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Buildings Energy Performance in a Market Comparison Approach

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Abstract: The current regulations on the energy certification of buildings represent for the real estate market and the building sector a real cultural revolution. In recent years, the focus on the energy efficiency of buildings has grown exponentially. It is therefore necessary that the property valuations and methodologies used for this purpose bear in mind the energy quality of buildings. This study aims to determine the contribution of an energy performance feature to the real estate property value. This information can help, on the one hand, to understand the energy savings and the corresponding savings income in the property management and, on the other, to control the air pollution from CO_2 emission reduction. The energy performance hedonic price and the CO_2 emission price are appraised in the Market Comparison Approach (MCA).

Keywords: sustainability; energy efficiency; real estate market; hedonic price; value

1. Introduction

The relationship between energy efficiency and building production is to be found in the ever increasing importance that this topic has acquired in all productive sectors of most industrialized countries. Energy is a factor of economic growth, welfare, and technological progress as well as social progress. The industrial and social development, which in the last fifty years has undergone significant acceleration and caused rapid and profound changes that have inevitably produced strong tensions in the global energy system, has highlighted the importance of the concept of sustainable development. The question about sustainable development, which is really relevant today, has among its main objectives to guarantee a conscious development of the world energy system without compromising the earth's balance.

The unconstrained growth of global consumption, however, is not the only energy problem; in fact, to make the efficiency issue one of crucial importance in the years ahead, there is also the environmental issue. The production of energy, together with the use of fossil fuels, has serious 'side effects' on the environment, Earth's climate, and human health, which are caused by emissions of harmful pollutants and greenhouse gases, which cause global warming and environmental changes such as melting glaciers and rising sea levels. An important part of such climate change could be avoided through a reduction of the final consumption of heat and electricity, which explains once again the centrality of the issue of energy efficiency.

Energy is at the same time the question and the solution of problems related to the progress of society because, on the one hand, it is essential and irreplaceable component of the development of man's activities and, on the other, is one of the main causes of the negative effects of such activities on environmental and climate stability, both on a local and global scale.

Concerning building activities, it is crucial to encourage and promote interventions that both allow better energy performance of buildings and respond to a primary environmental need to reduce polluting emissions. A boost in this direction can come from fiscal policy actions that result in the internalization of environmental costs into the value of the buildings, resulting in a loss of the value of real estate that consumes fossil fuels and pollutants and a corresponding revaluation of energy-efficient buildings.

The promotion of sustainable development thus has a direct impact on the housing market. If in the past, in fact, the real estate market was characterized by a purely quantitative question, today the same is characterized by a substantially qualitative demand. The concept of the quality of building manufacturing concerns very closely the issue of energy performance. The latter can be considered a proxy of several real estate characteristics, related in some measure to the constructive and technological features.

To address the climate problem created by the greenhouse effect and to promote energy efficiency, the European legislator with Directive/91/EC, 2002, on the energy performance of buildings set the laws, regulations, and administrative provisions designed to comply with the new obligations to reduce energy consumption and to make transparent to the energy operators' performance in the property market through energy certification. It constitutes a potential tool of transformation for the real estate market by providing objective information on the energy performance of the property to be acquired or to be rented. The mandatory certification should then generate a positive effect on the market value of properties that have good performance in the medium term and promote the upgrading of low-energy performance buildings. This study's issue is to determine the hedonic contribution of energy performance to the property value from a quantitative point of view. The objective is pursued through an economic analysis of the main detectors of the energy performance of a building, which are found in most of the energy certificates of European countries, thus making possible the international implementation of repeatable proposed estimation methodology. The energy certificate should be an important comparison document between different properties under the same conditions from the very first stages of market research. The proposed methodology makes reference to the Market Comparison Approach (MCA) by identifying an exogenous determination math mode of the hedonic price related to the energy performance and carbon dioxide (CO_2) features. In this way, it is possible to quantify the increase or decrease of property values linked to the energy performance and carbon dioxide (CO_2) components.

