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Sustainable Development and Energy Efficiency Requirements in Buildings

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ABSTRACT

Energy is essential for all human activities. Energy is necessary for poverty alleviation and the production of essential goods and services. Energy is a vital element for the social and economic progress of all countries. Therefore, it is like oil that runs the engine of national economic progress. Governments worldwide are committed to achieving sustainable development goals. In a situation where urban complexes consume almost 80% of global energy, energy-efficient buildings can make a significant contribution to achieving sustainable development goals. As a result, energy efficiency in buildings has increasingly attracted the attention of governments and people. The overall result of this study is that with the adoption of initial measures, there are credible energy technology approaches that may allow governments to continue social and economic development for at least the next 50 years while ensuring energy supply stability and improving local, regional, and international environmental quality. Findings indicate that effective energy policy provides consumers with reliable information and establishes a sustainable monitoring environment for project developers. Rational investment behavior and responsiveness to reliable information lead to a shift towards sustainable building choices.

1. Introduction

In the light of the current global challenge that advocates for sustainable economic development through carbon reduction, energy efficiency (EE) has the potential to enhance economic-social growth and promote sustainable development, which is a prerequisite for gaining a competitive advantage in today's business environment [1]. Addressing energy efficiency as a strategy to reduce carbon emissions, limit energy consumption, improve building energy performance, and reduce energy consumption has recently attracted more attention. In the 21st century, sustainable buildings are crucial for many developed and developing countries. By the end of this century, there will be over 10.9 billion people on Earth, up from 7.7 billion in 2019, leading to an increase in demand for water, electricity, and environmental assets directly proportional to the global population increase. This increase puts biological systems under pressure and gradually worsens nature through increased energy consumption, which will have a comprehensive impact on the built environment. Based on the energy intensity balance sheet, Iran's final energy consumption intensity is 5.1 times the global average, which for the building sector is 9.1 times higher [1]. According to this statistic, about 30% of the country's annual natural gas production is consumed in buildings, with this amount reaching very high levels during peak consumption in winter. Electricity consumption in residential, public, and commercial sectors, all primarily related to electricity consumption in buildings, accounts for 6.5% of the total electricity distributed in the country. Also, according to the monitoring conducted in 2017, the daily energy consumption in the residential sector is equivalent to one million barrels of crude oil, thus energy consumption intensity in Iran's building sector is 3 to 4 times higher than the global average [2].

Therefore, energy management, in addition to its global importance and trend, should receive more attention in the country. Considering the energy subsidies applied to energy consumption in the building sector, alongside the fact that energy consumption in this sector is essentially non-productive, the importance of reducing and properly managing energy consumption in buildings doubles. Therefore, every effort should be made to reduce energy consumption to redirect energy towards developing infrastructure and productive industries to create added value [2].

Advantages of low-energy buildings, which are related to strategies currently under discussion, are more significant for families in terms of energy savings than limiting global temperature rise to "well below 2 degrees Celsius." If no action is taken to improve EE, global energy demand is predicted to increase by 50% by 2050 [3]. This notable increase in energy demand can be attributed to the rapid growth of the construction and related services sector and the increased demand for improved living conditions and new products. Energy efficiency is a policy goal and a means to reduce carbon dioxide (CO_2) emissions. Therefore, it is not surprising that energy-efficient buildings are central to environmental and energy-focused initiatives. A study linking energy-efficient buildings to Sustainable Development Goals (SDGs) is appropriate as such buildings can significantly contribute to sustainability. Low-energy buildings can be linked to SDG 11, aiming to "make cities and human settlements inclusive, safe, resilient, and sustainable," and SDG 13, which calls for "urgent action to combat climate change and its impacts" [4].

In the context of increased CO_2 emissions and resource limitations exacerbated by changes in the global economy, the future sustainability of the built environment and the substantial potential contribution of energy-efficient buildings to reducing CO_2 emissions have become urgent concerns. However, it is important to note that improving EE does not necessarily support carbon reduction unless energy is produced from fossil fuels. On the other hand, the impact of energy produced from low-carbon sources is weak. Since the clear relationship between Energy Efficiency Measures (EEMs) and sustainability is evident, increasing public awareness of the importance and ease of energy-efficient buildings for both private and social benefits is increasingly essential. Given that, significant investment will be required to provide high-performance buildings in the decades to come.

