  Until: 09:00, 1, Until: 18:00, 0,
  Until: 23:00, 1, Until: 24:00, 0,
  For: Holidays, Until: 24:00, 0,
  For: WinterDesignDay AllOtherDays, Until: 24:00, 0;
  - Luminaire Type: suspended
  - Radiant fraction: 0.42
  - Visible fraction: 0.18
  - Lighting contol ON (linear type)
  - Maximun allowable glare index: 22.0

Bathroom 1:

- Occupancy: density= 0.02 people/m^2
- Schedule:Compact, Dwell_DomCirculation_Occ,
  Fraction, Through: 31 Dec,
  For: Weekdays SummerDesignDay, Until: 07:00, 0,
  Until: 09:00, 0.1, Until: 18:00, 0,
  Until: 23:00, 0.05, Until: 24:00, 0,
  For: Weekends, Until: 09:00, 0, Until: 24:00, 0.05,
  For: Holidays, Until: 24:00, 0,
  For: WinterDesignDay AllOtherDays, Until: 24:00, 0;
- Metabolic activity: light work= 120.0 (metabolic rate per person)
- Clothing: winter clothing (clo)= 1.00 summer clothing (clo) 0.50
- DHW (domestic hot water): comsuption rate (l/m^2-day) = 0.53
- Environmental control:
    - Heating Setpoint Temperatures: heating (°C)= 21.0
      Heating set back (°C) = 12.0
    - Cooling Setpoit Temperature: cooling (°C) = 25.0
      Cooling set back (°C) = 28 °C
    - Ventilation Setpoint Temperature
      Natural Ventilation cooling (°C): 22
      Max in-out ΔT : -50
    - Minimum Fresh air (l/s-person): 10.0
    - Lighting, target illuminance (lux) : 150
- Computers: OFF
- Office Equipment: OFF
- Lighting: (template = Italy) ON
  Lighting energy (W/m^2-100 lux) = 3.4
  Schedule:Compact, Dwell_DomBath_Light,
  Fraction, Through: 31 Dec,
  For: Weekdays SummerDesignDay,Until: 07:00, 0,
  Until: 09:00, 1, Until: 19:00, 0,
  Until: 22:00, 1, Until: 24:00, 0,
  For: Weekends, Until: 09:00, 0,
  Until: 11:00, 1, Until: 19:00, 0,
  Until: 21:00, 1, Until: 24:00, 0,
  For: Holidays, Until: 24:00, 0,

For: WinterDesignDay AllOtherDays, Until: 24:00, 0;
- Luminaire Type: suspended
- Radiant fraction: 0.42
- Visible fraction: 0.18
- Lighting contol ON (linear type)
- Maximun allowable glare index: 22.0

Bathroom 2:

- Occupancy: density= 0.04 people/m^2
- Schedule:Compact, Dwell_DomCirculation_Occ,
  Fraction, Through: 31 Dec,
  For: Weekdays SummerDesignDay, Until: 07:00, 0,
  Until: 09:00, 0.1, Until: 18:00, 0,
  Until: 23:00, 0.05, Until: 24:00, 0,
  For: Weekends, Until: 09:00, 0, Until: 24:00, 0.05,
  For: Holidays, Until: 24:00, 0,
  For: WinterDesignDay AllOtherDays, Until: 24:00, 0;
- Metabolic activity: light work= 120.0 (metabolic rate per person)
- Clothing: winter clothing (clo)= 1.00 summer clothing (clo) 0.50
- DHW (domestic hot water): comsuption rate (l/m^2-day) = 0.53
- Environmental control:
  - Heating Setpoint Temperatures: heating (°C)= 21.0
    Heating set back (°C) = 12.0
  - Cooling Setpoit Temperature: cooling (°C) = 25.0
    Cooling set back (°C) = 28 °C
  - Ventilation Setpoint Temperature
    Natural Ventilation cooling (°C): 22
    Max in-out ΔT : -50
  - Minimum Fresh air (l/s-person): 10.0
  - Lighting, target illuminance (lux) : 150
- Computers: OFF
- Office Equipment: OFF
- Lighting: (template = Italy) ON
  Lighting energy (W/m^2-100 lux) = 3.4
  Schedule:Compact, Dwell_DomBath_Light,
  Fraction, Through: 31 Dec,

For: Weekdays SummerDesignDay,Until: 07:00, 0,
Until: 09:00, 1, Until: 19:00, 0,
Until: 22:00, 1, Until: 24:00, 0,
For: Weekends, Until: 09:00, 0,
Until: 11:00, 1, Until: 19:00, 0,
Until: 21:00, 1, Until: 24:00, 0,
For: Holidays, Until: 24:00, 0,
For: WinterDesignDay AllOtherDays, Until: 24:00, 0;

- Luminaire Type: suspended
- Radiant fraction: 0.42
- Visible fraction: 0.18
- Lighting contol ON (linear type)
- Maximun allowable glare index: 22.0

After completed the section “Activity” the programs allows to add information related to construction and materials. Walls, roof, ceilings and floors, doors etc…can be defined for the specific case.

First of all walls can be devided in external walls and internal walls or partitions. When the Floor/slab/ceiling representation model option is set to “Combined” the surface types and the constructions will be applied automatically according to the locations or orientation.

The properties added for each are listed as follow:

- External Walls:
  Category: Walls, Region: Italy
  Number of layers: 3
  - Outermost layer: Plaster (Dense)
    Thickness (m): 0.02

    Thermal properties
    - Conductivity (W/mK): 0.500
    - Specific heat (J/kgK) 1000.0
    - Density (kg/m^3) 1300.0

    Surface properties
    - Thermal absorptance: 0.900
    - Solar absorptance: 0.500
    - Visible absorptance : 0.500

- Layer 2: Tuff

  Thickness ((m): 0.350

  Source: ISO 10456

  Thermal properties
  - Conductivity (W/mK): 0.630
  - Specific heat (J/kgK) 1300.0
  - Density (kg/m^3) 1500.0

  Surface properties
  - Thermal absorptance: 0.900
  - Solar absorptance: 0.600
  - Visible absorptance : 0.600
  - Color : yellow

- Innemost layer: Plaster (lightweight)

  Thickness (m): 0.0150

  Thermal properties
  - Conductivity (W/mK): 0.160
  - Specific heat (J/kgK) 1000.0
  - Density (kg/m^3) 600.0

  Surface properties
  - Thermal absorptance: 0.900
  - Solar absorptance: 0.500
  - Visible absorptance : 0.500

• Internal Walls (partitions):
  Category: Walls; Region: Italy
  Number of layers: 3

- Outermost layer: Plaster

  Source: ISO 10456

  Thickness (m): 0.025

  Thermal properties
  - Conductivity (W/mK): 0.250
  - Specific heat (J/kgK) 1000.0
  - Density (kg/m^3) 900.0

  - Thermal absorptance: 0.900

Surface properties Solar absorptance: 0.500
Visible absorptance: 0.500

- Layer 2: Laterizio forato
  Thickness (m): 0.100
  Source: user defined
  Thermal properties
  Conductivity (W/mK): 0.182
  Specific heat (J/kgK) 840.0
  Density (kg/m^3) 700.0

  Surface properties
  Thermal absorptance: 0.900
  Solar absorptance: 0.700
  Visible absorptance : 0.700

- Innemost layer: Plaster
  Source: ISO 10456
  Thickness (m): 0.0250
  Thermal properties
  Conductivity (W/mK): 0.250
  Specific heat (J/kgK) 1000.0
  Density (kg/m^3) 900.0

  Surface properties
  Thermal absorptance: 0.900
  Solar absorptance: 0.500
  Visible absorptance : 0.500

• Roof: Falt roof
  Category: Roofs;
  Number of layers: 3
- Outermost layer: Bitumen, felt/sheet
  Source: ISO 10456
  Thickness (m): 0.019
  Thermal properties
  Conductivity (W/mK): 0.700
  Specific heat (J/kgK) 1000.0
  Density (kg/m^3) 2100.0

  Surface properties
  Thermal absorptance: 0.900
  Solar absorptance: 0.850

Visible absorptance: 0.850

- Layer 2: Fibreboard

Thickness (m): 0.013

Thermal properties
- Conductivity (W/mK): 0.060
- Specific heat (J/kgK) 1000.0
- Density (kg/m^3) 300.0

Surface properties
- Thermal absorptance: 0.900
- Solar absorptance: 0.600
- Visible absorptance : 0.600

- Innemost layer: XPS Expanded Polystirene

Thickness (m): 0.1220

Thermal properties
- Conductivity (W/mK): 0.034
- Specific heat (J/kgK) 1400.0
- Density (kg/m^3) 35.0

Surface properties
- Thermal absorptance: 0.900
- Solar absorptance: 0.600
- Visible absorptance : 0.600

Unintentional infiltration rate can be set and is constant:
Airtightness (building): 0.05 ac/h
Airtightness (roof): 1.00 ac/h

Once defined materials and thermal properties of walls and roof, properties of windows has to be defined.

As said in the previous paragraph the site inspection revealed a lack of uniformity in the condition of the neighbourhood, not all the current owners raplaced windows with new, and more efficient, ones, but the double glazing and wood frame seems to be the more popular, so in this case the “initial condition” or so called “current” one is the one with new (or semi-new) windows.

- Windows (Dbl clr6mm/13mm Air)
  - Source: EnergyPlus dataset
  - Region: General
  - Layers: 3

  Outermost pane: generic clear 6mm

	Thickness (mm): 6.00
Thermal properties	Conductivity (W/mK): 0.900
Solar properties	Solar trasmittance: 0.775 Outside solar trasmittance: 0.071 Inside solar trasmittancece : 0.071
Visible properties	Visibler trasmittance: 0.881 Outside visible reflectance: 0.080 Inside visible reflectance : 0.080

  Windows gas type: Air 13mm

  Source: BS EN 673 / E+

  Innermost pane: generic clear 6mm

	Thickness (mm): 6.00
Thermal properties	Conductivity (W/mK): 0.900
Solar properties	Solar trasmittance: 0.775 Outside solar trasmittance: 0.071 Inside solar trasmittancece : 0.071
Visible properties	Visibler trasmittance: 0.881 Outside visible reflectance: 0.080 Inside visible reflectance : 0.080

Last step is to define the HVAC: Heating, Ventilation and Air Conditioning.

As done before no mechanical ventilation was provided, the first resource used for summer cooling has been natural ventilation, assisted by the use of air conditioning to achieve an acceptable level of indoor comfort during the hottest hours of summer days.

Following are features and operating modes of heating, cooling and DHW (Domestic Hot Water).

Natural ventilation (and its schedule) have been added only later, as last step of the analysis.

HVAC Template: Hot water radiator heating, mixed mode with natural ventilation and local comfort cooling.

- Heating:
  - Fuel: Natural Gas
  - CoP[5] (Coefficient of Performance): 0.650
  - Heating distribution loss (%): 5.0
  - Heating Type: Convective
  - Operation: Schedule
    From January to April and from October to December: ON
    Schedule: customized
    From 7:30 to 9:00 ON
    From 9:00 to 12:00 OFF
    From 12:00 to 20:00 ON
    From 20:00 to 24:00 OFF
-
- Cooling:
  - Fuel: Electricity from Grid
  - CoP (Coefficient of Performance): 1.670
  - Supply air temperature (°C): 12.00
  - Supply air humidity ratio (g/g): 0.008
  - Operation: Schedule
    From June to September ON
    Schedule: customized
    From 12:00 to 18:00 ON
    From 18:00 to 12:00 OFF

[5] Heating/cooling system CoP is the whole seasonal coefficient of performance.

- DHW:
  - Type: Instantaneous DHW only
  - CoP (Coefficient of Performance): 0.85
  - Fuel: Natural gas
  - Delivery water temperature (°C): 65.00
  - Main supply temperature (°C): 10.0
  - Operation: Schedule
    From January to December ON
    Schedule: customized
    From 0:00 to 6:00 OFF
    From 6:00 to 10:00 ON
    From 10:00 to 12:00 OFF
    From 12:00 to 15:00 ON
    From 15:00 to 17:00 OFF
    From 17:00 to 23:00 ON

Default boundary conditions for CFD are the same as before:

Inside surface temperature (internal surface) (°C): 20.00
Inside surface temperature (external surface) (°C): 20.00
Inside surface window temperature (°C): 10.00
Average zone air temperature (°C): 22.00
Incoming air temperature (°C): 20.00
Aperture position: top
Aperture size (% total opening area) : 20.0

5.3 Methodology

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)

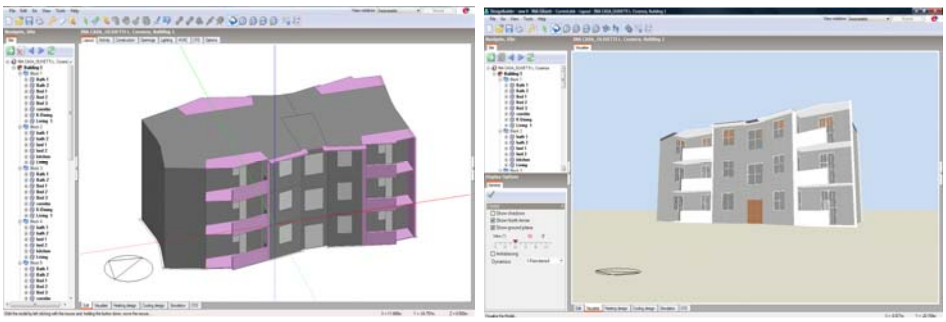

Fig. 5. 9: DesignBuilder Layout (editing mode) and rendering. Case study II: INA-Olivetti, Luigi Cosenza, Pozzuoli, (NA).

As done for the first study case, to make clear the benefits of each intervention, the study was conducted comparing consumption (annual) 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.

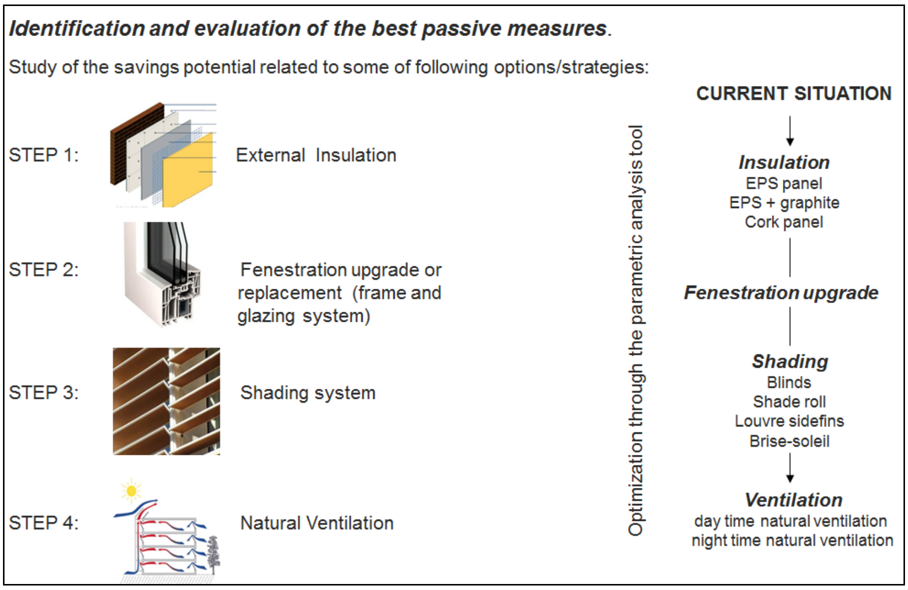

Fig. 5. 10: Schematic diagram showing the subsequent steps procedure applied to the case study.

5.3.1 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 m2k/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 m2k/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/m2K 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^{2}K, 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.

The following graphs and tables show the beneficial effect of the use of thermal insulation in terms of energy savings

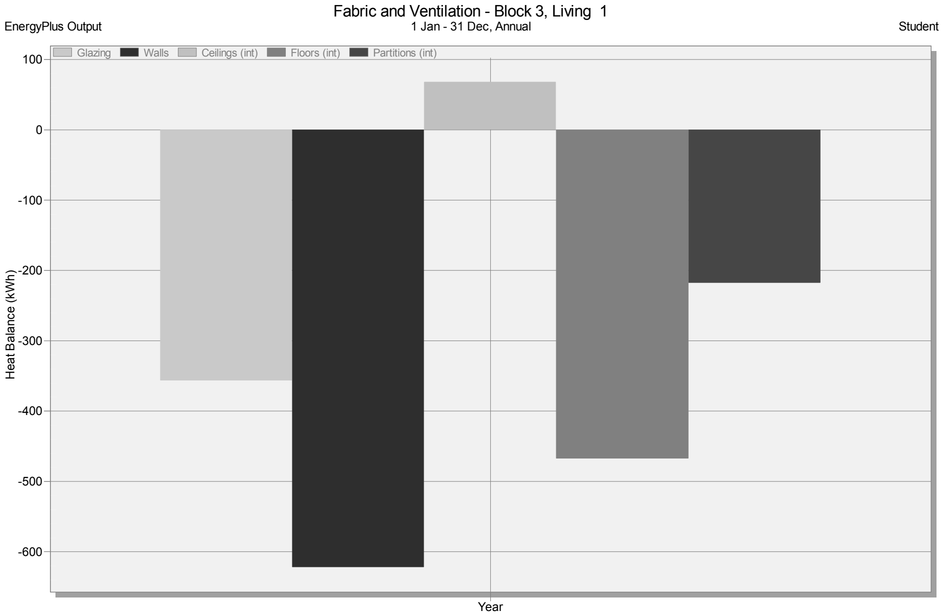

Fig. 5. 11: Current situations, no insulating system. Heat Balance: -622,31 KWh

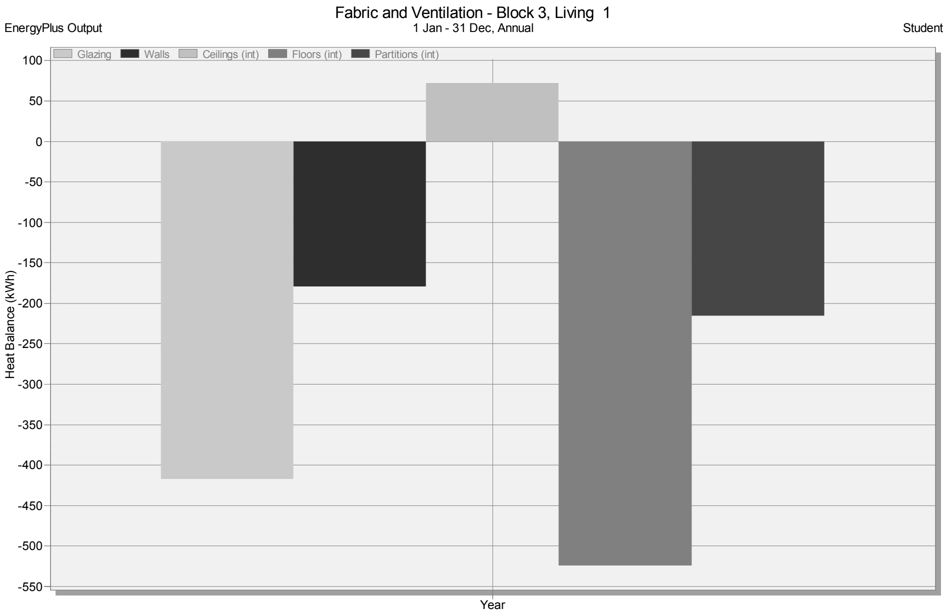

Fig. 5. 12: EPS panel, Heat balance: (through walls: -179,21 KWh)

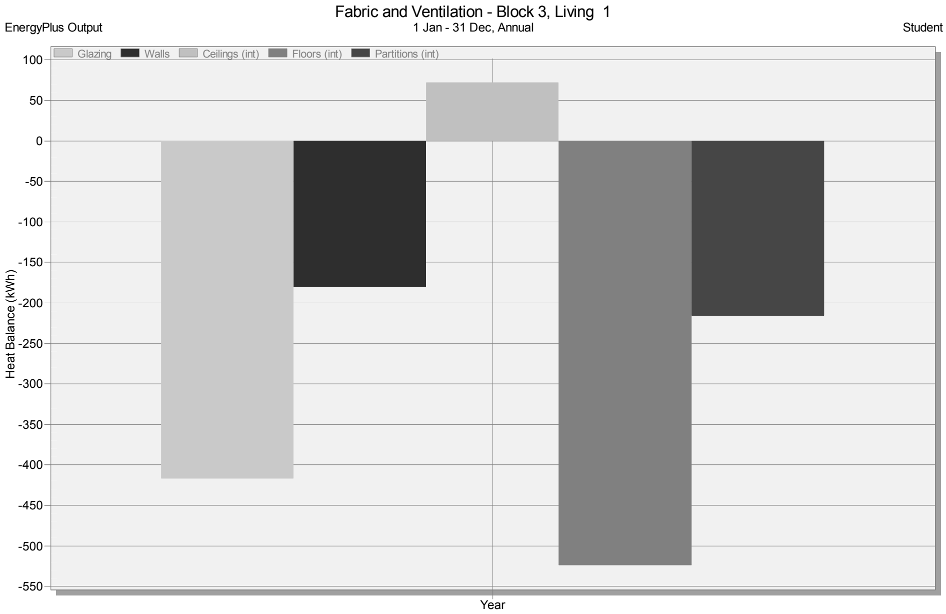

Fig. 5. 13: EPS panel + graphite, Heat balance: (through walls: -180,92 KWh)

