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Analysis of COVID-19 crisis-related building energy retrofit incentives in Italy

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Abstract

The advent of the COVID-19 pandemic led to an economic crisis of the construction industry and to an increasing of energy consumption in the residential sector for all the world. The European Union highlights the crucial role of building sector for both energy gains and economic growth, defining a “Renovation Wave” plan combining regulation, financing and technical support with the aim of greening the buildings, creating jobs and improving lives. In Italy a great support mechanism for energy refurbishment of existing buildings has been launched by means of tax deduction of 110% over 5 years. The present study aims to analyze this new funding mechanism, under energy, environmental and economic point of views. By means of a real case study, representative of highly widespread southern Italy HVAC-building system, it will be highlighting advantages and contradictions of the incentive mechanism developed, proposing possible future improvements. It is found that, if on one hand, the best refurbishment measure under energy/environmental point of view is the external insulation, windows replacement, electric heat pump and PV-system installation, with a global not renewable performance index reduction of 81%, on the other hand it is not the best solution considering the cost/saving ratio.

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1. Introduction

In the 2019 the CO₂ emissions from building sector reaches the highest peak ever, due to the use of natural gas, oil and coal for heating and cooking combined to the indirect emission (≈55% of global electricity consumption) [1]. Moreover, the COVID-19 pandemic impacted on the global construction industry bringing a drop of 10÷25% in the construction activities compared to 2019 [2]. According to International Energy Agency [3] this recession
could bring reduction on the energy efficiency improvement rate (lowering to 0.7% at 2025). So, many countries implemented stimulus programs in order to respond to the COVID-19 crisis in the building sector [4]. For instance, Chile foresaw 20’000 houses/year renovated with 1’800 GWh of distributed residential electricity generation; Japan introduced energy saving standards for new buildings and efficient remodeling of existing ones [2]. In Europe with the NextGenerationEU the recover investment instrument (about 800 billion euro) requires the EU countries to spend at least 37% on greening their economy. With attention to buildings sector, the strategy “A Renovation Wave for Europe” [5] that doubles the annual energy renovation rates (to 2%) in the next 10 years with the aim to reduce emissions (60% in 2030), enhance quality of life and create additional jobs in the construction sector.

2. Incentive mechanisms

Within this frame, the Italian social policies to face the COVID-19 emergency are enclosed in the “Recovery Decree” [6], converted in law 77 on July 17, 2020. In order to support the building sector, the law foresees a tax deduction rate to 110% for energy efficiency measures (EEMs), when the expenses incurred from July 1, 2020 to December 31, 2023. It is called “Super-bonus” and it concerns both EEMs on multi-family buildings than individual homes. The tax reduction of 110% is delivered in 5 years if at least one of “driving measure” is applied:

1. thermal insulation of building envelope which affects an area greater than of 25% of the total gross dispersing surface, by means of sustainable materials in accordance with [7];

2. replacement of heating systems with condensing boiler or heat pump or micro-cogeneration system or hybrid system or solar collectors or district heating with specific performance.

They have to bring an improvement of at least two energy classes, or, if it is not possible, it should be proved the achievement of the highest possible class.

Moreover, there are other EEMs, called “driven measures”, that can also be under tax reduction of 110% if carried out jointly with at least one of the “driving measures”. They are PV system and electric storage, window replacement and shading system, devices for home automation and facilities electric vehicles charge. In addition to direct tax deduction it is also possible to transfer credit to suppliers or other parties.

Is this type of incentive mechanism, that provides a full refund of expenses on any type of EEM (to the envelope or to the Heating, ventilation, and air conditioning (HVAC) system-really effective? or is it better to make incentives aimed only at certain EEM? What could be the limits and the negative consequences that derive from it? This paper aims to analyze it under energy, economic and environmental impact point of view, in order to give guidelines for Italian government and a method to be replicated in other countries as well.

3. Case study

The case study regards a real building placed in Avellino (498 a.s.l.), a city in southern Italy (41.01°N, 14.53°) characterized by a temperate climate, with 1938 Heating Degree Days (HDD) and −3.8 °C of winter design temperature. It is a residential building built in 1962 (Fig. 1 a). The structure has a rectangular plan and consists of two floors above ground (Fig. 1 b). The maximum overall dimensions in plan are 15x6.0 m. The ground floor includes a kitchen, a living room, a service bathroom and a closet; while in the first floor there are two bedrooms, a multipurpose room and a bathroom. The opaque elements of the building envelope are made by tuff and without...
thermal insulation. The main thermo-physic characteristics are shown in Fig. 1c. The window to wall ratio is 11%, with single float glazing and wood frame.