According to the introduction mentioned and aimed at reducing building energy consumption, the first edition of Chapter 19 of the National Building Regulations was initially drafted in 1991, albeit largely overlooked in practice. This chapter underwent review in the years 2002 and 2010, and its second and third editions were introduced. Although Chapter 19 deviates significantly from globally up-to-date regulations and standards such as ASHRAE 1.9 and ASHRAE 2.0 standards, which pertain to energy requirements for tall and short buildings respectively, it also neglects topics such as energy generation from renewable sources. However, adherence to these standards will certainly reduce energy consumption levels, at least in newly constructed buildings in the country. Moreover, the analysis of EEMs opportunities and values should be carried out in a straightforward manner [2].

However, due to several obstacles, this opportunity has not been fully realized to a great extent. It is now well recognized that the construction industry cannot continue to improve energy efficiency in buildings without proper governmental guidelines. Nevertheless, many governments at national and local levels lack knowledge and expertise regarding existing policy tools and can be effective in their local context.

In the absence of well-designed policy measures that balance both demand and supply sides of the equation, the pace of improving energy efficiency in buildings will continue at a slower rate. Governments play a role in enforcing regulations that create a level playing field and support industry capacity building. Therefore, this article was conducted with the aim of sustainable development and energy efficiency requirements in buildings. For this purpose, empirical data published by EEFIG were analyzed with the aim of providing information that can facilitate the alignment of priorities of suppliers (project financiers and developers) and demand (usually building owners).

2. Literature Review

Successfully limiting the global warming temperature increase to 2 degrees Celsius requires coordinated and swift actions, unprecedented global political consensus and agreement to achieve a reduction in greenhouse gas emissions from buildings. Regional changes in the energy trend related to the construction sector are significant and depend on factors such as climatic conditions, building lifespan, income levels, urbanization rates, among many other factors [5], as depicted in Figure 1. The main greenhouse gases are CO_2, constituting 75% of greenhouse gases, accompanied by methane (CH_4), nitrous oxide (N_2O), and fluorinated gases including hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6) that are emitted as a result of human activities. Electricity generation is the primary source of greenhouse gas emissions along with being the main energy source used in buildings through purchased electricity and direct consumption of natural gas and oil for heating and cooling purposes [5].