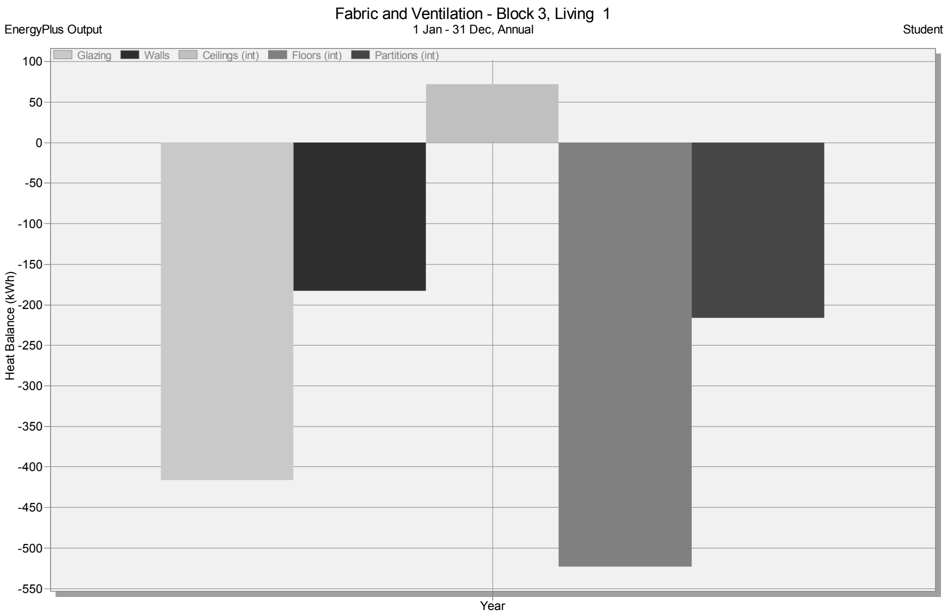

Fig. 5. 14: Cork, Heat balance: (through walls: -183,19 KWh)

Current Situation						
Building	Block	Zone	Comfort Temperature (°C)	Steady-State Loss (kW)	Heat Design (kW)	Capacity
Building 1	I floor	K-Dining	19,2		1,17	1,41
Building 1	I floor	Bed 3	18,84		0,87	1,04
Building 1	I floor	Bed 1	18,87		0,99	1,19
Building 1	I floor	Living 1	19,44		1,13	1,35
Building 1	I floor	Bath 1	19,56		0,18	0,22
Building 1	I floor	Bath 2	19,61		0,16	0,19
Building 1	I floor	corridor	20,28		0,28	0,33
Building 1	I floor	Bed 2	19,52		0,52	0,63
Building 1	I floor	bed 2	19,25		0,63	0,76
Building 1	I floor	Living	19,46		1,28	1,53
Building 1	I floor	bed 1	18,92		0,76	0,91
Building 1	I floor	bath 2	18,7		0,24	0,29
Building 1	I floor	kitchen	19,3		0,49	0,59
Building 1	I floor	bath 1	19,55		0,15	0,18
Building 1	II floor	K-Dining	19,31		1,12	1,34
Building 1	II floor	Bed 3	18,95		0,83	1
Building 1	II floor	Bed 1	18,99		0,95	1,14
Building 1	II floor	Living 1	19,56		1,06	1,28
Building 1	II floor	Bath 1	19,65		0,17	0,2
Building 1	II floor	Bath 2	19,7		0,15	0,18
Building 1	II floor	corridor	20,42		0,24	0,29
Building 1	II floor	Bed 2	19,65		0,49	0,59
Building 1	II floor	bed 2	19,36		0,6	0,73
Building 1	II floor	Living	19,57		1,2	1,44
Building 1	II floor	bed 1	19,03		0,72	0,87
Building 1	II floor	bath 2	18,76		0,24	0,29
Building 1	II floor	kitchen	19,41		0,47	0,56
Building 1	II floor	bath 1	19,63		0,15	0,18
Building 1	III floor	K-Dining	19,23		1,17	1,41
Building 1	III floor	Bed 3	18,88		0,87	1,04
Building 1	III floor	Bed 1	18,92		0,99	1,19
Building 1	III floor	Living 1	19,47		1,13	1,35
Building 1	III floor	Bath 1	19,58		0,18	0,22
Building 1	III floor	Bath 2	19,63		0,16	0,19
Building 1	III floor	corridor	20,32		0,28	0,33
Building 1	III floor	Bed 2	19,56		0,52	0,63
Building 1	III floor	bed 2	19,28		0,63	0,76
Building 1	III floor	Living	19,5		1,27	1,52
Building 1	III floor	bed 1	18,96		0,75	0,9
Building 1	III floor	bath 2	18,71		0,24	0,29
Building 1	III floor	kitchen	19,33		0,49	0,59
Building 1	III floor	bath 1	19,57		0,15	0,18
		TOT			26,07	31,31

Table 5. 1: Summary of heating design, initial situation, defined as “current”.

The tables show the summary of comfort temperature, steady state heat loss and design heating capacity.

Cappotto EPS					
Building	Block	Zone	Comfort Temperature (°C)	Steady-State Heat Loss (kW)	Design Capacity (kW)
Building 1	I floor	K-Dining	19,78	0,82	0,98
Building 1	I floor	Bed 3	19,83	0,48	0,58
Building 1	I floor	Bed 1	19,86	0,55	0,66
Building 1	I floor	Living 1	19,86	0,85	1,01
Building 1	I floor	Bath 1	20,06	0,12	0,14
Building 1	I floor	Bath 2	20,05	0,11	0,13
Building 1	I floor	corridor	20,45	0,23	0,28
Building 1	I floor	Bed 2	19,97	0,38	0,46
Building 1	I floor	bed 2	19,92	0,4	0,48
Building 1	I floor	Living	19,92	0,92	1,1
Building 1	I floor	bed 1	19,79	0,45	0,54
Building 1	I floor	bath 2	19,75	0,12	0,15
Building 1	I floor	kitchen	19,72	0,38	0,45
Building 1	I floor	bath 1	19,98	0,11	0,13
Building 1	II floor	K-Dining	19,91	0,76	0,91
Building 1	II floor	Bed 3	19,98	0,44	0,53
Building 1	II floor	Bed 1	20,01	0,5	0,6
Building 1	II floor	Living 1	20	0,78	0,93
Building 1	II floor	Bath 1	20,17	0,11	0,13
Building 1	II floor	Bath 2	20,16	0,1	0,12
Building 1	II floor	corridor	20,6	0,2	0,24
Building 1	II floor	Bed 2	20,12	0,35	0,42
Building 1	II floor	bed 2	20,05	0,37	0,44
Building 1	II floor	Living	20,05	0,84	1,01
Building 1	II floor	bed 1	19,93	0,41	0,49
Building 1	II floor	bath 2	19,83	0,12	0,14
Building 1	II floor	kitchen	19,85	0,35	0,42
Building 1	II floor	bath 1	20,08	0,1	0,12
Building 1	III floor	K-Dining	19,81	0,82	0,98
Building 1	III floor	Bed 3	19,87	0,48	0,58
Building 1	III floor	Bed 1	19,9	0,55	0,66
Building 1	III floor	Living 1	19,9	0,85	1,02
Building 1	III floor	Bath 1	20,09	0,12	0,14
Building 1	III floor	Bath 2	20,07	0,11	0,13
Building 1	III floor	corridor	20,48	0,23	0,28
Building 1	III floor	Bed 2	20,01	0,38	0,46
Building 1	III floor	bed 2	19,95	0,4	0,48
Building 1	III floor	Living	19,96	0,91	1,1
Building 1	III floor	bed 1	19,83	0,45	0,54
Building 1	III floor	bath 2	19,77	0,12	0,15
Building 1	III floor	kitchen	19,75	0,38	0,46
Building 1	III floor	bath 1	20	0,11	0,13
		TOT		17,26	20,7

CONFRONTO Current situation- EPS							
Building	Block	Zone	Comfort Temperature (°C)	Steady-State Heat Loss (kW)	Design Capacity (kW)	% reduction heat losses	% reduction design capacity
Building 1	I floor	K-Dining	0,58	0,35	0,43	30%	30%
Building 1	I floor	Bed 3	0,99	0,39	0,46	45%	44%
Building 1	I floor	Bed 1	0,99	0,44	0,53	44%	45%
Building 1	I floor	Living 1	0,42	0,28	0,34	25%	25%
Building 1	I floor	Bath 1	0,5	0,06	0,08	33%	36%
Building 1	I floor	Bath 2	0,44	0,05	0,06	31%	32%
Building 1	I floor	corridor	0,17	0,05	0,05	18%	15%
Building 1	I floor	Bed 2	0,45	0,14	0,17	27%	27%
Building 1	I floor	bed 2	0,67	0,23	0,28	37%	37%
Building 1	I floor	Living	0,46	0,36	0,43	28%	28%
Building 1	I floor	bed 1	0,87	0,31	0,37	41%	41%
Building 1	I floor	bath 2	1,05	0,12	0,14	50%	48%
Building 1	I floor	kitchen	0,42	0,11	0,14	22%	24%
Building 1	I floor	bath 1	0,43	0,04	0,05	27%	28%
Building 1	II floor	K-Dining	0,6	0,36	0,43	32%	32%
Building 1	II floor	Bed 3	1,03	0,39	0,47	47%	47%
Building 1	II floor	Bed 1	1,02	0,45	0,54	47%	47%
Building 1	II floor	Living 1	0,44	0,28	0,35	26%	27%
Building 1	II floor	Bath 1	0,52	0,06	0,07	35%	35%
Building 1	II floor	Bath 2	0,46	0,05	0,06	33%	33%
Building 1	II floor	corridor	0,18	0,04	0,05	17%	17%
Building 1	II floor	Bed 2	0,47	0,14	0,17	29%	29%
Building 1	II floor	bed 2	0,69	0,23	0,29	38%	40%
Building 1	II floor	Living	0,48	0,36	0,43	30%	30%
Building 1	II floor	bed 1	0,9	0,31	0,38	43%	44%
Building 1	II floor	bath 2	1,07	0,12	0,15	50%	52%
Building 1	II floor	kitchen	0,44	0,12	0,14	26%	25%
Building 1	II floor	bath 1	0,45	0,05	0,06	33%	33%
Building 1	Block 5	III floor	0,58	0,35	0,43	30%	30%
Building 1	Block 5	III floor	0,99	0,39	0,46	45%	44%
Building 1	Block 5	III floor	0,98	0,44	0,53	44%	45%
Building 1	Block 5	III floor	0,43	0,28	0,33	25%	24%
Building 1	Block 5	III floor	0,51	0,06	0,08	33%	36%
Building 1	Block 5	III floor	0,44	0,05	0,06	31%	32%
Building 1	Block 5	III floor	0,16	0,05	0,05	18%	15%
Building 1	Block 5	III floor	0,45	0,14	0,17	27%	27%
Building 1	Block 6	III floor	0,67	0,23	0,28	37%	37%
Building 1	Block 6	III floor	0,46	0,36	0,42	28%	28%
Building 1	Block 6	III floor	0,87	0,3	0,36	40%	40%
Building 1	Block 6	III floor	1,06	0,12	0,14	50%	48%
Building 1	Block 6	III floor	0,42	0,11	0,13	22%	22%
Building 1	Block 6	III floor	0,43	0,04	0,05	27%	28%
		TOT		8,81	10,61	34%	34%

Table 5. 2 Summary of heating design using EPS panels, as thermal insulation, and comparison with the current situation. Reduction of design heating capacity and heat losses in percentage: 34%

EPS + GRAFITE					
Building	Block	Zone	Comfort Temperature (°C)	Steady-State Heat Loss (kW)	Design Capacity (kW)
Building 1	I floor	K-Dining	19,78	0,82	0,98
Building 1	I floor	Bed 3	19,83	0,48	0,58
Building 1	I floor	Bed 1	19,86	0,55	0,66
Building 1	I floor	Living 1	19,86	0,85	1,02
Building 1	I floor	Bath 1	20,06	0,12	0,14
Building 1	I floor	Bath 2	20,05	0,11	0,13
Building 1	I floor	corridor	20,45	0,23	0,28
Building 1	I floor	Bed 2	19,97	0,38	0,46
Building 1	I floor	bed 2	19,92	0,4	0,48
Building 1	I floor	Living	19,92	0,92	1,11
Building 1	I floor	bed 1	19,79	0,45	0,54
Building 1	I floor	bath 2	19,74	0,12	0,15
Building 1	I floor	kitchen	19,72	0,38	0,45
Building 1	I floor	bath 1	19,98	0,11	0,13
Building 1	II floor	K-Dining	19,91	0,76	0,91
Building 1	II floor	Bed 3	19,98	0,44	0,53
Building 1	II floor	Bed 1	20,01	0,5	0,6
Building 1	II floor	Living 1	20	0,78	0,94
Building 1	II floor	Bath 1	20,17	0,11	0,13
Building 1	II floor	Bath 2	20,16	0,1	0,12
Building 1	II floor	corridor	20,6	0,2	0,24
Building 1	II floor	Bed 2	20,12	0,35	0,42
Building 1	II floor	bed 2	20,05	0,37	0,44
Building 1	II floor	Living	20,05	0,84	1,01
Building 1	II floor	bed 1	19,93	0,41	0,5
Building 1	II floor	bath 2	19,83	0,12	0,14
Building 1	II floor	kitchen	19,85	0,35	0,42
Building 1	II floor	bath 1	20,08	0,1	0,12
Building 1	III floor	K-Dining	19,81	0,82	0,98
Building 1	III floor	Bed 3	19,87	0,48	0,58
Building 1	III floor	Bed 1	19,9	0,55	0,66
Building 1	III floor	Living 1	19,9	0,85	1,02
Building 1	III floor	Bath 1	20,08	0,12	0,14
Building 1	III floor	Bath 2	20,07	0,11	0,13
Building 1	III floor	corridor	20,48	0,23	0,28
Building 1	III floor	Bed 2	20,01	0,38	0,46
Building 1	III floor	bed 2	19,95	0,4	0,48
Building 1	III floor	Living	19,96	0,91	1,1
Building 1	III floor	bed 1	19,83	0,45	0,54
Building 1	III floor	bath 2	19,76	0,12	0,15
Building 1	III floor	kitchen	19,75	0,38	0,46
Building 1	III floor	bath 1	20	0,11	0,13
		TOT		17,26	20,74

Confronto Current situation- EPS grafite							
Building	Block	Zone	Comfort Temperature (°C)	Steady-State Heat Loss (kW)	Design Capacity (kW)	% reduction heat losses	% reduction design capacity
Building 1	I floor	K-Dining	0,58	0,35	0,43	30%	30%
Building 1	I floor	Bed 3	0,99	0,39	0,46	45%	44%
Building 1	I floor	Bed 1	0,99	0,44	0,53	44%	45%
Building 1	I floor	Living 1	0,42	0,28	0,33	25%	24%
Building 1	I floor	Bath 1	0,5	0,06	0,08	33%	36%
Building 1	I floor	Bath 2	0,44	0,05	0,06	31%	32%
Building 1	I floor	corridor	0,17	0,05	0,05	18%	15%
Building 1	I floor	Bed 2	0,45	0,14	0,17	27%	27%
Building 1	I floor	bed 2	0,67	0,23	0,28	37%	37%
Building 1	I floor	Living	0,46	0,36	0,42	28%	27%
Building 1	I floor	bed 1	0,87	0,31	0,37	41%	41%
Building 1	I floor	bath 2	1,04	0,12	0,14	50%	48%
Building 1	I floor	kitchen	0,42	0,11	0,14	22%	24%
Building 1	I floor	bath 1	0,43	0,04	0,05	27%	28%
Building 1	II floor	K-Dining	0,6	0,36	0,43	32%	32%
Building 1	II floor	Bed 3	1,03	0,39	0,47	47%	47%
Building 1	II floor	Bed 1	1,02	0,45	0,54	47%	47%
Building 1	II floor	Living 1	0,44	0,28	0,34	26%	27%
Building 1	II floor	Bath 1	0,52	0,06	0,07	35%	35%
Building 1	II floor	Bath 2	0,46	0,05	0,06	33%	33%
Building 1	II floor	corridor	0,18	0,04	0,05	17%	17%
Building 1	II floor	Bed 2	0,47	0,14	0,17	29%	29%
Building 1	II floor	bed 2	0,69	0,23	0,29	38%	40%
Building 1	II floor	Living	0,48	0,36	0,43	30%	30%
Building 1	II floor	bed 1	0,9	0,31	0,37	43%	43%
Building 1	II floor	bath 2	1,07	0,12	0,15	50%	52%
Building 1	II floor	kitchen	0,44	0,12	0,14	26%	25%
Building 1	II floor	bath 1	0,45	0,05	0,06	33%	33%
Building 1	III floor	K-Dining	0,58	0,35	0,43	30%	30%
Building 1	III floor	Bed 3	0,99	0,39	0,46	45%	44%
Building 1	III floor	Bed 1	0,98	0,44	0,53	44%	45%
Building 1	III floor	Living 1	0,43	0,28	0,33	25%	24%
Building 1	III floor	Bath 1	0,5	0,06	0,08	33%	36%
Building 1	III floor	Bath 2	0,44	0,05	0,06	31%	32%
Building 1	III floor	corridor	0,16	0,05	0,05	18%	15%
Building 1	III floor	Bed 2	0,45	0,14	0,17	27%	27%
Building 1	III floor	bed 2	0,67	0,23	0,28	37%	37%
Building 1	III floor	Living	0,46	0,36	0,42	28%	28%
Building 1	III floor	bed 1	0,87	0,3	0,36	40%	40%
Building 1	III floor	bath 2	1,05	0,12	0,14	50%	48%
Building 1	III floor	kitchen	0,42	0,11	0,13	22%	22%
Building 1	III floor	bath 1	0,43	0,04	0,05	27%	28%
		TOT		8,81	10,57	34%	34%

Table 5. 3 Summary of heating design using EPS panels enriched with graphite, as thermal insulation, and comparison with the current situation. Reduction of design heating capacity and heat losses in percentage: 34%

CORK					
Building	Block	Zone	Comfort Temperature (°C)	Steady-State Heat Loss (kW)	Design Capacity (kW)
Building 1	Block 1	K-Dining	19,77	0,82	0,99
Building 1	Block 1	Bed 3	19,82	0,49	0,58
Building 1	Block 1	Bed 1	19,84	0,56	0,67
Building 1	Block 1	Living 1	19,86	0,85	1,02
Building 1	Block 1	Bath 1	20,05	0,12	0,14
Building 1	Block 1	Bath 2	20,04	0,11	0,13
Building 1	Block 1	corridor	20,44	0,23	0,28
Building 1	Block 1	Bed 2	19,96	0,38	0,46
Building 1	Block 2	bed 2	19,91	0,41	0,49
Building 1	Block 2	Living	19,91	0,93	1,11
Building 1	Block 2	bed 1	19,77	0,45	0,54
Building 1	Block 2	bath 2	19,73	0,13	0,15
Building 1	Block 2	kitchen	19,72	0,38	0,46
Building 1	Block 2	bath 1	19,97	0,11	0,13
Building 1	Block 3	K-Dining	19,9	0,76	0,91
Building 1	Block 3	Bed 3	19,96	0,45	0,54
Building 1	Block 3	Bed 1	19,99	0,51	0,61
Building 1	Block 3	Living 1	19,99	0,78	0,94
Building 1	Block 3	Bath 1	20,17	0,11	0,13
Building 1	Block 3	Bath 2	20,15	0,1	0,12
Building 1	Block 3	corridor	20,6	0,2	0,24
Building 1	Block 3	Bed 2	20,12	0,35	0,42
Building 1	Block 4	bed 2	20,04	0,37	0,45
Building 1	Block 4	Living	20,04	0,85	1,02
Building 1	Block 4	bed 1	19,92	0,42	0,5
Building 1	Block 4	bath 2	19,81	0,12	0,14
Building 1	Block 4	kitchen	19,84	0,35	0,43
Building 1	Block 4	bath 1	20,07	0,1	0,12
Building 1	Block 5	K-Dining	19,8	0,82	0,99
Building 1	Block 5	Bed 3	19,86	0,49	0,58
Building 1	Block 5	Bed 1	19,88	0,56	0,67
Building 1	Block 5	Living 1	19,89	0,85	1,02
Building 1	Block 5	Bath 1	20,08	0,12	0,14
Building 1	Block 5	Bath 2	20,06	0,11	0,13
Building 1	Block 5	corridor	20,48	0,23	0,28
Building 1	Block 5	Bed 2	20	0,38	0,46
Building 1	Block 6	bed 2	19,94	0,41	0,49
Building 1	Block 6	Living	19,95	0,92	1,1
Building 1	Block 6	bed 1	19,81	0,45	0,54
Building 1	Block 6	bath 2	19,75	0,13	0,15
Building 1	Block 6	kitchen	19,75	0,38	0,46
Building 1	Block 6	bath 1	19,99	0,11	0,13
		TOT		17,4	20,86

