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The energy certification of buildings through the dynamic simulation of variable consumption

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1 Preface

The problem of energy quality control in buildings was officially recognised for the first time at a European level in the EEC directive no. 93/76 of 1993 [1]. This directive represented the formal act of an undertaking to promote actions that would lead to a reduction in global carbon dioxide (CO_2) emissions. Article 2 of this directive established that states should carry out programmes concerning the energy certification of buildings, which were consistent in the description of their energy parameters, so as to allow future users of a building to know and understand its energy efficiency.

Italy acknowledged this directive [2], along with the subsequent European directive 2002/91/CE on energy efficiency in the building industry, with the Legislative Decree 192 of 2005.

With this decree general guidelines to regulate, on the one hand the methods of design and implementation of building systems, and on the other, the management and maintenance procedures of the systems, were laid down [3]. The directive provides for the certification of both newly constructed buildings, and buildings that already exist, have an inhabited surface area of more than 1000 m² and are being restructured. Moreover, the certification is based on a methodology that involves some fundamental factors like the architectural characteristics of the building, the type of air-conditioning system, the use renewable energy sources, the characteristics of the site where the building is being built, the climatic conditions and the orientation.

The certification document must be issued by specific organizations and must contain not only the evaluation of the energy efficiency of the building, but also recommendations for improvements in terms of costs and profits [4].

All in all, the strategy to reduce energy consumption, and in that context to respond to the demand for greater environmental well-being [5], sets out three objectives:

- To reduce the thermal load of buildings, in accordance with the environmental well-being required;
- To use the most efficient technology in technological installations to improve environmental well-being;
- To design building systems and integrated systems that exploit the possible synergies as much as possible.

In order to determine the energy classification of a building, the regulations set out a complicated method of calculation, above all for existing buildings, as they require a significant amount of data, including instrumental data, which is often not detectable after the costruction [6].

The regulations also provide for the classification of the building in consumption classes, labelled with letters of the alphabet that go from G (the worst) to A (the best). This classification is shown in table 1, where the coefficient C can be determined by two parameters: the first, *asset rating* is based on the use of energy consumed by the building, calculated under normal conditions of occupation; the second, *operational rating*, is based on the energy performance of the building in use, and therefore documents the actual performance.

Table 1. Performance classification

Energetic Class	**Values range**		
A		C	< 0,5
B	0,5 ≤	C	< 1
C	1 ≤	C	< 1,5
D	1,5 ≤	C	< 2
E	2 ≤	C	< 2,5
F	2,5 ≤	C	< 3
G	3 ≤	C	

Asset rating is based on a calculation of the energy used by the building for heating, cooling, ventilation, producing hot water and

illumination, according to input standards related to the climate and the occupation rate [7].
Operational rating is based on a calculation of the energy consumed by the building, as a weighed average of the actual measured consumption [8].
Since the two coefficients can be different, as in the example of figure 1, the same building can be classified in class C or in class D.

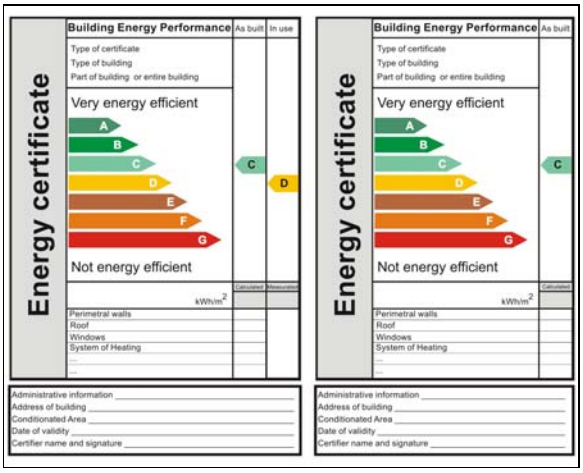

Figure 1. Examples of energy certification in the two different classifications

Consequently the possibility of using a method for evaluating the energy performance of a building through energy simulations, helps not only during the design phase, but above all to resolve the problems associated with the instrumental gathering of data during use, which would require the continuous monitoring of various aspects of energy consumption [9].
This study therefore makes better use of the certification of two existing buildings, which are believed to be in need of an intervention for the purpose of improving overall energy use.