In order to meet the winter thermal demand hot water radiators fueled by a biomass fireplace (nominal power of 20 kW) are installed. The same system is used for the domestic hot water, while the building has no cooling systems. Thus, according the Italian law, the only two energy services of the building are: heating and domestic hot water.

This configuration of the HVAC-envelope building system is highly widespread in the Italian region in which it is located, thus making the building a representative case study.

4. Methodological approach

The study has been developed following the regulatory requirements in force with an asset rating level according to the European directive [8] and the technical standards adopted in Italy. Thus the numerical model of the building (Fig. 2a) and the semi-stationary calculations have been carried out by means of TerMus BIM, the BIM tool able to carry out the energy label and all information for incentives access.

The main energy, environmental and economic indices taken into account in this study are:

- \( \text{EP}_{\text{gl,ren}} \), \( \text{EP}_{\text{gl,tot}} \) the overall energy performance index of the building corresponding to the non-renewable or total primary energy requirement, per unit area, for services in standard use (kWh/ m\(^2\) year).
- \( \text{CO}_2 \): overall carbon dioxide emissions, per unit area (kgCO\(_2\)/ m\(^2\) year).
- \( \text{NPV}_{20} \): the Net Present Value on lifetime equal to 20 years, with a discount rate of 3% (€/year).
- \( \text{DPB} \): the discounted pay-back period with a discount rate of 3% (year).
- \( \text{ISI} \): the investment/saving index, the ratio between the investment cost and the annual primary total or non-renewable energy saving (€ year/kWh).

5. Existing state and energy refurbishment scenarios

The results of building performance in its existing state (ES) are shown in Fig. 2. More in depth on the basis of “envelope performance” (Fig. 2c) the winter thermal performance of the envelope is “low quality”, while the summer one is “average quality”. On the other hand, the energy label is equal to B, this means that the building has a \( \text{EP}_{\text{gl,ren}} \) similar to the one of its reference building. So, according the Italian normative, a building with a low quality envelope can still reach a high energy class, thanks to an efficient HVAC and/or a renewable supply energy vector, such as solid biomass (firewood in this case). This also entails greater planning complexity in implementing the double class leap required to access incentives.

As regard the energy refurbishment, different scenarios have been developed. Scenario 1 deals with six energy efficiency measures on the opaque and transparent building envelope, by means of three different external insulation materials and two different windows type. The insulation materials chosen are:

- rock wool (\( \lambda = 0.035 \text{ W/m K}; \rho = 40 \text{ kg/m}^3; c_p = 1030 \text{ J/kg K} \)), following called WOL;
- expanded polyurethane (\( \lambda = 0.022 \text{ W/m K}; \rho = 40 \text{ kg/m}^3; c_p = 1400 \text{ J/kg K} \)), following called PUR;
- hemp-kenaf fiber (\( \lambda = 0.038 \text{ W/m K}; \rho = 38 \text{ kg/m}^3; c_p = 2000 \text{ J/kg K} \)), following called HEM.
Table 1. The Energy Efficiency Measures (EEM) put in place for Scenario 1.

| Building element          | Ante opera | Post Opera | Post Opera | Post Opera | Post Opera |
|---------------------------|------------|------------|------------|------------|------------|
|                           | U-value    | U-value    | WOL        | PUR        | HEM        | LIMIT      |
| External wall ground floor| 0.82 W/m² K | 0.21 W/m² K | 0.21 W/m² K | 0.19 W/m² K | 0.18 W/m² K | ≤0.26 W/m² K |
| External wall first floor  | 1.05 W/m² K | 0.23 W/m² K | 0.20 W/m² K | 0.19 W/m² K | 0.18 W/m² K | ≤0.26 W/m² K |
| Slab                      | 1.71 W/m² K | 0.22 W/m² K | 0.19 W/m² K | 0.21 W/m² K | 0.21 W/m² K | ≤0.22 W/m² K |

