

**MULTIDISCIPLINARY DESIGN PROCESS: URBAN, ARCHITECTURAL
AND TECHNOLOGICAL ANALYSES FOR ENERGY-EFFICIENT
RESIDENTIAL BUILDINGS IN NORTHERN ITALY**

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ABSTRACT

The aim of this paper is to present the multidisciplinary design process developed for a research on recent residential buildings in Northern Italy. The novelty of the approach is the concrete application on case studies of holistic analysis process. The multidisciplinary team, composed by urban planners, architectural designers, and experts in energy-efficiency techniques, has examined two buildings preventively designed under the Biocasa protocol© of a cooperative company active in Northern Italy.

The aim of the project was to identify an integrated procedure to increase the environmental quality (specifically in term of energy efficiency) of these houses. The research was articulated in three levels: 1. Urban, 2. Architectural, 3. Technological. The plan was to investigate alternative designs for the buildings proposed by the cooperative developer, driving the design towards the realization of climate-sensitive buildings: minimizing the negative effects on the climate using the smallest amount of resources and energy and, at the same time, making maximum use of the positive

effects, such as the sun, to create a “healthy” interaction between indoor and outdoor climate conditions in buildings.

The alternative outcomes have been compared with the original ones in order to understand and to measure the positive and negative effects, using the tools: CENED (steady-state) and TRNSYS for the estimation of energy consumption and ECOTECT for daylight analyses. The parameters considered for the alternative projects belong to different fields: environmental at urban scale (wind, solar exposure, orientation, climate condition), architectural (shapes, internal layout, building types), constructive (insulation, shadows, openings, etc.), and systems (HVAC, renewable energy sources).

The multidisciplinary nature of the research emphasizes the importance of the process, which integrates different disciplinary approaches, to carry out a sustainable house and to transform the generic concept of sustainability into a measurable element with some comparable pointers.

Key words: Multidisciplinary Design Process, Urban Scale, Bioclimatic Approach, Energy Audit.

Introduction

This paper presents the results of a multidisciplinary research, with the goal of providing designers, architects, or engineers with an operating tool to support a sustainable design process. The outcome of the work may be used as a handbook for the design of low energy residential buildings in Northern Italy, which helps building designers to approach the potential of sustainable strategies in terms of comfort and energy efficiency.

The paper's main purpose is to supply a methodology of analysis and optimization of residential buildings, applying it to a case study realized by an Italian cooperative building developer, which works mostly in the geographic area of the Piemonte, Lombardia and Veneto regions.

The case study is a residential building, which is the most common type required by the current market. The average flats go have one to four rooms. The case study is localized in the region of Lombardia in Northern Italy with a DD equal to 2861, climatic zone E, according to the Italian regulations.

The analysis started with the study of the current condition of the project (Initial Project, IP) and foresees a deep check on the IP with its optimization (Optimized

Project, OP), concluding with the definition of a new proposal (New Project, NP), which considers the best strategies individuated in the phases before.

The Multidisciplinary Design Process

Object and outcome

The research allowed to identify the most adapted technological and design strategies to the temperate climate in order to guarantee a suitable comfort. In Italy relatively few experiences have been made in this field, even if there are many examples of buildings with “spontaneous and passive behaviour” in milder or dry climate. Italy is not characterized by extreme temperatures and humidity, while limited thermal excursions exist between night and day.

The main goal of the project is to provide the building with appropriate morphologic and constructive choices, in order to cover both the winter solar gains and heat conservation and to reduce the overheating in the summer. Many variables are mutually combined toward this objective, known in literature as a “climate sensitive building”: orientation, morphology, thermal insulation, window dimensions, shadows, thermal capacity and absorption of material surfaces. The multidisciplinary design process presented aims to combine these variables and organize them in order to define a methodological approach reusable for other projects.

Methodology

The evaluation of the influence of each aspect (urban, typological and technological) on energy efficiency follows the same steps for all three projects (IP, OP, NP) through the definition of simulation models with the software: CENED (steady-state) and IDA ICE (dynamic).

The critical review of the results becomes, at each phase, the input data for the following one.