2. Literature Review

In an era of environmental awareness and concerted action toward sustainable energy management, energy efficiency is a key challenge. Buildings account for 40% of the energy consumption in Europe [1], and residential homes contribute to around one sixth of emissions globally [2]. Supplementary literature has begun to emerge on the willingness to pay for energy efficiency [3–10], whether energy savings are considered in buying decisions [11,12], and if financing should stem from private or public sources [13–16].

The majority of empirical evidence on the impact of energy certificates on building prices supports the assumption that people are willing to pay extra for more efficient properties in both the commercial and residential sectors. Studies in the commercial sector, primarily in the United States, suggest that green offices acquire a price premium from 13% to 30% [17–22]. Similarly, positive results of a lower magnitude are observed in the residential sector. Studies on the influence of an energy certificate on the value of properties were conducted in Netherlands and in Ireland [9].

A wider study undertaken by the European Commission [8] compares residential premiums associated with Energy Performance Certificates (EPCs) in five European countries; Austria, Belgium, France, Ireland, and the UK. The sales price effects from increased energy efficiency are significant and positive in all cases apart from Oxford in the UK.

Further studies in Europe, Australia, the United States, and Singapore confirm findings that residential buyers are willing to pay a premium for energy efficient housing [5–7,23–28], although some papers have produced more mixed results [11,12,29,30].

To ascertain the extent of the impact of energy efficient investments on the existing building stock, there has been a growing focus on measuring the impact of energy efficiency on the overall value of buildings [19,31,32].

This methodology deploys econometric techniques to identify the impact of building characteristics on value and can thus be used to identify the impact of green investments on building value. Hedonic regression is frequently used in real estate economics to establish consumers' willingness to pay for a given feature ranging from views to trees to clean air to proximity to amenities [33,34]. This analytical technique allows appraisers, investors, and policy makers to understand the value of otherwise hard to quantify property features. At its core, the approach compares the price of two buildings deemed otherwise identical apart from the feature in question. In the case of green labels, researchers use data on building rent and value, controlling for building class, size, age, and other relevant features to determine how green labels alone influence the price [35–38]; worker satisfaction [20,39]; and the occupancy rate [20,39,40]. Although this method does not necessarily provide insight into the micro-scale decisions that go into appraisal of green label buildings, it does indicate how those decisions culminate in the macro-scale price premiums associated with these labels [41,42].

3. Policy Background

The United Nations Framework Convention on Climate Change (UNFCCC), established in 1992, initiated an international framework for negotiating greenhouse gas emissions targets for participating countries in an effort to stabilise global warming. The European Union is among 195 parties that are currently signatories of the Kyoto Protocol, an extension of the UNFCCC, which was signed in December 2012 at Qatar National Convention Centre in Doha, Qatar, and has an internationally binding target to reduce emissions by at least 18% compared to 1990 levels by 2020 (UNFCCC 2012). International commitment to reducing greenhouse gas emissions was most recently reinforced by an agreement by the G7 (Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States) to decarbonise the global economy by the end of the century [43]. In conjunction with carbon and renewable policies, the European Union's Energy Efficiency Directive (2012/27/EU) aims for a 20% reduction in energy demand in the European Union as a whole by 2020 [44]. One of the main policy tools for reducing energy consumption in the buildings sector and advancing awareness of the energy performance of buildings are EPCs. EPCs are provided for benchmark ranking for buildings based on their predicted energy consumption per square meter and the associated CO_2 emissions. Since the 1990s, a combination of voluntary and mandatory EPC schemes across residential, commercial, and/or public buildings have emerged in countries such as Australia (NatHERS, Green Star), Russia (Energy Passport), the United States (LEED, Energy Star, HERS Index), Japan (CASBEE), and Singapore (Energy Smart, BCA Green Mark). In the European Union, the 2002 EU Directive on the Energy Performance of Buildings (EPBD 2002/91/EC recast 2010) introduced a mandatory requirement for member states to provide specific information on a building's energy performance and recommendations for energy saving measures to prospective purchasers and tenants in property transactions. From 2013 onwards, amongst other things, the recast EPBD ensures that all properties advertised for sale or for rental, excluding certain buildings such as protected structures, include an official energy certificate (The European Parliament the Council of the EU 2010b).

