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# Energy retrofit and economic evaluation priorities applied at an Italian case study

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**Abstract**

In OCSE and developed Countries, the sectors which mostly suffered the 2008 financial and economic crisis, was the construction and real estate sectors. Furthermore, the buildings are responsible of about 40% of incidence on emission. The economic crisis did not allow realizing new buildings, and the existing buildings have too much greenhouse emission, that needs to be reduced. The Energy Retrofit could be a way to improve both sectors, because it reduces emissions and helps the real estate sector. However, the Energy Retrofit has some difficulties in order to evaluate both economic and technical solution.
In this paper we present an Energy Retrofit simulation about an Italian case study: one building typology that is supposed realized in several different periods, having different thermo-physic parameters. For each period, four energy retrofit actions will be applied, together with the software evaluation of energy performance.



*Keywords:* Energy Retrofit, Energy saving scenarios; energy priorities;

## 1. Introduction

In 2007 the European Union adopted the Energy Policy strategy “Horizon 20-20-20”. The goals are:

- To reduce 20% of greenhouse gas and energy consumption, described in Directive 2010/31/UE [1] for buildings sector;
- To increase of 20% the renewable energy sources, with Directive 2009/28/CE [2] that include building sector;
- To increase of 20% the energy efficiency approved in Directive 2012/27/UE [3] that include building sector, new and existing building.

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The economic investments in building sector follow energy strategy "Horizon 20-20-20" [4] also in order to improve employment, especially in the construction sector, which actually suffers a deep crisis after real estate crack in 2008 (Lehman Brothers and subprime crisis). The building sector has specific difficulties to obtain EU goals; they depend on two factors: the specific EU Member State legislation and the several kinds of stakeholders.

The studies about energy retrofit and costs regard evaluation of methods used to determine and to realize energy saving and relation between energy saving and growth factor. Several articles [5-9] analyzed and described the European situation and described different methods to develop indicators able to evaluate energy saving technologies. The Netherlands Normalisation Institute (NNI) [10] development the Energy Performance Coefficient (EPC) and Assady [11] adopted multi-objective methods. The stakeholders could by divide in:

- (a) building owner or building user, also real estate, for all existing buildings;
- (b) builder entrepreneur and real estate sector in case of new buildings o building retrofit.

The energy retrofit benefit evaluation problems are: to define energy saving and/or energy efficiency levels for each building typology and scenarios. The Directive 2010/31/UE defines Cost-Optimal Level, but COL are related to energy requirements and they do not concern energy efficiency scenarios. The existing building C/B evaluations are difficult, how shown in the IEA Report [12].

## 2. Aim of paper

The goals of the present paper are to study the relation between energy efficiency and costs. The case study consists of a single-house, located in Italy, and the simulation regards a tool for Small and Medium Enterprises (SME) having the purposes to evaluate, to communicate and to explain the benefits to the common people. We decided to compare 4 energy improvement scenarios for a single-house that we supposed they were built in 4 different periods, i.e. with specific technology, thermo-physic values and HVAC, for each period. Therefore, 4 scenarios for each period, for a total 16 scenarios, were analyzed. On this way it was possible to individuate the relations between the year of construction and the scenario technologies.

### *2.1. Framework Buildings in Italy*

In Italy, historic thresholds are different, how described in Fabbri et. al. [13]: the 60.44% of buildings were built before 1976 (more precisely 13.15 % of these before 1919 and 22.90 % was built between 1919 and 1945. Most of them are heritage buildings). The 1976 represents a threshold because in that year a specific law was issued: the law 373/1976 [14]. It was the first law which introduced an energy minimum requirement in building insulation. The 11.23% of buildings were built between 1976 and 1991. In 1991 another important law was issued: the Law 10/1991 [15] about National Energy Plan and energy saving of building. The 11.24% of buildings were built between 1991 and 2005 year of Directive 2002/91/CE EPBD transposition. The last 3.93 % consists of buildings that were built with respect to EPBD energy minimum requirements.

## 3. Methods

In this research we considered a single-house building that we supposed it was built in 4 period thresholds: 1950, 1970, 1985 and 1995. For each of these periods, we evaluated 4 energy efficiency improvement scenarios. The building geometry was the same, but we changed the thermo-physic parameters and HVAC for each period threshold. Moreover, for each period threshold we evaluated the energy building performance index, in kWh/m$^2$year of primary energy, evaluated following the standards UNITS 11300 part 1 [16], part 2 [17] and part 4 [18]. Therefore, we obtained 4 energy performance baselines for each state-of-art. The main results are reported in table 1. Energy performance index EPtot, expressed in kWh/m$^2$year, decreased when the thresholds were recent because the building was realized with better technologies. The thermo-physic parameters were obtained following Annex A of UNITS 11300 part 1, which reports a national value, an abacus ad a table of the most common walls, roofs, basements and windows characteristics for each year-period. The 4 scenarios were evaluated for each of 4 the baselines. The 4 improvements were the following:

- (a) wall insulation improvement: we supposed to put in 8 cm of insulation in order to reduce wall transmittance;
- (b) substitution of windows, with a new glazing with low-energy glass;
- (c) substitution of existing boiler with a new condensing boiler;
- (d) new solar thermal system for Domestic Hot Water (DHW).