Figure 1 shows the methodology path of the analyses. Starting from the IP, after the simulation, the elaboration of the results permits to define the input for the OP. Secondly, making the analyses on the optimized project, the path is the same until the definition, again, of the input for the following steps.

Finally the analyses on NP have allowed quantifying the possible reductions, for every considered parameter, of the annual consumption for a residential building.

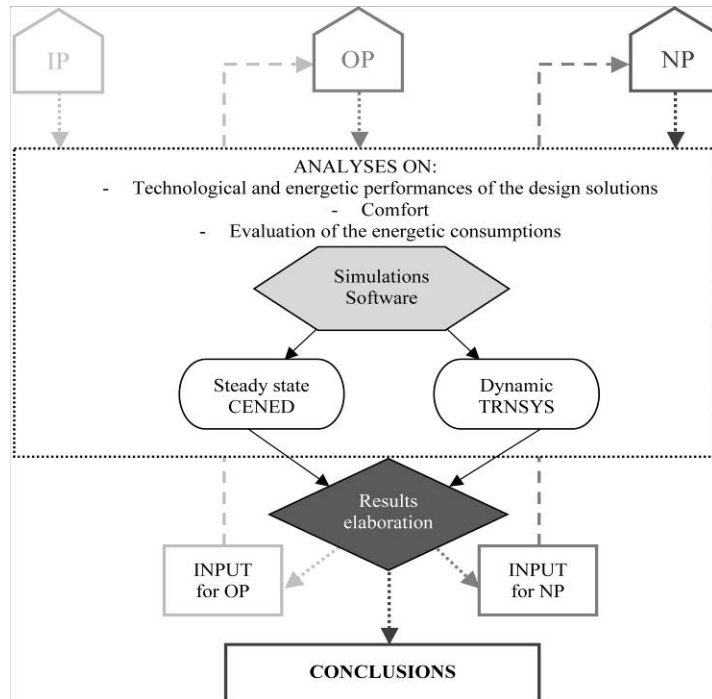


Figure 1: Methodology for the analysis of case studies

Urban Design Level

The general goal of the research was interpreted at the urban design level. For “urban design”, a term more preferable than “urban planning” (which is related to the production of rules and urban plans), the goal was to identify a process (or an ordered series of steps and actions) in order to make a preliminary evaluation of a site designated, by the urban plan, for predominant residential use. The meaning of the process is to drive the subsequent phases of the project, the placement of the buildings on the site analysis, the in-site relations between them and the surrounding landscape and resources. This preliminary evaluation would be helpful to take into consideration, since the very first step of the process is to give concern to the issues related to the reduction of energy consumption, particularly those from non-renewable resources or, to their production.

The belief that stands at the base of this part is that, from an energy point of view, a proper design lies not only in the arrangement of openings in the facade, or in the chosen building skin, or in the selection of alternative energy sources, or in the choice of technologies and materials suited to the case, but also in the selection of proper building types and a preliminary and deep site-analysis.

To drive the site-analysis a multifactor tool was prepared to describe the issues to be taken into consideration in the analysis of the chosen site for the construction of a residential project. The tool is organized around these elements:

- an indicators check-list;
- the ways to measure them or, where available, software to be used –freeware preferably-, or official sources where data is found regarding the specific issue;
- a copy, or a link, to grey literature ("information produced on all levels of government, academics, business and industry in electronic and print formats not controlled by commercial publishing") on the specific matter. Preliminary to the analysis of the indicators are some general aspects to take into consideration, such as:
 - topography and physiography (using geographic or satellite maps as a base),
 - accessibility (through car roads, bike and walking paths),
 - constraints and guidelines (according to urban plans or zoning ordinances and/or conservation rules).

As an example, Table 1 presents a synthesized version of the indicators' check-list.

