

Building Industry and Energy Efficiency: A Review of Three Major Issues at Stake

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Abstract. During the last two decades, the European Union regulation has paid more and more attention to the issue of energy efficiency, especially as far as the building sector is concerned. Lately, the adoption of the European Green Deal (EGD) has further fueled interest in the topic. The building industry is expected to step forward towards decarbonization, as well as to mobilize towards a clean and circular economy, so supporting the pursuit of climate neutrality. In this position paper, we aim to discuss three major issues at stake, which are crucial to increase the renovation rate of the building stock and, hence, to the success of the EGD. The first key issue is whether a cost premium has to be expected due to retrofit projects. The second key issue is whether or not the large swing currently experienced in the price premium for building energy efficiency undermines stakeholders' confidence. The third key issue is whether we need tailored evaluation methodologies for energy-efficient building portfolios.

Keywords: Building energy efficiency · Cost premium · Price premium · Construction industry · Real estate market · Spatial econometrics

1 Introduction

Energy-saving, first, starting from the seventies, and energy efficiency, later, from the nineties, have attracted growing attention among policy-makers and have established themselves as prolific research strands, especially as far as the building industry is concerned. In Europe, the first national regulations on energy-saving in buildings date back to the mid-seventies, mostly in the wake of the oil shocks of the time. Remarkable examples are the thermal insulation rules and other codes and standards meant to improve the energy use in residential buildings adopted in France (1974) [1], UK (1975), Italy (1976) [2], Germany (1976–1978) [3, 4], Denmark (1979) [5], and Sweden (1979) [6]. However, as time passed, the regulation focus changed to energy efficiency in buildings as an essential strategy to pursue the long-term sustainability goals [7, 8]. The evolution is clearly noticeable as objectives shifted: no more the mere energy-saving (and money-saving) per se but mostly environmental preservation and climate change adaptation [9]. Also, an evolutionary trend affects the policies, leading to the substitution of command-and-control tools with incentive schemes [10, 11].

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Starting from the early 2000s, the effort to improve building energy efficiency escalated thanks to the Energy Performance of Buildings Directive (EPBD, Directive 2002/91/EC), with a recast in the early 2010s (Directive 2010/31/EU). The recent adoption of the European Green Deal (EGD) [12] has further fueled interest in building energy efficiency. This action plan meant to protect and improve health and wellbeing of citizens [13] has introduced new keywords into the common lexicon of the related research fields. Due to growing concerns for the human footprint on the environment [14–16], among the pillars of the EGD is climate neutrality, to be achieved by 2050. The decarbonization of the energy system is a critical step to that end. Accordingly, the building industry is asked and expected to mobilize, along with manufacturing and transportation industries, towards a clean and circular economy. Specifically, the construction industry is required to at least double the yearly renovation rate of the building stock [17], involving both private and public buildings and bringing together a variety of stakeholders to address the known barriers to renovation.

In this position paper, we aim to discuss three major issues at stake concerning energy efficiency in the building industry and the real estate market. Addressing these issues is, in our view, crucial to increase the renovation rate of the building stock and, hence, to the success of the EGD. The first key issue is whether or not the large swing currently experienced in the price premium for building energy efficiency undermines stakeholders' confidence. Namely, does the evidence support the assumption that energy-efficient buildings command a price premium and rent premium over conventional ones? And also, is there still too much uncertainty in the estimated magnitude of that price and rent premium, which reflects in a gap between the expected and actual interest of the stakeholders? The second key issue is whether a cost premium has to be expected due to retrofit projects. Namely, should we expect the refurbished, energy-efficient buildings to cost more than those reflecting baseline building standards? And if that is the case, what the anticipated magnitude of the cost premium is? The other key issue can be summarized as follows: do we need tailored evaluation methodologies for energy-efficient building portfolios? Namely, when shifting the focus from an individual building to a whole building portfolio, can we envision innovative evaluation tools that outperform the usual ones? The discussion here benefits from reviewing the most recent literature, especially the studies modeling construction costs and real estate prices employing spatial econometric methods.

2 Three Major Issues at Stake

2.1 Does the Large Swing in Price Premiums for Building Energy Efficiency Undermine Stakeholders' Confidence?

The recast of the EU Energy Performance of Buildings Directive (2010/31/EU) identifies the energy performance certificate (EPC) as a cornerstone of its strategy. The same act makes it mandatory to hand over the EPC "to the buyer or new tenant" each time "buildings or building units are constructed, sold or rented out" (art. 12, 2nd clause). Although its effectiveness has been questioned [18, 19], the EPC scheme has been interpreted as a useful tool to mitigate the energy efficiency gap - namely, to reduce the information

asymmetries characterizing the real estate markets - and increase investments in energy-efficient buildings [20, 21]. Despite several flaws and issues are ascribed to the energy performance certification [22–25], with problems especially credited to misassessment [26, 27], EPCs have been implemented by national regulations and turned into practice in the real estate markets.

