Examining the role of the superbonus 110% incentive in Italy through analyses of two residential buildings

Harold E. Huerto-Cardenas[1*], *Niccolò* Aste[1], *Michela* Buzzetti[1], *Claudio* Del Pero[1], *Fabrizio* Leonforte[1], and *Alessandro* Miglioli[2]

[1]ABC Department, Politecnico di Milano, 20133 Milan, Italy
[2]ZH Srl, 20123 Milan, Italy

Abstract. Over the past few years, the Covid-19 pandemic has triggered an economic crisis, impacting various sectors including building construction. Within this sector, the residential section represents one of the main causes of energy consumption and pollutant emissions. To address this challenge the European Union has devised a strategic plan aimed at promoting energy efficiency and environmental sustainability, with a special focus on revitalizing the building sector. Within this strategic framework, the tax incentive Superbonus 110% introduced in 2020 has emerged as a pivotal program, incentivizing specific energy efficiency measures for existing buildings in alignment with the EU Directives. In this regard, this study aims to analyse the retrofit intervention of two existing residential buildings subsidized through the Superbonus 110% mechanism. A critical analysis of several passive and active energy efficiency measures is performed considering energy, environmental and economic indicators, employing a dynamic simulation approach. This work demonstrates how the proposed Italian funding program can enhance the diffusion of energy efficiency interventions. However, thanks to the analysis of real case studies, the criticalities and implications that such a mechanism has brought to the construction sector were highlighted, in the perspective of future incentives.

1 Introduction

In the light of the recent approval by the European Union of Directive (EU) 2023/1791 the role of building retrofit incentives is pivotal to increase the current renovation rate equal to 1% and to achieve the decarbonization goals set for 2050 [1].

In accordance with the European Framework, over 70% of EU member states have implemented the EU EPBD through strategies or schemes to fund energy renovations in buildings, primarily focusing on the residential sector [2]. Furthermore, at least six countries (including Italy) have enhanced or expanded their funding initiatives to boost building energy efficiency in 2021, following the outbreak of the Covid-19 pandemic [2]. In order to promote energy efficiency interventions, tax incentives have been implemented in certain EU nations across residential, commercial, and public administration sectors. Among these countries, Belgium, France and Portugal are notable for the number of incentive measures enacted [3]. It should be noted that incentives in EU countries have different levels of tax deduction and take more or less into account the household income of those who intend to retrofit the building. As well known, the construction sector accounts for the final energy consumption and carbon emissions of about 40% and 37% respectively in the European Union (EU) [4], therefore, the decarbonisation of the building stock is one of the most important goals that must be addressed [5]. In Italy, over 51% [6] of the existing building stock was built before 1970 and is generally characterized by poor efficiency, both due to poor thermal insulation of the envelope and the use of conventional centralized boilers [7]. Therefore, in order to improve their efficiency, a number of incentive policies for energy retrofit were proposed during the past few years.

Before 2020, the financial support in Italy for energy retrofit of private buildings was centred on a tax deduction ranging from 50% to 85% in 10 years (called “Eco-bonus”), for energy efficiency measures including envelope insulation, windows replacement, sunscreen systems, partial or total replacement of HVAC systems with more efficient ones, solar thermal collectors, building automation components, etc. In May 2020, with the spread of Covid-19 pandemic, it was emanated the so-called "Recovery Decree" [8], which increased the tax deduction rate to 110% of investment cost for categories of retrofit interventions addressed between July 2020 and June 2023. The "Superbonus 110%" incentive offers a tax reduction spread over 5 annual rates for expenses made by December 31, 2021, and 4 for those incurred in 2022. Moreover, the credit can be transferred to active parties/suppliers, or alternatively, a direct discount on the invoice cost can be obtained from the construction company. In this scenario, the construction company holds ownership of the credit. The tax deduction applies to investments targeted at

* Corresponding author: haroldenrique.huerto@polimi.it

enhancing the energy efficiency of both multi-family buildings and individual homes. Such incentive can be accessible if at least one of the main energy efficiency measures, called “Driving measures” (e.g. thermal insulation, replacement of heating generation systems and anti-seismic interventions), is applied and the energy refurbishment enhances at least 2 classes according to the Italian building energy certification system. If the conditions described above are satisfied, energy efficiency measures listed for the previous Eco-Bonus can also be implemented along with the driving measures.