CONFRONTO Current situation - Sughero							
Building	Block	Zone	Comfort Temperature (°C)	Steady-State Heat Loss (kW)	Design Capacity (kW)	% reduction heat losses	% reduction design capacity
Building 1	Block 1	K-Dining	0,57	0,35	0,42	30%	30%
Building 1	Block 1	Bed 3	0,98	0,38	0,46	44%	44%
Building 1	Block 1	Bed 1	0,97	0,43	0,52	43%	44%
Building 1	Block 1	Living 1	0,42	0,28	0,33	25%	24%
Building 1	Block 1	Bath 1	0,49	0,06	0,08	33%	36%
Building 1	Block 1	Bath 2	0,43	0,05	0,06	31%	32%
Building 1	Block 1	corridor	0,16	0,05	0,05	18%	15%
Building 1	Block 1	Bed 2	0,44	0,14	0,17	27%	27%
Building 1	Block 2	bed 2	0,66	0,22	0,27	35%	36%
Building 1	Block 2	Living	0,45	0,35	0,42	27%	27%
Building 1	Block 2	bed 1	0,85	0,31	0,37	41%	41%
Building 1	Block 2	bath 2	1,03	0,11	0,14	46%	48%
Building 1	Block 2	kitchen	0,42	0,11	0,13	22%	22%
Building 1	Block 2	bath 1	0,42	0,04	0,05	27%	28%
Building 1	Block 3	K-Dining	0,59	0,36	0,43	32%	32%
Building 1	Block 3	Bed 3	1,01	0,38	0,46	46%	46%
Building 1	Block 3	Bed 1	1	0,44	0,53	46%	46%
Building 1	Block 3	Living 1	0,43	0,28	0,34	26%	27%
Building 1	Block 3	Bath 1	0,52	0,06	0,07	35%	35%
Building 1	Block 3	Bath 2	0,45	0,05	0,06	33%	33%
Building 1	Block 3	corridor	0,18	0,04	0,05	17%	17%
Building 1	Block 3	Bed 2	0,47	0,14	0,17	29%	29%
Building 1	Block 4	bed 2	0,68	0,23	0,28	38%	38%
Building 1	Block 4	Living	0,47	0,35	0,42	29%	29%
Building 1	Block 4	bed 1	0,89	0,3	0,37	42%	43%
Building 1	Block 4	bath 2	1,05	0,12	0,15	50%	52%
Building 1	Block 4	kitchen	0,43	0,12	0,13	26%	23%
Building 1	Block 4	bath 1	0,44	0,05	0,06	33%	33%
Building 1	Block 5	K-Dining	0,57	0,35	0,42	30%	30%
Building 1	Block 5	Bed 3	0,98	0,38	0,46	44%	44%
Building 1	Block 5	Bed 1	0,96	0,43	0,52	43%	44%
Building 1	Block 5	Living 1	0,42	0,28	0,33	25%	24%
Building 1	Block 5	Bath 1	0,5	0,06	0,08	33%	36%
Building 1	Block 5	Bath 2	0,43	0,05	0,06	31%	32%
Building 1	Block 5	corridor	0,16	0,05	0,05	18%	15%
Building 1	Block 5	Bed 2	0,44	0,14	0,17	27%	27%
Building 1	Block 6	bed 2	0,66	0,22	0,27	35%	36%
Building 1	Block 6	Living	0,45	0,35	0,42	28%	28%
Building 1	Block 6	bed 1	0,85	0,3	0,36	40%	40%
Building 1	Block 6	bath 2	1,04	0,11	0,14	46%	48%
Building 1	Block 6	kitchen	0,42	0,11	0,13	22%	22%
Building 1	Block 6	bath 1	0,42	0,04	0,05	27%	28%
		TOT		8,67	10,45	33%	33%

Table 5. 4 : Summary of heating design using cork panels as thermal insulation, and comparison with the current situation. Reduction of design heating capacity and heat losses in percentage: 33%.

Monthly System Loads

Current Situation			
Date/Time	Sensible Cooling	Total Cooling	Zone Heating
	kWh	kWh	kWh
JANUARY	0	0	5598,829
FEBRUARY	0	0	4794,714
MARCH	0	0	4085,138
APRIL	0	0	1827,359
MAY	0	0	0
JUNE	-1026,87	-1284,17	0
JULY	-2522	-3346,84	0
AOGUST	-2801,32	-3763,33	0
SEPTEMBER	-590,609	-822,608	0
OCTOBER	0	0	264,1477
NOVEMBER	0	0	3034,122
DICEMBER	0	0	5426,88
ANNUAL	-6940,8	-9216,95	25031,19

EPS			
Date/Time	Sensible Cooling	Total Cooling	Zone Heating
	kWh	kWh	kWh
JANUARY	0	0	3558,791
FEBRUARY	0	0	3069,591
MARCH	0	0	2534,285
APRIL	0	0	964,816
MAY	0	0	0
JUNE	-1082,54	-1357,67	0
JULY	-2237,18	-3004,11	0
AOGUST	-2437,69	-3328,98	0
SEPTEMBER	-761,269	-1042,84	0
OCTOBER	0	0	49,05027
NOVEMBER	0	0	1745,744
DICEMBER	0	0	3493,804
ANNUAL	-6518,68	-8733,59	15416,08

EPS+graphite			
Date/Time	Sensible Cooling	Total Cooling	Zone Heating
	kWh	kWh	kWh
JANUARY	0	0	3565,8
FEBRUARY	0	0	3075,662
MARCH	0	0	2539,959
APRIL	0	0	967,7988
MAY	0	0	0
JUNE	-1081,81	-1356,8	0
JULY	-2237,76	-3004,84	0
AOGUST	-2438,58	-3330,06	0
SEPTEMBER	-760,517	-1041,87	0
OCTOBER	0	0	49,53519
NOVEMBER	0	0	1750,2
DICEMBER	0	0	3500,443
ANNUAL	-6518,67	-8733,57	15449,4

Cork panel			
Date/Time	Sensible Cooling	Total Cooling	Zone Heating
	kWh	kWh	kWh
JANUARY	0	0	3574,505
FEBRUARY	0	0	3083,326
MARCH	0	0	2546,668
APRIL	0	0	973,914
MAY	0	0	0
JUNE	-1078,76	-1353,16	0
JULY	-2242,08	-3009,41	0
AOGUST	-2448,36	-3341,44	0
SEPTEMBER	-762,378	-1043,95	0
OCTOBER	0	0	50,2131
NOVEMBER	0	0	1747,709
DICEMBER	0	0	3503,766
ANNUAL	-6531,58	-8747,96	15480,1

Internal Gains

Current Situation						
Date/Time	General Lighting	Computer Equip	+ Occupancy	Solar Gains Exterior Windows	Zone Sensible Heating	Zone Sensible Cooling
	kWh	kWh	kWh	kWh	kWh	kWh
JANUARY	397,2667	202,4532	151,3373	1373,686	5598,829	0
FEBRUARY	341,8624	188,161	137,3703	1557,783	4794,714	0
MARCH	362,3216	216,1449	152,6203	1987,881	4085,138	0
APRIL	296,541	197,6891	143,5654	2301,909	1827,359	0
MAY	281,845	202,4532	133,4719	2659,201	0	0
JUNE	260,3985	211,3808	112,5284	2757,032	0	-1023,846
JULY	261,9827	202,4532	101,215	2953,08	0	-2513,25
AOGUST	293,848	209,2991	99,99586	2788,443	0	-2792,26
SEPTEMBER	326,8295	204,535	114,7114	2304,288	0	-589,2129
OCTOBER	367,7183	202,4532	137,3654	2009,901	264,1477	0
NOVEMBER	379,1176	204,535	146,3578	1421,477	3034,122	0
DICEMBER	404,6263	209,2991	152,3069	1363,775	5426,88	0
ANNUAL	3974,3576	2450,8568	1582,84596	25478,456	25031,1897	-6918,5689

EPS						
Date/Time	General Lighting	Computer Equip	+ Occupancy	Solar Gains Exterior Windows	Zone Sensible Heating	Zone Sensible Cooling
	kWh	kWh	kWh	kWh	kWh	kWh
JANUARY	397,2667	202,4532	150,6868	1373,686	3558,791	0
FEBRUARY	341,8624	188,161	136,7669	1557,783	3069,591	0
MARCH	362,3216	216,1449	151,8103	1987,881	2534,285	0
APRIL	296,541	197,6891	142,0363	2301,909	964,816	0
MAY	281,845	202,4532	130,8856	2659,201	0	0
JUNE	260,3985	211,3808	111,4478	2757,032	0	-1079,513
JULY	261,9827	202,4532	103,9136	2953,08	0	-2229,934
AOGUST	293,848	209,2991	102,8105	2788,443	0	-2430,269
SEPTEMBER	326,8295	204,535	112,1136	2304,288	0	-759,4672
OCTOBER	367,7183	202,4532	130,8768	2009,901	49,05027	0
NOVEMBER	379,1176	204,535	145,1096	1421,477	1745,744	0
DICEMBER	404,6263	209,2991	151,6687	1363,775	3493,804	0
ANNUAL	3974,3576	2450,8568	1570,1265	25478,456	15416,08127	-6499,1832

EPS+graphite						
Date/Time	General Lighting	Computer Equip	+ Occupancy	Solar Gains Exterior Windows	Zone Sensible Heating	Zone Sensible Cooling
	kWh	kWh	kWh	kWh	kWh	kWh
JANUARY	397,2667	202,4532	150,6893	1373,686	3565,8	0
FEBRUARY	341,8624	188,161	136,7692	1557,783	3075,662	0
MARCH	362,3216	216,1449	151,8143	1987,881	2539,959	0
APRIL	296,541	197,6891	142,0464	2301,909	967,7988	0
MAY	281,845	202,4532	130,9057	2659,201	0	0
JUNE	260,3985	211,3808	111,4549	2757,032	0	-1078,788
JULY	261,9827	202,4532	103,9072	2953,08	0	-2230,513
AOGUST	293,848	209,2991	102,8029	2788,443	0	-2431,149
SEPTEMBER	326,8295	204,535	112,1241	2304,288	0	-758,7175
OCTOBER	367,7183	202,4532	130,911	2009,901	49,53519	0
NOVEMBER	379,1176	204,535	145,118	1421,477	1750,2	0
DICEMBER	404,6263	209,2991	151,6711	1363,775	3500,443	0
ANNUAL	3974,3576	2450,8568	1570,2141	25478,456	15449,39799	-6499,1675

Cork panel						
Date/Time	General Lighting	Computer Equip	+ Occupancy	Solar Gains Exterior Windows	Zone Sensible Heating	Zone Sensible Cooling
	kWh	kWh	kWh	kWh	kWh	kWh
JANUARY	397,2667	202,4532	150,6887	1373,686	3574,505	0
FEBRUARY	341,8624	188,161	136,771	1557,783	3083,326	0
MARCH	362,3216	216,1449	151,8188	1987,881	2546,668	0
APRIL	296,541	197,6891	142,0845	2301,909	973,914	0
MAY	281,845	202,4532	131,0407	2659,201	0	0
JUNE	260,3985	211,3808	111,4921	2757,032	0	-1075,755
JULY	261,9827	202,4532	103,8924	2953,08	0	-2234,823
AOGUST	293,848	209,2991	102,7533	2788,443	0	-2440,919
SEPTEMBER	326,8295	204,535	112,1124	2304,288	0	-760,5737
OCTOBER	367,7183	202,4532	130,9696	2009,901	50,2131	0
NOVEMBER	379,1176	204,535	145,1209	1421,477	1747,709	0
DICEMBER	404,6263	209,2991	151,6696	1363,775	3503,766	0
ANNUAL	3974,3576	2450,8568	1570,414	25478,456	15480,1011	-6512,0707

Table 5. 5: Internal gains and System loads

Internal Gains include:

•"Task Lighting - heat gain due to task lighting.
•General Lighting - heat gain due to general lighting.
•Miscellaneous - heat gain due to miscellaneous equipment.
•Process - heat gain due to process equipment.
•Catering - heat gain due to cooking.
•Computer and Equipment - heat gain due to computer and other IT-related equipment.
•Occupancy - sensible gain due to occupants. (this can vary depending on the internal conditions. With very high temperatures the sensible gain can drop to zero with all cooling effects taking place through latent heat transfer.)
•Solar Gains Exterior Windows - (used to be called 'Transmitted solar gains'). Short-wave solar radiation transmission through all external windows. For a bare window, this transmitted radiation consists of solar radiation passing through the glass and diffuse radiation from solar reflected from the outside window reveal, if present. For windows with a shade, this transmitted radiation is totally diffuse (shades are assumed to be perfect diffusers). For windows with a blind, this transmitted radiation consists of beam + diffuse short-wave radiation that passes between the slats and diffuse radiation from beam-to-diffuse reflection from the slats. The heating effect of solar radiation on opaque roofs and walls is accounted for in the Roofs and Walls fabric heat conduction data. Solar re-reflected back out of the external window and transmitted through interior windows is not subtracted.
•Solar Gains Interior Windows - Total beam + diffuse solar radiation transmission through interior windows. Requires the 3-Full interior and exterior solar model option to be set.
•Zone Sensible Cooling - is the sensible cooling effect on the zone of any air introduced into the zone through the HVAC system. It includes any 'free cooling' due to introduction of relatively cool outside air and the heating effect of any fans present. Cooling always shows as a negative heat gain in the results. It is therefore not the same as a cooling coil energy delivery when mechanical ventilation is

involved. It is best thought of as the HVAC cooling contribution to the zone heat balance.
•Zone Sensible Heating - is the sensible heating effect of any air introduced into the zone through the HVAC system including any 'free heating' due to introduction of relatively warm outside air and the heating effects of fans. It is therefore not the same as a heating coil energy delivery when mechanical ventilation is involved. It is best thought of as the HVAC heating contribution to the zone heat balance" .6

DesignBuilder EnergyPlus simulations can generate extensive data on environmental conditions within the building and resultant occupant comfort levels.
Comfort-related output inclues:

•"Internal air temperature - the calculated average temperature of the air.
•Internal radiant temperature - the average Mean Radiant Temperature (MRT) of the zone, calculated assuming that the person is in the centre of the zone, with no weighting for any particular surface.
•Internal operative temperature - The mean of the internal air and radiant temperatures.
•Outside dry-bulb temperature - site data.
•Relative Humidity - the calculated average relative humidity of the air.
•Fanger PMV - Fanger Predicted Mean Vote calculated according to ISO 7730
•Pierce PMV ET - the Predicted Mean Vote (PMV) calculated using the effective temperature and the Pierce two-node thermal comfort model.
•Pierce PMV SET - the Predicted Mean Vote (PMV) calculated using the 'Standard' effective temperature and the Pierce two-node thermal comfort model.

[6] From http://www.designbuilder.co.uk/helpv2/

•Pierce Discomfort Index (DISC) - the Discomfort index calculated using the Pierce two-node thermal comfort model.
•Pierce Thermal Sens. Index (TSENS) - the Thermal Sensation Index (PMV) calculated using the Pierce two-node thermal comfort model.
•Kansas Uni TSV - the Thermal Sensation Vote (TSV) calculated using the KSU two-node thermal comfort model.
•Discomfort hrs (summer clothing) - the time when the combination of zone humidity ratio and operative temperature is not in the ASHRAE 55-2004 summer clothes region.
•Discomfort hrs (winter clothing) - the time when the combination of zone humidity ratio and operative temperature is not in the ASHRAE 55-2004 winter clothes region.
•Discomfort hrs (all clothing) - the time when the combination of zone humidity ratio and operative temperature is not in the ASHRAE 55-2004 summer or winter clothes region.
•Mech Vent + Nat Vent + Infiltration - The sum of outside air (in ac/h) flowing into the zone through:
•The HVAC air distribution system +
•Infiltration +
•Natural ventilation"[7]

[7] From: http://www.designbuilder.co.uk/helpv2/

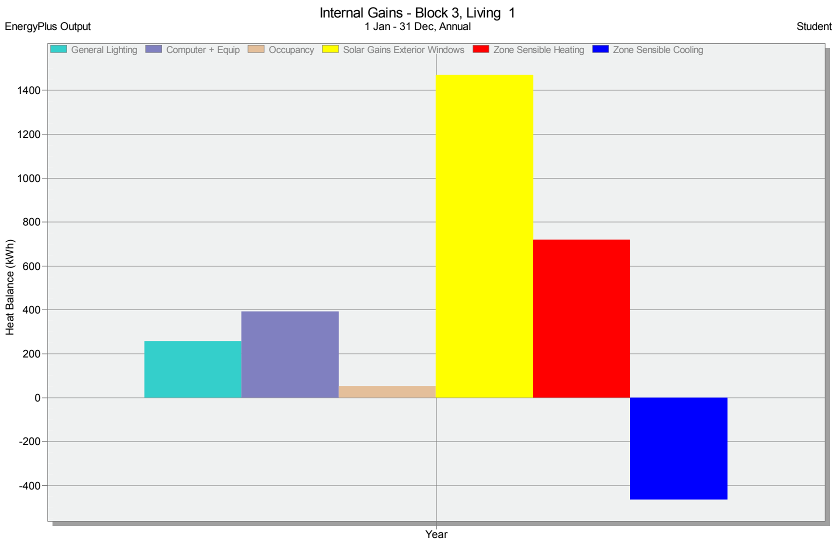

Fig. 5. 15: Internal gains Living room II floor, current situation Zone sensible heating 720 KWh. (Annual Simulation)

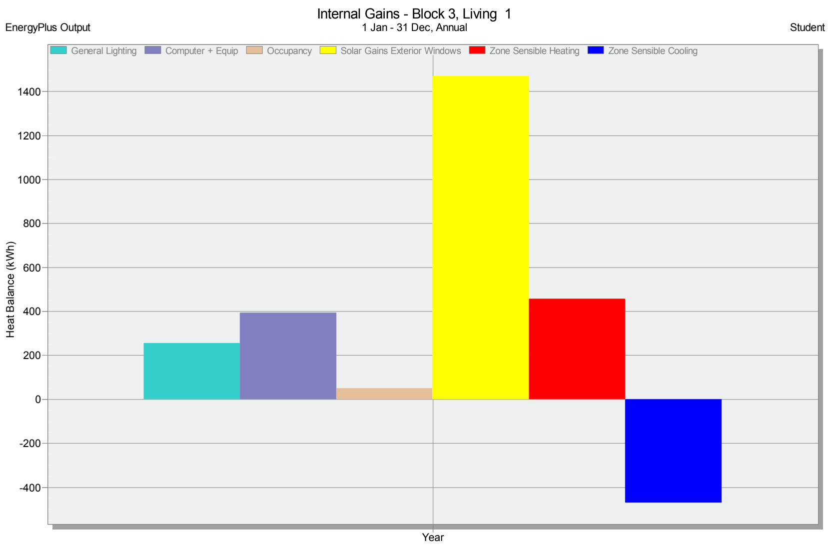

Fig. 5. 16: Internal gains Living room II floor, with insulation EPS + graphite. Zone sensible heating 457 KWh. (Annual Simulation).