Table 1 : indicator check list summary

Indicators category	Indicator	Description/goal	Software or tools
Local climate and/or microclimate	Local climate factors are determining factors for the arrangement of buildings on a site. Human beings adopt land use decisions, types and technological systems to live in places under special conditions. The responses of human communities, often very effective, to different climatic conditions, mark spontaneous constructions and architecture. Sometimes these adaptations have been forgotten or cancelled because of trust in technology.		Bioclimatic diagrams (see ASHRAE diagrams – American Society of Heating, Refrigerating, and Air-Conditioning Engineers, www.ashrae.org/). The website contains documents on <i>Advanced Energy Design Guidance & Green Tips</i> .
	Solar radiation Identify and take advantage of "solar radiation" and avoid shadows produced by other buildings.		Solar radiation diagrams can be obtained with ECOTEC Software (free trail).
	Wind Recognize the direction and intensity of the wind during different seasons to be used for cooling, or to reduce the loss of energy during the winter. (The results of the survey should influence the shape and location of the building, or the use of screening).		Wind models can be obtained with ECOTEC Software (free trail) <i>Fluent</i> is a software designed by ENEA, sometimes applied to urban areas).
	Geographical positions Source: Adaptive thermal comfort and sustainable thermal standards for buildings, Nicol, Humphreys, Oxford Centre for Sustainable Development, School of Architecture, Oxford Brookes University.		<i>Colin graph</i> can be used to identify strategies used on a specific site due to its geographical position.
	Exposure (for sites on mountains, hills, or slopes) The exposure particularly affects typological and technological choices.		Solar diagrams can be obtained with ECOTEC Software (free trail).

Architectural and Technological Design Level

This part of the research is dedicated to the architectural and technological dimensions, with the aim to analyse the meaningful parameters which can influence energy consumptions at different levels:

- external areas of the building in connection with the context and the morphology of the construction complex;
- a building, with particular attention to the volumetric characteristics, to the main orientation, to the vertical and horizontal connection;
- a flat, above all regarding the summer behaviour, by means of the correct distribution of spaces in order to activate the natural ventilation.

Each element must be estimated in close relation to the climatic characteristics of the location. Especially at Italian latitudes, the cooling system is an important aspect that must be considered; not only because the climatic conditions are varied, but above all, because the expectations of the users have changed and they are now accustomed to work in air-conditioned offices or to ride in air-conditioned vehicles. At the architectural level of the flat it is also important to consider the new lifestyle, which is continuously evolving: because of the variable composition of customers (number and new lifestyle) or because of the expectations that evolve extremely quickly nowadays (Figure 2). Therefore, it is also necessary to design flexible flats not only to satisfy new user requirements, but also to match the climatic seasonal conditions.



Figure 2 : Plan and south façade of the case study

At the technological level, the software presented in the paragraph about methodology are used to estimate performance and the influence of the parameters, which can influence the thermal behaviour of a building.

The Case Study

The Initial Project (IP)

The case study, realized in 2009, presents an articulated shape that is composed by different parts. The south wing was an existing building, incorporated in the new realization. The structure includes five floors (the first on “pilotis”) and a basement for a private garage (Figure 3).

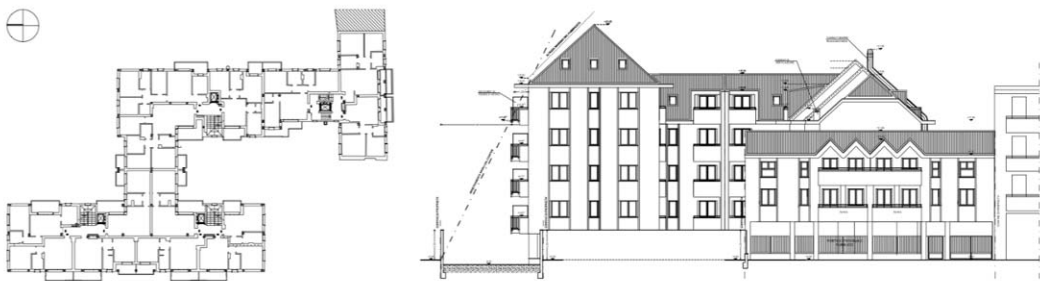


Figure 3 : Plan and south façade of the case study

The construction technology is traditional with blocks and a concrete frame. Mechanical systems are composed by a heating system with a remote control for every flat and a solar collector for DHW. The performance of the construction are as follows: the envelope has a U-value equal to $0.44 \text{ W/m}^2\text{K}$, the roof to $0.39 \text{ W/m}^2\text{K}$, the basement to $0.42 \text{ W/m}^2\text{K}$ and the windows (glass+frame) to $2.16 \text{ W/m}^2\text{K}$.