Although early analyses on the topic can be traced back to the late eighties [28, 29], the growing availability of EPCs for properties for sale or rent has made it possible to analyze whether a relationship occurs between the property price or rent and the energy performance of the building unit, as summarized by the energy performance index or the energy rating band [8, 30, 31]. The properties characterized by higher energy performance are likely to be sold at a premium, and the same is expected to hold in the case of a tenancy.

So far, to the best of our knowledge, only two studies find huge price premiums in residential properties, far higher than 50% in the comparison between A and G, namely, the best and the worst energy rating band. The first study [32] focuses on the German residential market. A price premium up to 114.3% characterizes the B-labeled properties compared to the G-rated ones. The second study [33] presents an analysis of a medium-size city and a town in Southern Italy. At its maximum, the price gap between high-performance and low-performing dwellings is found to vary in the range of 45.5–84.0%.

However, when comparing the most efficient residential units (energy rating bands B, A, A+, and A1 to A4) to the mid-tier performance ones (energy rating band D), double-digit percentage premiums are usually reported. For instance, a price advantage between 20% and 30% is found in the analysis of housing prices in Belfast, Northern Ireland [34], Wales [35], Helsinki, Finland [36], and Portugal [37]. Furthermore, a price premium of about 10% or more is found concerning the housing markets in the Netherlands [38], Denmark [39], and Northern Ireland [40]. Evidence supporting the occurrence of significant premiums is also identified in several contemporary studies [41–44].

Depending on the estimation methodology, and especially on the functional form used to model the relationship between the energy consumption and property prices, a few other works shift the focus to the elasticity of housing price to energy performance. There, a double-logarithmic (log-log) function is used instead of the common semi-logarithmic (semi-log or log-linear) one. Again, the findings point to the fact that higher performance is rewarded with larger prices. The price change is estimated to be quite small in two early studies: from 0.09% for a percent change in consumption concerning homes in Dublin, Ireland [45], to 0.40% for a percent change in consumption as far as the Swedish private housing market is concerned [46]. Much larger – up to 9.0% – is the price effect of energy efficiency found in another study of single-family homes in Sweden [47] but the sign of the relationship is different than expected since the property prices grow as the energy consumption increases. Also worth noting are the results of an analysis on nine thousand properties located in the Alicante province, Southern Spain [48]. The latter study, which controls for different climate regimes in the analyzed area, tests the hypothesis of the existence of a green premium by assessing the sensitivity of the (asking) price to changes in either the level of energy consumption or the amount of carbon dioxide emissions and find an effect up to 3.10%.

Almost all of the above-referenced studies focus on the European EPC scheme and the housing market. Nonetheless, confirmations of the assumption that energy efficiency commands a price premium are found elsewhere [49–52], which also means according to different energy rating schemes [53–59], and concerning commercial properties too [60–68]. Notably, a growing number of studies focus on rating schemes other than those in place in the Western Countries, signally on the Green Mark labels as adopted in Singapore [69–74]. They all converge towards the occurrence of a price premium, though its magnitude is highly uncertain: from 1% to 9% as far as certified buildings are concerned, 2–40% for the Gold rating, 8–17% for the Platinum rating.

The results above in their own way and, in wider terms, the findings summarized earlier make it clear the issue at stake is about ambiguity and vagueness. To date, uncertainty is an inherent feature of the assessments on building energy efficiency [75], and estimating the price premium makes no exception. Incidentally, uncertainty is further magnified by the finding that the price premium is likely to be non-stationary over time [37, 57, 76]. Aside from that, the large swings experienced in the available studies can be partly explained by the differences in the methodological setting, sample size, climate area, building typology, market features, socioeconomic background, and so forth. Still, they are too wide to answer the stakeholders' demand for sound and viable investment opportunities [2, 77–79]. The econometric research in building energy efficiency is thus asked to go to the roots of this issue. The forthcoming studies are expected to narrow down the uncertainty range and unequivocally identify the reasons behind it. Lately, a great step forward has been taken thanks to the adoption of spatial dynamic models, especially those in the classes of Geographically Weighted Regression (GWR) [80], Spatial Autoregressive (SAR) [81–83], and Spatial Error Models (SEM) [74, 84]. Further research into robust space-time modeling is welcome and should commit to delivering robust estimates.

2.2 Building Industry and Retrofit: Should We Worry About a Cost Premium?

The evaluation of the profitability of green real estate investments must not be confined to a mere estimate of a premium price in terms of market and income values. The eligibility criteria for green investments on traditional ones must take into consideration the possibility of experiencing an increase in the costs due to the use of more expensive materials and processes.