In transposing the Directive 2002/91/EC Energy Performance of Buildings Directive (EPBD), which establishes the obligation of energy certification of buildings, the Member States have launched or are launching national measures requiring the adoption of energy certificates, first for new buildings and only later for existing ones.

Almost all countries have adopted a national methodology that sets the performance requirements for new buildings. For countries with existing regulatory requirements prior to 2002 (for example, Czech Republic, Belgium, Estonia, Bulgaria, Hungary, Ireland, and Poland), there was a holistic approach to the entire building. In some cases, performance requirements for individual technical elements were added, ensuring the overall energy efficiency of the building (for example, Denmark). Other countries will adopt alternative methods, to which there are two parallel approaches (for example, Norway, Spain, Poland, and Switzerland).

It is important not to compare the performance requirements established by the Member States, given the variety of the methods of calculation used and the main different definitions (for example primary and final energy, heated floor surface, the carbon conversion factor, energy consumption, total energy requirements, etc.). The setting of the energy performance requirement is generally expressed in $kWh/m^2 \cdot year$, which depending on the value, corresponds to a literal scale from A to G (for example, in Italy, France, the United Kingdom, etc.). Some countries (for example Belgium and Germany) instead express the performance requirements relating to a score in numbers.

You can earn from all certificates of energy performance three representative indicators of energy efficiency of the building, which are:

- The index of energy performance;
- The energy class;
- CO_2 emissions.

These parameters are representative of the energetic quality of the building and therefore can be considered nomenclatures, able to take into account energy efficiency in the appraisal of the most probable market value of a property.

4. Methods

The contribution of a building's energy performance feature to price formation is designed according to the Market Oriented approach, one of the three approaches considered in the International Valuation Standards (IVS) [45].

The IVS (International Valuation Standards) define the Market Oriented Approach, the Income Approach, and the Cost Approach as the internationally recognized appraising methods. When the real estate market is active and all necessary market data are available, the Market Comparison Approach (MCA) is the most direct, probative, and documented method used to appraise real estate market values; in particular, the MCA is the most important method referable to the Market Oriented Approach.

The Market Comparison Approach is known by several different names in the appraisal literature. In some of the older literature, it is called the Market Data Approach, while elsewhere it is referred to as the Grid Adjustment Technique [46]. The Market Comparison Approach (MCA) is an assessment procedure that leads to the evaluation of the market value of a property based on a comparison with the prices of similar properties recently purchased or sold. The MCA comes to determine the property value through a complex series of monetary adjustments. The MCA is suitable for the evaluation of any kind of property, from condominiums to agricultural land or buildings with special architectural value, provided that there is an adequate number of recent transactions of similar properties through which you can make the comparison. The MCA is a systematic procedure based on adjustments, corrections in monetary terms, to be made at the market prices of real estate comparables, to take account of the differences between the characteristics of real estate comparables and those of the property to be appraised. The MCA is constituted of the followings steps:

1. market analysis, designed to collect the real estate transaction dates of properties similar to that being valued;
2. choice of the characteristics which will drive the comparison;
3. compilation of the data table and drafting of technical documents (photos, plans, etc.);
4. hedonic price analysis;

5. sales adjustment grid;
6. reconciliation.

The hedonic price analysis (step 4) is the central phase of the proceedings, hedonic prices being the basic adjustments of the MCA. In particular, for each feature a hedonic price is calculated and used to adjust the observed prices. The evaluation of the hedonic prices makes use of the substitution principle, the complementarity principle, and the evaluation criteria (market value and cost value). The hedonic price can assume positive values when the variation in the increase of the characteristic corresponds to an increase in the price, negative values when a variation in the increase of the characteristic corresponds to a decrease in the price, and null values if a variation of the characteristic does not produce any change in the price.

