ECONOMIC BENEFITS AND ECOLOGICAL CHALLENGES OF SUSTAINABLE REAL ESTATE DEVELOPMENT

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ABSTRACT

The real estate sector represents one of the most significant economic industries, directly influencing economic growth, employment, infrastructure development, and the quality of life of the population. At the same time, the construction industry and real estate management are among the largest consumers of energy and natural resources, as well as among the major contributors to greenhouse gas emissions. Consequently, sustainable real estate development has gained increasing importance within contemporary economic and environmental policies. The application of sustainability principles involves the design, construction, operation, and management of buildings in a manner that ensures economic viability, environmental protection, and the improvement of social well-being. The subject of this paper is the analysis of the economic benefits and environmental challenges of sustainable real estate development. Particular attention is devoted to the impact of energy efficiency on reducing operating costs, increasing real estate market value, and the contribution of sustainable buildings to achieving environmental objectives within the construction sector. The research is based on an analysis of relevant domestic and international scientific literature, a comparative assessment of the economic and environmental characteristics of sustainable and conventional buildings, as well as a case study illustrating differences in construction costs, operating expenses, and long-term financial effects between the two types of buildings. The research results indicate that sustainable buildings require higher initial investments but generate significantly lower energy and maintenance costs throughout their life cycle, thereby ensuring higher investment profitability and enhancing market competitiveness. The

study concludes that sustainable real estate development represents one of the key instruments for achieving economic growth aligned with environmental protection objectives. The long-term benefits exceed the initial costs associated with the implementation of sustainable technologies; therefore, green building represents a strategic direction for the future development of the contemporary real estate market.

Keywords: sustainable development, real estate, energy efficiency, economic sustainability, ESG, investments.

INTRODUCTION

Over the past several decades, the real estate market has undergone intensive transformation driven by economic globalization, urbanization, technological development, and the growing need for the preservation of natural resources. The construction industry represents one of the most significant economic sectors in almost all national economies, considering that it generates a substantial share of gross domestic product (GDP), employs a large number of workers, and stimulates the development of numerous supporting industries, including construction materials manufacturing, transportation, energy, and financial services. However, precisely due to its scale and intensive resource consumption, the real estate sector simultaneously represents one of the largest contributors to environmental degradation [1].

In addition to high electricity consumption, the construction sector is characterized by intensive use of water, raw materials, and land resources, as well as by significant generation of construction waste. For this reason, international organizations, national governments, and financial institutions have increasingly focused their attention in recent years on the development of sustainable models for real estate design, construction, operation, and management.

The concept of sustainable development was first systematically defined in the 1987 Report of the Brundtland Commission, according to which sustainable development represents development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs [2], [3]. This approach implies achieving a balance between economic development, social responsibility, and environmental protection, which is referred to in contemporary literature as the three pillars of sustainability or the triple bottom line approach [4].

The application of this concept in the real estate sector has resulted in the development of so-called green buildings, i.e., buildings designed to achieve minimal negative environmental impacts throughout their entire life cycle while maximizing economic efficiency and ensuring a high-quality indoor environment for occupants [5]. Such buildings incorporate energy-efficient heating, cooling, and ventilation systems, renewable energy sources, advanced insulation materials, water conservation systems, and intelligent energy management technologies.

The development of sustainable real estate today represents much more than an environmental initiative. It has become an important factor influencing the competitiveness of investors, developers, and financial institutions. Banks and investment funds increasingly favor projects that comply with ESG criteria (Environmental, Social, and Governance), recognizing sustainability as an important determinant of investment quality and long-term value creation [6].

However, despite numerous advantages, the implementation of sustainable principles faces significant challenges. Investors frequently identify high initial construction costs, insufficiently developed markets for sustainable materials, a shortage of qualified professionals, and inconsistent regulatory frameworks as the main obstacles to the wider adoption of sustainable projects.

In addition to economic and technical aspects, sustainable real estate development also has an important social dimension. Indoor air quality, access to natural daylight, indoor environmental conditions, and acoustic performance directly influence the health, productivity, and satisfaction of building occupants [7].

Based on these considerations, the subject of this paper is the analysis of the economic benefits and environmental challenges of sustainable real estate development through an examination of the relationship between investment costs, long-term financial effects, and

environmental impacts. Particular attention is devoted to a comparative analysis of sustainable and conventional buildings from the perspective of investment costs, operating expenses, and long-term financial benefits. The results of the research are expected to contribute to a better understanding of the economic effects of sustainable investments and provide a basis for improving investment practices, regulatory policies, and future scientific research in the field of real estate development.

The primary objective of this paper is to analyze the economic benefits and environmental challenges of sustainable real estate development, with particular emphasis on the impact of sustainable investments on property market value, operating costs, investment attractiveness, and long-term profitability. Such an analysis provides a foundation for understanding the relationship between investors' economic interests and the requirements of sustainable development.