COMFORT

CURRENT

Date/Time	Relative Humidity	Fanger PMV	Pierce PMV ET	Pierce SET	PMV Kansas Uni TSV	Air Temperature	Radiant Temperature	Operative Temperature	Discomfort hrs (all clothing)	Outside Dry-Bulb Temperature
	%					°C	°C	°C	hrs	°C
JANUARY	55,68	-2,08	-1,32	-0,54	-0,53	18,31	17,44	17,87	271,02	9,00
FEBRUARY	54,71	-2,06	-1,30	-0,52	-0,51	18,37	17,58	17,98	248,02	9,00
MARCH	52,97	-1,93	-1,21	-0,45	-0,42	18,77	18,18	18,48	252,05	10,00
APRIL	54,01	-3,12	-0,69	-0,95	-0,78	19,85	19,62	19,74	178,59	13,00
MAY	51,27	-2,09	-0,14	-0,49	-0,26	22,31	22,56	22,43	85,01	18,00
JUNE	54,58	-0,93	0,48	0,09	0,17	24,92	25,37	25,14	93,06	22,00
JULY	56,96	-0,24	0,90	0,53	0,36	26,32	27,04	26,68	225,28	25,00
AOGUST	58,55	-0,15	0,97	0,60	0,39	26,47	27,22	26,84	234,30	25,00
SEPTEMBER	61,41	-1,03	0,46	0,08	0,14	24,59	24,92	24,75	162,21	21,00
OCTOBER	55,22	-0,90	-0,44	0,21	0,10	21,84	21,92	21,88	83,16	18,00
NOVEMBER	57,88	-1,73	-1,06	-0,33	-0,30	19,29	18,78	19,04	218,08	12,00
DICEMBER	59,27	-2,04	-1,28	-0,51	-0,50	18,35	17,52	17,94	263,14	9,00

EPS

Date/Time	Relative Humidity	Fanger PMV	Pierce PMV ET	Pierce SET	PMV Kansas Uni TSV	Air Temperature	Radiant Temperature	Operative Temperature	Discomfort hrs (all clothing)	Outside Dry-Bulb Temperature
	%					°C	°C	°C	hrs	°C
JANUARY	51,75	-1,83	-1,15	-0,40	-0,36	18,99	18,62	18,80	249,83	9,00
FEBRUARY	50,87	-1,82	-1,14	-0,40	-0,35	19,02	18,70	18,86	223,11	9,00
MARCH	49,29	-1,72	-1,07	-0,34	-0,28	19,35	19,16	19,25	227,27	10,00
APRIL	50,77	-2,88	-0,59	-0,86	-0,63	20,35	20,42	20,39	141,30	13,00
MAY	49,70	-1,88	-0,05	-0,40	-0,15	22,85	23,14	22,99	67,79	18,00
JUNE	53,78	-0,85	0,51	0,13	0,19	25,10	25,59	25,35	90,99	22,00
JULY	58,15	-0,34	0,85	0,48	0,34	26,12	26,76	26,44	220,52	25,00
AOGUST	59,93	-0,26	0,92	0,55	0,36	26,26	26,91	26,58	230,43	25,00
SEPTEMBER	59,84	-0,89	0,53	0,15	0,18	24,89	25,30	25,10	160,66	21,00
OCTOBER	51,81	-0,61	-0,23	0,40	0,20	22,77	23,02	22,90	40,08	18,00
NOVEMBER	54,36	-1,52	-0,92	-0,21	-0,17	19,86	19,74	19,80	175,07	12,00
DICEMBER	55,66	-1,80	-1,12	-0,37	-0,34	19,01	18,65	18,83	242,81	9,00

EPS+GRAFITE

Date/Time	Relative Humidity	Fanger PMV	Pierce PMV ET	Pierce SET	PMV Kansas Uni TSV	Air Temperature	Radiant Temperature	Operative Temperature	Discomfort hrs (all clothing)	Outside Dry-Bulb Temperature
	%					°C	°C	°C	hrs	°C
JANUARY	51,77	-1,83	-1,15	-0,40	-0,36	18,99	18,61	18,80	249,95	9,00
FEBRUARY	50,88	-1,82	-1,14	-0,40	-0,35	19,02	18,70	18,86	223,25	9,00
MARCH	49,31	-1,72	-1,07	-0,34	-0,28	19,34	19,15	19,25	227,43	10,00
APRIL	50,78	-2,88	-0,59	-0,86	-0,63	20,35	20,42	20,39	141,45	13,00
MAY	49,71	-1,88	-0,05	-0,40	-0,15	22,85	23,14	22,99	67,87	18,00
JUNE	53,78	-0,85	0,51	0,13	0,19	25,10	25,59	25,34	91,00	22,00
JULY	58,14	-0,34	0,85	0,48	0,34	26,12	26,76	26,44	220,54	25,00
AOGUST	59,93	-0,26	0,92	0,55	0,36	26,26	26,91	26,58	230,74	25,00
SEPTEMBER	59,84	-0,89	0,53	0,14	0,18	24,89	25,30	25,09	160,66	21,00
OCTOBER	51,83	-0,61	-0,23	0,40	0,20	22,77	23,02	22,89	40,15	18,00
NOVEMBER	54,38	-1,52	-0,92	-0,21	-0,17	19,86	19,74	19,80	175,30	12,00
DICEMBER	55,68	-1,80	-1,12	-0,37	-0,34	19,01	18,65	18,83	242,89	9,00

CORK

Date/Time	Relative Humidity	Fanger PMV	Pierce PMV ET	Pierce SET	PMV Kansas Uni TSV	Air Temperature	Radiant Temperature	Operative Temperature	Discomfort hrs (all clothing)	Outside Dry-Bulb Temperature
	%					°C	°C	°C	hrs	°C
JANUARY	51,81	-1,83	-1,15	-0,40	-0,36	18,98	18,61	18,80	250,00	9,00
FEBRUARY	50,92	-1,82	-1,14	-0,40	-0,35	19,02	18,69	18,86	223,37	9,00
MARCH	49,32	-1,72	-1,07	-0,34	-0,28	19,34	19,15	19,24	227,57	10,00
APRIL	50,82	-2,89	-0,59	-0,86	-0,63	20,34	20,41	20,38	141,97	13,00
MAY	49,77	-1,89	-0,05	-0,40	-0,16	22,83	23,11	22,97	68,13	18,00
JUNE	53,80	-0,86	0,51	0,13	0,19	25,10	25,58	25,34	90,94	22,00
JULY	58,13	-0,34	0,85	0,48	0,34	26,13	26,76	26,44	220,45	25,00
AOGUST	59,90	-0,26	0,92	0,55	0,36	26,26	26,91	26,59	230,91	25,00
SEPTEMBER	59,84	-0,89	0,53	0,15	0,18	24,89	25,30	25,10	160,69	21,00
OCTOBER	51,85	-0,61	-0,23	0,40	0,20	22,76	23,01	22,88	40,17	18,00
NOVEMBER	54,38	-1,52	-0,92	-0,21	-0,17	19,86	19,74	19,80	175,48	12,00
DICEMBER	55,68	-1,80	-1,12	-0,37	-0,34	19,01	18,65	18,83	242,92	9,00

Table 5. 6: Comfort output, comparison between different insulating options.

AREA		
Block 1 (3 an	115	m^2
Block 2 (4 an	70	m^2
scale	14	m^2
floor	185	m^2
Building	555	m^2

ENERGY CONSUMPTION CURRENT SITUATION				
Date/Time	Total Cooling	Zone Heating	TOT	per m2
Annual	kWh	kWh	kWh	
Building	-9216,95	25031,19	34248	62
II floor	-1746,96	5151,98	6899	60

ENERGY CONSUMPTION 1_Insulation EPS panel										
Date/Time	Total Cooling	Zone Heating	TOT	per m2	Reduction cooling	Reduction heatin	TOT Reduction	partial	TOT Reduction/m2	partial/m2
	kWh	kWh	kWh		%	%	%			
Annual	-8733,59	15416,08	24150	44	5%	38%	29%	29%	29%	29%
II floor	-1637,31	3092,57	4730	41	6%	40%	31%	31%	31%	31%

ENERGY CONSUMPTION 2_insulation EPS+graphite										
Date/Time	Total Cooling	Zone Heating	TOT	per m2	Reduction cooling	Reduction heatin	TOT Reduction	partial	TOT Reduction/m2	partial/m2
	kWh	kWh	kWh		%	%	%			
Annual	-8733,57	15449,4	24183	44	5%	38%	29%	29%	29%	**29%**
II floor	-1637,34	3099,71	4737	41	6%	40%	31%	31%	31%	**31%**

ENERGY CONSUMPTION 3_insulation CORK										
Date/Time	Total Cooling	Zone Heating	TOT	per m2	Reduction cooling	Reduction heatin	TOT Reduction	partial	TOT Reduction/m2	partial/m2
	kWh	kWh	kWh		%	%	%			
Annual	-8747,96	15480,1	24228	44	5%	38%	29%	29%	29%	29%
II floor	-1640,68	3107,96	4749	41	6%	40%	31%	31%	31%	31%

Table 5. 7: Comparison, in terms of energy consumption/m^2, between different insulating systems. Annual simulation.

Table 5.7 shows the results of a heating design simulation trying all the three insulating system in order to check heat losses reduction/ m^2 in percentage.

From an energetic point of view EPS panel and EPS enriched with graphite seems to guarantee the same performance, but EPS enriched with graphite will obtain better results with a small thickness and a price that is almost the same.

For this reason was considered the “best” solution and the rest of the analysis is based on the use of this kind of panels.

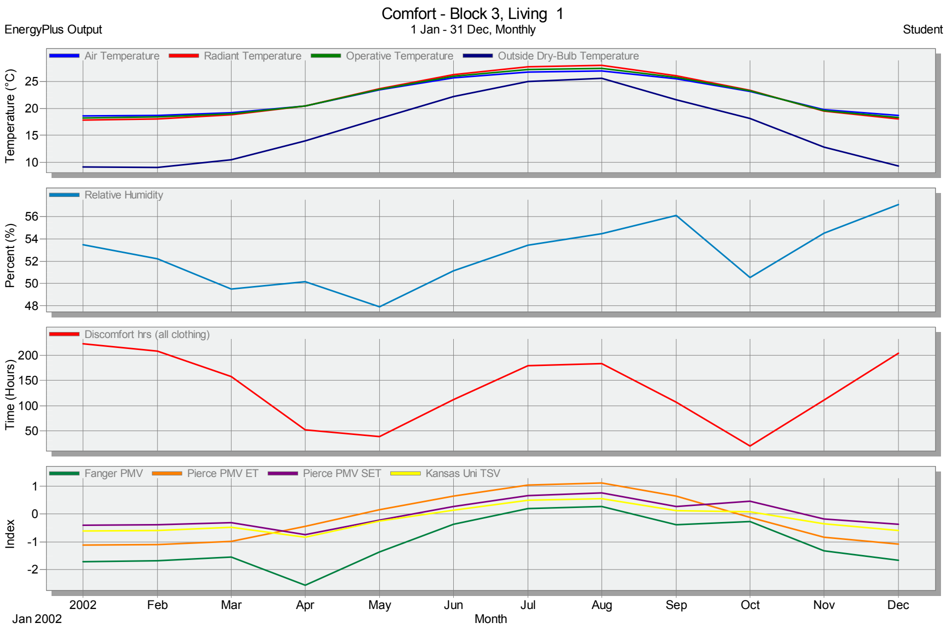

Fig. 5. 17: Comfort , current situation, living room II floor.

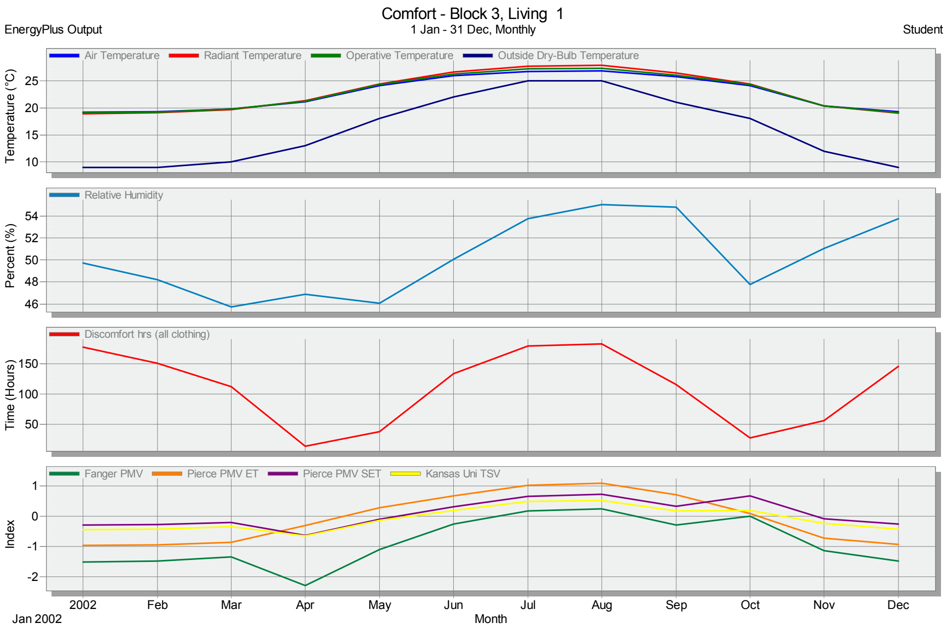

Fig. 5. 18 Comfort, EPS + graphite insulation, living room II floor.

5.2.2 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/m2k much lower than the value indicated by the standard DM 26-01-2010, where U = 2.1 W/m2k 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.

Fig. 5. 19: Only one original frame remained.

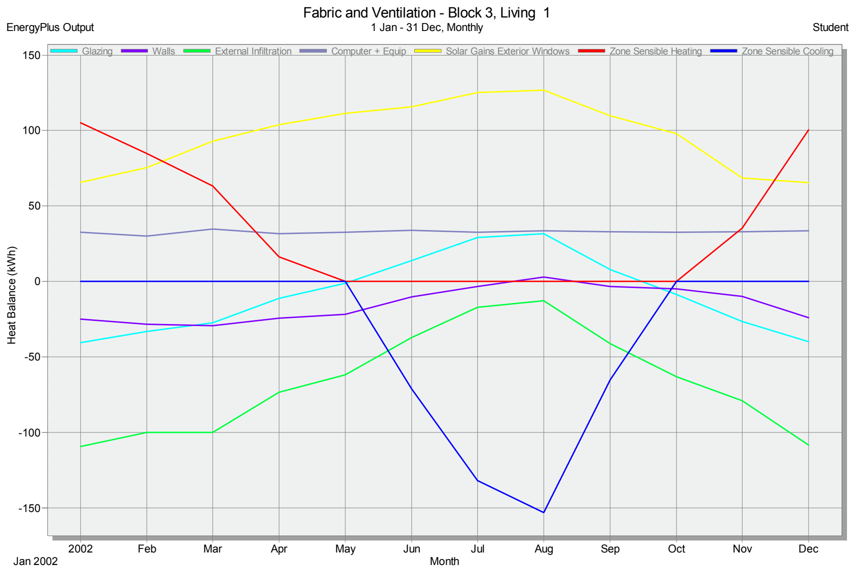

Fig. 5. 20: Fabric and ventilation (grazing, walls external infiltration) + Internal gains (Zone sensible heating, zone sensible cooling, solar gains exterior windows) [KWh] Living room II floor, with low emission windows, (Scenario1)

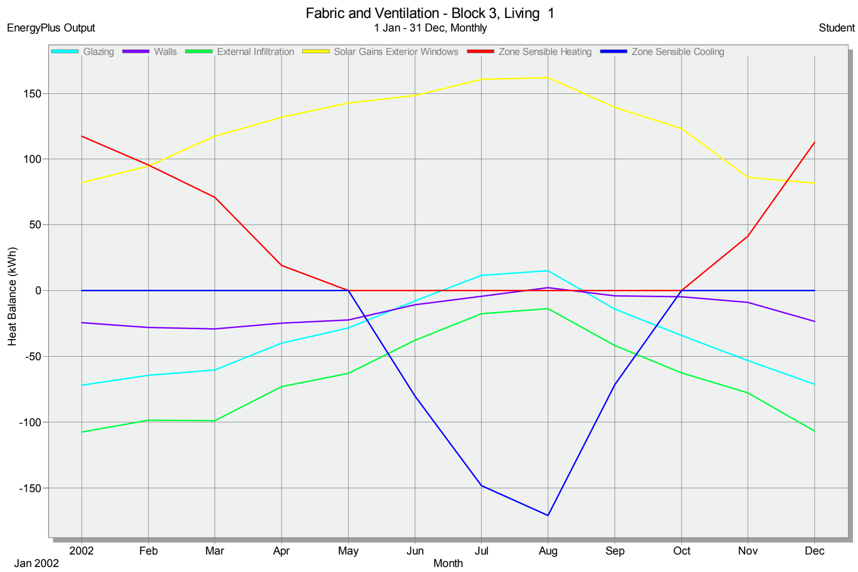

Fig. 5. 21: Fabric and ventilation (grazing, walls external infiltration) + Internal gains (Zone sensible heating, zone sensible cooling, solar gains exterior windows) [KWh] Living room II floor, EPS + graphite insulation (Scenario2).

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 11%, with the economic feasibility analysis performed later, a very long pay-back period is observed.

The question raised is it really worth the additional cost, which can be anything from 30 - 50% higher than conventional double glazed sealed units, and does the south Italy weather really warrant it? Probably not.

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.

5.2.3 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
- side fins (projection 70 and 75 cm)
- brise soleil (angle 0° 30° and 36° to the horizontal)

Fig. 5. 22: Different shading devices used. From the top left, the original brise soleil designed by Cosenza, Shade roll and venetian blind chosen by the users.

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.

Properties of each shading device are listed below:

- *Blinds (Window shading device)*:
  Blind with low reflective slats - position outside,
  Source: E+
  Blind to glass distance (m): 0.050
  Slat orientation: horizontal
  Slat width (m): 0.025
  Slat separation (m): 0.0188
  Slat thickness (m): 0.0010
  Slat angle (°): 45
  Slat conductivity (W/mK): 0.900
  Slat beam solar transmittance: 0.000
  Slat beam solar reflectance (front and back side): 0.200
  Slat beam visible transmittance: 0.000
  Slat beam visible reflectance (front and back side): 0.200
  Control type: schedule
  Schedule:
    From January to May: OFF
    From June to September:
      From 0:00 to 9:30 OFF
      From 9:30 to 18:30 ON
      From 18:30 to 24:00 OFF
    From October to December: OFF

- *Shade rolls (Window shading device)*:
  Medium opaque - position outside,
  Thickness (m): 0.003
  Conductivity (W/mK): 0.100
  Solar trasmittance:0.050
  Solar reflectance: 0.350
  Visible trasmittance:0.050

Visible reflectance : 0.350
Long-wave emissivity: 0.900
Long-wave transmittance: 0.00
Control type: schedule
Schedule:
 From January to May: OFF
 From June to September:
  From 0:00 to 9:30 OFF
  From 9:30 to 18:30 ON
  From 18:30 to 24:00 OFF
 From October to December: OFF

- *Venetian blinds (Window shading device)*:
  Medium modelled as diffusing - position outside,
  Thickness (m): 0.003
  Conductivity (W/mK): 0.100
  Solar trasmittance:0.600
  Solar reflectance: 0.090
  Visible trasmittance:0.140
  Visible reflectance: 0.090
  Long-wave emissivity: 0.900
  Long-wave transmittance: 0.00
  Control type: schedule
  Schedule:
   From January to May: OFF
   From June to September:
    From 0:00 to 9:30 OFF
    From 9:30 to 18:30 ON
    From 18:30 to 24:00 OFF
   From October to December: OFF

- *Louvre Side fins 70 cm (local shading device)*:
  Blade material: Pine 20% moist
  Geometry:
  Left
   Projection (m) 0.700
   Horizontal offset from window left (m): 0.00
   Top overlap (m): 0.00

Bottom overlap (m): 0.00

Right
- Projection (m) 0.700
- Horizontal offset from window left (m): 0.00
- Top overlap (m): 0.00
- Bottom overlap (m): 0.00

- *Louvre Side fins 75 cm (local shading device)*:
  Blade material: Pine 20% moist
  Geometry:

Left
- Projection (m) 0.750
- Horizontal offset from window left (m): 0.00
- Top overlap (m): 0.00
- Bottom overlap (m): 0.00

Right
- Projection (m) 0.750
- Horizontal offset from window left (m): 0.00
- Top overlap (m): 0.00
- Bottom overlap (m): 0.00

- *Brise soleil 0° finestra (Local shading device_louvres)*:
  Blade material: Pine 20% moist
  Blade geometry:
  Number of blades: 20
  Vertical spacing (m): 0.090
  Angle (°): 00.00
  Distance from window (m): 0.40
  Blade depth (m): 0.060
  Vertical offset from window top (m): 0.00
  Horizontal window overlap (m): 0.20

- *Brise soleil 0° balcone :*
  Blade material: Pine 20% moist
  Blade geometry:
  Number of blades: 20

Vertical spacing (m): 0.090
Angle (°): 00.00
Distance from window (m): 2.00
Blade depth (m): 0.060
Vertical offset from window top (m): 0.00
Horizontal window overlap (m): 1.60

- *Brise soleil 36° finestra (Local shading device_louvres)*:
  Blade material: Pine 20% moist
  Blade geometry:
  Number of blades: 20
  Vertical spacing (m): 0.155
  Angle (°): 36.00
  Distance from window (m): 0.40
  Blade depth (m): 0.060
  Vertical offset from window top (m): 0.00
  Horizontal window overlap (m): 0.20

- *Brise soleil 36° balcone :*
  Blade material: Pine 20% moist
  Blade geometry:
  Number of blades: 20
  Vertical spacing (m): 0.155
  Angle (°): 36.00
  Distance from window (m): 2.00
  Blade depth (m): 0.060
  Vertical offset from window top (m): 0.00
  Horizontal window overlap (m): 1.60

- *Brise soleil 30° finestra (Local shading device_louvres)*:
  Blade material: Pine 20% moist
  Blade geometry:
  Number of blades: 20
  Vertical spacing (m): 0.100
  Angle (°): 30.00
  Distance from window (m): 0.40

Blade depth (m): 0.060
Vertical offset from window top (m): 0.00
Horizontal window overlap (m): 0.20

- *Brise soleil 30° balcone :*
  Blade material: Pine 20% moist
  Blade geometry:
  Number of blades: 20
  Vertical spacing (m): 0.100
  Angle (°): 30.00
  Distance from window (m): 2.00
  Blade depth (m): 0.060
  Vertical offset from window top (m): 0.00
  Horizontal window overlap (m): 1.60

The simulations on the entire can generate extensive data on environmental conditions within the building and resultant occupant comfort levels.