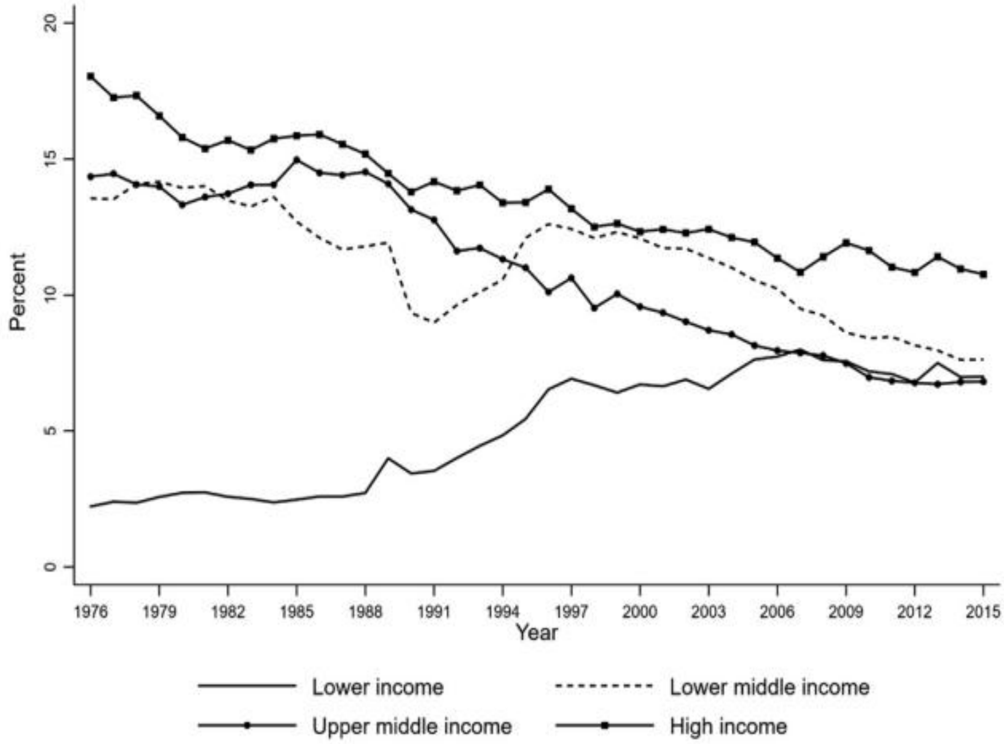

Figure 1: CO_2 Emissions from Residential, Commercial, and Public Service Buildings (percentage of total fuel combustion)

Global trends in energy consumption indicate improvements in energy efficiency (EE) and reduction in CO_2 emissions across several sectors [6], including buildings. Currently, urban areas accommodate approximately 55% of the world's population, consuming up to 80% of global energy, with buildings accounting for 40% of this energy consumption. Therefore, evaluating the additional costs of energy-efficient buildings and retrofitting existing buildings to improve EE is important. As shown in Table 1, in the residential sector, the incremental costs of achieving passive house standards range from 6 to 16% of the costs compared to standard construction expenditures [7].

Table 1: Additional Investment Costs by Energy Performance Type

CCE (US$/kWh)	Extra Investment Costs (USD)	Type and Energy Efficiency	
-	5% ($69 per square meter)	standard inert house (N)	inert house: block flats (EU)
-	0.070e0.120 ($/kWh; CCE)	standard (N)	very low-energy houses (USA)
-	$2719	42% energy consumption savings (N)	hypothetical 6000-square-meter office building (USA)
-	3.4% ($115 per square meter):	14 kWh/square meter/year (heating) vs. 45 (N)	residential building with 10 floors and 7000 square meters (EU)
-	4-10% based on hard construction costs	NZEB (N)	Leslie Shao-Ming sun field station (USA)
-	0.000	NZEB (N)	IAMU office (USA)
0.068-0.140	$305-$762 per square meter	59-48%/234-192 (R)	19th century apartment (Britain)

Source: Author's explanation based on [7]. N = New building, R = Reinforced building, Reference year for $ = 2010

- **Goals of energy efficiency requirements:**

The aim of energy efficiency requirements is to:

• Reduce energy consumption and peak energy demand
• Decrease greenhouse gas emissions
• Enhance the health and well-being of occupants [8].

Energy efficiency requirements ensure that buildings efficiently use energy for artificial heating, cooling, lighting, and other services without compromising the health and well-being of occupants or building performance. It is widely accepted that energy efficiency has direct and indirect impacts on economic activity, employment, energy prices, and social equity goals. Therefore, energy-efficient buildings have the potential to contribute to increased economic growth, improved social development, and environmental sustainability.

According to a World Bank report, the negative effects of carbon dioxide emissions on human health result in over 7 million premature deaths annually, incurring healthcare costs exceeding $4 billion. Similarly, the social benefits of energy efficiency can be measured and monetized using existing methods. A recent study demonstrated a correlation between improvements in building energy efficiency and enhancements in health and well-being [8].

- **Energy-Efficient Buildings (BBE):**

Simply building green buildings and greening existing buildings alone cannot address global environmental issues. It is not enough to lead to energy self-sufficiency or reduced utility bills by itself. However, this is perhaps the most crucial area, given that the entire world faces challenges of climate change adaptation. Our inclination towards building energy efficiency is not just about turning off air conditioning or lights, but it is about doing a lot more with less. Consumers can anticipate much higher energy consumption in the next decade. These advancements allow hundreds of millions of people to live and work more comfortably in offices and apartments [9]. The methods designed and constructed today will not only impact their operational costs but also influence energy consumption habits and global environmental conditions for several years in the future. Malaysia's energy audit program attempts to confirm, contrary to common beliefs, debates, and industrial research, that multiple energy-saving initiatives can be realized with minimal or no cost through precise building design delegated by project developers and good management practices adopted by building occupants and stakeholders [10]. This financial awareness empowers businesses to assess, respond, and steer development towards better energy efficiency. For building constructors, smart design strategies and high-efficiency building elements will be a solution to increase energy efficiency. The starting point for operators and occupants is to view energy management as a commercial concern. Overall, a comprehensive cost analysis throughout the structure's lifecycle should be the basis for decision-making for anyone associated with a building.