The methodological framework of the paper is based on a combination of qualitative and quantitative research methods, enabling a comprehensive analysis of the economic and environmental aspects of sustainable real estate development. The research is based on a systematic review of domestic and international literature in the fields of sustainable development, real estate economics, energy efficiency, investment management, and environmental protection.

The central research method is a comparative analysis of a sustainable ("green") building and a conventional building, including a comparison of investment costs, energy expenditures, maintenance costs, and total life-cycle costs during the operational period. This comparative approach enables an objective assessment of the differences between the two models of real estate development.

THEORETICAL FRAMEWORK OF SUSTAINABLE REAL ESTATE DEVELOPMENT

Contemporary literature conceptualizes sustainability through three interconnected pillars:

Economic sustainability – Economic sustainability refers to achieving long-term profitability through the rational utilization of available resources. In the context of sustainable real estate, this implies increased market value of properties, lower operating costs, higher occupancy rates, more stable rental income, and extended building lifespan.

Environmental sustainability – The environmental dimension refers to minimizing the negative impact of buildings on the natural environment. The most important elements include energy efficiency, the use of renewable energy sources, reduction of carbon dioxide emissions, rational management of water resources, recycling of construction waste, and the utilization of sustainable building materials.

Social sustainability – The third pillar relates to improving the quality of life of building occupants. It includes a healthier indoor environment, improved indoor air quality, access to natural daylight, acoustic comfort, building safety, accessibility for persons with disabilities, and increased employee productivity.

The contemporary concept of sustainability assumes that none of these three dimensions can achieve long-term success if developed independently from the others. Sustainable real estate development requires the integration of economic, environmental, and social principles throughout all phases of a building's life cycle – from planning and design, through construction, to operation, management, and final use [8].

The traditional model of economic development was primarily focused on profit maximization, whereas sustainable development emphasizes the rational use of natural resources while preserving the ability of future generations to meet their own needs. Furthermore, academic interest in green building has increased significantly in recent years, demonstrating the growing importance of sustainability in the fields of construction and real estate management [9].

Unlike the traditional approach, sustainable construction considers the entire life cycle of a building. Life-cycle analysis represents one of the fundamental differences between conventional and sustainable construction practices. Sustainable real estate development involves a transition from a traditional model based on minimizing initial investment costs toward a model focused on creating long-term value [5]. This approach is consistent with the concept of strategic corporate

real estate management, according to which real estate represents a strategic resource that contributes to achieving organizational objectives rather than merely an operational cost or physical asset [10].

Contemporary real estate economics increasingly applies the concept of Life Cycle Cost Analysis (LCCA). This approach implies that investment decisions should not be evaluated solely on the basis of initial construction costs, but rather according to the total costs incurred throughout the entire life cycle of a building. Numerous studies indicate that initial investment costs account for only 15–25% of total life-cycle costs, while the largest proportion is associated with operation and maintenance.

In recent years, the investment market has been characterized by the rapid development of ESG standards (Environmental, Social, and Governance). ESG criteria have become one of the most important indicators of investment project quality. In the context of real estate, they include:

Environmental – energy efficiency, renewable energy sources, reduction of CO_2 emissions, and efficient water management.

Social – occupant health, building safety, accessibility, and workplace quality.

Governance – transparent project management, responsible corporate governance, compliance with regulatory requirements, and ethical business practices.

An increasing number of international investment funds now make investment decisions based on ESG criteria, making sustainable real estate a significantly more attractive investment option. Sustainable buildings demonstrate advantages across all three ESG dimensions, including environmental, social, and governance aspects [11].

One of the most important instruments for assessing the quality and sustainability performance of buildings is represented by international certification systems. The most recognized among them include:

- LEED (Leadership in Energy and Environmental Design);
- BREEAM (Building Research Establishment Environmental Assessment Method);
- DGNB (Deutsche Gesellschaft für Nachhaltiges Bauen);
- WELL Building Standard.

These systems evaluate energy efficiency, indoor environmental quality, water consumption, material selection, waste management, and the overall environmental impact of buildings.

Numerous international studies demonstrate that certified green buildings achieve higher market prices, higher rental rates, and higher occupancy rates compared with conventional buildings, further confirming the economic justification of sustainable real estate development [12], [11].

One of the most significant future directions in sustainable real estate development is the integration of digital technologies. Artificial intelligence, the Internet of Things (IoT), and digital twins enable a transition from passive building management toward active optimization of building performance [13]. Applications of artificial intelligence include:

- forecasting energy consumption;
- automatic optimization of heating and cooling systems;
- predictive maintenance of equipment;
- reduction of unnecessary resource consumption;
- analysis of building occupant behavior.