### *3.1. The Case Study*

The case study is a single-house (figure 1), as a rectangle with 117 $m^2$ of surfaces, locate in Cesena, Emilia-Romagna, north-east of Italy. The climate data are related to Cesena, and obtained following the Italian standards. The building is composed by living-room, kitchen, bathroom and 3 bed-rooms, and the storage space under the roof of the house, without ventilation and not accessible. At the above geometry we applied the thermo-physic parameters for each year-period of construction: 1950, 1970, 1980 and 1995. The Annex A, B an d C of Standard 11300 part 1 have a table with a fixed value of transmittance for each wall, roof and basement year of construction and typologies. These values are standardized by statistic a technical literature, and we can consider it similar at real average condition. The years of building construction was choose following a statistic percentage of building by ISTAT census in 2001 [19] The baseline for each year-period are the results of energy building performance evaluation for each year-period (table **1**). The decrease of index EPtot value follows the improvement of building industry sector.

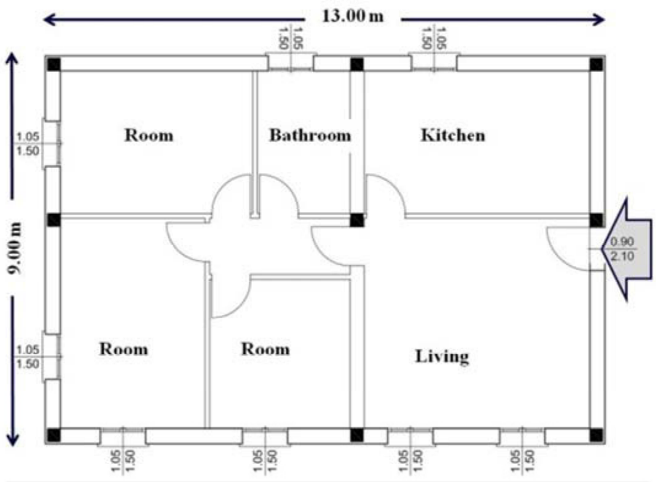


Fig. 1. Case study single-house

The energy building performance depends on several factors: orientation, geometry, climate, envelope transmittance, ventilation, internal heat gain, solar heat gain, HVAC and renewables. The energy performance building evaluation follows the Italian standard UNITS 11300 part 1 2 and 4, and correlated standards. The Energy building performance index EPtot, in kWh/$m^2$year of primary energy, is the summa of energy index for heating EPi, (we suppose a building locate in northern Italy with 183 day of heating and 2256 DayDegree) and energy index for DHW EPacs (evaluated for 365 days, i.e. all year long).

Table 1. Case study – 4 baselines for each period threshold

| Year of building threshold | EP total [kWh/m$^2$year] | Column B (*t*) EP heating [kWh/m$^2$year] | $EP_{DHW}$ (Domestic Hot Water) [kWh/m$^2$year] |
|---|---|---|---|
| 1950 | 260.54 | 239.47 | 21.07 |
| 1970 | 220.37 | 196.53 | 23.84 |
| 1980 | 150.75 | 127.34 | 23.41 |
| 1995 | 112.69 | 91.52 | 21.17 |

## 4. Results – Energy building performance improvement scenarios

We defined 4 scenarios of energy improvement in order to evaluate energy saving for each baseline reported in table 1. In this paragraph we described each scenario. The energy performance evaluation considers each scenario at the same time, with only one variable: reduced transmittance, heating performance, etc. We did not consider multiple scenarios, e.g. wall insulation and windows substitution together. We clarify to adopt the same technologies for each year-period building, and not the same transmittance value. If we had supposed to obtain the same transmittance value, the variables would have become an insulation thickness, and they were not the aim of this study.

The *first scenario* proposed a new insulation layer outside of wall: 5 cm of expanse polyester, with a conductivity $\lambda$ = 0.038 W/mK, in order to reduce U-wall transmittance. The results of U-wall transmittance for each year-period building are reported in table 2.