2 Introduction

The two buildings chosen for the dynamic consumption simulation are situated in the centre of the city of Palermo, but they were built in different historical periods, and each one has construction characteristics that were avant-garde when they were constructed.
A picture of the principle façade of the first building is shown in figure 2 and a plan of the standard plane in figure 3. This building is made entirely of reinforced concrete. It demonstrates some interesting solutions, both distributive and apparent, with the presence of important sun-breakers on the two façades facing South and West respectively.
The building was constructed in the 1970s and has a total usable space of 9300 m². It is equipped with a centralised air conditioning and heating system powered by an electric heat pump, as well as independent hot water production systems for individual flats powered by methane gas [10].

Figure 2. Facade of building 1

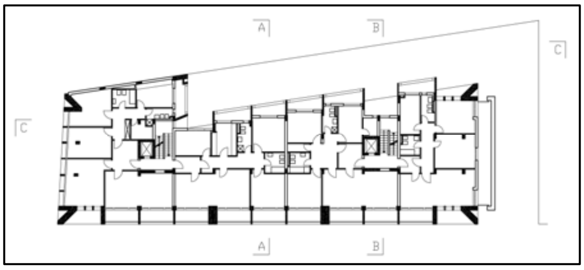

Figure 3. Plan of the standard plane of building 1

A picture of the principle façade of the second building is shown in figure 4, and figure 5 shows a plan of the standard plane. It was built in 1880, it has a stone structure and it has undergone significant modifications over the years, the most important of which is the super-elevation of additional floors, as well as a different layout introduced following building industry innovations and adaptation in line with new standards (such as the addition of lift shafts in the main stairways). The building, that has a total habitable space of 4200 m², is equipped with a centralised air conditioning and heating system, powered by an electric heat pump, as well as independent hot water production systems for individual flats, powered by methane gas. From the description of the two buildings it can be deduced that the configuration of the systems is very similar, but that the two buildings are differentiated by the thermo-physical [11] characteristics of their external shells, and by different fittings. From the point of view of the urban climate, the buildings are not far apart and present the same orientation.

Figure 4. Facade of building 2

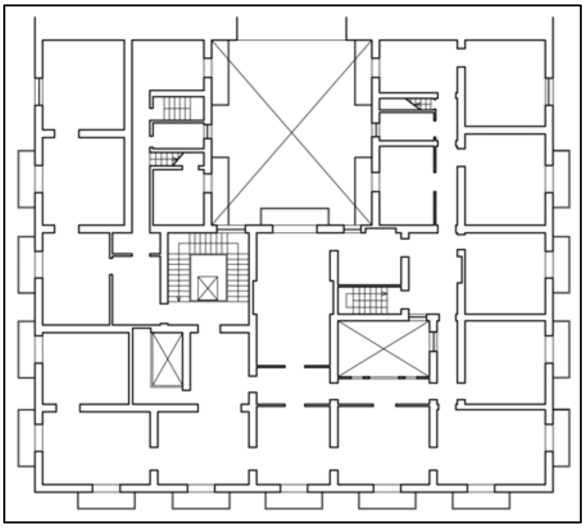

Figure 5. Plan of the standard plane of building 2

3 Methodology

The software used for the dynamic simulation of the thermo-physical behaviour of the two buildings originates from the previous software DOE-2, developed by James J. Hirsch & Associates, and it is identified using the initials e-QUEST [12], an acronym of Quick Energy Simulation Tool. It allows the energy behaviour of the building to be simulated, both through the analysis and the simulation of the thermo-physical behaviour of the shell, and through the analysis of the efficiency of the systems.

The simulation is carried out with a combination of a schematic system for creating the plan, a system for measuring the energy efficiency (*EEM*) [13], and a module that allows the graphical results to be visualised with an updated version of the Doe-2 software. The software implements a model of the building through a process involving the creation of an "energy model" characterised by a series of steps that help to describe the characteristics of the plan and their impact on energy use, including: the architectural plan; the systems for air conditioning, heating and producing hot water; the type of structure and the construction materials; the end use and the occupation percentage; time periods of use, etc…

The program first requires general information about the plan of the building, through the application of techniques of simulation of the energy use, in order to then descend to an even more accurate level of detail, providing very realistic results, without having to edit very detailed and complex representative models of the building. In figures 6 and 7 below, the initial screens in the editing process are shown, in which the shape and the principal dimensions of the two buildings are highlighted.