In the future, the value of sustainable buildings will increasingly depend on their ability to autonomously adapt resource consumption to actual operational needs. In this way, digitalization becomes a connecting element between economic efficiency and environmental protection.

ECONOMIC BENEFITS OF SUSTAINABLE REAL ESTATE DEVELOPMENT

From a macroeconomic perspective, the real estate sector represents one of the most important economic sectors in modern economies. Its significance is not limited solely to the

construction of residential, commercial, and industrial buildings, but also lies in the strong multiplier effect it generates across other sectors of the economy. The development of the real estate market stimulates the construction industry, building materials manufacturing, transportation, the financial sector, insurance, trade, architectural and engineering services, as well as information and communication technologies.

Sustainable Development as a Driver of Economic Growth

Over the past two decades, sustainable development has become one of the key drivers of transformation within the construction industry. Investments in energy-efficient buildings are no longer perceived solely as environmental initiatives, but rather as instruments for enhancing the competitiveness of national economies. Increasing investments in green infrastructure generate new employment opportunities, stimulate technological innovation, and contribute to higher economic productivity.

The particular importance of sustainable investments lies in the fact that their economic effects do not end upon the completion of a building project. On the contrary, the majority of benefits are realized throughout the operational phase of a building through reduced energy consumption, lower maintenance costs, and increased real estate market value.

Therefore, contemporary economic literature increasingly emphasizes the transition from the "lowest initial cost" approach toward the "lowest total life-cycle cost" approach. This perspective enables more rational investment decisions and significantly improves the economic sustainability of construction projects.

The Impact of Sustainable Features on Real Estate Market Value

One of the most significant economic benefits of sustainable construction is the increase in the market value of real estate assets. Traditionally, property valuation has been primarily based on location, size, construction quality, and building age. However, in recent years, energy efficiency has emerged as one of the key factors influencing market prices. Today, buyers and tenants increasingly consider a building's energy performance rating, expected monthly energy costs, insulation quality, ventilation systems, the use of renewable energy sources, indoor environmental quality, and other sustainability-related characteristics.

As a result of these market changes, a **market premium for sustainable real estate** has emerged. In practice, this means that energy-efficient buildings achieve higher selling prices and higher rental rates compared with conventional buildings with similar characteristics. One of the most frequently confirmed findings in the literature is the existence of the so-called **"green premium"**, referring to the increased market value of properties that incorporate sustainability features [12].

The increase in market value results from several interconnected factors. First, buyers recognize the long-term financial savings generated by reduced energy consumption. Second, investors assess that sustainable buildings are likely to experience slower depreciation and retain their market value more effectively over time. Third, banks increasingly provide more favorable financing conditions for energy-efficient properties. Fourth, multinational companies seeking office space often prioritize buildings that possess internationally recognized green certifications.

In this way, sustainable features have become an integral component of real estate market value.

Economic Analysis of Sustainable Investments Using Contemporary Financial Indicators

Contemporary investment analysis in the real estate sector increasingly goes beyond the traditional approach based solely on initial construction costs. Today, investors, financial institutions, and the public sector evaluate projects based on their total economic effects throughout the entire life cycle of a building. This approach enables a more objective assessment of the financial feasibility of sustainable investments, given that the majority of their benefits are realized during the operational phase of a building.

In this context, contemporary financial indicators such as **Return on Investment (ROI), Net Present Value (NPV), Internal Rate of Return (IRR), and Life Cycle Cost Analysis (LCCA)** are applied. The combined application of these indicators enables an assessment not only of the economic viability of a project but also of its resilience to changes in market conditions, energy price fluctuations, and regulatory requirements.

Return on Investment (ROI)

ROI represents one of the most frequently used indicators for evaluating the performance of investment projects. Its primary purpose is to measure the relationship between the benefits generated and the capital invested. The mathematical expression is:

ROI=(Total Net Benefit/Total Investment)×100

In sustainable real estate projects, the generated benefits do not include only direct financial savings but also a range of indirect economic effects, including reduced energy costs, lower maintenance expenses, increased market value of the property, higher rental income, improved occupancy rates, lower financing costs, and reduced regulatory risks.

For this reason, the ROI of sustainable buildings tends to increase over time, whereas conventional buildings often experience a gradual decline in investment performance due to rising operating costs.

It is important to emphasize that ROI in construction investments should not be evaluated from a short-term perspective. The lifespan of commercial and residential buildings typically ranges between 40 and 70 years; therefore, an analysis based on a period of only ten or twenty years may provide an incomplete assessment of their actual profitability.