The results of the application of external insulation are reported in Table 1. The old windows \((U_f = 2.00 \text{ W/m}^2\text{K}) \) and \((U_g = 5.40 \text{ W/m}^2\text{K}) \) could be replaced with a thermal insulate frame \((U_f = 1.10 \text{ W/m}^2\text{K}) \) with two different glass type:

- double float glass \((4-6-4 \text{ mm}) \) Argon filled with \(U_g = 3.00 \text{ W/m}^2\text{K} \), following called FLO;
- double glass \((4-6-4 \text{ mm}) \) Argon filled low emission with \(U_g = 2.20 \text{ W/m}^2\text{K} \), following called LOW.

The second scenario refers to the thermal plants, in particular the replacement of generation, regulation and emission systems. The old radiators will be replaced by 10 fan-coils with a climatic regulation. The biomass fireplace is replaced by:

- a condensing gas boiler (4 star energy efficiency according to 92/42EEC), following called BOI;
- an electric air-to-water heat pump (COP=3.6 at 7 °C air and 45 °C water) following called HP.

In the third scenario considers only a PV system made by 13 m² of mono-crystalline silicon roof integrated \((22°\) tilted with a pick power of 2.00 kW. Finally, a combination of several previous configurations is proposed in the scenario 4. In total 21 EEMs will be considered. Scenario 1, 2 and 4 contain “driving measures” so they got tax reduction to 110%. All EEMs respect the limit cost imposed by the law.

6. Results

In this section the percentage variation of all indices with respect the EC is shown by \(\Delta\) symbol. In Fig. 3(a) is evident that the \(\text{EP}_{gl,\text{tot}}\) is greater than \(\text{EP}_{gl,\text{nren}}\) and they both reduce with an EEM with respect the EC; but in
the cases of BOI installation the \( \text{EP}_{\text{gl,ren}} \) is greater of \( \text{EP}_{\text{gl,tot}} \) and the \( \text{EP}_{\text{gl,ren}} \) increases with respect the EC. In this latter case there is an increase of \( \text{CO}_2 \) emissions and a reduction of energy label. This is due to the fact that in the BOI cases the energy source is no longer biomass (characterized by a high percentage of renewable primary energy, 60%) but natural gas (characterized by a null percentage of renewable primary source).

For the Scenario 1 the optimal solution (minimum \( \text{EP}_{\text{gl,ren}} \)) is HEM-LOW; it has been as the envelope EEM for the combinations in Scenario 4. In the second scenario the best solution, considering the \( \text{EP}_{\text{gl,ren}} \) is the HP. In general, the best solution is HP-HEM-LOW-\( \text{PV} \) characterized by the greatest reduction of \( \text{EP}_{\text{gl,ren}} \) (68%), a significative reduction of \( \text{CO}_2 \) (−53%) and an improvement of 4 energy labels. Not all EEMs are suitable for obtain the increase of 2 energy labels, as required for the incentive access.

In Fig. 3(b) the ISI index has been not calculated for the EEMs which do not bring an energy saving. The calculations considered the last energy prices on the market: electricity \( \approx 0.147 \) €/kWh; wood \( \approx 0.13 \) €/kg; natural gas \( 0.70 \) €/Sm\(^3\). In the table the NPV\(_{\text{20}}\) and the DPB with and without incentive are also shown. The incentive is calculated only for the EEM that can be obtained it. Analyzing the ISI in terms of \( \text{EP}_{\text{gl,ren}} \) the best solution (minimum ISI) is the \( \text{PV} \). This EEM is also the one that guarantees the lowest number of years of DPB without incentive, because in the face of not renewable primary energy saving of about 30% (which is not the maximum savings that can be achieved), however, it is characterized by the minimum investment cost (\( \approx 4'000 \) €).

It should be noted that the interventions on the envelope, which make it possible to achieve very high energy savings (about 30%), are characterized by very high investment costs (\( \approx 20'000 \) €), which entails a value of ISI not very advantageous. In general, this histogram could provide an indication to the administrators on which types of building energy requalification interventions provide incentives in the next future: they are mainly those related to interventions on the envelope.