Within this framework, the Superbonus 110% incentive in 2021 led to exceptional performances for the construction sector, which came from an extended period of crisis and diverging from the trajectory of the broader economy [9]. Furthermore, from a government revenue perspective, it can be viewed as a rise in income and consequently an increase in tax revenue. Additionally, it’s crucial to consider job creation which in 2021 showed a significant leap with respect to the last 10 years [10]. However, as stated by some authors, there are some controversial aspects caused by the implementation of this incentive. L. Daglio [11] listed some negative aspects, e.g. poor social equity due to easier access to the incentives by wealthy beneficiaries and the high payback periods borne by the state budget. Moreover, the Superbonus 110% incentive leads to inflationary consequences due to the faulty incentive framework, the constrained timeframe for project completion, and the perception of the incentive program as transient and overly generous swiftly triggering a surge in demand surpassing available supply by a wide margin [10]. This disparity between constrained supply and heightened demand precipitated sector-wide inflation, impacting all consumers within the industry, not solely those benefiting from the mechanism. This led to a notable escalation in prices of building materials and technical components, soaring up to about 25.4% [12] alongside a significant shortage of construction labour. Of course, part of such amount is due to the Covid-19 pandemic (which spread from the beginning of 2020), which accounts for a share of about 13% [13]. In this regard, this study aims to analyse the retrofit intervention of two existing residential buildings through the Superbonus 110% mechanism, highlighting the expenses of the interventions and the obtained energy savings. In such respect, the weaknesses and strengths of such mechanism were discussed from the perspective of orienting future incentive programmes.

2 Method

The method adopted in this work and applied to two case studies is described hereafter and shown in Figure 1:

- Collection of pre-and post-intervention building data and pre-intervention energy bills;
- Characterization and calibration of dynamic simulation models to estimate the energy savings achieved through retrofit;
- Estimation of the cost involved in the retrofit process, pointing out the differences from the effective cost of the intervention, the increased cost due to the spread of the Covid-19 pandemic and the increase related to the introduction of the Superbonus 110% tax deduction;
- Calculation of the Simple Payback Time (PBT) of the investment;
- Exploration of the tax deduction rate that allows owners to carry out retrofit interventions without causing the overload of the construction sector, as happened with the Superbonus 110%.

3 Case studies before and after the retrofit intervention

The analysed case studies consist of two residential condominium buildings, located in Cinisello Balsamo, a city in the northern suburban area of Milan (Italy), characterized by 2404 heating degree days. The first one, named hereafter Case Study n.1, was built in 1962, it is a linear building oriented along the north-south axis with two stairwells connecting 9 floors. The ground floor hosts commercial spaces while the upper levels comprise 32 apartments. The structure is made of reinforced concrete with brick infill walls characterized by an air gap, except for the precast concrete infill on the west side. In terms of the technical systems, a centralized gas boiler with radiators provides the heating demand, while domestic hot water (DHW) is supplied by individual gas water heaters. The energy consumption of the building before retrofit (heating, DHW and condominium electric consumption), as reported in according to the energy bills, is about 224 kWh_{EP}/m^2y.

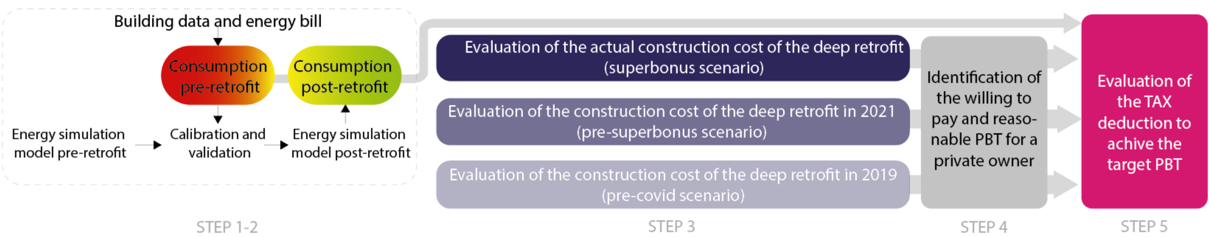

Fig. 1. Flowchart of the method adopted in this work.

Table 1. Main information related to the two buildings before and after the retrofit intervention.