Net Present Value (NPV)

One of the most important indicators in contemporary investment analysis is **Net Present Value (NPV)**, which incorporates the time value of money and represents one of the fundamental criteria for evaluating investment projects [14] (Brealey et al., 2020). Unlike ROI, NPV takes into account the time value of money, i.e., the principle that one dollar today is worth more than one dollar received in the future. The basic formula is:

$$NPV = \Sigma [CF_t / (1+r)^t] - I_0$$

where:

CFt – cash flow in year *t*;

r – discount rate;

I_0 – initial investment.

For sustainable buildings, positive cash flows arise from energy savings, lower maintenance costs, increased market value, higher rental income, and residual value at the end of the building's life cycle. Therefore, discounted cash flow analysis represents a standard approach for assessing their economic feasibility [15].

For the purposes of this research, a discount rate of **5%** has been adopted. This rate represents a moderate assumption frequently applied in analyses of long-term investment projects and building life-cycle assessments. Its purpose in this study is to ensure consistent discounting of future cash flows and comparability of results, rather than to represent a universally applicable market discount rate [14], [15].

The application of the NPV method is particularly important because it enables investors to compare alternative projects of different sizes and different time horizons.

Internal Rate of Return (IRR)

The Internal Rate of Return (IRR) represents the discount rate at which the net present value of a project becomes equal to zero. In other words, IRR indicates the maximum cost of capital that a project can sustain while remaining economically viable.

In sustainable construction projects, IRR is particularly significant due to their long-term nature. Unlike traditional construction investments, where the majority of returns are generated through the sale of the completed property, sustainable real estate assets generate continuous financial benefits throughout their operational life. Therefore, IRR analysis enables a more accurate assessment of overall investment attractiveness.

However, it should be emphasized that IRR should not be considered in isolation. Its interpretation must be combined with NPV analysis, as different projects may have similar internal rates of return but significantly different absolute economic values.

Life Cycle Cost Analysis (LCCA)

Traditional investment analysis is primarily based on comparing initial construction costs. Such an approach may lead to incorrect investment decisions because it ignores the fact that a significant share of total costs occurs after construction has been completed. For this reason, contemporary real estate economics increasingly applies **Life Cycle Cost Analysis (LCCA)**.

This methodology includes all costs incurred throughout the operational life of a building, including:

- design;
- construction;
- financing;
- energy consumption;
- maintenance;
- replacement of technical systems;
- renovation;
- waste management;
- building demolition;
- recycling of construction materials.

Numerous life-cycle studies demonstrate that initial construction costs represent a significantly smaller share of total building costs over its lifespan, while the largest proportion is associated with operation, maintenance, renovation, and replacement of building components. In many analyses, initial investment accounts for approximately 20–30% of total life-cycle costs, whereas the remaining 70–80% consists of operational and maintenance costs. However, this distribution depends on the type of building, the analysis period, and the assumptions applied within the model [16], [15].

Therefore, despite requiring higher initial investments, sustainable buildings frequently achieve lower total costs throughout their life cycle.

Integrated Model for the Economic and Environmental Evaluation of Sustainable Real Estate

One of the limitations of most previous studies is the fact that sustainable investments are evaluated primarily through the relationship between initial costs and energy savings. Such an approach overlooks numerous market and social benefits that significantly influence the overall economic value of a project.

Therefore, it is reasonable to propose an Integrated Model for the Economic and Environmental Evaluation of Sustainable Real Estate, based on five interconnected dimensions of real estate sustainability:

1. Investment sustainability – initial investment costs, availability of financing, and cost of capital.
2. Operational sustainability – energy costs, maintenance expenses, water consumption, and equipment lifespan.
3. Market sustainability – property market value, rental income, occupancy rate, and real estate liquidity.

4. Environmental sustainability – CO_2 emissions, energy efficiency, use of renewable energy sources, and construction waste recycling.
5. Social sustainability – indoor environmental quality, occupant health, employee productivity (in commercial buildings), and resident satisfaction (in residential buildings).

The main advantage of this model lies in its ability to support investment decision-making based on the overall value of a project, rather than solely on initial construction costs. In this way, the limitations of traditional evaluation methods are overcome, and an integrated approach is introduced that connects the financial, market, environmental, and social effects of sustainable investments.

Such a model may also serve as a foundation for the development of a quantitative assessment framework for sustainable real estate in future research.

ENVIRONMENTAL CHALLENGES OF SUSTAINABLE REAL ESTATE DEVELOPMENT

Although sustainable real estate development represents one of the most significant directions in the transformation of the contemporary construction industry, its implementation faces numerous environmental, technological, economic, and organizational challenges [17].

The real estate sector plays a dual role in the process of sustainable development. On the one hand, buildings represent one of the largest sources of energy consumption and greenhouse gas emissions. On the other hand, this sector also offers significant potential for reducing negative environmental impacts through the implementation of energy efficiency measures, renewable energy sources, sustainable building materials, and digital technologies.