- **Features of Energy-Efficient Buildings:**

The fundamental principle of building energy efficiency is to consume much less energy for heating, cooling, and lighting a home without compromising the comfort of the building occupants. High-performance buildings not only preserve energy costs and natural resources but also signify higher indoor environmental quality. The main benefits of energy-efficient buildings include:

1) Healthier Indoor Environment Quality:

Efficient buildings also necessitate a healthier indoor environment for everyone residing or working in them. For instance, by using attractive architectural designs to brighten workspaces with natural light instead of electricity, without causing excessive glare. Comfortable temperatures and tranquil workspaces are usually characteristics of high-performance buildings.

2) Minimizing Lifecycle Costs:

Enhancing building energy efficiency reduces the energy required to operate the building and decreases the costs for building occupants.

3) Reducing Resource Consumption:

Improving the energy efficiency of buildings as a new form of energy storage significantly reduces the need for new resources such as oil and investments in new power plants.

4) Less Environmental Impact:

Buildings contribute to the emission of four main pollutants: nitrogen oxides (NO_X), sulfur oxides (SO_X), CO_2, and particles. Improving building energy efficiency minimizes reliance on fossil fuels and reduces greenhouse gas emissions.

5) Improved Workforce Efficiency:

Enhanced comfort for building occupants leads to higher workforce efficiency. Current research shows that increased workforce efficiency is evident when buildings feature attributes such as natural light, better temperature management, and more intelligent space usage [11].

- **Implemented Solutions at a Global Level:**

- **Regulations:**

Regulations are governmental tools that regulate the performance of energy market players. Regulations define pre-set standards and impose minimum enforceable limits, leading to behaviors such as providing specific information. Indirectly, regulations provide useful information for creating an active market and thereby addressing financial barriers.

- **Budget Funding through Loans:**

Loans are financially viable solutions. The volume of lending and the level of interest rates depend on demand and financial reserves. The main motivation for lenders is to profit from financial leverage. Naturally, lenders consider a predetermined interest rate. Therefore, lenders need information about the income capacity of borrowers before granting loans. Ambiguities in energy-saving schemes create challenges for lenders and borrowers [12].

- **Off-balance sheet financing:**

In off-balance sheet financing, expectations rely on the project's cash flow, while financing through loans depends on individuals' creditworthiness. The general rule for off-balance sheet financing is to spread risk among different actors.

Overall, ambiguities in the exact level of savings from a specific energy efficiency project create difficulties in its financial funding.

- **Subsidies:**

Through financial assistance programs and subsidies, a temporary financial gap is directly addressed, and at least a temporary change is brought to the market. By aiming to set a specific benchmark in the market, a clear message is sent to market participants. Consequently, these programs usually have a very strong impact [12].

- **Financial Incentives:**

Financial incentives are always included in financial schemes to encourage market players to invest in energy efficiency. The government promotes energy efficiency by creating financial incentives, specifically aimed at overcoming liquidity obstacles. The goal is to stimulate demand in the market for energy-efficient equipment.

Effective regulations and policies can reduce the costs of new energy-consuming buildings and retrofitted buildings. These policy tools, some of which are listed in Table 2, can facilitate or incentivize investments by reducing risks and increasing existing rewards for project proponents.

Regarding financial rewards, there are exemptions from import duties and sales tax for machines used for energy efficiency that are not produced domestically. Equipment purchased from domestic companies benefit from sales tax exemptions.

- **Building Energy Assessment and Audit:**

One of the very attractive programs in manufacturing industries and building owners is to audit their energy consumption to reduce energy costs and increase efficiency.

- **Building Energy Efficiency Standards:**

In 1986 and 1987, Malaysia created the first draft guidelines for energy efficiency in commercial buildings and launched it as a voluntary national guideline in December 1989. The guidelines cover building envelope, HVAC systems, lighting, electricity and power distribution, and energy management. This initial version of the regulations incorporated many key strategies and significant materials from the 1983 Singapore standard and initial drafts from the ASHRAE 1.9 standard in the United States.

- **Regional Energy Efficiency Movements:**

Many countries actively participate in regional energy efficiency programs. These programs involve contributing to the growth and development of regional energy standards for buildings and energy-efficient building incentive programs.