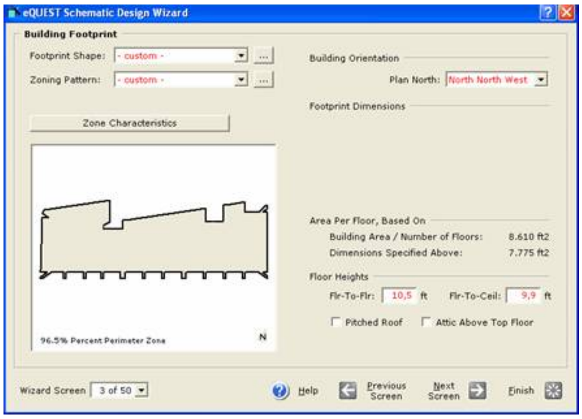

Figure 6. Editing of the shape factor of building 1

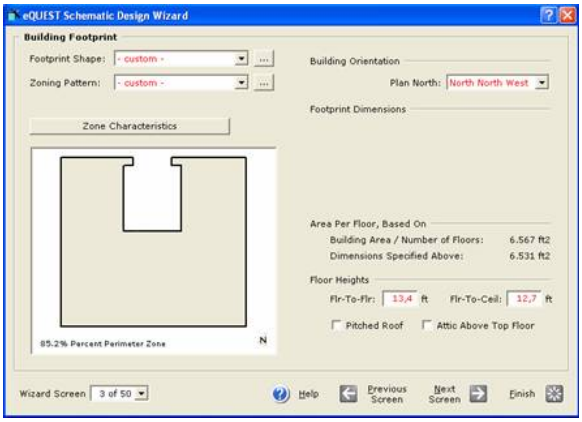

Figure 7. Editing of the shape factor of building 2

Once the process of data input required by the software is finished, it is possible to have both a visual output of the project, and to visualise the installation plans inputted. In figures 8 and 9, the screens relating to the perspective views of building 1 and of the plan of the central heating system are shown.

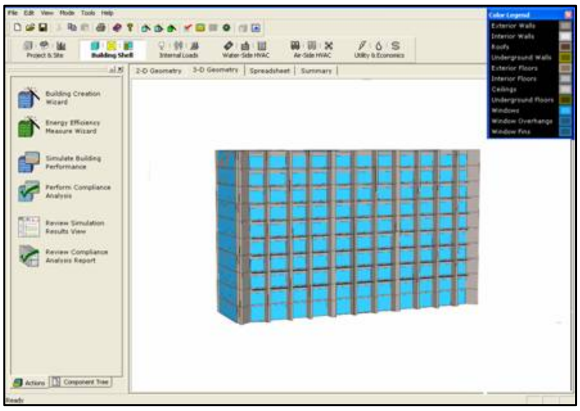

Figure 8. Render of the perspective of building 1

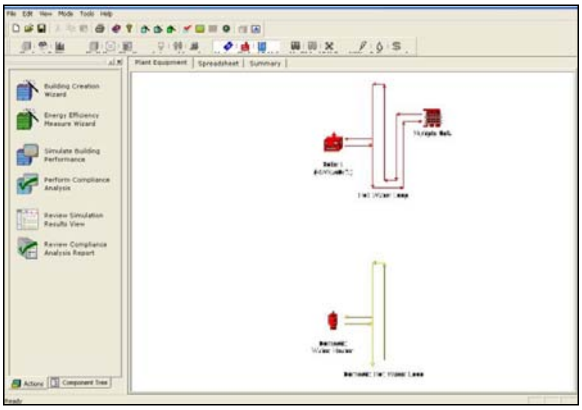

Figure 9. Render of the plan of the heating system.