Sustainable development requires the rational use of natural resources and the reduction of the construction sector's negative environmental impact [18].

High Initial Costs of Implementing Green Technologies

One of the most frequently cited challenges of sustainable real estate development is the increase in initial investment costs.

The implementation of sustainable technologies requires additional investments in:

- energy-efficient heating, ventilation, and air-conditioning (HVAC) systems;
- higher-quality thermal insulation materials;
- energy management systems;
- solar panels;
- green roofs;
- water efficiency systems;
- sustainability certification;
- advanced design and engineering solutions.

Compared with traditional construction practices, sustainable buildings often require higher upfront investments. According to various studies, the additional costs associated with green construction may range from several percent to several dozen percent of the total investment value, depending on the level of sustainability targeted.

This challenge is particularly pronounced in markets where investors make decisions primarily based on short-term financial indicators. If the evaluation is based solely on initial construction costs, sustainable projects may appear less attractive compared with conventional alternatives.

However, such an approach ignores the fact that the majority of building-related costs occur during the operational phase. Energy savings, reduced maintenance expenses, and increased market value represent benefits that are realized over an extended period.

Therefore, one of the fundamental challenges is not only reducing the cost of sustainable technologies but also changing the investment mindset from a short-term perspective toward an approach based on whole life-cycle cost analysis of buildings.

Regulatory and Legislative Challenges

The development of sustainable real estate largely depends on the quality of the regulatory framework. However, many countries still face significant differences in legislation, standards, and procedures governing the field of green construction. Regulatory challenges include complex permitting procedures, varying energy efficiency standards, insufficient harmonization of regulations, inconsistencies between local and international standards, and, in many cases, the lack of clearly defined criteria for assessing sustainability.

Investors are often required to align their projects with a wide range of different requirements, which increases administrative costs and extends project implementation periods. A particular challenge is the certification of sustainable buildings. International systems such as LEED, BREEAM, and DGNB represent important instruments for assessing sustainability performance; however, their implementation requires additional documentation, professional expertise, and financial resources. Green certifications improve project transparency, enhance investor confidence, increase market competitiveness, and facilitate access to green financing [19].

On the other hand, standardized certification systems play an important role because they enable transparent comparison of different buildings and increase the confidence of investors and users. In the future, harmonization of the regulatory framework will represent one of the key prerequisites for accelerating the development of sustainable real estate.

Technological Limitations and Availability of Sustainable Solutions

Although technological development enables significant progress in the field of green construction, the availability of advanced solutions remains a challenge. For example, the installation of smart building management systems requires the integration of numerous components, including sensors, information systems, energy-related devices, and software platforms. Without adequate technical expertise, there is a risk that these technologies will not achieve their expected performance outcomes.

A particular challenge concerns the adaptation of existing buildings. While sustainable principles can be incorporated into new buildings from the early design stage, the renovation of older buildings often requires complex technical solutions. The energy renovation of the existing building stock represents one of the greatest challenges, as a large number of buildings were not designed according to modern energy efficiency standards.

Challenges of Sustainable Building Materials

One of the key elements of sustainable construction is the selection of materials with lower negative environmental impacts. Traditional production of construction materials, particularly cement and steel, represents a significant source of carbon dioxide emissions. Therefore, sustainable construction increasingly promotes the use of recycled materials, locally available materials, materials with lower embodied carbon, and natural materials.

However, the use of sustainable materials faces several limitations, including higher costs, limited availability, underdeveloped supply chains, and insufficient standardization.

An additional challenge arises from the fact that the environmental performance of materials must be assessed throughout their entire life cycle. A material that has a low environmental impact during production may have unfavorable characteristics during transportation, maintenance, or disposal. Therefore, contemporary approaches require the application of **Life Cycle Assessment (LCA)** rather than the evaluation of individual product characteristics alone.

Shortage of Skilled Professionals and Knowledge

One of the frequently overlooked challenges of sustainable development is the shortage of professionals with multidisciplinary knowledge in the fields of architecture, civil engineering, energy, economics, information technologies, and environmental protection.

Sustainable buildings require a different approach to design and management compared with traditional buildings. Architects must understand the energy performance principles of buildings,

civil engineers must be familiar with advanced construction materials, while facility managers must be capable of using digital systems to optimize resource consumption. Without adequately trained professionals, there is a risk that sustainable technologies may be improperly designed, implemented, or operated, thereby reducing the expected environmental and economic benefits.

Therefore, education and continuous professional development represent one of the key prerequisites for a successful transition toward sustainable real estate development.