For this reason the results about the most effective shading system are expressed (in the following tab and graph) in terms of comfort.

COMFORT MONTHLY										
	Air Temperature [°C]						**% of reduction Air Temperature**			
Date/Time	No shading system	Blinds	Shade rolls	Venetian	Louvre Sidefins	Brise soleil	Blinds	Shade roll	Louvre Sidefins	Brise soleil
Maggio	22,85	22,84	22,84	22,84	22,33	22,51	0%	0%	0%	2%
Giugno	25,10	24,71	24,66	24,99	24,88	24,97	2%	2%	0%	1%
Luglio	26,12	25,84	25,80	26,03	26,00	26,05	1%	1%	0%	0%
Agosto	26,26	25,98	25,95	26,16	26,14	26,18	1%	1%	0%	0%
Settembre	24,89	24,39	24,35	24,73	24,69	24,75	2%	2%	1%	1%
SUMMER	77,48613	76,5377	76,40734	77,18401	77,02269	77,20179	1%	1%	0%	1%
	Radiant Temperature [°C]						**% of reduction Radiant Temperature**			
Date/Time	No shading system	Blinds	Shade rolls	Venetian	Louvre Sidefins	Brise soleil				
Maggio	23,14	23,13	23,13	23,13	22,57	22,77	0%	0%	0%	2%
Giugno	25,59	25,03	24,96	25,42	25,27	25,40	2%	2%	1%	1%
Luglio	26,76	26,28	26,21	26,60	26,54	26,63	2%	2%	1%	1%
Agosto	26,91	26,42	26,37	26,74	26,70	26,76	2%	2%	1%	1%
Settembre	25,30	24,62	24,57	25,09	25,02	25,11	3%	3%	1%	1%
SUMMER	79,24889	77,73863	77,54346	78,76325	78,51779	78,78754	2%	2%	1%	1%
	Operative Temperature [°C]						**% of reduction Operative Temperature**			
Date/Time	No shading system	Blinds	Shade rolls	Venetian	Louvre Sidefins	Brise soleil				
Maggio	22,99	22,99	22,99	22,98882	22,44572	22,63942	0%	0%	0%	2%
Giugno	25,34	24,87	24,81	25,20569	25,078	25,18514	2%	2%	1%	1%
Luglio	26,44	26,06	26,01	26,31731	26,27274	26,33762	1%	2%	0%	1%
Agosto	26,58	26,20	26,16	26,45063	26,41949	26,4719	1%	2%	0%	1%
Settembre	25,09	24,50	24,46	24,91001	24,85466	24,93126	2%	3%	1%	1%
SUMMER	78,36751	77,13817	76,97539	77,97363	77,77023	77,99466	2%	2%	1%	1%
	Discomfort hrs (all clothing)						**% of increase comfort hours**			
Date/Time	No shading system	Blinds	Shade rolls	Venetian	Louvre Sidefins	Brise soleil				
Maggio	67,87	67,88	67,88	67,88	76,10	70,81	0%	0%	0%	-12%
Giugno	91,00	81,73	81,19	86,79	86,33	86,73	10%	11%	5%	5%
Luglio	220,54	213,24	212,71	217,22	216,25	217,19	3%	4%	2%	2%
Agosto	230,74	224,24	223,94	227,69	227,54	228,36	3%	3%	1%	1%
Settembre	160,66	165,07	165,55	160,48	161,93	161,78	-3%	-3%	0%	-1%
SUMMER	542,29107	519,19896	517,83435	531,70118	530,12058	532,2859	4%	5%	2%	2%

Table 5. 8: Comparison between different solutions, shade roll, louvre sidefins, brise soleil. Monthly Comfort

Solar Gains Exterior Windows											
Date/Time	NO shading system	Blinds	% of reduction	Shade rolls	% of reduction	Venetian	% of reduction	Sidefins	% of reduction	Brise soelil	% of reduction
	kWh	kWh				kWh		kWh			
May	142,47	142,53	0%	142,5334	0%	142,5334	0%	105,2738	26%	104,8689	26%
June	148,42	44,80	70%	44,79703	70%	109,4974	26%	111,194	25%	109,2772	26%
July	160,55	46,29	71%	46,28681	71%	118,2998	26%	120,3693	25%	116,9694	27%
August	162,14	39,21	76%	39,21446	76%	114,5111	29%	117,9752	27%	114,3988	29%
September	139,43	33,06	76%	33,0619	76%	95,27678	32%	103,2034	26%	98,29285	30%

Table 5. 9: Percentage of reduction of annual solar gains

Zone sensible Cooling											
Date/Time	NO shading system	Blinds	% of reduction	Shade rolls	% of reduction	Venetian	% of reduction	Sidefins	% of reduction	Brise soelil	% of reduction
	kWh	kWh		kWh				kWh			
May	0	0,00	-	0	-	0	-	0	-	0	
June	-80,25	-30,40	62%	-30,40	62%	-68,080	15%	-54,18	32%	-57,04	29%
July	-148,11	-73,31	51%	-73,31	51%	-127,633	14%	-115,17	22%	-117,08	21%
August	-170,83	-86,01	50%	-86,01	50%	-146,111	14%	-134,35	21%	-134,55	21%
September	-71,44	-19,39	73%	-19,39	73%	-55,455	22%	-47,74	33%	-46,11	35%

Table 5. 10: Zone sensible cooling, summer time analysis. % of reduction for each shading devices.

General Lighting											
Date/Time	NO shading system	Blinds	% of reduction	Shade rolls	% of reduction	Venetian	% of reduction	Sidefins	% of reduction	Brise soelil	% of reduction
	kWh	kWh		kWh				kWh			
May	18,85	18,85	0%	18,85	0%	18,85	0%	19,35	-3%	19,68	-4%
June	17,24	24,71	-43%	24,91	-44%	22,06	-28%	17,78	-3%	18,33	-6%
July	17,26	23,45	-36%	23,55	-36%	20,88	-21%	17,70	-3%	18,21	-6%
August	19,44	26,14	-34%	26,10	-34%	23,10	-19%	20,04	-3%	19,96	-3%
September	21,23	27,17	-28%	26,99	-27%	24,58	-16%	21,73	-2%	21,59	-2%

Table 5. 11: General lighting, summer time analysis. % of reduction for each shading devices

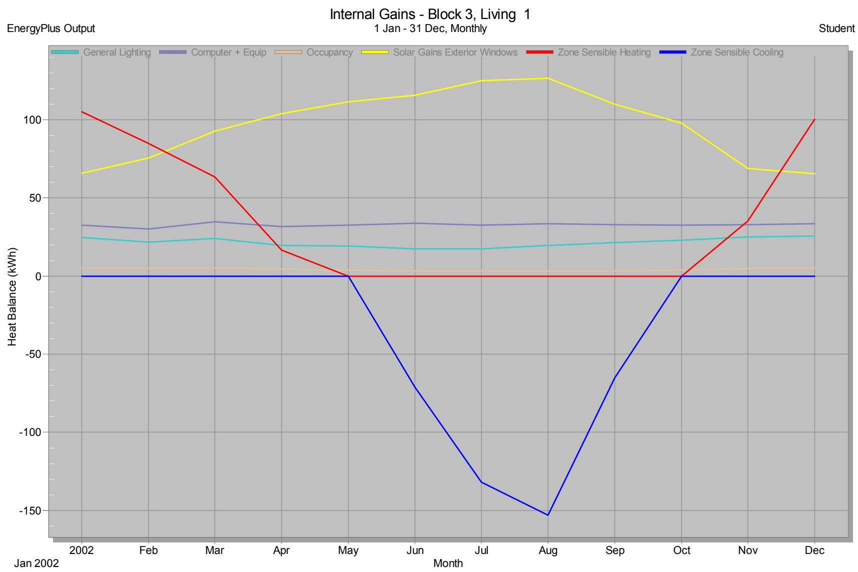

Fig. 5. 23: Internal gains [kWh] Living room II floor, without shading system. (red= zone sensible heating, blue=zone sensible cooling, yellow=solar gains, pink=occupancy, violet=computer and equipment, light blue=general lighting)

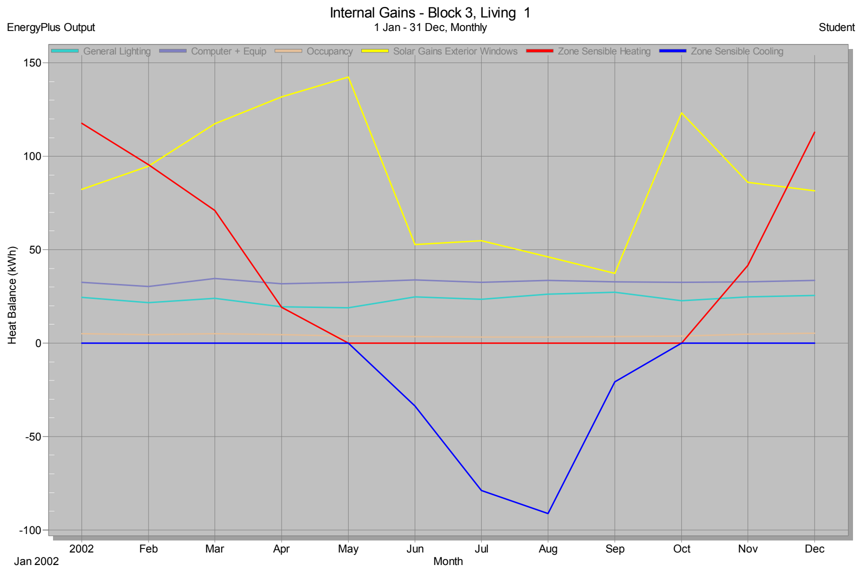

Fig. 5. 24: Internal gains [kWh] Living room II floor, Slatted Blinds (slat orientation= horizontal, slat width [m]=0,0250; slat separation[m]= 0,0188; slat thickness= 0,0010; slat angle = 45°.

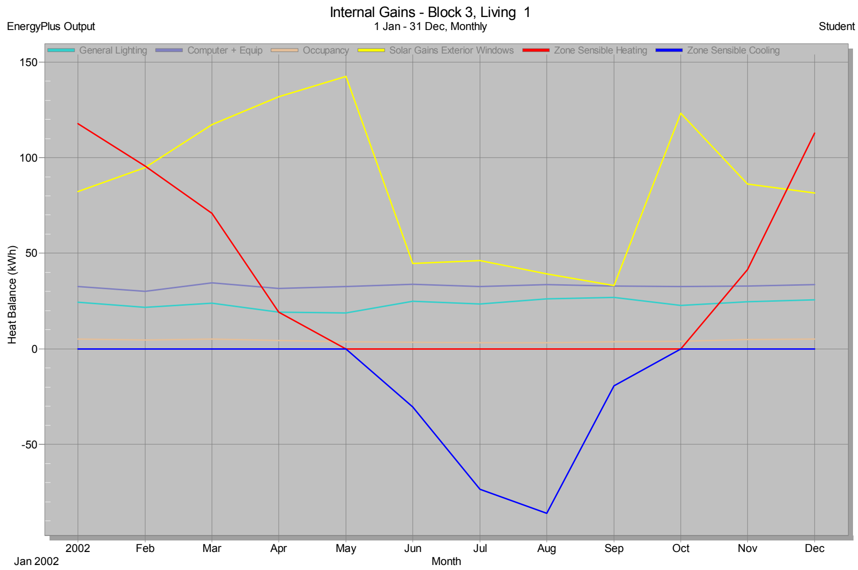

Fig. 5. 25: Internal gains [kWh] Living room II floor, Shade rolls, (thickness=0,0030m; conductivity W/m-K=0,1; Solar transmittance= 0,050; Solar reflectance= 0,35)

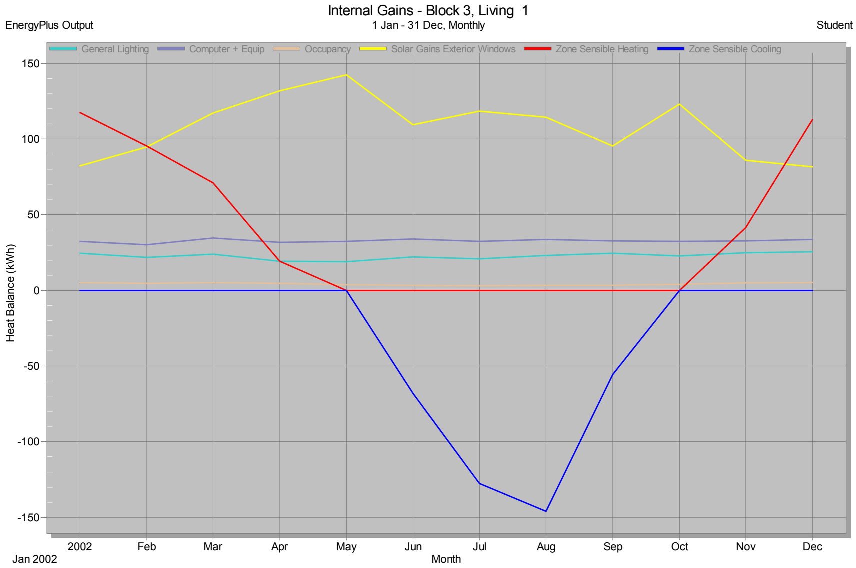

Fig. 5. 26**:** Internal gains [kWh] Living room II floor, Venetian, diffusive blinds (thickness=0,0030m; conductivity W/m-K=0,1; Solar transmittance= 0,60; Solar reflectance= 0,090).

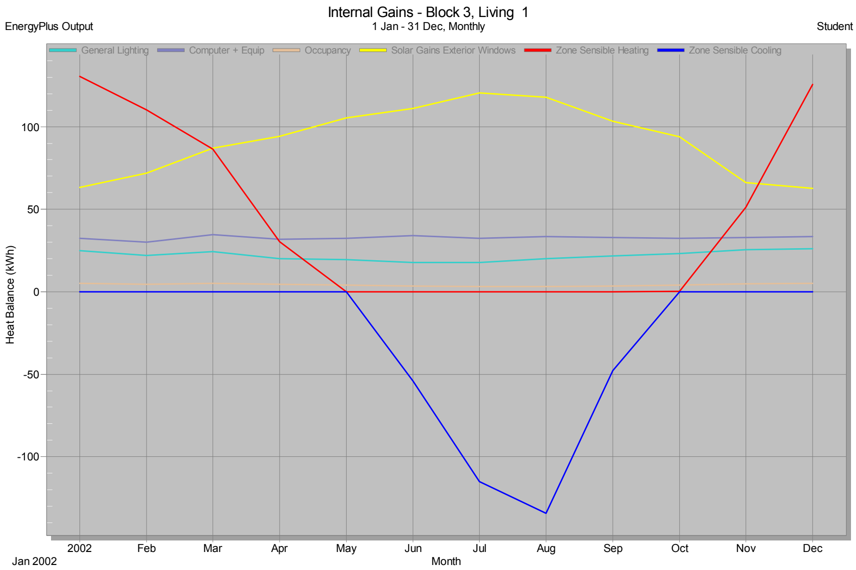

Fig. 5. 27: Internal gains [kWh] Living room II floor, Louvre Sidefins, Pine (20% moist) **Projection [m] 0,70.**

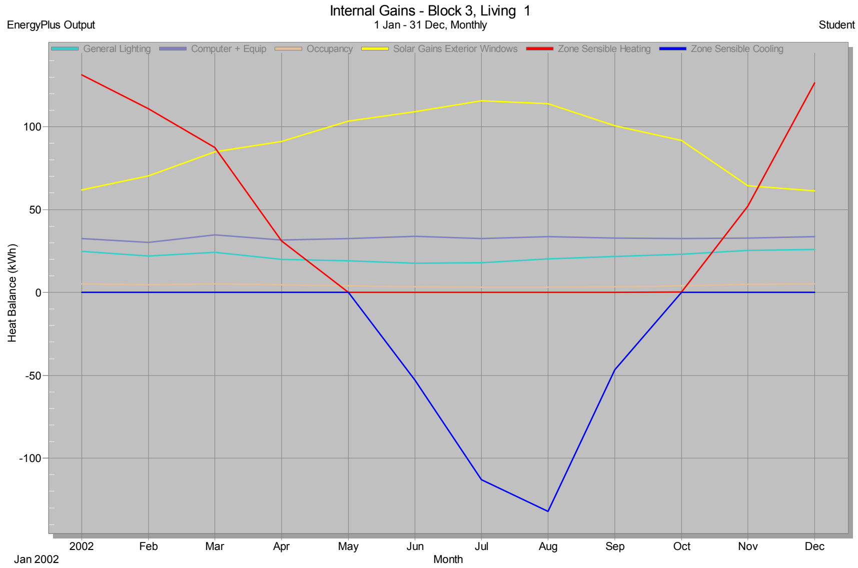

Fig. 5. 28: Internal gains [kWh] Living room II floor, Louvre Sidefins, Pine (20% moist) **Projection [m] 0,75**

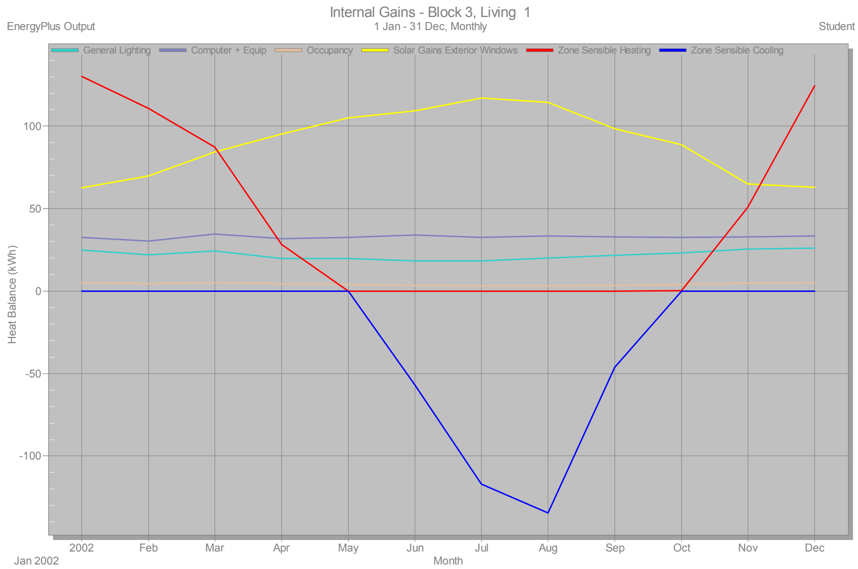

Fig. 5. 30: Internal gains [kWh] Living room II floor, Brise soleil, Blade= Pine (20% moist) vertical spacing [m]= 0,090; **Angle =0°,** blade depth [m]=0,06