Table 2. Scenario 1 – Wall insulation

| Year of building threshold | (Before) Baseline | | (After) Scenario 1 | | ΔU [W/m$^2$K] | % ΔU [W/m$^2$K] |
|---|---|---|---|---|---|---|
| | Thickness [mm] | U before [W/m$^2$K] | Thickness [mm] | U after [W/m$^2$K] | | |
| 1950 | 400 | 1.223 | 450 | 0.473 | 0.75 | - 73.14 % |
| 1970 | 310 | 0.998 | 360 | 0.438 | 0.560 | - 56.11 % |
| 1980 | 350 | 0.635 | 400 | 0.350 | 0.285 | - 44.88 % |
| 1995 | 360 | 0.472 | 410 | 0.294 | 0.178 | - 37.71 % |

The *second scenario* proposed the substitution of existing window, with correspondent year-period U-window. New windows with low energy emission gas (argon) and PV frame were chosen. In this case the geometry of windows and new window transmittance, were the same. However, the gap of ΔU (W/m$^2$K) between the value before and after window substitution, changed. The results of U-window transmittance for each year-period building are reported in table 3.

Table 3. Scenario 2 – New windows

| Year of building threshold | (Before) Baseline | (After) Scenario 1 | ΔU [W/m$^2$K] | % ΔU [W/m$^2$K] |
|---|---|---|---|---|
| | U before [W/m$^2$K] | U after [W/m$^2$K] | | |
| 1950 | 4.621 | 1.194 | 3.472 | - 74.16 % |
| 1970 | 3.668 | 1.194 | 2.474 | - 67.45 % |
| 1980 | 2.293 | 1.194 | 1.099 | - 47.93 % |
| 1995 | 2.275 | 1.194 | 1.081 | - 47.52 % |

The *third scenario* provided the substitution of the existing heating boiler with a new condensing boiler, 27.4 kW of power (6.2 kW only for heat, 27.4 for combined heat and DHW), energy performance 107% with 30/50°C temperature of furniture. We supposed a traditional boiler for each year-period buildings.

The *fourth scenario* was a new Solar Thermal system with 6.06 $m^2$ of absorber area for DHW. In this case energy improvement regarded only EPacs.

Tables 4 reports the results for each scenario and each year-period building.

Table 4. Energy improvement scenarios

| Year of building threshold | Baseline | Wall insulation | | New windows | | Condensing boiler | | Solar Thermal | |
|---|---|---|---|---|---|---|---|---|---|
| | [kWh/$m^2$year] | [kWh/$m^2$year] | % | [kWh/$m^2$year] | % | [kWh/$m^2$year] | % | [kWh/$m^2$year] | % |
| 1950 | 260.54 | 191.93 | 26.33 % | 24.40 | 13.87 % | 219.00 | 15.94 % | 245.06 | 5.94 % |
| 1970 | 220.37 | 173.86 | 21.11 % | 99.18 | 9.62 % | 171.89 | 22.00 % | 204.86 | 7.04 % |
| 1980 | 150.75 | 127.06 | 15.71 % | 41.24 | 6.31 % | 115.16 | 23.61 % | 136.33 | 9.57 % |
| 1995 | 112.69 | 99.62 | 11.60 % | 04.37 | 7.38% | 95.71 | 15.07% | 100.09 | 11.18% |

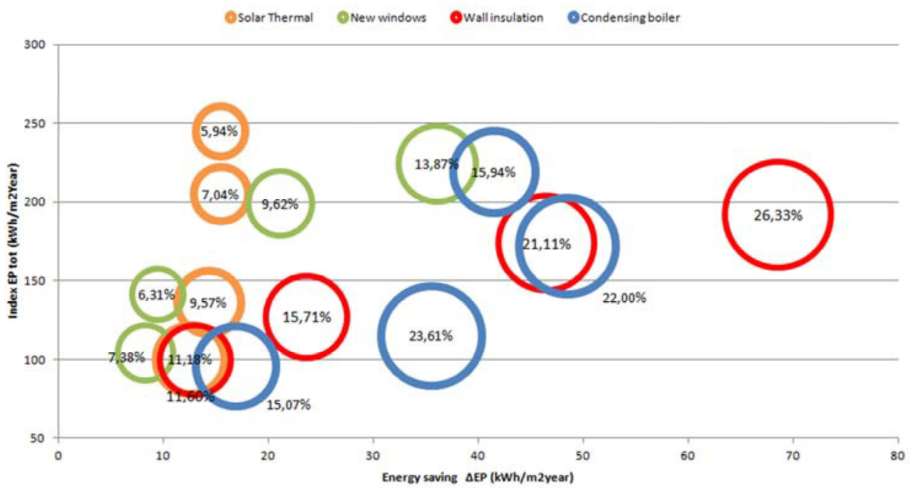


Fig. 2. Results Comparison: x-axis energy saving value, y- axis index EP value. The circle diameter is the percentage of improvement. No linear correlation exists between different technologies and energy improvement.

## 5. Conclusions

In present paper we considered only one building typology (single family), in case of buildings-block, condominium, office and other kind of buildings, the technologies cost incidence could be lesser than this case study. The research allows putting in evidence some consideration between the comparison of improvement scenario and buildings with several kind of thermo-physic and HVAC value. The goal of study was to find a relation between building year scenario technologies and energy building performance improvement. How we can see in table 4 and figure 2, does not exist a linear relation between energy improvement and technological solution.

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