In the following paragraphs, the appraisal methodology will be illustrated according to the coefficients used to simplify the traditional application of the MCA [47,48]. As explained in theory, this has been then applied to a case study.

4.1. Hedonic Price of Energy Performance Index Feature

The energy performance index indicates how much energy is consumed so that the building (or building unit) has the required comfort conditions.

The determination of the hedonic price of the energy performance index (EPI) in the MCA was treated as a quantitative feature the same way as the surface characteristics, a level floor, technological systems, etc.

The hedonic price of the energy performance feature can be performed by applying a financial method, namely the Discounted Cash Flow Analysis (DCFA) [49]. The DCFA considers the impact of a series of costs and incomes on the current revenues generated by the characteristic of 'energy performance', from purchase to resale. This means we need to expect during the reference period (availability period) the expected revenue in terms of lower energy consumption and, at the end of the period, the residual value of the same feature.

The hedonic price of Energy Performance Index characteristic P_{EPI} is calculated by:

$$P_{\mathrm{EPI}} = \sum_{t=1}^{n} C_{\mathrm{E}} \cdot (1+i)^{-t} \; + \; P_{\mathrm{EPI}} \cdot \; (1+i)^{-n}$$

where:

- P_{EPI} is the hedonic price of the characteristic energy performance expressed in €/kWh m^2·year;
- C_{E} is the variable annual income during the transitional period, coinciding with the annual cost of energy, expressed in €/kWh m^2·year;
- $P_{\mathrm{EPI}} \cdot (1 + i)^{-n}$, is the value of the characteristic energy performance index at the end of the availability period of the property expressed in €/kWh m^2·year.
- i is the capitalization rate;
- t is the generic year of the transitional period expressed in years;
- n is the duration of the investment in the period of possession of the property (years).

Real estate investments have medium and long-term time horizons, and the appraised hedonic price of energy performance index feature at the end of the availability period of the property is for a magnitude far into the future. In addition, the annual energy costs may vary during the period of availability.

In particular, the C_{E} annual energy cost is assumed to be variable in geometric progression at a constant rate g, and the value of the index of energy performance characteristics at the end of the availability period of the property (P_{IPE}) has appreciated or depreciated gradually at a rate of d for the duration at the rate n.

For $i > g$:

$$P_{\mathrm{EPI}} = C_{\mathrm{E}} \cdot \frac{1-\left(\frac{1+g}{1+i}\right)^n}{i-g} \cdot \frac{1}{1-\left(\frac{1\pm d}{1+i}\right)^n}\,.$$

For $i < g$:

$$P_{\mathrm{EPI}} = C_{\mathrm{E}} \cdot \frac{\left(\frac{1+g}{1+i}\right)^n - 1}{g-i} \cdot \frac{1}{1-\left(\frac{1\pm d}{1+i}\right)^n}\,.$$

Assuming that the investment period is comparable to the useful life period of the property, which can be considered unlimited, calculating the limit as n to tend to infinity ($n \to \infty$) with $i > g$, the hedonic price of the energy performance index is expressed as follows:

$$P_{\mathrm{EPI}} = \frac{C_{\mathrm{E}}}{i-g}\,.$$

For $i < g$, the hedonic price is equal to:

$$P_{\mathrm{EPI}} = \frac{C_{\mathrm{E}}}{g-i}\,.$$

4.2. The Characteristic of the Carbon Dioxide Emissions Value

A further energy performance indicator is the carbon dioxide emission from buildings. Heating, lighting, air conditioning, ventilation, and refrigeration are the main factors that determine the direct energy and thus carbon emissions. While the energy performance index component directly affects the portfolio of potential buyers and may result in a corresponding increase/decrease of the property value, the component of carbon dioxide emissions is an externality, which is a benefit for the purchaser but not for the community. The latter can be quantified in order to measure the compensation to those who generate it in the form of tax deductions or incentives. The value of the characteristic related to carbon dioxide emissions energy performance has been formulated according to the same methodological approach used to define the hedonic price index of energy performance.