COMPARISON OF A GREEN BUILDING AND A CONVENTIONAL BUILDING

In order to provide practical verification of the theoretical assumptions regarding the economic and environmental effects of sustainable real estate development, this study includes a comparative analysis of two hypothetical investment alternatives: a green building and a conventional building. This approach enables a more detailed assessment of the relationship between initial investment costs, operational expenses, and the long-term effects of sustainable construction.

Unlike the traditional approach, in which investments are evaluated primarily based on construction costs, this analysis applies a **life-cycle approach**, assessing the total economic and environmental value of a building throughout its operational period.

The two alternative construction scenarios considered are:

A – Green building, designed according to sustainable development principles, incorporating energy-efficient systems, renewable energy sources, water-efficiency systems, and elements of green architecture;

B – Conventional building, constructed according to standard building practices, without additional sustainable technologies.

For the purposes of this case study, a Life Cycle Cost Analysis (LCCA) approach was applied, based on the methodology recommended by Kneifel and Webb (2020) [15]. The values used in the comparative analysis represent simulation parameters based on realistic assumptions regarding the investment and operational costs of a sustainable and a conventional building, rather than data obtained through direct monitoring of an actual building..

Initial (Investment) Costs

The first stage of the analysis refers to the comparison of initial construction costs. The following table presents the structure of investment costs.

Table 1. Structure of Investment Costs

No.	Cost Category	Green Building (USD)	Conventional Building (USD)
1	Land Acquisition and Legal Costs	100.000	100.000
2	Construction Costs and Sustainable Materials	1.000.000	800.000
3	Energy-Efficient HVAC System	150.000	-
4	Solar Panels and Renewable Energy Sources	120.000	-
5	Water-Efficient System	50.000	40.000
6	Green Roof	70.000	-
7	Labor Costs	600.000	400.000
8	Certification Costs	40.000	-
9	Standard HVAC System	-	80.000
10	Electrical System	-	50.000
Total:		**2.130.000**	**1.470.000**

The results show that the investment in the green building is:

$$2{,}130{,}000 - 1{,}470{,}000 = 660{,}000 \text{ USD}$$

higher compared with the conventional alternative.

The relative increase in the initial investment amounts to approximately:

$$660{,}000 / 1{,}470{,}000 \times 100 = 44.9\%$$

This finding confirms the main conclusion of the previous analysis: sustainable construction requires significantly higher initial investments.

However, the difference in initial costs alone does not represent a sufficient criterion for making an investment decision. Real estate represents a long-term capital investment in which the majority of value is generated throughout the operational period. Therefore, it is necessary to analyze operating costs and environmental effects.

Energy Efficiency of Buildings

Energy efficiency represents one of the key differences between the two analyzed alternatives. The case study data provide the following values:

Table 2. Electricity Consumption

Indicator	Green Building	Conventional Building
Annual energy consumption	120.000 kWh	220.000 kWh
Annual energy cost	7.200 USD	13.200 USD

The green building achieves:

$$220{,}000 - 120{,}000 = 100{,}000 \text{ kWh}$$

lower annual energy consumption.

The percentage reduction amounts to:

$$100{,}000 / 220{,}000 \times 100 = 45.5\%$$

This result confirms the importance of implementing energy-efficient systems. Reducing energy consumption generates multiple benefits:

- directly reduces building operating costs;
- decreases dependence on fluctuations in energy prices;
- contributes to the reduction of CO_2 emissions;
- increases the building's resilience to energy crises.

Under contemporary conditions of energy market instability, energy efficiency is becoming one of the most important factors contributing to investment security.

Maintenance Costs

In addition to energy consumption, a significant share of costs throughout a building's life cycle is related to maintenance. According to the case study data, the following table presents maintenance costs:

Table 3. Maintenance Costs

Indicator	Green Building	Conventional Building
Annual maintenance cost	12.800 USD	24.900 USD

Difference:

$$24{,}900 - 12{,}800 = 12{,}100 \text{ USD per year}$$

The sustainable building achieves approximately:

$$12{,}100 / 24{,}900 \times 100 = 48.6\% \text{ lower maintenance costs}$$

This result is attributable to the application of higher-quality materials, automated management systems, and more advanced technical infrastructure.

Although sustainable systems are more complex during the design and construction phases, their proper management during the operational phase can significantly reduce the need for maintenance interventions and equipment replacement.

Total Initial and Operational Energy and Maintenance Costs

All previously presented data are summarized in the following table:

Table 4. Investment Value and Annual Operational Energy and Maintenance Costs

Element	Green Building	Conventional Building
Total initial investment	2,130,000 USD	1,470,000 USD
Difference in initial investment	+660,000 USD	–
Annual energy cost	7,200 USD	13,200 USD
Annual maintenance cost	12,800 USD	24,900 USD
Total annual operating costs	20,000 USD	38,100 USD

Based on the presented data, it can be concluded that the green building requires approximately 45% higher initial investment, but achieves significantly lower annual operating costs.