By analyzing the table in Fig. 3(b) for all EEMs without incentive, except for \( \text{PV} \), the DPB years are greater than 20 years. Until a few years ago, some EEMs, especially those related to the replacement of the HVAC system, would certainly have a DPB less than 20 years. It is the result of a surge in the prices of components and raw materials used in the construction sector, which occurred following the advent of the COVID-19 pandemic and, in Italy, by the introduction of 110% incentive. This means that, in the absence of incentives, no EEM would be economically advantageous. In the case of tax reduction, however, since they are 110% for 5 years, the DPB varies from 4 to 5 years. On the other hand, considering the profitability of the intervention based on the NPV\(_{\text{20}}\), it was found that, if the 110% tax reduction applied, the most profitable EEM is HP-HEM-LOW-\( \text{PV} \), namely the optimal result of energy analysis. This means that a 110% incentive would allow the end user to choose the optimal solution not only from an economic point of view but also from an energy point of view, with benefits both for the individual citizen and for the whole society.

Finally, a sensitivity analysis has been conducted, considering other two climate zones in Italy, in addition to the D zone: (i) Zone C (1034 HDD and +2.0 °C of winter design temperature); (ii) Zone E (2214 HDD and −3.4 °C of winter design temperature). These latter have been chosen because they are the other ones in which the building typology under study is widespread. For them, different the thickness of the insulation was changed with regard to Scenario 1, in order to comply the limits, set by the incentives. The results are shown in Fig. 4. For all climate zones the best solution under economic point of view is the \( \text{PV} \), with positive NPV\(_{\text{20}}\) an energy saving equal to −9% in Zone C, and equal to −6% in Zones E and D. On the other hand, the best solution under the energetic point of view is, in all zones, the HP-HEM-LOW-\( \text{PV} \).
7. Conclusions

The study analyzed is representative of a HVAC-building typical of southern Italy. The first conclusion found is that a building envelope poorly performing if coupled to a performing HVAC system and/or powered by a renewable energy could obtain a high energy label, with greater difficulties for designers to improve it. Considering only the energy/environmental aspects the best EEM is the one with external insulation, windows replacement, electric heat pump and PV-system installation, with a primary not renewable energy saving of 81% and 4 labels improvement. It is also the best solution if the Net Present Value on lifetime equal to 20 years is considered, while the best solution considering the cost/saving ratio is the replacement of the generation system or the installation of a PV. Hence this type of incentive mechanism put in place by Italian government, leads to preference energy efficiency measures characterized by the best energy performance, and not the best cost/saving ratio, resulting in economic benefits for the individual user, but, above all, energy and environmental benefits for the entire community. Moreover, if the incentive mechanism is not considered, no intervention would have discounted pay-back period less than 20 years. It is the result of a surge in the prices of components and raw materials used in the construction sector, which occurred following the advent of the pandemic and also the introduction of 110% tax reduction in Italy. Thus the proposed histogram about cost/saving ratio could provide an indication to the administrative bodies on which types of building energy measures envisage the next incentives once the 110% tax reduction has been exceeded. This method can be replicated to other building types and climatic areas.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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References

[1] International Energy Agency. Energy Technology Perspectives 2020. Paris: IEA; 2020, https://www.iea.org/reports/energy-technology-perspectives-2020.
[2] United Nations Environment Programme. 2020 Global status report for buildings and construction: Towards a zero-emission. In: Efficient and Resilient Buildings and Construction Sector. 2020, Nairobi.
[3] International Energy Agency. Energy Efficiency 2020. Paris: IEA; 2020, https://www.iea.org/reports/energy-efficiency-2020.
[4] Economou M, Todeschi V, Bertoldi P, D’Agostino D, Zangheri P, Castellazzi L. Review of 50 years of EU energy efficiency policies for buildings. Energy Build 2020;225:110322.
[5] EUROPEAN COMMISSION, COM. 662 Brussels, 14.10.2020. 2020, A Renovation Wave for Europe - greening our buildings, creating jobs, improving lives..
[6] Law decree 19 2020, n. 34, Urgent measures in the field of health, support for work and the economy, as well as social policies related to the epidemiological emergency from COVID-19. (20G00052). In Italian..
[7] Decree 11 2017, n.259, Minimum environmental criteria for the award of design services and works for the new construction, renovation and maintenance of public buildings. (17A07439). In Italian..
[8] Official Journal of the European Union, DIRECTIVE (EU) 2018/844 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 30 May 2018.

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