	Case Study n.1		**Case Study n.2**	
	Pre-retrofit	Post-retrofit	Pre-retrofit	Post-retrofit
				
ENVELOPE	Average U-value	Average U-value	Average U-value	Average U-value
Windows	2.90 W/m^2K	1.2 W/m^2K	2.90 W/m^2K	1.2 W/m^2K
Walls	0.91 W/m^2K	0.18 W/m^2K	0.58 W/m^2K	0.18 W/m^2K
Roofs	1.08 W/m^2K	0.17 W/m^2K	0.60 W/m^2K	0.16 W/m^2K
Floors	1.37 W/m^2K	0.20 W/m^2K	1.65 W/m^2K	0.21 W/m^2K
TECHNICAL SYSTEMS				
Heating system	Centralized gas boiler with radiators $\eta_{overall}$= 0.61	New centralized gas boiler with radiators $\eta_{overall}$ = 0.85	District heating with radiators $\eta_{overall}$ = 0.69	District heating with radiators $\eta_{overall}$ = 0.69
DHW system	Autonomous gas water heater	Centralized gas boiler	District heating	District heating
PV system	-	11.4 kW_p	15.2 kW_p	111.1 kW_p

The retrofit intervention provided the insulation of the envelope with a thermal coat and a plaster finish, the replacement of windows with double glass and PVC frame and shutter boxes. Moreover, the intervention involves the replacement of the existing boiler, the centralization of the DHW as well as the installation of a PV system with a peak power of 11.4 kW_p. The Case Study n.2 was built in 1981, is characterized by three blocks with 4 floors high. The ground level of the northern and west blocks hosted commercial activities, while the other spaces included 43 apartments connected by three external stairwells. The structure is made of reinforced concrete with brick infill walls provided by an air gap and a thin insulation layer. In terms of technical systems, the building is connected to the local district heating network, with two dedicated heat exchangers both for heating and DHW. According to the energy bills, the energy consumption before retrofit was approximately 127 kWh_{EP}/m^2y. Similarly to Case Study n.1, the retrofit intervention includes the insulation of the envelope with a thermal coat and a finishing layer of reconstituted stone, the replacement of windows with double glass and wooden frame and shutter boxes. Moreover, the intervention included the installation of a 95.9 kW_P PV system on a wooden shelter installed on the roof [14]. In Table 1 are listed the main properties of building envelope and technical system of the two case studies.

4 Dynamic energy simulation

Since the energy retrofit of two case studies was recently completed (December 2023), the expected energy saving due to the interventions has been assessed through EnergyPlus simulations. Such software represents one of the main reference tools for detailed and accurate building energy analysis [15–17]. In such regard, detailed modelling of the two case studies has been done, by defining thermal zones for all different spaces (apartments, stores, unheated areas, etc.) and applying the thermal features reported in Section 3. After that, an Air Change per Hour (ACH) equal to 0.3 vol/h, and an internal mean heat gains value equal to 4 W/m^2, have been defined by adopting average conditions based on the Italian standard UNI/TS11300 [18]. The heating period has been assumed from October 15th to April 15th, according to the national Climatic Zone E, with a setpoint of 20°C.

The model calibration and validation have been done by comparing the energy demand collected from the bills (before retrofit) with the simulated one. The process to reduce the discrepancy between measured and simulated data has been done mainly by adjusting some input parameters, such as the implementation of thermal bridges, the optimization of the thermal and solar absorption of the finishing layers, the implementation of a weather file for the same year of the bills, etc.

In such regard, the discrepancy between measured and simulated energy demand is below 10%, which has been considered acceptable according to [19]. After that, the before-retrofit validated energy model of the two case studies was implemented by adding the features of the retrofit interventions. In such respect, the energy savings have been calculated as reported in the following section.

5 Results

The section shows the energy savings obtained through the retrofit interventions and the related costs. Moreover, the calculation of the payback time of the investments and the estimation of the incentive rate that could allow for the economic sustainability of interventions for private citizens without overburdening the market is proposed.

Table 2. Energy consumption to the two buildings before and after the retrofit intervention.

	Case Study n.1		Case Study n.2	
	Pre-retrofit	Post-retrofit	Pre-retrofit	Post-retrofit
Primary energy - Heating [kWh_{EP}/m^2 y]	162	42	119	70
Primary energy - DHW [kWh_{EP}/m^2 y]	48	39		
Primary energy - Electrical uses [kWh_{EP}/m^2 y]	14	14*	8	8*
Total Primary energy [kWh_{EP}/m^2 y]	224	81	127	70
Energy Class (Italian Certification)	F	A1	E	C

* Energy consumption totally supplied by the new PV system installed

5.1 Energy and environmental saving assessment

As previously mentioned, the energy demand of the buildings was estimated by means of the energy simulation model, which was then converted into primary energy consumption by adopting the conversion factors of 1.05 and 2.42 for natural gas and electricity respectively.

A summary of the energy savings obtained in the two case studies is provided in Table 2.