- **New Energy Tariffs:**

The price of energy for commercial buildings in most countries around the world is heavily subsidized. The non-subsidized price of electricity is more than double the subsidized value. New electricity tariffs were implemented in June 2006 to discourage inefficient energy use among larger consumers [13].

Table 2: Policies (Adapted from [14])

Objective, Realistic	Policy	Tools
compensate loss of long-term investors via OPEX savings	determine mandatory standards with higher CAPEX assistance	technical standards
encourage investment through insurance rights in WACC, set insurance rights at existing levels, it is attractive to project developers	encourage investment through insurance rights in WACC	insurance rights
help project developers identify the best investments, alternatives and options	laws related to anticipated investments	laws for forecasting investments
support operators in creating performance failure risks	exempt operators from performance requirements within a period	exemption from productivity requirements
provide project developers with guaranteed oversight stability	various tools	stability arrangements
make the investment payback period more attractive	define depreciation laws	adjusted depreciation
provide desired and stable information about investments in assets that are still under development	consider special arrangements for CWIP	early identification of costs

Figure 2 illustrates the cost-saving curve using energy efficiency solutions in the Lithuanian residential buildings sector.

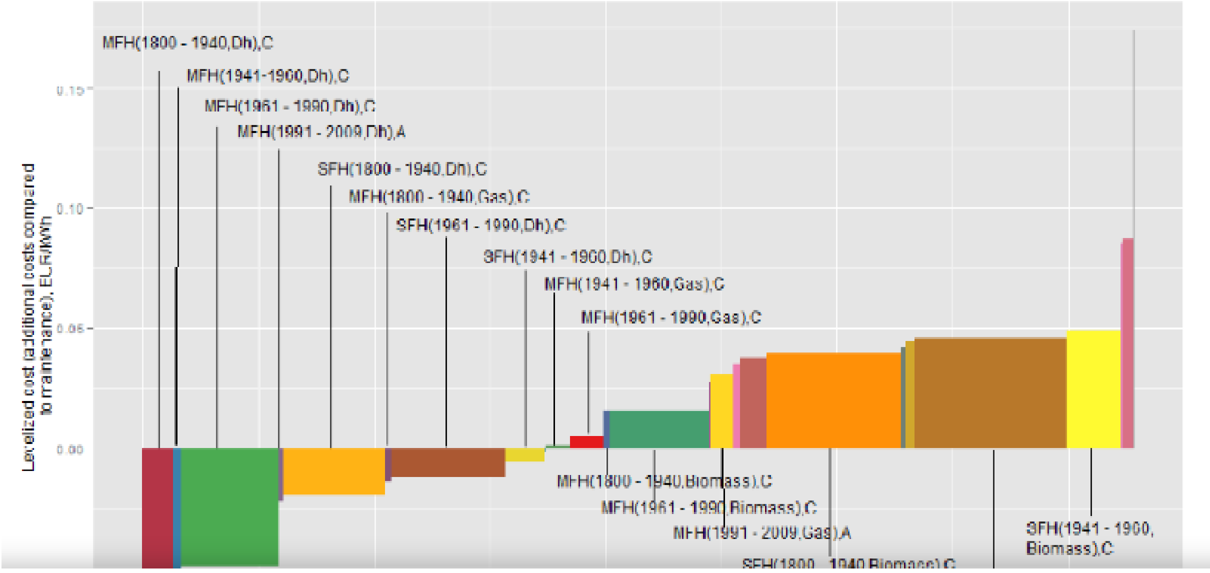

Figure 2: Energy Efficiency Cost Curve Using Energy Efficiency Solutions in the Lithuanian Residential Building Sector

The X-axis shows energy consumption savings from 2012 to 2030, and the Y-axis shows the additional cost of investment in energy efficiency solutions for each type of building.

