

# Energy Savings in Buildings: A Global Approach

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## ABSTRACT

The present paper reports a set of considerations and analysis of energy efficiency in buildings by approaching the problem from a full life-cycle perspective. In particular, the impact of the embodied energy, i.e. the energy necessary to produce a specific material, is analyzed, as it has a pivotal role in assessing the real energy saving obtained after a retrofitting.

Considerations related to the country of production of insulating materials are also provided, as the energy mix of a specific location has an impact on the embodied energy of the materials.

Finally, some numerical examples are provided in three Italian cities, namely Milan, Rome and Naples. A typical Italian building is considered in all of these three locations and a refurbishing intervention is hypothesized, namely the installation of an external insulation layer on the walls. Then, the global heating energy saving is assessed, i.e. also the embodied energy is considered in the calculation, to evaluate the energy effectiveness of the intervention.

It is found that in warmer locations, i.e. Naples and Rome, the installation of an insulation layer has a limited, or even negative impact, on the energy saving if embodied energy is considered. This means that the energy necessary to produce the insulating material is higher than the energy saved during its operating life.

## INTRODUCTION

Buildings sector is responsible for 40% of carbon emissions worldwide [1], therefore it is mandatory to implement appropriate actions to reduce the number of emissions. On the basis of this, there are many initiatives which promote the energy

retrofitting of existing buildings and the adoption of the most modern approaches for the new ones [2].

Usually, when performing energy analysis on the effect of the installation of insulating panels on the envelope of buildings, only the operating energy, namely the one utilized to heat the internal environment, is taken into account [3]. Therefore, the energy saving is represented by the difference between energy used in the case without insulation and that used in the case with insulation.

Actually, this approach tends to overestimate the energy saving involved in the process, because the energy balance is based only on a partial portion of the lifecycle of the insulating material. If the perspective is enlarged the situation can radically change [4].

In particular, if a life cycle perspective is considered, then it is necessary to consider all the energy involved into all the phases of the life of the insulating material, namely extraction of basic substances, production process, logistics chain, installation, maintenance, removal, recycling and disposal treatment [5]. All these phases imply the utilization of energy, which must be accounted in the total balance, in order to assess the real energy saving of the insulation installation (or implementation of other energy efficiency measures). The energy associated with all the life-cycle of the insulating materials is called *embodied energy*, since it represents all the energy stored in the material, in other words, it can be seen as the *energy cost* of a specific material, therefore it is to be accounted in the energy balance.

To perform a full life-cycle analysis of insulating interventions, both embodied and operating energy should be taken into account and, according to the operating life of a specific material, it is possible to determine the global energy saving (or waste) of energy associated with a specific intervention.

Different studies on the impact of embodied energy are available in the literature. Koezjakov et al. [6] analyzed the impact of the embodied energy contribution in Dutch houses and determined that the impact of the embodied energy is 10%-12% in standard houses and 36%-46% in energy-efficient buildings. Furthermore, Rossellò-Batle et al. [7] performed different analysis in a Mediterranean climate to evaluate the impact of embodied energy on the feasibility of energy retrofitting of existing buildings. Similarly, Cellura et al. [8] developed a case study for Italy and detected that, if embodied energy is considered, the primary energy demand is nearly doubled.

The above mentioned literature highlights the relevant impact that the inclusion of embodied energy can have on buildings energy analysis, therefore its contribution must be considered if total energy savings are to be estimated.

On the basis of these considerations, the present paper aims at analyzing a set of typical Italian archetypes located in different cities, in order to evaluate the energy performances of standard energy retrofitting measures from the life-cycle perspective, therefore the embodied energy is estimated and taken into account.

In particular, the typical building blocks built in the period 1961-1975 are considered for the analysis, because they did not include any wall insulation, which was introduced by the Italian building code only starting from 1977. This class of buildings is a good candidate for energy retrofitting; therefore it is necessary to estimate the effective energy-saving potential.

For this purpose, an energy simulation model is set up and validated in order to perform all the energy calculations. The model is based on dynamic simulations with an hourly based resolution and historical average meteorological data are considered. The considered model allows a detailed representation of energy consumption in buildings and it is considered appropriate for the proposed analysis.

It is supposed that the present paper stimulates the debate on the issue of energy efficiency in buildings and it can serve to promote the utilization of more accurate energy savings estimation methodologies.

## **BUILDING MODELLING**

A model of a building block built in the period 1961-1975 is considered. It consists of seven blocks and a basement. The building is divided into two thermal zones, a heated one, i.e. the inside of the apartments, and a cold one, i.e. the stairs.

The model is generated by using SketchUp Make and energy requirements were calculated through the Openstudio 2.4.0 – EnergyPlus program and then post-processed with IDF-editor 8.9.0.

The characteristics of the buildings were taken from the Tabula project [9] and comparison with the provided energy consumption data is performed by showing a high degree of correspondence. Once assessed the quality of the simulation results, different insulation typologies are considered in order to retrofit the building. In particular, three different types of insulation are taken into account, namely polyurethane foam, rock wool and resin-bonded fiberboard. The performance of a layer of 10 cm of the insulator is analyzed.

