SCENARIO-BASED ENERGY RENOVATION OF A TYPICAL 1970s ITALIAN RESIDENTIAL BUILDING: A REPLICABLE SOLAR-ELECTRIC STRATEGY ALIGNED WITH EU TAXONOMY AND DNSH CRITERIA

Summary

The decarbonization of the European residential building stock requires scalable and replicable renovation strategies aligned with climate and financial regulations. This study presents a scenario-based energy renovation analysis of a typical multi-family Italian residential building constructed in the 1970s, representative of a large share of the national existing building stock. Different renovation scenarios were simulated, including photovoltaic integration, heat pumps and envelope improvements. Energy performance, primary energy demand, renewable integration and CO_2 emission reductions were assessed through building energy modelling. In addition to technical evaluation, the proposed interventions were screened against the requirements of the EU Taxonomy Regulation [1] and the Do No Significant Harm (DNSH) [2] framework to verify substantial contribution to climate mitigation and compliance with environmental safeguards. Results indicate that solar-driven electrification combined with moderate envelope retrofitting can significantly reduce operational emissions while maintaining regulatory alignment. The proposed methodology provides a replicable framework to support large-scale residential decarbonization strategies across Mediterranean residential contexts.

Keywords: Deep Renovation, Residential buildings, Photovoltaics, Heat pumps, EU Taxonomy, DNSH, Decarbonization, Solar electrification

Field of application for the findings: Residential building stock renovation in Mediterranean climate zones

Addressed audience: Researchers, policy analysts, public authorities, energy planners

1. Introduction

The European building sector plays a central role in achieving climate neutrality targets, accounting for a significant share of final energy consumption and greenhouse gas emissions (GHG)[3]. Recent European regulatory developments, including the recast of the Energy Performance of Buildings Directive (EPBD IV) [4], reinforce the need for large-scale renovation strategies aimed at reducing operational emissions and accelerating electrification[5]. In parallel, financial flows supporting renovation projects are increasingly guided by sustainability criteria defined under the EU Taxonomy Regulation, which requires a substantial contribution to climate change mitigation and compliance with the Do No Significant Harm (DNSH) framework.

According to national statistical analyses conducted by the Italian Istituto Nazionale di Statistica (ISTAT)[6], a significant share of the Italian residential building stock was constructed between the 1960s and 1980s, making these buildings a priority target for medium- and deep-renovation strategies. Multi-family buildings from the 1970s are particularly widespread and are typically characterized by poor thermal insulation, the presence of thermal bridges, inefficient centralized heating systems, and limited integration of renewable energy technologies. As these buildings were constructed before the introduction of modern energy efficiency regulations, they generally exhibit high primary energy demand and significant operational CO_2 emissions.

Given the widespread presence of these buildings within the national housing stock, the identification of a representative “recurring building” based on statistical housing data allows the development of replicable renovation scenarios with potential large-scale applicability. Within this context, this study proposes a scenario-based energy renovation assessment of a representative 1970s Italian multi-family building, integrating technical performance evaluation with regulatory screening under EU Taxonomy and DNSH criteria.

2. Methodology and results

The analysis started from the optimization of roof systems, which represent a key component both for thermal performance and for the integration of solar technologies. In addition to minimizing heat losses, roof design was treated as a critical enabling factor for photovoltaic (PV) installation and solar-driven electrification strategies. Particular attention was given to structural stability, slope configuration, waterproofing and resistance to wind and snow loads, ensuring compatibility with PV systems[7]. Flat roofs were analyzed for slope management and waterproofing, while pitched roofs were assessed with respect to anchoring systems and integration of PV modules.

Optimization strategies included the use of continuous insulation, low-conductivity materials at junctions, thermally optimized joints, vapor barriers, ventilated cavities, and breathable membranes. Advanced solutions such as aerogel insulation, reflective membranes and ventilated roof cavities[8] were also considered to enhance thermal performance while preserving installation feasibility for solar systems.

Building energy simulation was carried out using a representative residential building model applied across 18 Italian cities[9]. Four insulation solutions (rock wool, EPS sandwich, ventilated EPS and standard EPS) were evaluated for compliance with regulatory thermal-hygrometric requirements, including Glaser method verification. In parallel, electrification scenarios were analyzed, focusing on the replacement of conventional gas boilers with high-efficiency heat pumps powered by on-site photovoltaic generation.

Simulation results show that roof retrofits alone provide energy savings ranging from 11% to 18%. However, when combined with heat pump electrification and PV integration, total energy savings increase significantly, reaching up to 77%, highlighting the synergistic effect between envelope improvements and solar-electric systems.

Further simulations explored integrated renovation scenarios in six representative locations covering all Italian climate zones, combining roof and wall insulation, window upgrades, HVAC electrification and PV system. Annual energy savings ranged from 41% to 88%, confirming the significant potential of coordinated solar-electric renovation strategies.

The results demonstrate that electrification of heating systems, when coupled with optimized building envelopes and on-site renewable generation, is a key driver for deep decarbonization[10] of the existing residential building stock.