From a financial standpoint, there are tools currently in existence, as well as emerging ones, that align with the requirements for implementing Energy Efficiency Measures (EEMs) in buildings. These tools include dedicated credit lines, energy performance contracts, risk-sharing facilities, direct investments and assets, derivative loans and leasing, bill repayment and financial tax provisions, and energy services contracts. However, currently, several social, financial, technical, and administrative barriers still weaken the potential for sustainable energy production in buildings. Conversely, even virtuous behavior can act as an obstacle to project development. Typically, for example, when building owners carry out routine maintenance and repair work, they may avoid investing in sustainable energy because improved efficiency only provides short-term and marginal benefits. In fact, the decision-making and evaluation of investment occur in a space-time field that includes elements of uncertainty and irreversibility and where payback analyses are more dominant than internal rate of return or net present value analyses.

The final point is that EEMs differ for residential and commercial buildings. For residential buildings, common actions include increasing insulation, moisture insulation, installing double-glazed windows, and transitioning to technologies that require advanced solutions and demand-response (DR) capable measuring mechanisms.

- **Challenges in Energy Efficiency Improvement:**

1) Political and Organizational Barriers

Political and organizational barriers primarily exist in developing countries and include issues such as insufficient government intervention in energy efficiency, inadequate policy management resulting from restricted executive structures and institutions, lack of qualified personnel, and corruption.

2) Economic/Monetary Barriers

Acquiring more efficient equipment usually involves higher initial costs that many consumers are unwilling to bear, and low-income consumers cannot afford them due to limited capital. This could essentially be the most significant barrier to energy efficiency in buildings and various sectors in developing countries worldwide and may remain unresolved domestically. In developed countries, consumers usually do not need to pay initial costs as they may not be aware or feel that energy efficiency opportunities often pay back within a few years or perhaps months.

3) Information Barriers

Lack of knowledge about opportunities, strategies, and alternative energy efficiency solutions can be a major burden in developing countries. Providing energy services or entering the national grid without understanding their continuous integration benefits with energy efficiency considerations for essential electricity reduction is recognized.

4) Behavioral and Administrative Constraints

Individual behavioral traits and organizational features of companies hinder energy efficiency technologies and methods. Small but straightforward energy-saving opportunities are often overlooked, and changing behavior or lifestyle is very challenging. Lack of awareness and information regarding the outlook and minimal energy-saving costs is a related issue that is much more prevalent in developing countries compared to developed countries. In developed countries, possibly the most critical challenge in strengthening energy efficiency is the minor share of energy expenditure in the incomes of one-time consumers or financial returns of affluent homeowners and businesses, which leads to very limited interest in this subject among other concerns.

5) Market Failures

Market failures prevent the benefits of energy savings from continuous investment in specific energy-efficient investments [14]. The lack of assured incentives is undoubtedly a primary issue in the construction industry because building tenants likely pay the energy bill with no control over the system, while building owners have no interest in increasing energy efficiency. Consequently, utility companies have no direct involvement in their customers' energy consumption reduction measures. In the governmental sector, financial constraints are undoubtedly the main obstacle hindering energy efficiency investments.

6) Prices and Hidden Benefits

In addition to higher initial costs, there are hidden costs and benefits for end-users that are not directly understood in financial streams, such as costs related to achieving an efficient energy solution and risks associated with technology. Costs are usually high due to the scattered structure of the building sector with numerous small owners and representatives. New technologies may not be compatible with current sockets. On the other hand, indirect benefits of increasing energy efficiency, such as reducing environmental air pollution and enhancing health and well-being, are often overlooked.

Many options and technology policies for upgrading building energy efficiency worldwide, whether immediate or future, are executable. However, considering the constraints of available resources, prioritizing actions that will have the most significant impact in individual countries is clearly essential. Implementing Energy Efficiency Measures (EEMs) for buildings reduces energy consumption while maintaining or improving the comfort levels of building residents where they are introduced [18]. The most desirable financial options for EEMs currently are domestic financing and energy performance contracts [19]. Literature shows that numerous factors other than financial factors impact investment behavior and inclination [20]. These factors include technological opportunities, enhancement of standards, perceived levels of risk, lack of upgrading investments from small projects to more substantial investments, and the absence of regulations. Efforts have been made to formulate construction and urban planning to increase energy efficiency and reduce greenhouse gas emissions. However, precise energy performance evaluations, under the influence of complex interactions between buildings and urban ecosystems and feedback effects, among other factors, remain limited. The EE market offers multiple technological solutions that, if combined with appropriate incentives, may lead to significant results. In recent years, an increasing number of governments have provided incentives, actions, and temporary support for emerging technologies and strategic sectors [21]. The priorities of various stakeholders (such as industry, people, and government) differ based on different dimensions of sustainability, namely environmental, economic, and social. In fact, investigating whether individuals and companies have failed to carry out EE investments is problematic, leading to slower adoption of efficient energy solutions than anticipated [22].