However, in this case, the parameter to be considered in order to quantify the contribution of CO_2 to the value is the so-called carbon credits. Carbon markets are strategic tools of economic policy to reduce greenhouse gas emissions responsible for global warming, often used in combination with other policies such as the taxation of greenhouse gases or carbon taxes and regulations governing the use of low production technologies and greenhouse gas consumption. The reduction of greenhouse gas emissions is exchanged in the form of 'carbon credits', usually expressed in units tons of CO_2.

2003/87/EC Directive of the European Parliament and of the Council has set up a system for the exchange of greenhouse gas emission allowances in the European Union in order to promote the reduction of polluting emissions (European Union Emissions Trading Scheme—EU ETS) [50]. This is the first concrete implementation in Europe of one of the mechanisms under the Kyoto Protocol to counteract climate change. The average price of a carbon credit (or permit or emission quota), in reference to the prices varied from the year of birth of the market (2003) up to year of research (2015) traded in the carbon market, is established at around 15 €/tCO_2.

The equation used to quantify the hedonic price of energy performance for CO_2 emission then becomes:

- for $i > g$ and $n \to \infty$:

$$P_{CO_2} = \frac{C_{CO_2}}{i-g}\,,$$

- for $i < g$ and $n \to \infty$ the hedonic price is expressed as follows:

$$P_{CO_2} = \frac{C_{CO_2}}{g - i},$$

where:

- P_{CO_2} is the hedonic price of the characteristic related to CO_2 emissions. (€/m^2·kgCO_2 year);
- C_{CO_2} is the annual cost of the building's CO_2 emissions calculated according to the average of a carbon credit price (€/m^2·kgCO_2 year);
- i is the capitalization rate;
- i is the capitalization rate;
- g is the annual cost of carbon dioxide emissions variation rate.

5. Case Studies

In order to test the accuracy of the proposed approach, this case study follows a numerical example based on a concrete appraisal sample concerning flats in condominium located in Cetraro. Cetraro (39°31′3.36″ N, 15°56′32.64″ E) is an Italian town of 10,076 inhabitants, located on the Tyrrhenian coast in the Province of Cosenza (coastal/mountain area, elevation from 0 to 1.118 a.s.l) The district presents a surface of 66.14 km^2, with a population density of 152.34 inhabitants/km^2. It falls into the C climate zone, with 1.117 degree days. We proceeded to carry out the market analysis, designed to collect data relating to contracts in recent sales of properties similar to the one being valued. In this way, the analysis identifies three trades of properties similar to the one being valued, all located in the same neighbourhood in order to delete the locational component.

For the sample of data chosen to carry out the analysis, we have identified driver characteristics; that is, the features that are common to the entire sample but different in mode. These features are shown in Table 1.

Table 1. Data.

Sale Price and Real Estate Feature	Comparable A	Comparable B	Comparable C	Subject
Sale Price (SPR) €	159,000.00	172,000.00	165,000.00	?
Surface (SUR) mq	85.00	118.00	105.00	80.00
Restrooms (RES) No.	2.00	1.00	1.00	2.00
Maintenance (MAI) point	2.00	4.00	2.00	4.00
Floor level (FLO) level	4.00	6.00	5.00	3.00
Energy performance index (EPI) kWh/m^2·a	220	200	218	265
Carbon dioxide emission (CDE) kgCO_2/m^2·a	54	58	75	65

The most difficult step in the application of the proposed methodology is the analysis of the hedonic prices of real estate features. On the basis of the data table, the hedonic price of each feature is calculated as indicated in Salvo et al. [47]. In remainder of this paper, only the calculations related to energy performance characteristics will be presented in full. For other real estate characteristics, we reported only the results of some hedonic prices depending on what is indicated in the literature [48] (Table 2).