Analyses on the IP

The first energy analyses were conducted according to the regulations of region Lombardia and calculated with CENED on the IP, to individuate the elements able to limit the energy consumption. The primary energy results equal to $49.7 \text{ kWh/m}^2\text{a}$, while the heating and the cooling requirements respectively: 40.5 and $16.4 \text{ kWh/m}^2\text{a}$, with a contribution of $27.5 \text{ kWh/m}^2\text{a}$ from a renewable energy source (solar collectors).

The Optimized Project (OP)

The study on the IP defined the input for the optimization of the OP. The main factors that are taken into account are: the orientation, the percentage of windows on the

south facade, the quality of the frame and the glass and the envelope performance. After the analyses of each single optimization, a combination of the same optimizations was studied.

The Orientation and The Window Quality

The analyses were performed for two configurations in order to determine the influence of the orientation on the energy efficiency: the IP initial orientation North-South (NS) and a rotated one East-West (EW). The graph (Figure 4) clearly shows that the improvement of the U-value has a positive influence on the EW more than the NS orientation, with a decreased demand in winter; nevertheless the summer conditions could become a critical situation for the risk of overheating.

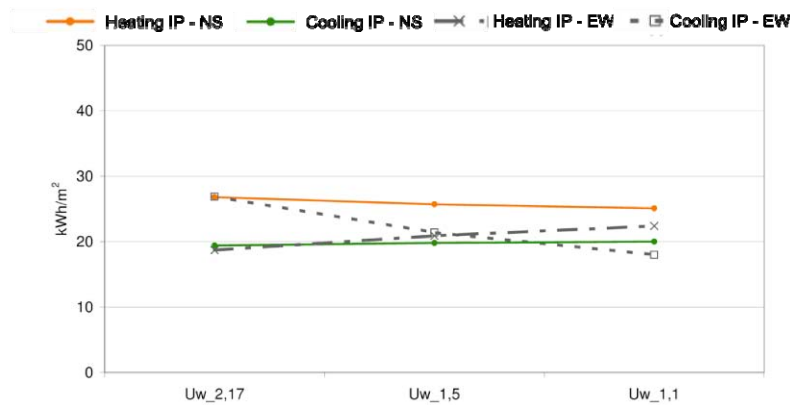


Figure 4 : Heating and cooling demand for the two orientations: north-south (NS) and east-west (EW)

The Dimension of the Windows

Another parameter linked to the windows considered for the optimization was the ratio between transparent and opaque of each façade. Such optimization is linked to other aspects, for example the shading systems. The analyses carried out in the case study, in fact, registered a potential reduction of 10% of the heating's annual requirements with an increase to the south windows surface with an accurate design of the shadings.

The Insulation Improvement

The performances optimization of the opaque envelope is developed considering the following increase of the insulation thickness starting from the value of the IP. In parallel the benefits/costs evaluation allowed to distinguish a better solution in order to improve energy efficiency spending to reasonable costs. For simplicity a pay back

of 10 years has been hypothesized with an energy cost of 0,17 €/kWh. For this case, the best solution results in the increase of 6 cm of insulation in relation to the line of costs (€/m²) represented for each unitary increase of the insulation thickness (Figure 5).

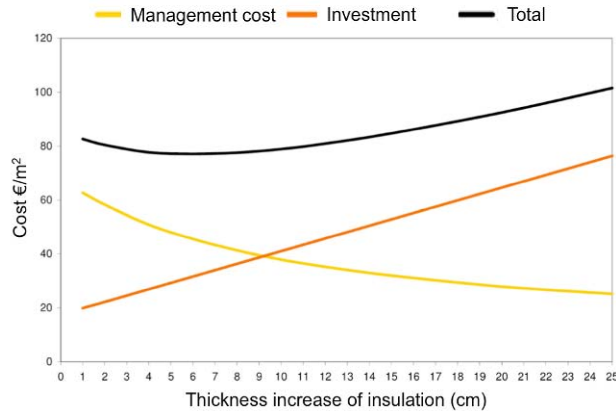


Figure 5 : Heating and cooling demand for the two orientations: north-south (NS) and east-west (EW)

The Combinations

The last analysis on the OP derived from a combination of the previous variables in order to estimate their interaction and to find more favourable strategies to design a low energy building.