3. Discussion and Conclusion

Well-designed EEMs contribute to achieving the core objectives of current environmental and energy policies, especially those aimed at supporting the transition towards a low-carbon economy through more sustainable built environments. This study demonstrates that the incentives of EEMs should align supply and demand sides of projects for their implementation. By highlighting the connections between EEMs and supply, the findings of this study contribute to dialogues and strategies for promoting global environmental welfare enhancement. Consequently, collaboration, political insight, and leadership must be harnessed through projects that successfully enhance the implementation of EEMs in alignment with the requirements of citizens and industries, thus influencing the transition towards decarbonized economies.

On the supply side, forms of support could include direct or indirect incentivizing mechanisms. On the demand side, various ways to promote EEMs through direct tools, including incentives and tax reductions and indirect methods, especially incentives and reducing costs paid to governmental agencies, exist. Such incentives aim to shift the risk-reward balance. Hence, there is a need for improving and stabilizing incentive forms over time.

Therefore, policies that foster the promotion of research and high-performance technology development are prerequisites for achieving this goal. The recommendation of the Energy Efficient Buildings Committee to expand the scope of research and innovation in the construction sector towards a low-energy built environment exemplifies a prioritization of goals [23]. The proposed method provides a starting point for the entire investment chain. One recommendation is for more efforts to increase knowledge and awareness of the economic, social, and environmental values of EEMs among stakeholders to convince building owners to undertake such investments primarily. Higher levels of knowledge among policymakers enable better evaluation of policy impacts [24], provided they commit to monitoring progress towards achieving sustainable development goals over regular time intervals. However, it is crucial to emphasize that this study also offers insights for policy formulation.

Policy makers are expected to commit to ensuring significant enhancements in policies, actions, and programs aimed at increasing resource efficiency and adapting to climate changes to achieve sustainable development goals. In the absence of any action, energy demand is projected to increase by 50% by 2050 and consequently restrict the attainment of sustainability goals. However, there is no single approach to reaching crucial milestones. What is needed is a combination of delivery strategies and policies tailored to local conditions [25] to support investments with positive external impacts [26] that initiate, for example, material production for buildings [27].

Regarding the built environment, policies aimed at reducing climate change should support both the retrofitting of existing buildings and well-designed new projects for implementing EEMs. Policymakers should particularly consider Cluster 1 incentives concerning design policies to stimulate investments and thereby increase the energy efficiency of buildings. Detailed technical and risk analyses are crucial to support Cluster 1 incentives. Specific monitoring policies and actions can be formulated, including those that facilitate investments in research and development and enhance incentives, subsidies, voluntary agreements, and tradable permits. Other actions include introducing EE certificates related to energy savings, commitments to produce or purchase renewable energy, and regulatory versions to encourage operators to take specific actions.

In general, governmental authorities, acknowledging the global impact that buildings and their construction have on the environment, have been seeking strategies for achieving better sustainability in the built environment. This particular pressure for superior energy efficiency and increased building sustainability has gradually become a commercial issue. Industry-led initiatives have been aiming to alter the current market practices across the construction sector. The trend towards energy-efficient buildings in the majority of countries has commenced in the past few years with significant federal government campaigns to promote building energy efficiency since 2000. Greater interest in the environmental impacts of buildings as a source of broader political concerns has become evident.

Overall, these initiatives by governments, industry organizations, and companies lay the groundwork for shifting the market towards higher sustainability in the built environment. There is at least a basic understanding of the impact of several policy tools, especially the reasons behind these impacts. Therefore, significant research gaps still exist, and the conditions in Malaysia clearly necessitate further policy steps accompanied by more studies as some of them have not been launched or simply offer policy tools for reducing greenhouse gas emissions from buildings.

The overall conclusion of this study is that with the adoption of initial measures, there are credible energy technology approaches that may enable governments to sustain social and economic development for at least the next 50 years while ensuring energy supply stability and enhancing local, regional, and international environmental quality.

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