5.1. Hedonic Price Energy Performance Index (P_{EPI})

The hedonic price energy performance index is calculated with C_E, the annual energy costs in the first year; i, the capitalization rate; and g, the annual rate of change in energy costs:

$$P_{EPI} = \frac{C_E}{i - g}.$$

where:

- C_E is the annual energy costs for the first year [51];
- i is the capitalization assay, evaluated for this market segment as 4% [52];
- g is the annual rate of change in energy costs, evaluated for this market segment as 1% [52].

Whereas in Italy the winter heating functions mainly using methane gas with a price of 0.091 €/kWh, summer air conditioning almost entirely is fed with electrical energy which can vary between 0.18 to 0.40 €/kWh, according to the type of electricity market used. With these assumptions, the average annual cost of energy required to guarantee comfort inside the building during both Summer and Winter can be assumed to be about 0.15 €/kWh. The annual cost of consumed energy (C_E) can thus be determined in the following way:

$$C^{A}{}_{E} = 0.15\left(\frac{€}{\text{kWh}}\cdot\text{a}\right) \times 85.00\left(\text{m}^2\right) = 12.75\,\frac{€}{\text{kWh}}\cdot\text{m}^2\text{a}\,,$$

$$C^{B}{}_{E} = 0.15\left(\frac{€}{\text{kWh}}\cdot\text{a}\right) \times 118.00\left(\text{m}^2\right) = 17.70\,\frac{€}{\text{kWh}}\cdot\text{m}^2\text{a}\,,$$

$$C^{C}{}_{E} = 0.15\left(\frac{€}{\text{kWh}}\cdot\text{a}\right) \times 105.00\left(\text{m}^2\right) = 15.75\,\frac{€}{\text{kWh}}\cdot\text{m}^2\text{a}\,,$$

The hedonic price of the characteristic energy performance is equal to:

$$P^{A}{}_{EPI} = \frac{12.75}{0.04 - 0.01} = 425.00\,€/\text{kWh}\cdot\text{m}^2\text{a}\,,$$

$$P^{B}{}_{EPI} = \frac{17.70}{0.04 - 0.01} = 590.00\,€/\text{kWh}\cdot\text{m}^2\text{a}\,,$$

$$P^{C}{}_{EPI} = \frac{15.75}{0.04 - 0.01} = 525.00\,€/\text{kWh}\cdot\text{m}^2\text{a}\,.$$

5.2. Hedonic Price Carbon Dioxide Emission (P_{CDE})

The carbon dioxide emission is calculated considering the annual cost of building emissions C_{CO_2}, calculated according to the average price of a carbon credit, capitalizing on the difference between the i and g rates. The annual rate of the cost of carbon dioxide emissions variation rate is:

$$P_{CDE} = \frac{C_{CO_2}}{i - g}\,.$$

The average price of a carbon credit (or permit or emission quota), traded in the market for carbon credits, is appraised as equal to 15.00 €/tCO_2 in order to determine the hedonic price of the characteristic energy performance related to CO_2 emissions

$$CO_{2A} = 0.015\left(\frac{€}{\text{kgCO}_2}\cdot\text{a}\right)\cdot 85.00\left(\text{m}^2\right) = 1.27\,€/\text{kgCO}_2\cdot\text{m}^2\text{a}\,,$$

$$CO_{2B} = 0.015\left(\frac{€}{\text{kgCO}_2}\cdot\text{a}\right)\cdot 118.00\left(\text{m}^2\right) = 1.77\,€/\text{kgCO}_2\cdot\text{m}^2\text{a}\,,.$$

$$CO_{2C} = 0.015\left(\frac{€}{\text{kgCO}_2}\cdot\text{a}\right)\cdot 105.00\left(\text{m}^2\right) = 1.58\,\frac{€}{\text{kgCO}_2}\cdot\text{m}^2\text{a}\,.$$