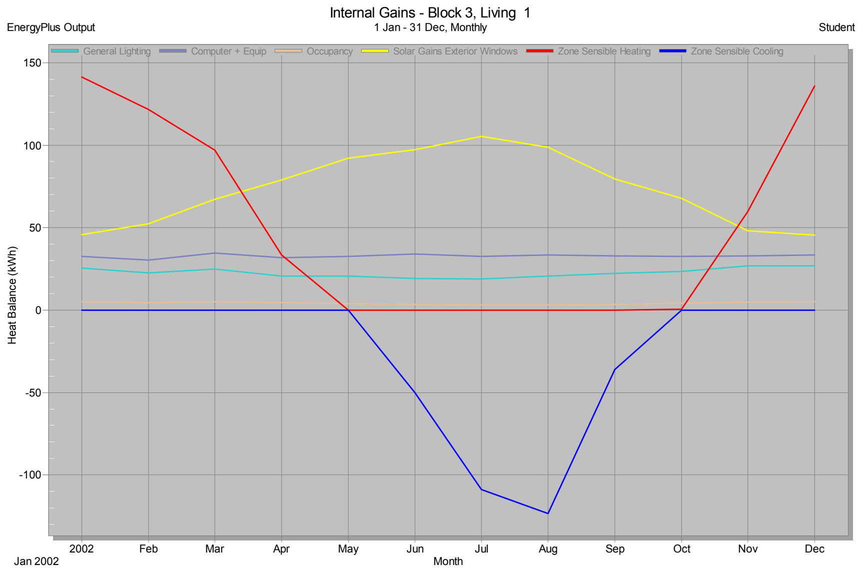

Fig. 5. 29: Internal gains [kWh] Living room II floor, Brise soleil, Blade= Pine (20% moist) vertical spacing [m]= 0,155; **Angle =36°,** blade depth [m]=0,10

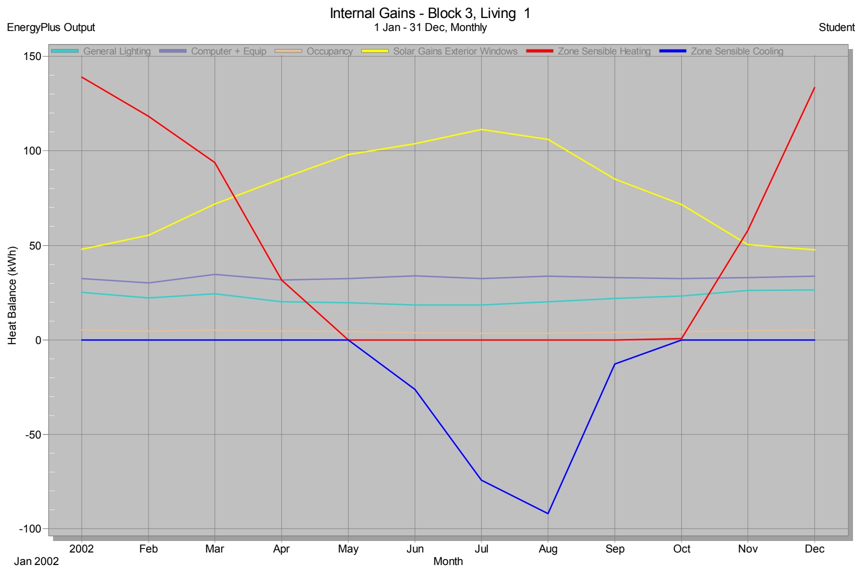

Fig. 5. 30: Internal gains [kWh] Living room II floor, Brise soleil, Blade= Pine (20% moist) vertical spacing [m]= 0,10; **Angle =30°,** blade depth [m]=0,06

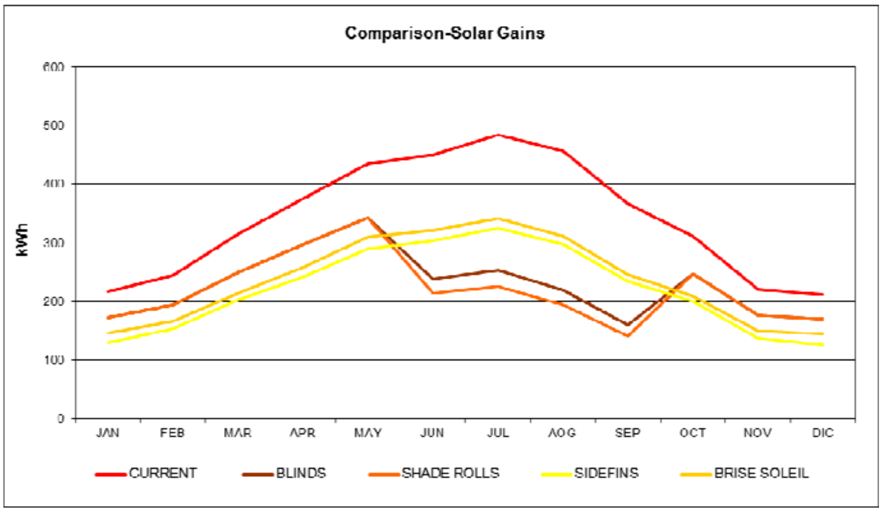

Fig. 5. 31: Solar gain through windows. Comparison of the effectiveness of the different sunscreen.

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.

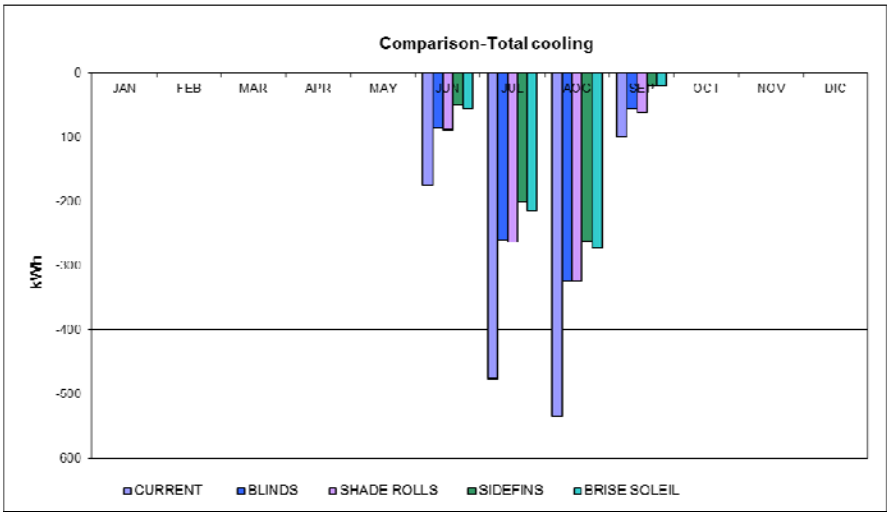

Fig. 5. 32: Solar gain through windows. Comparison of the effectiveness of the different sunscreen.

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.

ENERGY CONSUMPTION 5_nuovi infissi (EPS* graphite)+ BLINDS

Date/Time	Total Cooling kWh	Zone Heating kWh	TOT kWh	per m2	Reduction cooling %	Reduction heating %	TOT Reduction %	PARZIALE	TOT Reduction/m2	PARZIALE/m2
Annual	-6174.88	15458.09	21633	39	33%	38%	37%	11%	37%	11%
II floor	-1112.14	3101.18	4213	37	36%	40%	39%	11%	39%	11%

ENERGY CONSUMPTION 5bis nuovi infissi (EPS* graphite)+ venetian

Date/Time	Total Cooling kWh	Zone Heating kWh	TOT kWh	per m2	Reduction cooling %	Reduction heating %	TOT Reduction %	PARZIALE	TOT Reduction/m2	PARZIALE/m2
Annual	-7949.72	15453.93	23404	42	14%	38%	32%	3%	32%	3%
II floor	-1472.8	3100.42	4573	40	16%	40%	34%	3%	34%	3%

ENERGY CONSUMPTION 6_nuovi infissi (EPS + graphite) + shade roll

Date/Time	Total Cooling kWh	Zone Heating kWh	TOT kWh	per m2	Reduction cooling %	Reduction heating %	TOT Reduction %	PARZIALE	TOT Reduction/m2	PARZIALE/m2
Annual	-5925.23	15458.49	21384	39	36%	38%	38%	12%	38%	12%
II floor	-1062.89	3101.26	4164	36	39%	40%	40%	12%	40%	12%

ENERGY CONSUMPTION 7_nuovi infissi (EPS + graphite) + Louvre sidefins 70 cm

Date/Time	Total Cooling kWh	Zone Heating kWh	TOT kWh	per m2	Reduction cooling %	Reduction heating %	TOT Reduction %	PARZIALE	TOT Reduction/m2	PARZIALE/m2
Annual	-7532.37	16840.36	24373	44	18%	33%	29%	-1%	29%	-1%
II floor	-1375.61	3368.47	4744	41	21%	35%	31%	0%	31%	0%

ENERGY CONSUMPTION 8_nuovi infissi (EPS + graphite) + Brise soleil 0°

Date/Time	Total Cooling kWh	Zone Heating kWh	TOT kWh	per m2	Reduction cooling %	Reduction heating %	TOT Reduction %	PARZIALE	TOT Reduction/m2	PARZIALE/m2
Annual	-7848.11	16325.44	24174	44	15%	35%	29%	0%	29%	0%
II floor	-1454.14	3254.92	4709	41	17%	37%	32%	1%	32%	1%

Table 5. 12: Reduction in percentage in terms of energy consumption/m^2, between the shading devices studied[8]. Annual simulation.

[8] DesignBuilder define some devices like louvres side fines and brise soleil as “local shading device”. It means that it’s not possible to associate to these devices a schedule. The software assumes that they are “on” even in winter time (when they should not be opened). That’s way some appears to be less effective than others producing a growing in energy consumption for heating during winter, reducing the positive effects of solar gains.

Comparing the energy used for cooling in the "current" situation with that used in an upgraded hypothesis (whit polyurethane foam and shade roll) it's possible to get a reduction in energy consumption of about 38% for the whole building, and 40% if we consider the single flat. If we consider the energy reduction for cooling during summer, it is up to 12%.

5.2.4 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.

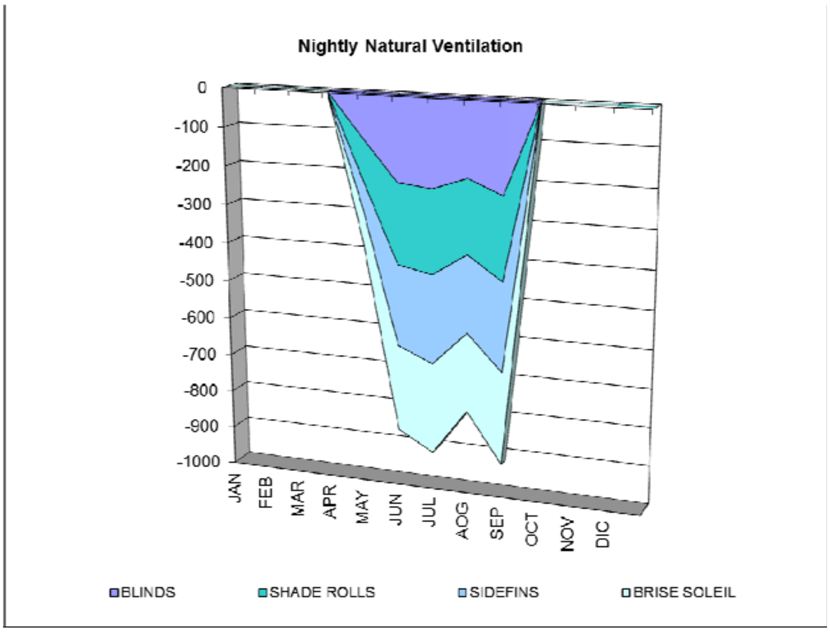

Fig. 5. 33: Percentage of natural ventilation, with different sunscreen. [ac/h].

	CURRENT	***BLINDS***	***SHADE ROLL***	***SIDEFINS***	***BRISE SOLEIL***
Date/Time	Nat Vent + Infiltration ac/h	Nat Vent + Infiltration ac/h	Nat Vent + Infiltration ac/h	Nat Vent + Infiltration ac/h	Nat Vent + Infiltration ac/h
	0	0	0	0	0
JAN	0	0	0	0	0
FEB	0	0	0	0	0
MAR	0	0	0	0	0
APR	0	-109.7299	-105.2957	-75.5796	-86.50668
MAY	0	-216.6404	-209.2404	-211.1207	-223.7984
JUN	0	-226.7456	-217.1945	-231.8343	-237.176
JUL	0	-194.9378	-190.6217	-200.9742	-205.3133
AOG	0	-231.7067	-215.3349	-232.4842	-242.3965
SEP	0	0	0	0	0
OCT	0	0	0	0	0
NOV	0	0	0	0	0
DIC					
ANNUAL	0	-979.7604	-937.6872	-951.993	-995.19088

Table 5. 13:Values [ac/h] of natural ventilation, with different sunscreen, brise soleil appears to be a bit more efficient.

Combining shading devices with night natural ventilation, and controlling the total energy required not only for summer cooling but also for heating during the winter period, unexpectedly the shading system that turns out to be more efficient in a simulation during a typical year, is the shade roll.

Probably because the solar gains tend to be very low when the shade roll is in use (from 9:30 to 18:30 from June to September) while is maximum in winter (when solar gains are helpful) because it is a type of rollaway system (i.e. during the hours when the sun is low or at night). Furthermore, when closed does not interfere with night ventilation.

Below is a brief report the values obtained in tables and graphics in a final summary.

ENERGY CONSUMPTION 9_nuovi infissi (EPS* graphite)+ BLINDS+NV										
Date/Time	Total Cooling kWh	Zone Heating kWh	TOT kWh	per m2	Reduction cooling %	Reduction heating %	TOT Reduction %	PARZIALE	TOT Reduction/m2	PARZIALE/m2
Annual	-4029.4	15644.86	19674	35	56%	37%	43%	9%	43%	9%
II floor	-694.41	3191.3	3886	34	60%	38%	44%	8%	44%	8%

ENERGY CONSUMPTION 9_nuovi infissi (EPS* graphite)+VENETIAN+NV										
Date/Time	Total Cooling kWh	Zone Heating kWh	TOT kWh	per m2	Reduction cooling %	Reduction heating %	TOT Reduction %	PARZIALE	TOT Reduction/m2	PARZIALE/m2
Annual	-5405.84	15331.7	20738	37	41%	39%	39%	11%	39%	11%
II floor	-957.09	3086	4043	35	45%	40%	41%	12%	41%	12%

ENERGY CONSUMPTION 10_nuovi infissi (EPS* graphite)+ Shade roll+NV										
Date/Time	Total Cooling kWh	Zone Heating kWh	TOT kWh	per m2	Reduction cooling %	Reduction heating %	**TOT Reduction %**	**PARZIALE**	TOT Reduction/m2	PARZIALE/m2
Annual	-3861.44	15336.7	19198	**35**	58%	39%	**44%**	**11%**	44%	11%
II floor	-661.67	3086.83	3749	**33**	62%	40%	**46%**	**11%**	46%	11%

ENERGY CONSUMPTION 11_nuovi infissi (EPS* graphite)+ louvre sidefins 70 cm +NV										
Date/Time	Total Cooling kWh	Zone Heating kWh	TOT kWh	per m2	Reduction cooling %	Reduction heating %	TOT Reduction %	PARZIALE	TOT Reduction/m2	PARZIALE/m2
Annual	-4970.92	16732.18	21703	39	46%	33%	37%	11%	37%	11%
II floor	-864.42	3357.78	4222	37	51%	35%	39%	11%	39%	11%

ENERGY CONSUMPTION 11_nuovi infissi (EPS* graphite)+ brise soleil 0° +NV										
Date/Time	Total Cooling kWh	Zone Heating kWh	TOT kWh	per m2	Reduction cooling %	Reduction heating %	TOT Reduction %	PARZIALE	TOT Reduction/m2	PARZIALE/m2
Annual	-5183.96	16213.39	21397	39	44%	35%	38%	11%	38%	11%
II floor	-915.73	3243	4159	36	48%	37%	40%	12%	40%	12%

Table 5. 14: Percentage reduction in terms of energy consumption/m^2, between the shading devices studied associated with nightly natural ventilation. Annual simulation.

Again, as done before, if we compare the energy used for cooling in the “current” situation with that used in the “final” upgraded hypothesis (whit polyurethane foam, shade roll, and a schedule of nightly natural ventilation) it’s possible to get a reduction in energy consumption for cooling in summer up to 58% for the whole building and up to62% for the single flat.

Just the good habit of ventilating at night can reduce energy consumption of about 11%.

5.4 Economic feasibility

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.[9]

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 simple products, not automatic.

Finally ventilation, that being natural and not mechanical, has no cost item, it's just a good habit, the only expense is the time to acquire it:

CASO STUDIO 2: INA-Olivetti								
Block 3 (II floor)			*Block 4 (II floor)*			*Building*		
Sup Laterale:	101.8	m^2	Sup Laterale:	61.2	m^2	Sup Laterale	489.0	m^2
sup vetrata	21.6	m^2	sup vetrata	19.4	m^2	sup vetrata	123.0	m^2
tende	12.3	m^2	tende	9.4	m^2	tende	65.1	m^2
brise soleil	14.8	m^2	brise soleil	14.8	m^2	brise soleil	88.8	m^2

Table 5. 15: Case study II INA Olivetti – Geometric properties

[9] As before 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 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)

Investment cost			€/m²	% labor costs	% security costs	Block 3 (flat 115 m$^{2)}$	Building
Insulation total expese							
EPS	E.10.60.30	m^2	40	5	0.7	4276	20538
ESP +grafite	E.10.60.30	m^2	45	5	0.7	4810	23105
Sughero	B ED MM 045	m^2	80	5	0.7	8551	41076
Replacement (of windows)							
infisso (fino a 3 mq)	D ED LL 075	m^2	336	3.67	0.08	7279	41449
rimozione	R 02. 110.10	m^2	7.84	73.21	2.21	443	600
totale						7722	42049
shading system							
veneziane e tende	01 01.P 13.E00	m^2	30	5		387	2050.7
Brise soleil	A.0072.0001.0003	m^2	44.46	5		691	4145.5
TOT [€]						**5198**	**25156**

Table 5. 16: Case study II INA Olivetti – Geometric properties and investment's costs

In this case as before an analysis, even a dynamic one, was conducted. The results are reported in the following tables.

Anni di vita del progetto		Consumi status quo	Consumi scenario finale	coeff. di attualizzazione (I+i)? i=4%	Consumi valore attuale dello status quo	Consumi valore attuale dello scenario	Risparmio annuo	Saldo
Anno	1	1035	562	0,9615	995	541	454	454
Anno	2	1035	562	0,9246	957	520	437	891
Anno	3	1035	562	0,8890	920	500	420	1311
Anno	4	1035	562	0,8548	885	481	404	1715
Anno	5	1035	562	0,8219	851	462	388	2104
Anno	6	1035	562	0,7903	818	444	373	2477
Anno	7	1035	562	0,7599	786	427	359	2836
Anno	8	1035	562	0,7307	756	411	345	3182
Anno	9	1035	562	0,7026	727	395	332	3514
Anno	10	1035	562	0,6756	699	380	319	3833
Anno	11	1035	562	0,6496	672	365	307	4140
Anno	12	1035	562	0,6246	646	351	295	4435
Anno	13	1035	562	0,6006	621	338	284	4719
Anno	14	1035	562	0,5775	598	325	273	4992
Anno	**15**	**1035**	**562**	**0,5553**	**575**	**312**	**262**	**5254**
Anno	16	1035	562	0,5339	553	300	252	5506
Anno	17	1035	562	0,5134	531	289	243	5749
Anno	18	1035	562	0,4936	511	278	233	5982
Anno	19	1035	562	0,4746	491	267	224	6207
Anno	20	1035	562	0,4564	472	257	216	6422

Table 5. 17: Economic viability of the upgrading investment. Whole building. Payback time estimated: 15 years.

Again taking into account an average value of the cost of energy (average between cost of electricity and natural gas) of 0,15 €/m^2 the payback period estimated is 15 years, definitely a reasonable one, both for the all building of considering just the single flat.