4 Simulation of performance

Once the data entry is finished, the simulation phase begins. Using the "*Energy Efficiency Function*" it is possible to select the type of simulations to be carried out, and for each one it is possible to change the parameters that have already been introduced, on the basis of a hypothetical *retrofitting* operation. For the purposes of improving the energy performance by acquiring a more efficient consumption class, interventions were carried out on thermo-physical aspects, principally involving: substituting the windowpanes, inserting insulation into the roof and walls; substituting the ventilation system of the heating and air-conditioning system with a model with high thermodynamic efficiency. Once the simulation is under way, the software allows a choice to be made between the possibility of limiting the intervention to a specific sector, or of examining all its possible alternatives. It also allows a comparison between the two alternatives to be examined. Once the simulation is finished it is possible to see a relationship that highlights different aspects, from economic ones to energy ones. This article presents the graphs relating to the consumption of electricity that are most significant, both in the current configuration (Baseline Design), and with the improvements obtained through each individual intervention, and adopting all of the improvements made simultaneously (External wall insul EEM, Roof insul EEM, Windows glass type EEM, Fan power EEM, totals gain). In figures 10-15 the results of the simulations for building 1 are shown. Through the simulations carried out it is possible to see the energy classification of the building before and after the intervention. In figure 16 the transition from *class E* to *class B* is highlighted (from 98 kwh/m² year, to 41 kwh/m² year). The same operations were carried out for building 2 and the results were demonstrated in figures 17 to 22. Finally, in figure 23 below, the transition from *class C* to *class A* is highlighted (from 68.5 kwh/m² year, to 28 kwh/m^2 year).

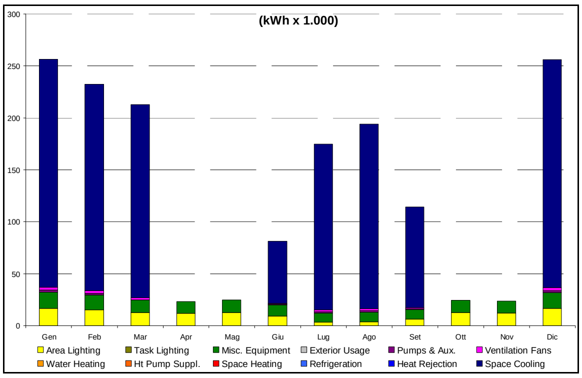

Figure 10. Electricity consumption in the "Baseline Design" configuration (building 1)

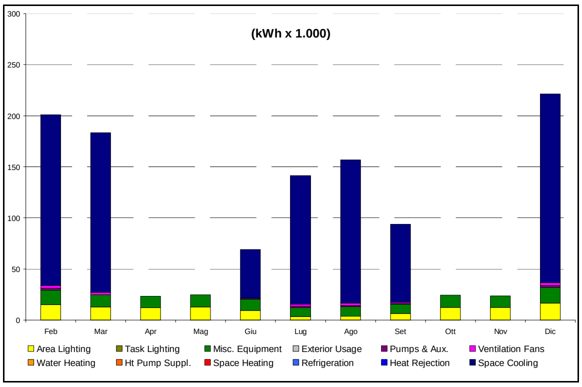

Figure 11. Electricity consumption with "External wall insul EEM" (building 1)

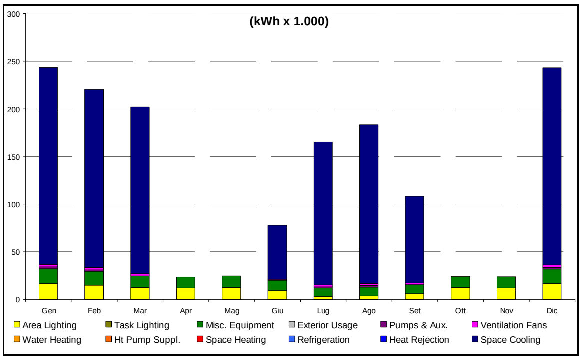

Figure 12. Electricity consumption with "Roof insul EEM" (building 1)

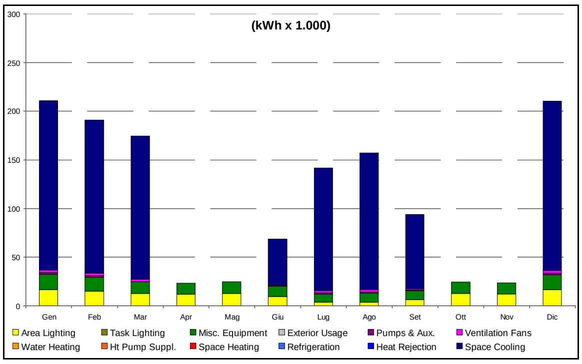

Figure 13. Electricity consumption with "Windows glass type EEM" (building 1)