Since the first decade of this century, several researchers have been dealing with the cost rate involved in projects aiming at higher levels of coherence than the targets of sustainability. A first overview of this issue deals with the general perception of sustainable buildings held by market operators: Ekung et al. [85] highlighted how often operators tend to tie up such products with consistent increases in the final cost, still referring to a few significant cases. Green architecture is always judged as more expensive, which indeed represents an obstacle to the application of new technologies [86].

Despite that, empirical research has pointed out that there is no differential cost between certified buildings and traditional buildings. According to the studies conducted by Kats [87], the Morrison Hershfield report [88] and Berry [89], the variation in their

costs is quite low, if not even absent at all. Matthiessen and Morris [90] make a comparison between 138 buildings not provided by certification and 83 certified ones: as a conclusion, there is no significant variation between their production costs.

Other researches highlight a possible differential cost rate in LEED constructions and traditional interventions, yet statistically not relevant [91]. Likewise, Bartlett and Howard [92] underline that there is no empirical proof for the common evaluation of a premium cost between 5 and 15%. These scenarios are in fact diverse and some researches might end up in different resolutions. Consistent differentiations in the final value have been detected by other studies in the form of a 5-to-10% deviation, with increasing values compared to the LEED certification levels of the cases in analysis [93]. Along the same lines, some researchers argue that marginal costs are quite irrelevant in lesser value LEED certifications, whereas they grow exponentially in the sight of higher quality standards [94], that is to say, gold and platinum. However, there is a substantial lack in collecting data on operating costs in buildings claimed as sustainable: as a result, it becomes difficult to make long-term comparisons both among them and to the Life Cycle Assessment analysis [95].

By comparing costs and benefits, some studies aim at taking stock by evaluating the overall profitability in support of green real estate investments [96] rather than determining their proper differential costs. As a matter of fact, this cost-analysis scenario reveals itself as wide and concerning. It in fact highlights a particular issue – that is the increasing cost rate in green investments – that finds no systemic consistency in the field of empirical studies. Similarly, profitability measures that bring together benefits and additional costs are still quite vague and therefore potentially subjected to useful insights both in theoretical and in empirical fields of application [97].

2.3 Do We Need Tailored Evaluation Methodologies for Energy-Efficient Building Portfolios?

In the last period, we are witnessing a new paradigm and a new change of mentality: improving the energy efficiency of real estate assets of public administrations, insurance companies, banks, social security institutions, real estate, and non-real estate funds has become a crucial element in the investors' agenda.

Maintenance and energy efficiency measures need to be carefully planned, considering existing and renewal leases and budget and time constraints. In addition to the problems related to the technical design of interventions, there is also the need to plan efficient actions over time and not make a large part of the portfolio involved in the interventions unproductive. Therefore, the energy efficiency of large property portfolios is bound by budgetary, technical, financial and regulatory constraints and requires a careful assessment of the many aspects that need to be considered simultaneously.

The evaluation must necessarily be able to deal with complexity, long-term issues, multiple actors and different points of view. Managing a plethora of edifices simultaneously, comparing numerous alternative design scenarios to achieve the optimal result, needs innovative solutions, complex evaluation techniques, and a multidisciplinary approach.

An extensive literature review on the methodological steps of real estate portfolio energy efficiency has been conducted in [98]. The methodology around which an intervention strategy is developed might involve several steps:

- Database construction: in this phase, the information provided by the client is collected and integrated with original data obtained from surveys and others created through simulation using specific software for energy modelling of buildings;
- Scenario and strategy mapping: possible scenarios are defined concerning the strategy of efficiency improvement, regeneration and adding value processes of the building stock, according to the goals that the investor intends to achieve;
- The assessment of economic and environmental impact: the feasibility of the retrofit actions is verified at the building level, considering the structural and technological aspects, but also at a portfolio level, considering all constraint and different criteria employed to value the best option when considering a plethora of buildings;
- Finally, the last phase of the process concerns optimization.

Concerning the data construction, research and case studies have also shown that handling a real estate portfolio faces a time-and money-consuming analysis. Surveys cannot be carried out for every single building, so a "reference building" (or "sample building") approach is adopted. The reference building is an existing building representative of a particular portion of the stock (cluster) [99–103]. A dataset of information about reference building's materials, geometry, technologies, facilities, users' behaviour and occupation, as well as climate zone, is collected. The results are then extended to all buildings that belong to the same cluster. European authorities have promoted the procedure of "reference building" when acting on different and several categories of buildings [104]. Rather than a real sample building, a building archetype artificially constructed to represent a specific class of building in the stock is also possible [105].