Figure 6 summarized the 13 combinations analyzed: the graph shows that the best combination comprises an increase of the insulation of 6 cm compared to the initial value of the IP, the use of windows with U value equal to 1,5 W/m²K and the increase of the transparent percentage of the façade jointly to an appropriate and accurate shading system.

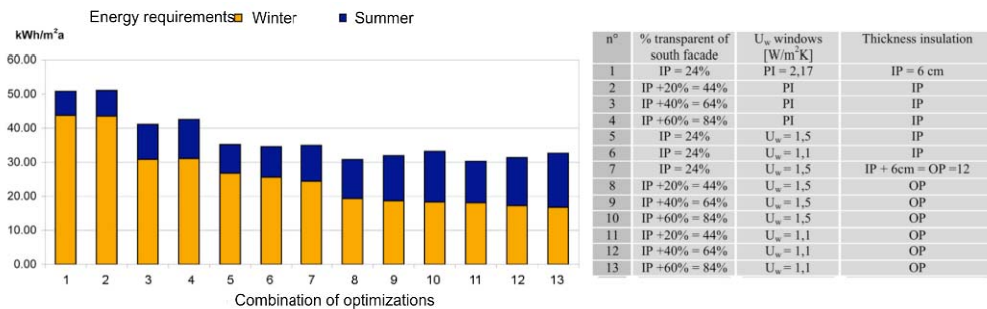


Figure 6 : Heating and cooling demand for the two orientations: north-south (NS) and east-west (EW)

The New Project (NP)

The NP design starts from the redefinition of the articulated shape into two simple bodies as an “L” and a “T”, connected from a balcony which define an internal courtyard, usable as a common area and a public space. The building façade is tilted to capture solar radiation and to adequately shade the south front. From the critical review of the IP, the NP presents the same number of flats but with different elements of distribution, taking advantage from the best orientation and creating natural ventilation to increase the indoor comfort (Figure 7).



Figure 7 : Plan and south façade of the case study

Analyses on the NP

The analyses on the NP investigated two possible integrations: the first focuses on the optimization of the mechanical systems, considering the same technological constructions of the IP, and the second optimizations regards both system plant, as the first, and the envelope performances with best performed solutions. The envelope, for example, has a U value equal to 0.26 W/m²K, roof and basement to 0.26 W/m²K and 1.85 W/m²K for the windows. All the analyses have been done with the CENED software for the purpose of understanding which strategies are necessary to reach the highest label classification. The results highlighted the limited influence of the S/V ratio and a more important influence of the orientation according to the percentage of windows and opaque façade on the energy consumption. The passage from label B to A, according to the classification of region Lombardia, was reached easily with the first optimization of the system plant. The second optimization of the envelope performances permitted to arrive at the A+ label.

Conclusion

The outcome of the research is a handbook on the integrated approach to sustainable buildings, which supplies practical answers and examples to help during the design process from urban, to architectural, to technological choices. The work demonstrates

the necessity to have a multidisciplinary team that works together to reach low energy residential buildings using active and passive strategies limiting initial costs. The innovative contribution of the project is the final tool, which summarized the results into operative suggestions. Each one makes an overview of the analyzed strategies, providing the quantification of the possible energy saving.

References

1. Grosso M., *Il raffrescamento passivo degli edifici in zone a clima temperato: principi e archetipi bioclimatici, criteri progettuali, metodi di calcolo, esempi progettuali*, Maggioli, Rimini, 2008.
2. Nicol, J.F. and Humphreys, M.A. New standards for comfort and energy use in buildings, *Building Research and Information*, Vol. 37 (2009), pp 68-73.
3. Santamouris, M. and Mumovic, D., *A Handbook of Sustainable Building Design and Engineering*, Earthscan, London, 2009.