The hedonic price of the carbon dioxide emission is equal to:

$$P^{A}{}_{CDE} = \frac{1.27}{0.04 - 0.01} = 42.33\ \frac{€}{kgCO_2} \cdot m^2 a\,,$$

$$P^{B}{}_{CDE} = \frac{1.77}{0.04 - 0.01} = 59.00\ \frac{€}{kgCO_2} \cdot m^2 a\,,$$

$$P^{C}{}_{CDE} = \frac{1.58}{0.04 - 0.01} = 52.70\ \frac{€}{kgCO_2} \cdot m^2 a\,.$$

5.3. Sales Adjustment Grid

The sales adjustment grid has been built according to the corrective factors indicated in Salvo et al. [47,48]. Table 3 reports the different features' hedonic prices.

To take account of duplication in the analysis of hedonic prices, we proceed to calculate the coefficient r. The r_j coefficient is calculated using the formula:

$$r_A = \frac{SUR_{Subject} - SUR_A}{SUR_A} = \frac{mq80.00 - mq85.00}{mq85.00} = -\,0.059\,,$$

$$r_B = \frac{SUR_{Subject} - SUR_B}{SUR_B} = \frac{80.00 - mq118.00}{mq118.00} = -0.322\,,$$

$$r_C = \frac{SUR_{Subject} - SUR_C}{SUR_C} = \frac{mq80.00 - mq105.00}{mq105.00} = -\,0.238\,.$$

The r_j coefficients are significant in the hedonic price table (Table 2).

In the sales adjustment grid, every single adjustment is made explicit; the last record reports the correct prices (Table 4). It is possible to see the convergence of corrected prices, calculated using the corrective factor r_j. Table 2 reports the different features' hedonic prices.

Table 2. Hedonic Price Table.

Hedonic Prices	Comparable A	Comparable B	Comparable C
SUR €/mq	1,870.59	1,457.63	1,571.43
RES €/No.	6,666.67	6,666.67	6,666.67
MAI €/point	10,000.00	10,000.00	10,000.00
FLO €/level	4,770.00	5,160.00	4,950.00
EPI €/kWh/m^2·a	425.00	590.00	525.00
CDE $kgCO_2/m^2$·a	42.33	59.00	52.70
r_j	−0.06	−0.32	−0.24

Table 3. Sales Adjustment Grid.

Sale Price and Real Estate Features	A	B	…….
Sale Price	P_A	P_B	
Feature	$p_{iA} \cdot (x_{0i} - x_{iA} \cdot (1 + r_A))$	$p_{iB} \cdot (x_{0i} - x_{iB} \cdot (1 + r_B))$	
……			
Correct Price	$P_{cA} = P_A + \sum_{i=1}^{n} p_A \cdot (x_{0i} - x_{iA} \cdot (1 + r_A))$	$P_{cB} = P_B + \sum_{i=1}^{n} p_B \cdot (x_{0i} - x_{iB} \cdot (1 + r_B))$	

Table 4. The case study Sales Adjustment Grid (€).