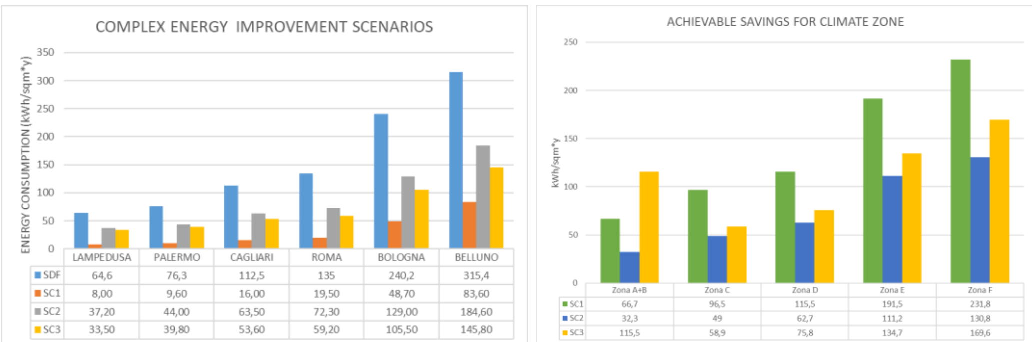

Fig. 1: Energy performances and achievable savings for complex scenarios in six different italian climate zone (A, B, C, D, E, F)

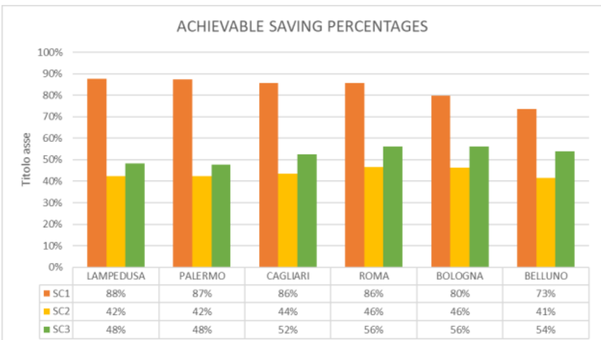

Fig. 2: Achievable savings percentage

3. EU Taxonomy Compliance and DNSH Assessment

All proposed interventions were evaluated according to the EU Taxonomy Regulation (Regulation 2020/852) and the associated DNSH criteria, ensuring that renovation measures provide a substantial contribution to climate change mitigation while avoiding negative impacts on other environmental objectives. The assessment addressed all six environmental objectives defined in the Taxonomy, including climate change mitigation and adaptation, water protection, circular economy, pollution prevention, and biodiversity protection.

Particular emphasis was placed on the role of solar-driven electrification as a key driver for Taxonomy alignment. The combined adoption of photovoltaic systems and high-efficiency heat pumps enables a significant reduction in fossil fuel consumption by shifting the building energy demand toward on-site renewable electricity. Envelope improvements, including roof and wall insulation and window replacement, were designed to reduce energy demand and enhance the effectiveness of electrified systems, creating a synergistic effect between demand reduction and renewable energy supply.

Material choices were aligned with Italian CAM (Criteri Ambientali Minimi) requirements, ensuring low environmental impact, reduced global warming potential, and compliance with circular economy principles. Heat pump systems were evaluated according to EN 14511 and EN 14825 standards to guarantee high seasonal performance, while photovoltaic systems were designed in accordance with IEC 61215 and 61730 standards, standards to ensure reliability and long-term efficiency.

The combined interventions were verified through energy and environmental modelling, confirming compliance with DNSH requirements, with no significant adverse impacts on air, water or soil quality. The results highlight that the integration of envelope optimization, HVAC electrification and on-site renewable generation represents a robust pathway to achieve Taxonomy-compliant deep renovation. The proposed methodology enables the rapid identification of compliant and replicable solutions across different building types and climatic contexts, supporting large-scale decarbonization of the residential building stock.

4. Conclusions

This study demonstrates that deep renovation of representative 1970s Italian multi-family buildings can achieve substantial energy savings, operational CO_2 reductions and alignment with EU sustainability objectives. The results show that integrated renovation strategies combining high-performance envelope measures with heat pump electrification and photovoltaic systems can reduce energy demand by up to 88% across different climatic zones.

The findings highlight the central role of solar-driven electrification in achieving both energy performance and regulatory compliance. Photovoltaic systems act as the primary decarbonization driver by supplying renewable electricity, while heat pumps enable the replacement of fossil-based heating systems, maximizing the effectiveness of envelope improvements through system integration.

The proposed methodology combines energy modelling with compliance screening under the EU Taxonomy Regulation and the Do No Significant Harm framework, demonstrating that deep renovation strategies can simultaneously deliver high energy performance and meet sustainability requirements. This integrated approach supports the identification of scalable and replicable solutions for the existing residential building stock.

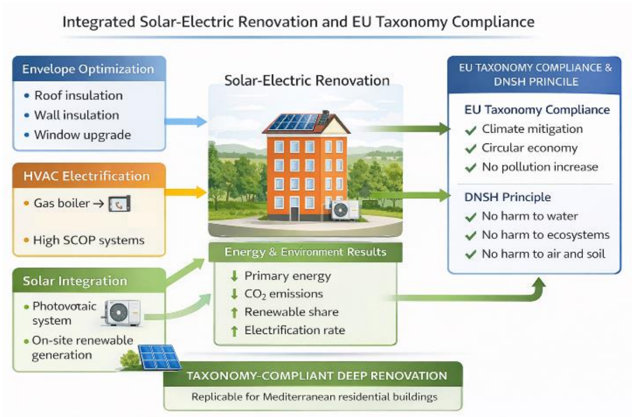

Fig. 1: Improvement actions and Taxonomy/DNSH compliance scheme

These results confirm the feasibility of large-scale solar-electric renovation pathways for post-war residential buildings, contributing to climate neutrality targets and facilitating access to sustainable finance. The proposed framework provides a practical tool for policymakers, designers and practitioners to support the transition toward low-carbon, electrified and Taxonomy-compliant buildings.

5. References

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