All interventions were simulated in EnergyPlus for the cities of Milan, Rome and Naples and the corresponding operational energy of the apartment block was compared with the reference operational energy based on the present envelope and system conditions.

The results of the dynamic simulations showed the real efficiency of the insulation interventions depending on the climate zones of the three cities. Polyurethane foam insulation leads to a significant site energy saving during the year, between 40% and 50%; the rock wool and resin-bonded fiberboard reached 40%. Also, the roof insulation was simulated but results showed less interesting savings as this intervention decreased the operational energy demand of only 2%.

Once estimated the operating energy through the simulation, the embodied energy is evaluated on the basis of cradle-to-gate values, which were taken from the Inventory of Carbon and Energy [10].

It has to be remarked that the embodied energy of the building materials has not been considered as this paper wants to propose an approach focused on the choice of the efficiency measures based on their embodied energy. The comparison between the embodied energy of the retrofit solutions and the corresponding energy savings in the use phase was finally carried out.

On the basis of the estimated parameters, it is possible to determine the energy pay-back of the energy efficiency interventions. The energy pay-back is given by the necessary time to recover the embodied energy of the energy saving interventions with the energy savings from operating energy.

It is intuitive that the higher is the operating energy saving and the shorter will be the energy payback period. Therefore, it can be said that if the savings in operating energy are limited, it could result to be not convenient to install an insulation layer on the buildings' walls. This conclusion can be reached only if the embodied energy is considered in the calculation.

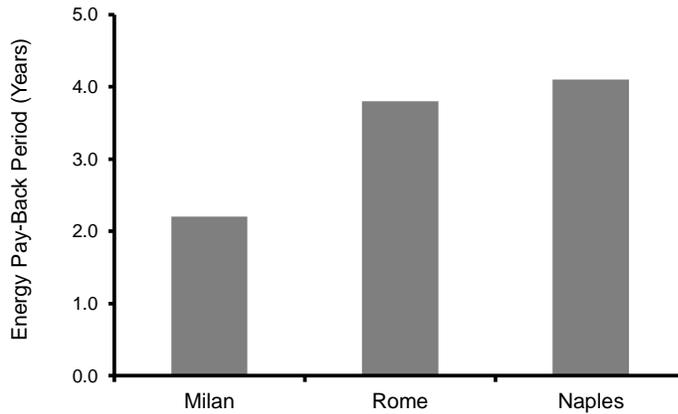


Figure 1. Energy pay-back period in the case of installation of polyurethane foam.

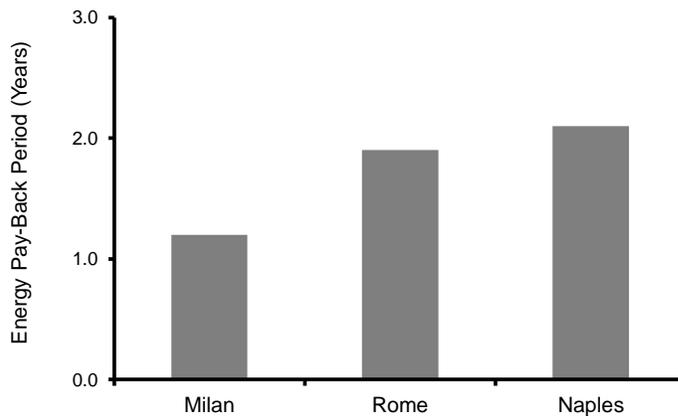


Figure 2. Energy pay-back period in the case of installation of rock wool.

## RESULTS

The proposed pictures show the results for the building block under investigation in terms of the energy payback period. The results are referred to the three cities under investigation, namely Milan, Rome, and Naples. In particular, it is useful to specify that Milan is located in the Northern part of Italy, therefore it is characterized by colder climatic conditions, Rome is located in the central part of Italy and it has intermediate climatic conditions, whereas Naples is located in the Southern part of Italy and it has warmer climatic conditions.

From the analysis of Figures 1 and 2, it can be noticed how the location largely influences the energy pay-back. This is due to the fact that the warmer is the climate and the lower is the energy saving in operating energy. This causes the increase of the energy payback period which is longer as the climatic conditions become warmer. In the present analysis, the operating life of the insulating layer is fixed in 15 years.

For locations warmer than Naples, the energy pay-back period can be much longer and exceeds the operating life of the insulator. If this is the case, it is not convenient to use any insulation layer.

## CONCLUSIONS

In conclusion, it can be said that specific attention is to be devoted to energy analysis of buildings and in order to assess the real impact of energy efficiency interventions, it is necessary to develop a life cycle analysis.

In order to develop a complete and significant energy assessment, it is mandatory to take into account the role of the embodied energy, which significantly the results of energy efficiency analysis. Embodied energy can be also seen as a design parameter for choosing an appropriate insulator according to the location of installation.

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