The following table shows the payback estimated for the single flat of about 115 m$^{2:}$

Anni di vita del progetto		Consumi status quo	Consumi scenario finale	coeff. di attualizzazione (l+i)^n i=4%	Consumi valore attuale dello status quo	Consumi valore attuale dello scenario finale	Risparmio annuo	Saldo
Anno	1	1035	569	0,9615	995	547	448	448
Anno	2	1035	569	0,9246	957	526	431	878
Anno	3	1035	569	0,8890	920	506	414	1292
Anno	4	1035	569	0,8548	885	487	398	1690
Anno	5	1035	569	0,8219	851	468	383	2073
Anno	6	1035	569	0,7903	818	450	368	2441
Anno	7	1035	569	0,7599	786	433	354	2795
Anno	8	1035	569	0,7307	756	416	340	3135
Anno	9	1035	569	0,7026	727	400	327	3462
Anno	10	1035	569	0,6756	699	385	315	3777
Anno	11	1035	569	0,6496	672	370	302	4080
Anno	12	1035	569	0,6246	646	355	291	4370
Anno	13	1035	569	0,6006	621	342	280	4650
Anno	14	1035	569	0,5775	598	329	269	4919
Anno	**15**	**1035**	**569**	**0,5553**	**575**	**316**	**259**	**5178**
Anno	16	1035	569	0,5339	553	304	249	5426
Anno	17	1035	569	0,5134	531	292	239	5665
Anno	18	1035	569	0,4936	511	281	230	5895
Anno	19	1035	569	0,4746	491	270	221	6116
Anno	20	1035	569	0,4564	472	260	213	6329

Table 5. 18: Economic viability of the upgrading investment. Single flat- Payback time estimated: 15 years.

Because of the pretty short period, even if we consider a dynamic analysis, as previously done for the first study case, it means taking into account the rising cost of electricity and natural gas, the payback period doesn't change a lot, as shown in the two tables below:

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 $(l+i)^n$ i=4%	Consumi valore attuale dello status quo	Consumi valore attuale dello scenario	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

Table 5. 19: Payback time of the investment. Building. Approximately 14 years. i=4%

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 $(l+i)^n$ i=4%	Consumi valore attuale dello status quo	Consumi valore attuale dello scenario	Risparmio annuo	Saldo
Anno	1	309,8	511,3	821,1	117,3	306,3	424	0,9615	789	407	382	382
Anno	2	320,6	528,1	848,7	121,4	316,4	438	0,9246	785	405	380	762
Anno	3	331,5	544,8	876,3	125,5	326,4	452	0,8890	779	402	377	1139
Anno	4	342,3	561,6	903,9	129,6	336,5	466	0,8548	773	398	374	1513
Anno	5	353,1	578,4	931,5	133,7	346,6	480	0,8219	766	395	371	1884
Anno	6	363,9	595,2	959,1	137,8	356,6	494	0,7903	758	391	367	2252
Anno	7	374,7	612,0	986,8	141,9	366,7	509	0,7599	750	387	363	2615
Anno	8	385,6	628,8	1014,4	146,0	376,7	523	0,7307	741	382	359	2974
Anno	9	396,4	645,6	1042,0	150,1	386,8	537	0,7026	732	377	355	3329
Anno	10	407,2	662,4	1069,6	154,2	396,9	551	0,6756	723	372	350	3679
Anno	11	418,0	679,2	1097,2	158,3	406,9	565	0,6496	713	367	346	4025
Anno	12	430,6	699,6	1130,1	163,1	419,1	582	0,6246	706	364	342	4367
Anno	13	443,5	720,5	1164,0	168,0	431,7	600	0,6006	699	360	339	4706
Anno	**14**	**456,8**	**742,2**	**1198,9**	**173,0**	**444,7**	**618**	**0,5775**	**692**	**357**	**336**	**5041**
Anno	15	470,5	764,4	1234,9	178,2	458,0	636	0,5553	686	353	332	5374
Anno	16	484,6	787,4	1272,0	183,5	471,7	655	0,5339	679	350	329	5703
Anno	17	499,1	811,0	1310,1	189,1	485,9	675	0,5134	673	347	326	6029
Anno	18	514,1	835,3	1349,4	194,7	500,5	695	0,4936	666	343	323	6352
Anno	19	529,5	860,4	1389,9	200,6	515,5	716	0,4746	660	340	320	6672
Anno	20	545,4	886,2	1431,6	206,6	531,0	738	0,4564	653	337	317	6989
Anno	21	561,8	912,8	1474,6	212,8	546,9	760	0,4388	647	333	314	7303
Anno	22	578,7	940,1	1518,8	219,2	563,3	782	0,4220	641	330	311	7613
Anno	23	596,0	968,3	1564,4	225,7	580,2	806	0,4057	635	327	308	7921
Anno	24	613,9	997,4	1611,3	232,5	597,6	830	0,3901	629	324	305	8226
Anno	25	632,3	1027,3	1659,6	239,5	615,5	855	0,3751	623	321	302	8528

Table 5. 20: Payback time of the investment. Single flat. Approximately 14 years. i=4%

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 € 220,000, the bonus can be considered equal to 14000 €.

Present value of the property in square meters: 1900 € /m²
Flat surface: 115 m
flat value: € 220,000
adjustment costs: ~ € 5,200
"bonus value "of green flat: 10% € ⟶ 22000

Tipologia	Stato conservativo	Valore Mercato (€/mq)		Superficie (L/N)	Valori Locazione (€/mq x mese)		Superficie (L/N)
		Min	Max		Min	Max	
Abitazioni civili	NORMALE	2800	4200	L	7	10,5	N
Abitazioni di tipo economico	NORMALE	1900	2900	L	4,8	7,3	N
Box	NORMALE	1650	2500	L	5,5	8,3	N
Ville e Villini	NORMALE	3100	4700	L	7,8	11,8	N

Table 5. 21: Risultato interrogazione: Anno 2010 - Semestre 2 Provincia: Napoli, Comune: Pozzuoli –

Fascia/zona: Semicentrale/Pozzuoli Alta - Variante Solfatara – Olivetti. Codice Di Zona: C1. Microzona Catastale N.: 2.

Tipologia prevalente: Abitazioni civili. Destinazione: Residenziale

Considering that the cost of the investment is about € 5000-5200 (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.

5.5 Reduction of CO_2 emissions

The software, as mentioned above, provides an estimate of CO_2 emissions[10] and even in this case, it's important to emphasize how the proposed measures are effective in reducing emissions, especially during the summer months, supporting the importance of these measures in countries with hot (and humid) climate.

CO2 Reduction								
Date/Time	Current	EPS	Cork	EPS+grafite	Shading System no ventilation	Shading System + ventilation	final solution	% of reduction
January	2308,7	1696,7	1701,5	1698,8	1699,7	1691,8	1691,8	27%
February	2017,7	1500,1	1504,2	1501,9	1501,1	1489,7	1489,7	26%
March	1846,7	1381,5	1385,2	1383,2	1383,4	1377,3	1377,3	25%
April	1111,0	852,2	855,0	853,1	853,3	851,9	851,9	23%
May	556,7	556,7	556,7	556,7	556,7	556,7	556,7	0%
June	1074,2	1104,3	1102,4	1103,9	922,2	754,3	754,3	30%
July	1919,2	1778,6	1780,8	1778,9	1469,4	1178,2	1178,2	39%
August	2113,2	1935,1	1940,2	1935,5	1603,1	1348,5	1348,5	36%
September	925,6	1016,0	1016,4	1015,6	815,0	682,3	682,3	26%
October	694,8	630,2	630,6	630,4	632,0	634,1	634,1	9%
November	1534,3	1147,8	1148,4	1149,1	1149,8	1143,6	1143,6	25%
Dicember	2276,9	1697,0	1699,9	1698,9	1698,9	1693,3	1693,3	26%
TOT	18379,0	15296,2	15321,3	15306,2	14284,6	13401,6	13401,6	27%

Table 5. 22: The table shows the monthly emission of CO_2 for each upgrading step and the percentage of reduction that can be achieved with the final solution.

[10] CO_2 emissions are calculated in DesignBuilder by multiplying fuel consumption by the kg CO_2 per kWh conversion factor for that fuel.

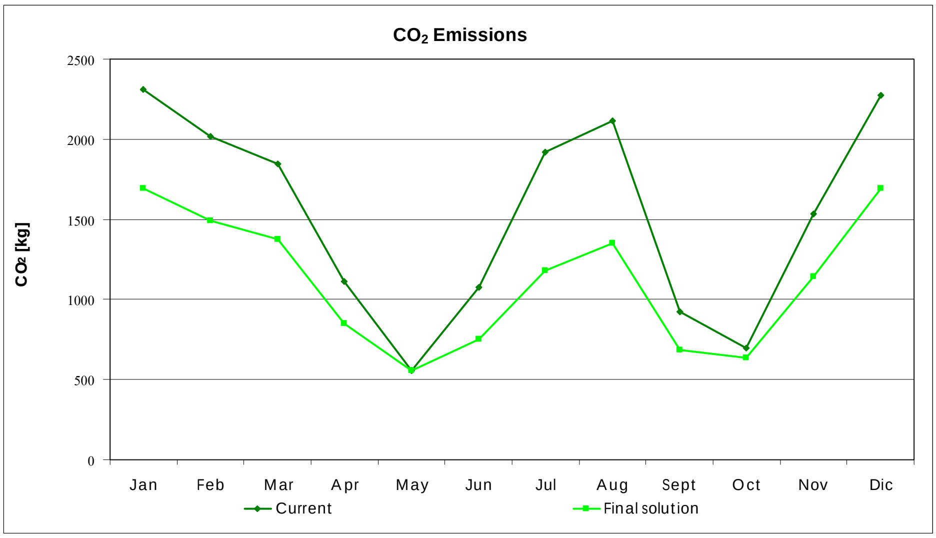

Fig. 5. 34: CO_2 Emissions, annual simulation.

Even more that what has been obtained in the first study case sunscreens and ventilation in a hot climate have an enormous importance.

The graph shows a reduction in annual CO_2 emissions (relative to energy consumption for heating and cooling) with an average of 27%, reaching a maximum of 39% just during the summer months, in relation to energy consumption for cooling.

5.6 Summary

In percentage terms it's possible to find a reduction, during winter, of energy consumption for heating around 29% for the only insulation.

It has been also obtained a reduction in consumption for summer cooling by 11% thanks to nightly natural ventilation and 12% due to the use of a shading system;

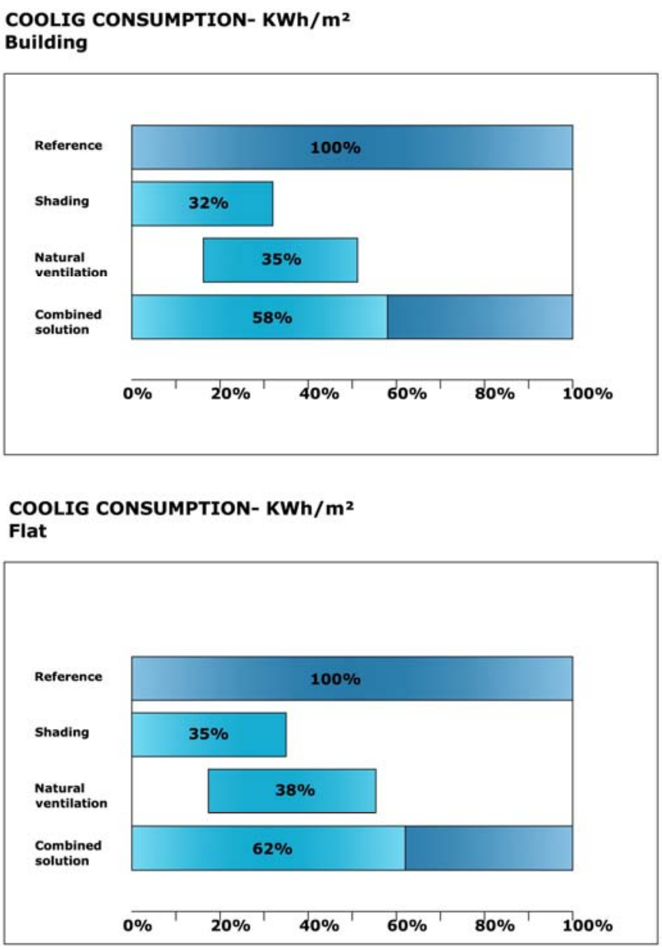

Fig. 5. 35: Reduction in cooling consumption for each step analyzed, in percentage.

A combined solution of all interventions would lead to a reduction in terms of consumption (on winter heating and summer cooling) by 44%.

The scenario1, as previously seen, showed a reduction of about 11% due to the replacement of windows with a low – emission type, but, as we noted earlier, is a type of investment is expensive and not particularly profitable.

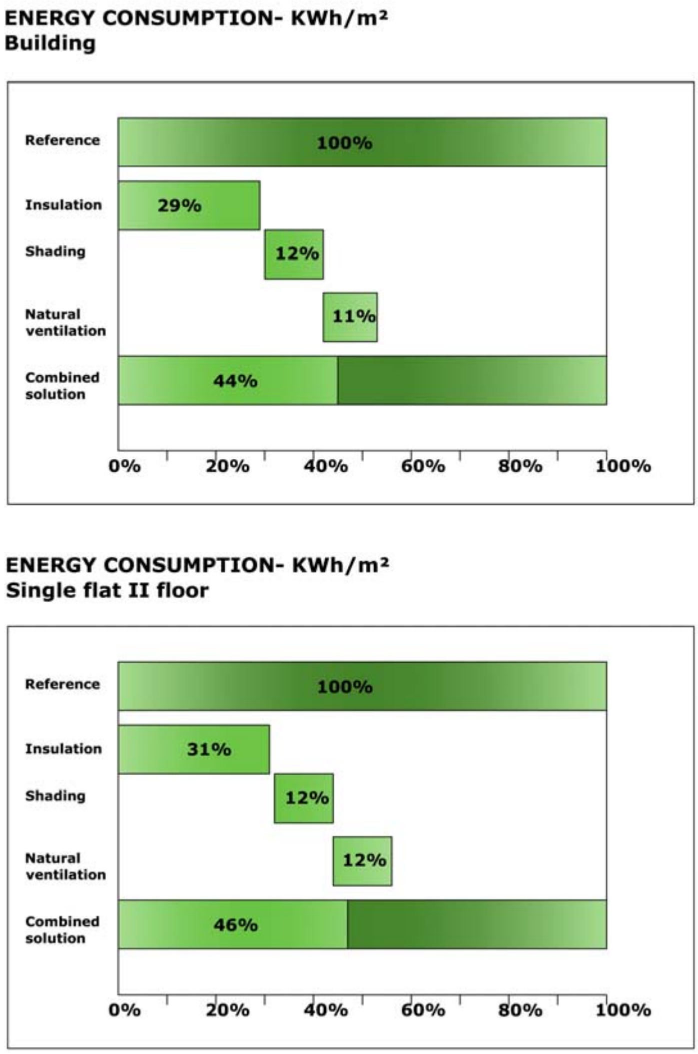

Fig. 5. 36: Reduction in energy consumption for each step analyzed, in percentage.

Chapter VI - Conclusion

6.1 Conclusions and final remarks

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 in these years. The overall aims of this work 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 with the purpose of reducing the energy consumption of apartment buildings and improving living conditions for occupants bringing about an overall reduction in CO_2 emission.

Through the two study cases, characterized by some similarities and differences, it is possible to outline some final remarks:

- Depending on the budget available for retrofitting, and on other motivations (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, depending on the climate/social/economical priority;
- The thermal insulation of the wall has a primary role in a hot climate too;

- Replacement of windows and some type of insulation of the façade are the most expensive measures, for this reason it is important to consider carefully what kind of window (it means of U value) is really required; not necessary an expensive product turns out to be advantageous or necessary.
- Another aspect we did not consider are the so called “co-benefits” of energy efficiency measures. The double glazed window element (upgraded from the original window system) will improve the energy conservation of the building by reducing heat losses through the fabric, but the windows will also improve the levels of IEQ (Indoor Environmental Quality) for the occupants by reducing draughts, improving noise insulation and improving the appearance of the building.
- In warm weather the consumption for cooling system is not negligible, also burdensome, if not more in some cases, than the heating one. Cooling consumption cannot be neglected;
- It is therefore essential to pay attention to the choice of an appropriate shading system, though simple. Nowadays on the market it is possible to find a lot of shading devices, we must find the one that suits just fine. Thou the function of solar control might be carried as a secondary function and shading devices might be installed primarily for privacy, security night insulation, or as a traditional semantic feature, however, the common practice and conclusions reinforced the beliefs that the response of the inhabitants of hot climate area, is powerful enough to initiate shading devices operation for the maintenance of indoor comfort.
- 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. Passive ventilation works well in mild summer weather, establishing a cross-breeze can really help in saving a bundle on air conditioning costs;
- It is essential not to forget the wisdom in traditional architecture, thou the mass knowledge and technology coming from the West should not be ignored, both in new building and in retrofitting action it is important to remind that “[…] passive responses of the traditional architecture to the local environmental conditions and

influences represent a treasury of knowledge and information patterns for modern solar and bioclimatic architecture. […] the architecture must be a synthesis of both aspects so that it is in harmony with the traditional values suitable for the contemporary societies, their cultural identity and human scale and based on the appropriate technology”[1].

- Costs for retrofitting investment similar to the ones proposed, choosing the best solution appropriately, can be recovered within at least two decade, a very reasonable time. If energy prices remain high and current policy measures are taken into account, energy-saving retrofits would be an highly attractive investment opportunity. The more a retrofitted apartment (or house) gets a bigger economic value and the *energy price* will be a relevant market factor for the future evolution of the economic potential.
- 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%.

In Italy the average energy use per area in domestic buildings is high, and building belonging to social housing show less sustainable measures in terms of energy features, energy performance, environmental features, and privacy.

Issues, considered in the assessment of buildings, such as energy use per square meter and CO_2 emission are alarming.

It is not possible to continue postponing facing the solution of these problems, as if they will have effect only in a distant future, not at all linked to the present that we are living.

Though nowadays concepts like low energy comfort buildings and energy savings measures are an integral part of the energy concept since the beginning of the design process, some of the techniques usually

[1] SERGHIDES D.K., The Wisdom of Mediterranean Traditional Architecture Versus Contemporary Architecture – The Energy Challenge, The Open Construction and Building Technology Journal, vol. 4, pg. 29-38, 2010.

adopted in the design phase are suitable to be implemented also in retrofitting actions.

National housing condition surveys showed a need to improve the standard of housing stock (especially buildings built from the fifties up to the eighties) in a bid to improve health of the occupants and reduce energy usage and the emission of CO_2.

Though the use of new and implemented techniques in new buildings can help gain new insight on performances and experience in correct implementation the truth is that the current trend is to retain old housing stock and adapt it to the needs of the current market, rather than to demolish old buildings in favour of new development.

Because of the worldwide economic crisis in which we are going through, this trend likely to continue for many years to come. With this in mind, retrofitting actions need to be increased as more buildings require upgrading.

How? First of all through information, not only of the "insiders" (i.e. architects, engineers, surveyors or builders), but of citizens, users, owners, who need to be informed and updated about the importance that their actions can have and benefits that can derive, both from an “individualistic” point of view, and from a more general point of view that takes into account the good of the community.

This kind of retrofit actions should be on the agenda, and should be the result of discussions with local authorities, housing associations and other large scale apartment building owners, that have to be involved with retrofitting actions.

Then from a policy point of view, it is important that Governments reduce legal, structural and socio-economic barriers to invest in energy-saving measures, by supporting the communication and information for decision makers namely consumers, investors and financial institutions.

Government should encourage refurbishment and retrofit projects which not only improve the structural condition of the buildings but also reduce the energy consumption and improve the living conditions of the occupants (resulting in savings for the national health sector).

6.2 Future scenario

Obviously, as mentioned earlier, studies researches, tools and actions, in the energy sector, must be appropriately adapted to the climate in which they have to be applied.

For example in Italy, the hot climate that characterizes the southern regions requires an "ad hoc" legislation, which defines in an accomplished way, the problem of consumption for cooling in summer.

One of the Keep Cool Program objectives, for example, consists in developing an approach for a bottom-up assessment of the energy savings related to sustainable summer comfort solutions.

But saving energy comes not only from the retrofitting actions of old buildings or from a policy of national, regional, or local incentives, it is realized by the individual user behavior before anything else.