In detail, for Case Study n.1 the savings achieved through the envelope insulation, replacement of windows and technical systems (generation and emission) is about 74%. While concerning the DHW, a saving of about 18% was obtained thanks to the centralization of the plant. On the other hand, with regard to the electric energy consumption for common spaces, it was totally covered by the integrated photovoltaic panels on the roof. Thus, the overall primary energy has been reduced from 224 kWh_{EP}/m^2y to 81 kWh_{EP}/m^2y, which corresponds to energy savings per year of about 64% and a reduction of 51,563 kg/CO_2 emissions. In such regard, the energy class (according to the Italian EPC) of the building goes from F to A1. Similarly, in Case Study n.2, the savings achieved through the envelope intervention is about 41%. With reference to the energy consumption for the common spaces, even in this case, it was totally supplied by the integrated photovoltaic modules on the roof. In such regard, the overall primary energy has been reduced from 127 kWh_{EP}/m^2y to 70 kWh_{EP}/m^2y, which corresponds to an annual energy savings of about 44% and a reduction of 74,996 kg/CO_2 emissions. The energy class of the whole building goes from E to C. It should be noted that the lower energy savings of the latter case study is mainly related to the fact that the heating system was not retrofitted, since the building is served by the local district heating.

5.2 Cost analysis

The cost of intervention of the two buildings was estimated through MS Excel considering the costs actually incurred. In particular, the total cost for the retrofit intervention for Case Studies n.1 and n.2 is 1,655,400 € and 3,011,550 €, respectively. It should be noted that in the estimation of such costs, the interventions which are not strictly related to the increased efficiency of the buildings were not included.

The calculation of the simple PBT of the investment has been estimated considering the intervention cost with respect to the economic savings in energy bills obtained thanks to the retrofit interventions, by considering a cost of gas, electricity and district heating of about 1.24 €/Nm^3, 0.312 €/kWh and 0.1 €/kWh, respectively.

In such regard, the PBT is estimated approximately to 57 and 83 years for case studies n.1 and n.2, respectively. It should be noted that in the case of the Superbonus 110% mechanism, the intervention costs for retrofit are entirely at the expense of the government, as it would be difficult to be supported by a private. In this sense, the incentive provided by the Superbonus 110% was a very attractive opportunity for privates and companies that gave a boost to the Italian construction sector [9]. However, the significant escalation in prices of building materials and technical components, mentioned in section 1, should be also considered.
In such regard, Figure 2 shows the comparison of the effective intervention cost and related payback time, with the estimated cost not considering the rise caused by the Covid-19 pandemic and the Superbonus 110% incentive.

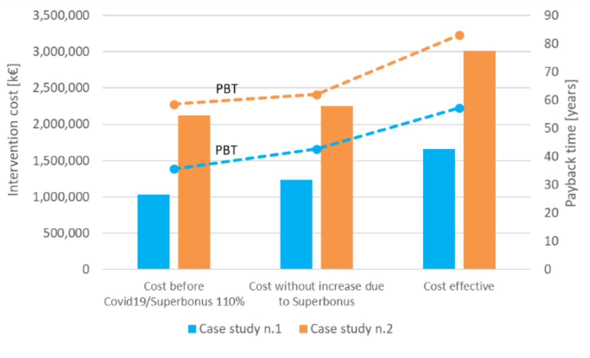

Fig. 2. Comparison of the intervention cost and the simple payback time in the different case.

Finally, considering the payback time that a private subject is usually willing to pay for an energy efficiency intervention, is on average equal to 10 years [20], it has been evaluated which would be the reasonable incentive that the government should provide. In detail, it ranges between 72-83% for Case Study n.1 while in between 83-88% for Case Study n.2. It is important to note that the magnitude of the intervals hinges on whether the construction material costs are based on pre-2020 or post-2020 pricing.

6 Conclusion and lesson learnt

In conclusion, as illustrated in this analysis and as underscored by certain authors in the literature, the incentives for building retrofitting, particularly those covering the entire intervention cost, may have adverse effects on the construction sector, as exemplified by the challenges encountered with the Superbonus 110% mechanism. Such negative aspects include delays in material delivery, labour shortages, and rising costs for materials and components. Hence, this study examined two condominiums situated in the suburban area of Milan, undergoing retrofitting under the Superbonus 110% incentive. It aimed to delineate the opportunities and challenges presented by this incentive, while also endeavoring to determine an optimal incentive range that avoids the overload of the construction market, overburdened the government coffers and ensures a reasonable payback time for privates.

In this context, a sustainable incentive varies from 72% to 88% depending if the intervention excludes or not the replacement of technical systems since it has a significant impact on the calculation of the payback time. Furthermore, given recent European directives, the promotion of incentives that are attractive, sustainable, accessible and do not cause stress on the construction market, is pivotal to ensuring long-term efficiency in the residential building sector and achieving the 2050 goals.