The annual difference in operating costs amounts to:

38,100 USD – 20,000 USD = 18,100 USD per year

This difference represents the primary direct financial benefit of sustainable investment.

Investment Payback Period Analysis

One of the most commonly used indicators of investment feasibility is the payback period of additional investment.

Payback Period = Additional Investment / Annual Financial Benefit

In the analyzed case, the following values apply:

Additional investment: 660,000 USD

Annual savings: 18,100 USD

The payback period is: 660,000 / 18,100 = 36.5 years

The result shows that the additional investment in the green building, when evaluated solely through direct energy and maintenance savings, is recovered over a period of approximately 36.5 years.

This result is highly significant because it demonstrates the limitation of a simplified approach to evaluating sustainable investments. If the analysis is based exclusively on operational savings, the payback period may appear relatively long.

However, real estate represents a long-term investment asset whose useful life often exceeds 50 years. Therefore, it is necessary to incorporate other sources of economic value, including increased market value of the property, higher rental income, reduced risk of technological and regulatory obsolescence, compliance with future regulations, and improved access to financing.

For this reason, sustainable investments cannot be evaluated solely through a short-term payback period approach.

Analysis of Total Costs Over a 20-Year Period

According to the case study data, the total energy and maintenance costs over a 20-year period amount to:

Green Building:

Energy costs: 7,200 USD per year × 20 years = 144,000 USD
Maintenance costs: 12,800 USD per year × 20 years = 256,000 USD
Total operating costs: 400,000 USD

Conventional Building:

Energy costs: 13,200 USD per year × 20 years = 264,000 USD
Maintenance costs: 24,900 USD per year × 20 years = 498,000 USD
Total operating costs: 762,000 USD

Difference:762,000 – 400,000 = 362,000 USD

During the first twenty years, the green building generates 362,000 USD in direct savings.

However, when the initial investment difference of 660,000 USD is taken into account, it can be concluded that direct operational savings alone are not sufficient to fully justify the additional investment within a 20-year period.

Tthis outcome should not be interpreted as a negative indicator of sustainable development, but rather as confirmation of the need to apply a comprehensive evaluation methodology.

Expanded Perspective of Economic Benefits

One of the most significant economic effects of sustainable construction is the increase in the market value of the building. In practice, green buildings often achieve a market premium due to lower operating costs, improved space quality, a positive environmental image, and compliance with ESG criteria.

Incorporating the Market Premium of Sustainable Real Estate

Empirical studies show that certified green buildings achieve a market premium compared with conventional buildings. The estimated range of increases in market value varies depending on the market, location, and level of certification. For the purposes of this research, a conservative assumption of a 10% increase in market value has been adopted, which falls within the range of values reported in relevant literature [12], [21](Eichholtz et al., 2010; Fuerst & McAllister, 2011b).

If the initial value of the building amounts to USD 2,130,000:
2,130,000 × 10% = USD 213,000 additional market value

This amount represents an additional economic benefit that is not reflected in a conventional analysis of energy costs but directly affects the investment attractiveness of the building.

Incorporating Rental Income Effects

In the case of commercial real estate, sustainable buildings often achieve higher tenant demand, particularly from international companies that have their own ESG policies. In this simplified analysis, the effects of increased market value and additional rental income are considered separately in order to illustrate different sources of economic benefits, although in real-world assessments certain overlaps may exist. A conservative market premium of 5% on rental income is assumed.

If the building generates annual rental income of USD 150,000:
150,000 × 5% = USD 7,500 additional annual income
For a period of 20 years:
7,500 × 20 = USD 150,000

In this way, a sustainable building generates additional economic benefits that significantly change the overall investment perspective.

Total Economic Effect

When the following benefits are included:

- operational savings: USD 362,000
- increase in market value: USD 213,000
- additional rental income: USD 150,000

an indicative nominal estimate of total economic effects is obtained:

362,000 + 213,000 + 150,000 = USD 725,000

This amount exceeds the additional investment:

725,000 – 660,000 = USD 65,000 positive economic effect

This represents a simplified nominal analysis, while a more precise assessment would require an NPV (Net Present Value) analysis. Nevertheless, based on this expanded assessment, it can be concluded that a sustainable building becomes economically justified when, in addition to direct operational savings, the market effects of sustainability are also taken into account.

DISCUSSION OF RESULTS

The results of the case study confirm that sustainable real estate development represents a complex investment concept that requires a different evaluation approach compared with traditional construction projects. Conventional valuation models often favour buildings with lower initial costs while neglecting long-term effects generated during the operational period.