It is import to re-educate people to a sort of "comfort codes of conduct" that "[…] systematically take advantage of behavior choices in order to improve comfort and take stock of opportunities of flexibility in the use of buildings, both new and existing. It is probably a combination of actions on existing buildings, guidelines and experience in the design of new buildings and well thought behavioural choices that can lead to sustainable summer comfort"[2].

Therefore, it would be economically wrong to renovate a house without simultaneous investment into energy efficiency. The potential cost degression for energy-efficient retrofits is significant but not strong enough to become the relevant driving factor for positive economic assessments within the next 50 years. It is essential to act simultaneously on several fronts.

If on the one hand, it is important to reduce the energy consumption of buildings and design new buildings with zero emissions, it is

[2] PAGLIANO L., GRIGNON-MASSÉ L., HELDER G., MARCHIO D., PIETROBON M., THÜR M., Evaluation of building envelope retrofit techniques for reducing energy needs for space cooling, Act! Innovate! Deliver! Reducing energy demand sustainably, eceee 2009 Summer Study Proceedings. Kph Trycksaksbolaget AB, Uppsala/Upplands Väsby, pg. 1649, Sweden 2009.

important to consider that neither buildings nor their inhabitants are "isolated entities". There is a larger reality, urban, in which the management of energy resources and consumption takes on far greater scale.

An increase in world population, that is one of the today's megatrends, would have as an immediate consequence, the rising demands for economic development and material commodities, not only housing, but also food, personal mobility etc.

It is important to understand the principles of smart growth that balances the need for analysis of resource consumption in the urban space coupled with an understanding of urban system and infrastructure linkages, the main goals has to be the stabilization of the disparity of materials and energy resources usage among developing and industrialized countries.

"Over half of humanity currently lives in urban centers and this proportion is expected to increase to nearly 60% in the next 50 years.[3] Not only the world's urban population is increasing, but also the area extent of individual cities is dramatically growing in size.[4] Cities have significant influences on natural ecosystems, and these impacts have become increasingly apparent as the size and number of cities continues to grow. With these urban changes the intensity and extent of urban impacts on ecosystems continues to increase.[5][…] Although urbanization is usually seen as a demographic and economic phenomenon, it is also a process of ecological transformation by humans, which significantly influences the functioning of local and global ecosystems. As a result, urbanization is one of the key drivers of global environmental change".[6]

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[3] United Nations: World Urbanization Prospects. New York: United Nations; 2001.

[4] Grimm NB, Faeth SH, Golubiewski NE, Redman CL, Wu J, Bai X, Briggs JM: Global change and the ecology of cities. Science 2008, 319:756-760.

[5] Hu D, Huang S-L, Feng Q, Li F, Zhao J-J, Zhao Y-H, Wang B-N: Relationships between rapid urban development and the appropriation of ecosystems in Jiangyin City, Eastern China. Landscape Urban Plan 2009, 87:180-191.

[6] Huang S., Yeh C., Chang L., The transition to an urbanizing world and the demand for natural resources, Curret Opinion in Environmental Sustainability, Vol.2, Isue 3, pg136-143, Elsevier 2010.

It is easy to understand that urbanization leads to conversion of a natural landscape into an urban area, that's why has direct and indirect influences on soil resources, water resources, food security etc…

"Water management for example is a primary problem both in the developed and developing world, and is seen as a critical issue in megacities, in the same way due to the population growth, the global demand for agricultural products is increasing, similarly timber consumption demand and biomass for heating."[7]

But urban growth should not be the only forces driving land use and land cover change. To maintain a global perspective and optimize the exploitation and processing of local resources would be desirable. This can be achieved through an in deep study of the urban metabolism of an area.

"Urban metabolism was first suggested by Wolman[8] as the materials, energy, and food supplies brought into cities, transformed within the cities, and the products and wastes then sent out from the cities. The concept of urban metabolism brings attention to the fact that the metabolic cycle is not completed until the residues of daily consumption have been removed and disposed of adequately with minimum nuisance and hazard to life".[9]

There are in fact ways to alleviate the increasing burden of urbanization on natural resources system, trying for example to re-use materials, or using locally available energy resources (solar, wind, water, geothermal, biomass etc.). "In order to achieve a more sustainable future in a rapid urbanizing world, a more multi-sectoral approach by including perspectives from economic development, resource conservation, planning and ecology at the urban policy making level is a must".[10]

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[7] Huang S., Yeh C., Chang L., The transition to an urbanizing world and the demand for natural resources, Curret Opinion in Environmental Sustainability, Vol.2, Isue 3, pg136-143, Elsevier 2010.

[8] Wolman A: The metabolism of cities. Sci Am 1965, 213:179-188.

[9] Huang S., Yeh C., Chang L., The transition to an urbanizing world and the demand for natural resources, Curret Opinion in Environmental Sustainability, Vol.2, Isue 3, pg136-143, Elsevier 2010.

[10] Ooi GL: Challenges of sustainability for Asian urbanization. Curr Opin Environ Sustain 2009, 1:187-191.

Strategies of reduction of energy consumption have to be associated with a wiser use of energy sources, in the domestic sector the use of renewable energies is still too low, as the *Rapporto Energia ed Ambiente* by ENEA, shows in the graph below:

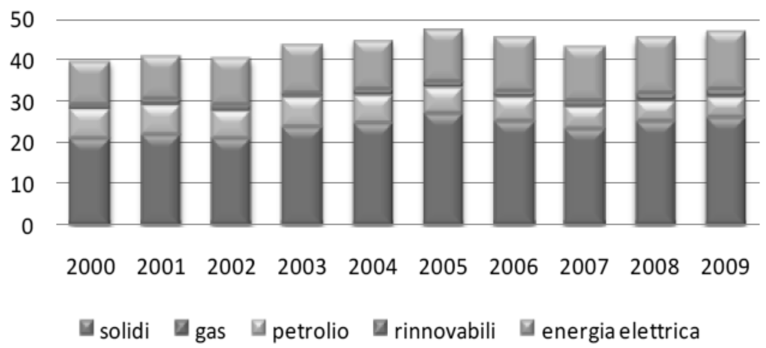

Fig. 6. 1: Italy, final consumption of energy by source and sector. Domestic sector. Years: 2000-2009 (Mtep). Rapporto Energia ed

Research is now moving towards a multidisciplinary approach beginning with the urban scale, and then moving on to regional and national approach.

In each city, in fact, it is possible to identify “homogeneous areas”, where existing buildings have the same date and are characterized, more or less, by the same structural characteristics, and therefore in good approximation by the same problems in terms of energy,(as can be seen from the example in Fig. 6.2 on the city of Zurich).

This spatial distribution of building areas should be based on

- aspect of the building site
- construction period
- aspect of construction process
- building type
- technical aspects
- social aspects
- ecological aspect.

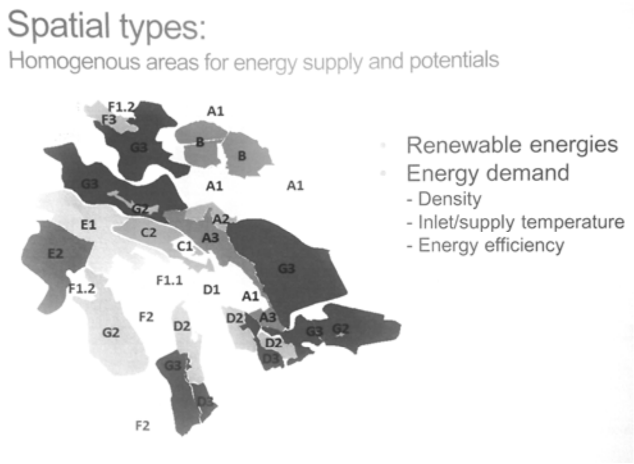

Fig. 6. 2: Example of identification of homogeneous area for Energy supply and potentials, city of Zurich. From: H Wallbaum, "New approaches and research methods for Sustainable Construction in the 21th century", Zurich, may 31, 2001 – colloquium on sustainable construction.

Once identified, these homogeneous areas could suggest also interventions to be made (to a large maximum) to get the buildings more energy efficient, with less energy consumption and CO_2 emission.

This sort of "map of energy-efficiency potential", should show the area of densification or new building areas, where it is possible to design and build smart building or green building, but also those sector where a retrofit of old buildings is needed, or where a demolition and reconstruction is desirable.

The areas of densification would have precise guideline for the new interventions, the area where a retrofitting is expected, would have general guidelines per building type.

Then the study should also integrate, in each macro areas, the identification of the most suitable renewable energy sources, the closest, available on site.

Homogenous areas for energy supply and potential should show same properties about energy demand (density, energy efficiency etc...) and renewable energy use opportunity.

This spatial distribution of resource areas should be based on:

- ecological aspects
- aspect of operating process
- aspects of planning process
- functional aspects
- economic aspects

In southern Italy, for example it would be possible to integrate the production of energy using renewable sources as: solar (thermal, photovoltaic), wind (already quite common) the biomass and bio-fuels, and finally geothermal energy.

About solar energy we can say that thanks to government incentives in recent years there has been a sharp increase in the production of solar energy. This is also favoured by the particular geographical position of our Country

The correct exposure of the photovoltaic modules to solar radiation is a key factor in order to obtain the optimum performance of the system in terms of electricity production.

For example, in Italy the best exposure is to the south at an angle of about 30-35 degrees. The map below shows for the Italian territory electricity potential of a photovoltaic plant optimally oriented and inclined.

Fig. 6. 3: Global irradiation and solar electricity potential in Italy –Optimally-inclined photovoltaic modules. web site: http://www.fotovoltaicoenergiasolare.it/

2009 was an extraordinary year for the photovoltaic market in Italy, with about 40,000 plants come on stream, with a capacity of almost 720 MW.

These results place our country, for power installed annually, second in the world, behind Germany and ahead of countries which have always been considered leader in this field, such as USA, Japan, Spain.

Although the map shows that southern regions are those with the greatest potential, the regional distribution of solar energy production shows high and fairly homogeneous values among some northern regions: Lombardy (10.5%), Trentino (10.0%), Emilia Romagna (9.1%).

In central Italy Umbria and the Marches excel with respectively 5.3% and 5.1%. In the southern regions and islands, Puglia holds national leader with 12.3% and Sicily with 5.5% came in second place. Campania region could do a lot in this direction.

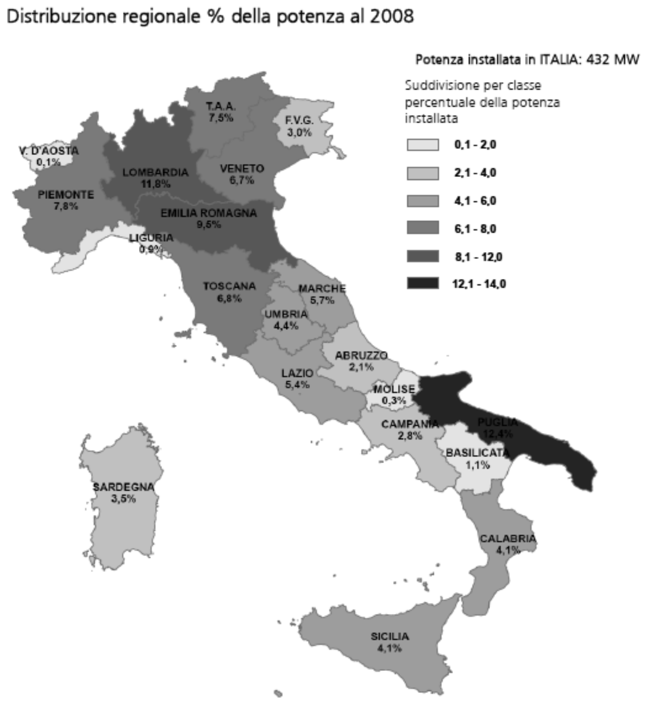

Fig. 6. 4: Regional distribution of power % in Italy, 2008. From GSE "*Il solare, dati statistici al 31 dicembre 2008*"

This positive result was undoubtedly due to the favourable conditions that have arisen in Italy for the development of photovoltaic systems, by virtue of both the entry into force of the *conto energia* and other supportive measures such as *scambio sul posto* and *ritiro dedicato* of the energy produced.

This scenario, combined with the significant reduction of plant costs recorded in the last two years following the sudden drop in the price of modules, led to a marked improvement in the pay back time of the investment. It is possible to predict, and to hope, that the photovoltaic market in Italy will continue to grow at a rapid pace.

About wind energy on the other hand the geographical position of Italy, plus the presence of mountain and water, causes a different pattern of winds over the year and from region to region.

Italy can still count, especially in the Mediterranean areas and in the southern islands, on winds of good intensity, such as the Mistral, the Scirocco and the southwest wind.

The results of an investigation, in which also ENEA took part, showed that the sites most suitable for the exploitation of wind energy are along the Apennine ridge, 600 m above sea level and, to a lesser extent, on coastal areas . The most interesting regions are those of the South, especially in Campania, Puglia, Molise, Sicily and Sardinia, and the area between the provinces of Trapani, Foggia, Benevento, Avellino wind power is the primary national hub.

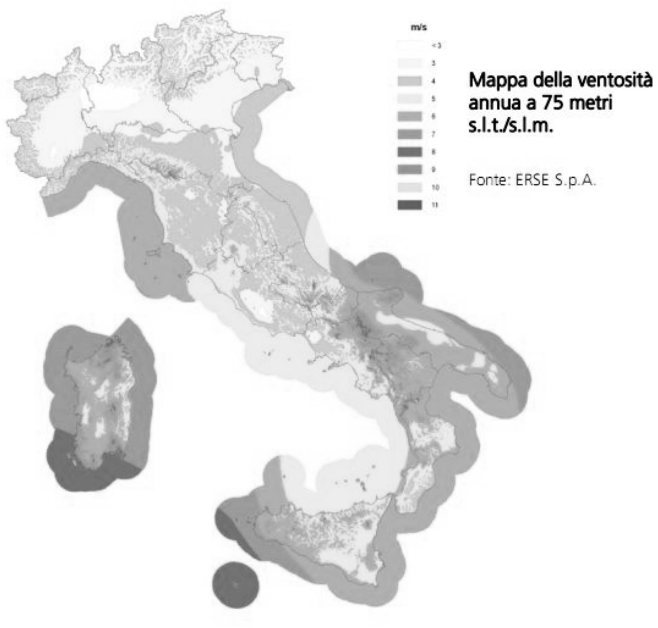

Fig. 6. 5: wind map (annual base) 75 m asl. Web site: http://atlanteeolico.rse-web.it/viewer.htm

In Italy about 760 MW of wind power were installed, corresponding to a total of more than 1,350 wind turbines. Campania and Puglia are leading regions. But still a lot can be done.

Finally the use of geothermal sources for energy purposes is not only relative to the electricity production, in fact the possibility to exploit the energy potential of sources with low-medium enthalpy for thermal purposes, is the most ancient and widespread use of geothermal energy.

In Italy and in Campania exists a large number of geothermal phenomena with characteristics compatible with existing plant, resources that have reached technical maturity and very high reliability.

Unfortunately the spread of such technologies is still hampered mainly by economic problems. In particular, the main problem is the influence of aggressive geothermal fluid used : in fact it usually presents fouling and corrosive substances associated that constrain a direct use.

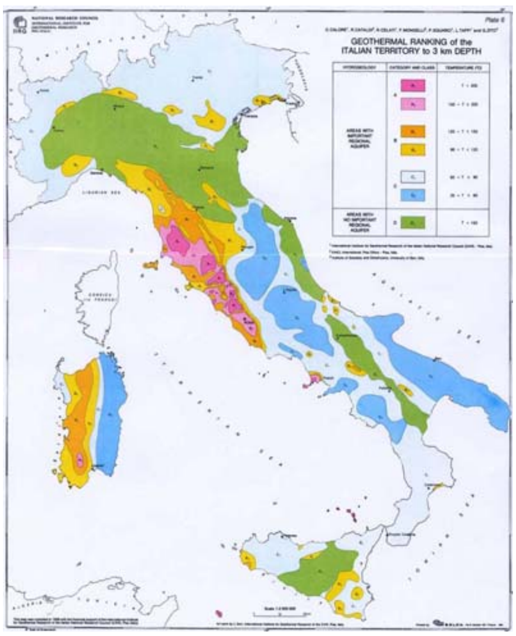

Fig. 6. 6: Geothermal ranking of the Italian territory to 3 km depth. From “ Piano Energetico comunale Regione Campania” web site: http://www.sito.regione.campania.it/energia/energia_studi/

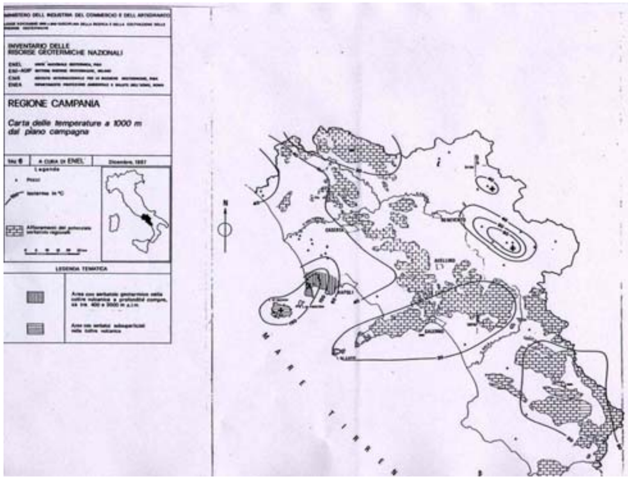

Fig. 6. 7: Temperature distribution- 1 km depth, Campania Region. From " Piano Energetico comunale Regione Campania" web site: http://www.sito.regione.campania.it/energia/energia_studi/

In the *Piano Energetico Regionale*. an analysis was conducted, about energy, economy, and environmental impact, with the aim to evaluate the potential of geothermal resources.

It was possible to estimate a minimum contribution of geothermal direct ascribable to the Campania region of 0.005 Mtoe/year (with an installed power of about 12 MW).

Such a scenario is also aiming at the rationalization of existing exploitation primarily designed for a partial use of the source for balneological purposes and limited winter heating.

In relation to the environmental impact, the emissions of CO_2 avoided, were then evaluated. In particular if normally in the calculation of greenhouse gases emissions a value of 2.8 tonnes of CO_2 per toe produced was considered, in geothermal energy this value is reduced to 2.3 tonnes of CO_2 equivalent to consider the direct emissions of CO_2,

	Energia risparmiata	Investimenti		CO_2 evitata
	[Mtep/a]	[M€]	[MD£]	[Mt di CO_2/a]
MIN	0,005	13,9	27	0,0115
MAX	0,01	77,4	150	0,023

Fig.6. 1: Energy savings, investment costs and emissions of CO_2 avoided From " Piano Energetico comunale Regione Campania" web site: http://www.sito.regione.campania.it/energia/energia_studi/

An approach of this type, studied in detail in an energy plan that not only turns his attention to the residential sector but also to transport, lighting, exploitation of water resources and food production, could change effectively how to tackle the energy problem.

"These structural changes direct individual countries and construction activity itself towards a more balanced, less vulnerable sector in the European economy. Actually experienced demand and musts in the near-future (efficient energy consumption, upgrading the built environment, housing replacement, new health utilities for the ageing population, lowering CO_2 emission buildings) are expected to force construction to turn into a higher value and higher quality performing sector. This will require new products, new technologies and new skills."[11]

"The management of a city's resource metabolism, including the natural capital that supports these flows, is becoming a central concern to cities that want to move toward sustainability".[12]

Would be desirable that the results obtained from this research process would be used to plan an effective refurbishment retrofit project,

[11] Anna Gáspár, Senior Advisor of Buildecon and the Hungarian Euroconstruc, from *"Resource-efficient construction - The role of eco-innovation for the construction sector in Europe". EIO Thematic Report April 2011*

[12] Wackernagel M, Kitzes J, Moran D, Goldfinger S, Thomas M: The Ecological Footprint of cities and regions: comparing resource availability with resource demand. Environ Urban 2006, 18(1):103-112.

maybe in association with a resource usage planning within a PEC (Piano Energetico Comunale), acting, in this way, both on reducing energy consumption and on using wisely local energy resources.

This could allows to develop individual scenarios and to analyze their evolving impact in the future. Applying these principles at a neighbourhood scale, analyzing for example each “building park” as done in the case of Zurich, such model could allow to identify the most important political and technological levers concerning efficiency of measures.

“From these levers recommendation can be inferred for decision markers (administration, municipalities, portfolio managers)”[13].

These efforts could contribute to improve urban resource efficiency and to provide pathways for the development of appropriate and effective sustainable technologies.

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[13] H. Wallbaum , D-BAUG, Annual report 2010, pg 38.

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