References

1. European Parliament and the Council of the Union, Directive 2023/1791 of the European Parliament and of the Council of 13 September 2023, (2023).
2. F. Ascione, R.F. De Masi, M. Mastellone, S. Ruggiero, G.P. Vanoli, Improving the building stock sustainability in European Countries: A focus on the Italian case, Journal of Cleaner Production 365 (2022) 132699. https://doi.org/10.1016/j.jclepro.2022.132699.
3. ENEA, Le detrazioni fiscali per l'efficienza energetica e l'utilizzo delle fonti rinnovabili di energia negli edifici esistenti. Rapporto annuale 2020., 2020. https://cdn.qualenergia.it/wp-content/uploads/2020/10/report_detrazioni_2020.pdf.
4. European Commission, In focus: Energy efficiency in buildings, Brussels, 2020. https://commission.europa.eu/news/focus-energy-efficiency-buildings-2020-02-17_en.
5. U. Berardi, A cross-country comparison of the building energy consumptions and their trends, Resources, Conservation and Recycling 123 (2017) 230–241. https://doi.org/10.1016/j.resconrec.2016.03.014.
6. Gotta, U. Mecca, M. Rebaudengo, Switching from Risks to Opportunities: The Application of a Superbonus Tax Incentive to Heritage Buildings from the 1960s in Fragile Mountain Contexts, Land 12 (2023) 1130. https://doi.org/10.3390/land12061130.
7. F. Calise, F.L. Cappiello, L. Cimmino, M. Dentice d'Accadia, M. Vicidomini, Dynamic modelling and thermoeconomic analysis for the energy refurbishment of the Italian building sector: Case study for the "Superbonus 110 %" funding strategy, Applied Thermal Engineering 213 (2022) 118689. https://doi.org/10.1016/j.applthermaleng.2022.118689.
8. DL n. 34 19/05/2020, 2020 - Misure urgenti in materia di salute, sostegno al lavoro e all'economia, nonchè di politiche sociali connesse all'emergenza epidemiologica da COVID-19, 2020.
9. T.D. Nardo, P. Saggese, E. Zanetti, L'impatto economico del Superbonus 110% e il costo effettivo per lo stato dei bonus edilizi, Fondazione Nazionale dei Commercialisti (2022).
10. L. Papi, La riqualificazione del patrimonio edilizio: un bilancio delle recenti misure di incentivazione, Moneta e Credito 75 (2022).
11. Laura Daglio, Chapter 56, The Urban Potential of Multifamily Housing Renovation, in: Technological Imagination in the Green and Digital Transition, n.d.: pp. 627–636.
12. GAD, 2022CCR - Construction Cost Report. Approfondimento relativo alla variazione dei prezzi nel mercato italiano delle costruzioni., 2022.
13. Eurostat Statistics Explained, ISTAT, Construction producer prices or costs, new residential buildings - monthly data, (2024).
14. ZH Srl, Efficientamento energetico di edifici residenziali ed accesso al meccanismo del "Superbonus," www.Zhspinoff.Com (2024). https://www.zhspinoff.com/it/120-efficientamento-energetico-di-edifici-residenziali-ed-accesso-al-meccanismo-del-%E2%80%9Csuperbonus%E2%80%9D.asp.
15. P. De Wilde, Building Performance Analysis, John Wiley & Sons Ltd, 2018.
16. N. Fumo, P. Mago, R. Luck, Methodology to estimate building energy consumption using EnergyPlus Benchmark Models, Energy and Buildings 42 (2010) 2331–2337. https://doi.org/10.1016/j.enbuild.2010.07.027.
17. J. Sousa, Energy simulation software for buildings: Review and comparison, in: Proceedings of the International Workshop on Information Technology for Energy Applications (IT4ENERGY 2012), Lisbon, 2012: pp. 57–68.
18. Ente Nazionale Italiano di Unificazione (UNI), UNI/TS 11300-1:2014 - Prestazioni energetiche degli edifici - Parte 1: Determinazione del fabbisogno di energia termica dell'edificio per la climatizzazione estiva ed invernale, 2014.
19. M. Pretelli, K. Fabbri, Historic Indoor Microclimate of the Heritage Buildings - A | Marco Pretelli | Springer, Springer, Swizerland, 2018. http://www.springer.com/it/book/9783319603414.
20. UBS Sustainability and Impact Institute, Retrofit revolution - Why the world needs one and how we can achieve it, 2023. www.ubs.com/better-buildings.