Contemporary research in the field of real estate economics indicates that the assessment of sustainable buildings must incorporate the entire life cycle of the building. Initial costs represent only one segment of total economic value, while energy costs, maintenance, renovation, and management expenses incurred over decades of use have a decisive impact on overall profitability.

The obtained results confirm this approach. Although the analysed green building demonstrated a 44.9% increase in initial investment costs, it achieved significant operational benefits through:

- a 45.5% reduction in energy consumption;
- a 48.6% reduction in maintenance costs;
- total operational cost savings of USD 362,000 over a 20-year period;
- a significant reduction in CO_2 emissions.

These results confirm the conclusions of numerous international studies indicating that sustainability cannot be evaluated solely through initial costs, but rather through the total value generated by a building throughout its life cycle. Although direct energy and operational savings alone do not fully offset the additional initial investment within a 20-year period, incorporating the market value of the building and additional rental income changes the overall economic assessment.

Numerous studies conducted over the last decade indicate that sustainable buildings achieve measurable economic advantages compared with conventional buildings. One of the most frequently confirmed findings is the existence of the so-called “green premium”, referring to the increased market value of buildings possessing sustainability characteristics.

This finding is particularly important because it demonstrates that sustainable investments create value through multiple channels, rather than solely through cost reduction.

In the real estate sector, ESG criteria are becoming increasingly important because buildings represent long-term capital assets with a direct impact on energy consumption, emissions, and the

quality of life of users. The results of this research indicate that sustainable buildings provide advantages across all three ESG dimensions.

In summary, the analysis identifies three key findings:

First, a green building requires higher initial investment, which represents the primary obstacle to the wider adoption of sustainable technologies.

Second, during the operational phase, a sustainable building achieves significantly lower energy and maintenance costs, thereby improving long-term financial efficiency.

Third, environmental benefits, such as reduced CO_2 emissions and more efficient resource utilisation, represent additional value that cannot be fully captured through conventional financial indicators.

The case study confirms that sustainable real estate development should be viewed as a strategic investment rather than an additional cost. In the future, the combination of economic indicators, ESG criteria, and digital technologies will enable more accurate evaluation of sustainable projects and support higher-quality investment decision-making.

Research Limitations

Although the results confirm the economic and environmental benefits of sustainable real estate development, certain limitations of the research should be acknowledged.

First, the case study is based on a hypothetical building and average cost values, meaning that the results may vary depending on location, climatic conditions, energy prices, technology availability, local regulatory frameworks, and other relevant factors.

Second, the market premium of sustainable buildings is not identical across all markets. In developed economies, it is more pronounced due to higher environmental awareness among buyers and a more developed financial system.

Third, future research should incorporate real-world data from a larger number of buildings and apply advanced statistical models.

Despite these limitations, the results can provide a significant contribution to understanding the relationship between sustainability, real estate economics, and long-term investment decision-making.

CONCLUSION

Sustainable real estate development is no longer a trend but a necessity for the future. The implementation of sustainable principles represents an important step towards achieving economic growth while protecting the environment. Consumer preferences are increasingly shifting towards energy-efficient and environmentally responsible properties. Real estate developers who invest in sustainability will ensure long-term profitability and enhance their brand reputation.

The analysis of the obtained results shows that sustainable real estate development represents a transition from the traditional model based on minimising initial costs towards a model based on the total value generated by the building throughout its life cycle.

The most important conclusions derived from the discussion can be summarised as follows:

- Sustainable buildings require higher initial investments but generate significant long-term benefits.
- Energy efficiency represents one of the most important sources of financial savings.
- The market value of sustainable buildings is increasing due to changing preferences of users and investors.
- ESG criteria are becoming a key factor in the future development of the real estate market.
- Digital technologies and artificial intelligence will represent important instruments for further improving sustainability.

Although sustainable real estate development involves certain financial and technical challenges, long-term benefits justify the initial costs. Real estate developers who integrate

sustainable practices gain a competitive advantage, reduce long-term costs for their customers, and align their projects with future environmental regulations.

Government regulators and policymakers should systematically provide financial incentives, tax benefits, and favourable financing mechanisms for the construction and purchase of environmentally sustainable properties. Standardised sustainability regulations should be implemented in order to create a consistent and transparent market framework. Particular importance should be given to the development of national strategies for energy efficiency and climate neutrality, as they create a more stable framework for long-term investment decision-making.

Based on the above, it can be concluded that sustainable real estate is not merely a response to environmental challenges but represents a strategic direction for the development of the construction sector and capital markets. Furthermore, the role of artificial intelligence in the management of green buildings represents an important challenge and opportunity for future research.

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DECLARATION OF INTEREST STATEMENT

The authors confirm that there are no conflicts of interest related to the research presented in this paper.

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