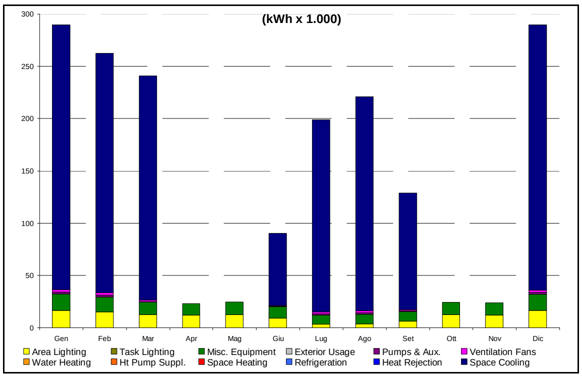

Figure 14. Electricity consumption with "Fan power EEM" (building 1)

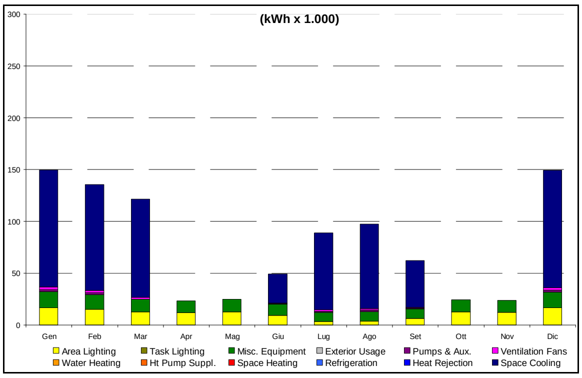

Figure 15. Electricity consumption with all the improvement solutions (building 1)

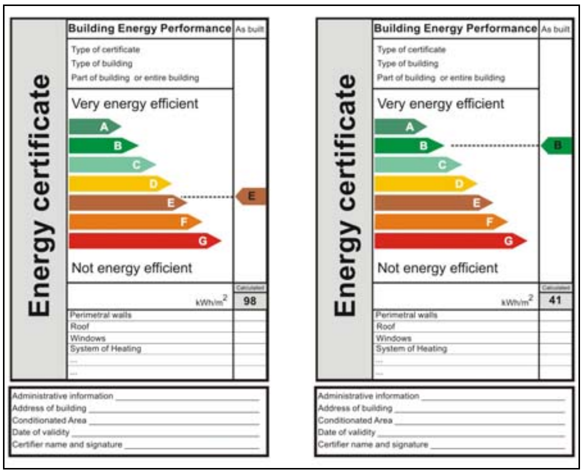

Figure 16. Energy certificates (building 1)

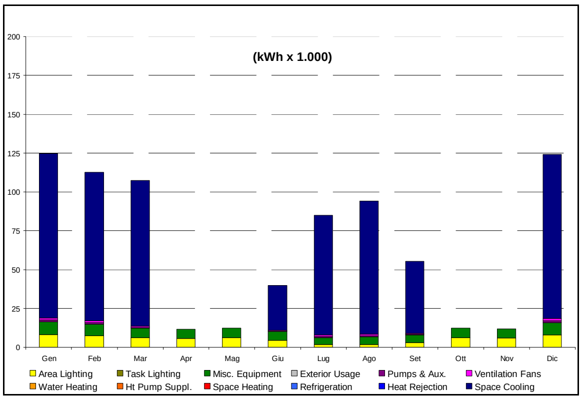

Figure 17. Electricity consumption in the "Baseline Design" configuration (building 2)

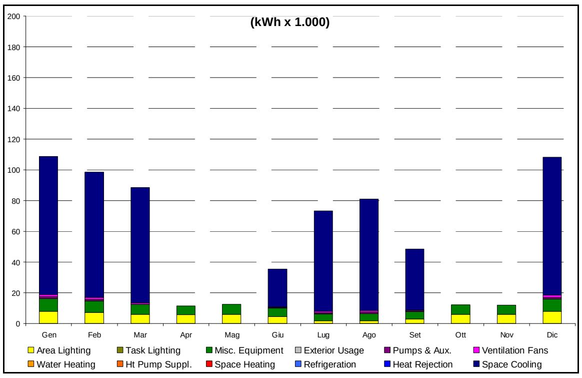

Figure 18 Electricity consumption with "External wall insul EEM" (building 2)