The mapping of scenarios and strategies for a portfolio is most similar to designing interventions conducted for individual buildings. Starting from a set of energy retrofit solutions, combinations can be assumed to achieve different energy consumption outcomes. Energy retrofit measures can be clustered into three groups [106], which concerns the use of renewable energy in buildings, i.e. solar and photovoltaic panels, wind and geothermal energy [107, 108]; the reduction of energy demand by introducing new and more efficient technologies, passive strategies, heating/cooling system upgrade, thermal insulation, windows and shading solutions, natural ventilation [109, 110]; and the change in energy consumption through different user behaviour, occupancy schedule, temperature settings, automation systems [111].

The third step regards the analysis of the economic, ecological, and social impacts. Reducing energy consumption or CO_2 emission is the most common indicator employed in supporting the decision-making process for planning retrofit actions. Nevertheless, the economic approaches are the most used indicators to quantify the efficiency of each retrofit option, allowing the evaluation of the economic and financial impact of the measures. Among the economic assessment techniques, there are Life Cycle Cost (LCC) analysis [100, 112–114] and Discounted Cash Flow [115–117].

Cultural/social criteria have rarely been used to evaluate the energy retrofit measure on buildings and portfolio. However, indicators regarding user/occupant health and indoor comfort are more frequently used among the qualitative indicators.

Few attempts have been made to introduce sustainability indicators in the evaluation, bringing the assessment of retrofits measures to a multi-criteria dimension, even if only the environmental criteria have been used in the techniques, ignoring the social issues [102, 118], as their assessment may seem less straightforward to implement. Multi-criteria evaluation techniques have been used mainly to prioritize different options [119] instead of valuing the retrofit options in all their aspects.

A fourth step rarely addressed in literature and practice is the optimization process, which helps to identify the best solution from the range of possible alternatives. It is an essential and crucial step if an investor wants to deal with energy efficiency at a portfolio level, both for the public and the private sector. At a portfolio level, the complexity of considering the budget restriction, the timetable, the architectural limitations and other constraints leads to optimization functions, where several dependent and independent variables and goals have to be analyzed simultaneously. Usually, multiple objectives are identified, including economic, environmental, cultural or social, and all of these are subject to financial and technical constraints. Reliable and flexible decision support models need to be implemented to help investors and owners of large portfolios increase the value of their properties by optimizing cash flows without excluding environmental, cultural and social objectives. In most of the cases studied in the literature, the optimization process is structured as a "cost-optimal analysis", which is performed by comparing, for each energy retrofit hypothesis, the total costs with the corresponding energy consumption. The cost-optimal methodology is required by the European Directive 2010/31/EU [104], and a methodological framework for cost-optimal estimation in the context of building retrofit has been set up [120].

However, this approach still does not reach the goal of pursuing multiple alternatives under multiple constraints. To this end, multi-attribute or multi-objective procedures can come to the aid of managing a multiplicity of criteria at the same time. In this sense, an important step has been taken in [121–123], where multiple objectives of sustainability, energy efficiency, indoor comfort, thus environmental and financial point of view are considered. In [122], a combination of LCC and LCA has been used to pursue an environmental and financial analysis.

An interdisciplinary approach should connect statistical techniques for the accurate prediction of energy consumption, economic evaluation methodologies, multi-attribute analysis, computer programming and optimisation algorithms, producing an integrated and unified decision-making model. Such a model was proposed by [124]: multiple aspects, architectural, economic, technical, energy, were placed in an optimisation function, including a risk analysis to assess the reliability of the results obtained with the alternative scenario evaluation process.

Such valuation techniques should leap scale and be adapted to real estate stocks belonging to a neighbourhood, a city, or a nation that intends to pursue energy efficiency, monetary savings, improvement of the inhabitants' living conditions, and citizens' health status. On a larger scale, policies and programmes must pay attention to long-term

actions. This will improve portfolio management and resource planning and facilitate energy efficiency as a long-term resource, achieving benefits for society.

On the other hand, long-term measures provide long-term value, which is essential for resource planning and can better support non-energy benefits, such as improved health and safety of citizens. These models can be used on many scales, be it at the urban or national level. Their results can be used to identify actions, risk, and possible performances to be achieved. Those methods contribute to decision making in two ways:

- by helping designers of individual buildings to understand how their n choices might influence – or be influenced by – the overall performance of the stock;
- by providing planners and policymakers at various scales (from local to national) with a more robust database on building costs, energy and resource use, environmental effects, and risk management.

3 Conclusions

Consistently with the reasonings above, we expect the growing trend of studies on building energy efficiency is bound to continue over the next years. We also expect new insights into the three issues we discuss here:

- the actual magnitude of the price premium for high-performance building units;
- the potential occurrence of a cost premium for energy-efficient buildings;
- the opportunity to use tailored evaluation methodologies when shifting the focus from an individual residential or commercial property to a building portfolio.

Each of them shapes a specific, prolific research strand. Most importantly, they are closely interconnected with each other, which is why we also expect to see them jointly addressed in forthcoming studies.

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