Sale Price and Real Estate Feature	Comparable A	Comparable B	Comparable C
Sale Price (SPR)	159,000.00	172,000.00	165,000.00
Surface (SUR)	$1,870.59 \times [(80.00 - 85.00)] = -9,352.95$	$1,457.63 \times [(80.00 - 118.00)] = -55,389.83$	$1,571.43 \times [(80.00 - 105.00)] = -39,285.72.$
Restrooms (RES)	$6,666.67 \times [2.00 - 2.00 \times (1 - 0.059)] = 784.31$	$6,666.67 \times [2.00 - 1.00 \times (1 - 0.322)] = -4,519.77$	$6,666.67 \times [2.00 - 1.00 \times (1 - 0.238)] = -5,079.36.$
Maintenance (MAI)	$10,000 \times [4.00 - (2.00 \times (1 - 0.059))] = 21,176.47$	$10,000 \times [4.00 - (4.00 \times (1 - 0.322))] = 12,881.35$	$10,000 \times [4.00 - (2.00 \times (1 - 0.238))] = 24,761.90$
Floor level (FLO)	$4,770.00 \times [3.00 - 4.00 \times (1 - 0.059)] = -3,647.65$	$5,160.00 \times [3.00 - 6.00 \times (1 - 0.322)] = -5,509.83$	$4,950.00 \times [3.00 - 5.00 \times (1 - 0.238)] = -4,007.14.$
Energy performance index (EPI)	$425.00 \times [265.00 - 220.00 \times (1 - 0.059)] = 24,625.00$	$590.00 \times [265.00 - 200.00 \times (1 - 0.322)] = 76,350.00$	$425.00 \times [265.00 - 218.00 \times (1 - 0.238)] = 51,925.00.$
Carbon dioxide emission (CDE)	$42.33 \times [65.00 - 54.00 \times (1 - 0.059)] = 524.53$	$59.00 \times [65.00 - 58.00 \times (1 - 0.322)] = 1,515.00$	$52.70 \times [65.00 - 75.00 \times (1 - 0.238)] = 414.07$
Correct Price	193,109.73	197,326.92	193,728.75

5.4. Reconciliation

The most probable market value of the subject is equal to the arithmetic average of the corrected prices:

$$V = \frac{€(193,109.73 + 197,326.92 + 193,728.75)}{3} = €194,721.80.$$

With the sales adjustment grid of every single feature you get the effect of the real estate feature on the market value. If we proceed to quantify the relative contribution of each property characteristic to the final value, we obtain:

Table 5 shows that the characteristic Energy Performance Index (EPI) is one of the different characteristics from the surface that more than any other (26%) contributes to the formation of the market value. The feature 'CO_2 emissions' has not been recognized yet by the prospective buyer as like an important factor of energy efficiency; in fact it has a very low relative weight (0.4%).

Table 5. Performance index.

Real Estate Feature	Performance Index (%)
SUR	18
RES	1.5
MAI	10
FLO	2.3
EPI	26
CDE	0.4

The MCA results and, in particular, the convergence of fixed prices obtained in the evaluation table show that it is crucial in the appraisal of the most probable value to consider the characteristics of the market value of a property, taking into account its environmental value. Indeed, it is essential not to overlook the characteristic 'energy performance' in the process of the formation of value, given the role that it plays in the price formation process.

6. Conclusions

This study addressed the issue of the energy performance of buildings, contextualizing it in a methodological proposal for appraising the contribution that it provides to the formation of real estate prices. The proposed methodology can be applied in Europe since the energy performance parameters (energy performance index and CO_2 emissions) are present in the energy certification documents of the buildings of the most important European countries including Spain, France, Austria, Belgium, Ireland, the United Kingdom, and Germany.

The reasons for the close relationship between energy performance and value of the property are to be related to the attention paid to property management budgets, which are strongly influenced by the energy consumption costs. The proposed methodology utility is due to the application of the MCA, which allows you to achieve reliable results in the property market value in market conditions characterized by a small number of transactions. The appraisal methodology gives other methods that are able to quantify the contribution of the inductive approach component of the energy performance of a building, such as the multiple regression models. These approaches, however, require a large number of trades, knowledge of statistical methods, and the ability to interpret the results obtained. Although the 'green economy' has grown significantly in many areas, there is still little empirical evidence to show the relationship between real estate prices and their sustainability characteristics, in spite of the economic and environmental benefits that are assured.

The proposed methodological approach is deductive and, for the simplicity of application, is well suited to be used by the valuers. This study arises as a means for the dissemination of an international appraisal methodology that considers the energy certification characteristic of buildings not insignificant.

The importance of including the energy certification of buildings in real estate appraisals may in turn be a stimulus for an improvement in energy efficiency in housing and an improvement in the environment in general. The proposed methodology quantifies the contribution of energy efficiency to the market value of the building so that the return linked to more efficient buildings is regarded as a long-term investment, and, if so perceived, it will produce a further boost to the growth of the real estate market for buildings with low environmental impact.

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