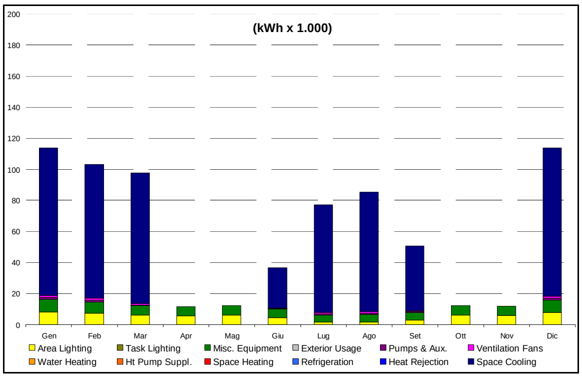

Figure 19. Electricity consumption with "Roof insul EEM" (building 2)

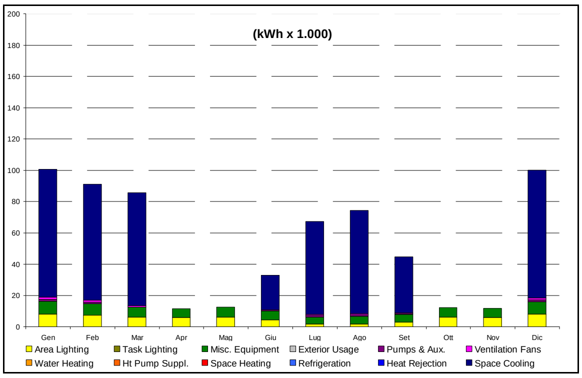

Figure 20. Electricity consumption with "Windows glass type EEM" (building 2)

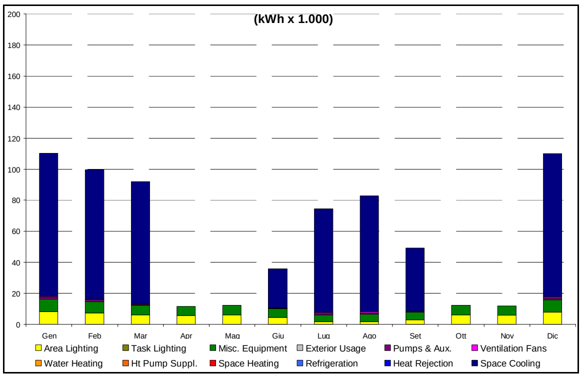

Figure 21. Electricity consumption with “Fan power EEM” (building 2)

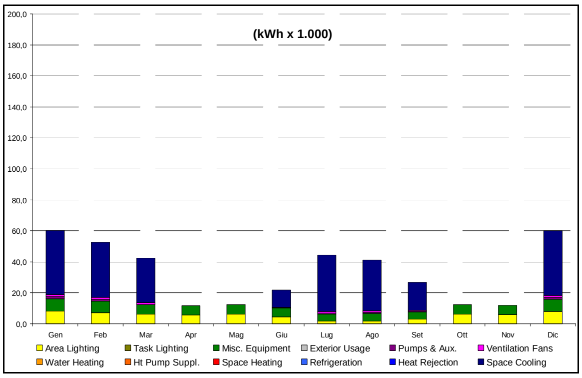

Figure 22. Electricity consumption with all the improvement solutions (building 2)

Figure 23. Energy certificates (building 2)

5 Conclusion

Through the simulations carried out it has been possible to find out what the current energy consumption of the building is, and what it would be if *retrofitting* interventions were carried out.

Knowing the consumption and the volumetric dimensions of the building, it is possible to identify which class they belong to, for the purpose of carrying out energy certification and verifying the suitability of the interventions, if possible.

Through a comparative analysis of all the simulations, it was possible to verify how the energy performance of the two buildings has improved, above all by substituting the windowpanes, which obtains a reduction in consumption of 20%, while the new insulation in the roof does not bring about a significant improvement, reducing energy consumption by just 5%.

The best performance was seen with the interventions carried out on building 2, demonstrating that interventions in old buildings can produce significant improvements.

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