Scientific Research Publishing

Open Journal of Civil Engineering, 2025, 15(2), 271-299
https://www.scirp.org/journal/ojce
ISSN Online: 2164-3172
ISSN Print: 2164-3164

Establishing Sustainable Architecture through Renewable Energy Sources: A Case Study of the United Kingdom

Nawar Berro

School of Business, University of Gloucestershire, Cheltenham, UK
Email: info@glos.ac.uk

How to cite this paper: Berro, N. (2025) Establishing Sustainable Architecture through Renewable Energy Sources: A Case Study of the United Kingdom. *Open Journal of Civil Engineering*, **15**, 271-299.
https://doi.org/10.4236/ojce.2025.152015

Received: May 5, 2025
Accepted: June 27, 2025
Published: June 30, 2025

Abstract

The paper explores how integrating alternative fuels and renewable energy technologies—like solar, wind, and geothermal—into the UK's sustainable design can promote sustainable design in the UK and address environmental issues of present days. The study combines quantitative analysis of energy use with qualitative case studies of existing sustainable buildings to assess the effectiveness of these technologies. The findings show that properly implemented renewable systems and sustainable green building design can considerably reduce carbon emissions and energy costs, with some homes reducing energy consumption by up to 40%. The study highlights two passive strategies, thermal mass and natural ventilation, particularly effective for improving energy efficiency. On a broader scale, incorporating renewable energy in architectural design supports environmental sustainability, social recognition, and economic benefits. The authors recommend policy measures to promote renewable technology use in new construction and suggest that collaboration among policymakers, engineers, and architects is essential to advancing sustainable architecture in the UK, paving the way for a more resilient and eco-friendlier built environment.

Keywords

Renewable Energy and Sustainable Architecture, UNEP (United Nations Environment Program), Like BREEAM (Building Research Establishment Environmental Assessment Method), LEED (Leadership in Energy and Environmental Design), LCA (Life Cycle Assessment) Model, ZEB (Zero Energy Building) Model, UK GBC (UK Green Building Council), Biomass Systems, Geothermal Energy, Wind Energy, Solar Energy, IRENA (International Renewable Energy Agency), UK Green Building Council, TAM (Technology Acceptance Model)

1. Introduction

1.1. Introduction to the Topic and Issues

Renewable energy and sustainable architecture are key to global efforts against climate change and achieving carbon neutrality in construction. As environmental degradation and resource depletion rise, the demand for sustainable solutions grows [1]. Sustainable architecture, a newer concept, focuses on energy efficiency, resource conservation, and renewable energy [2]. The UN Environment Program estimates that the construction sector accounts for 38% of global carbon emissions. Developed countries are leading in adopting green architecture as part of climate adaptation strategies. In the UK, reducing environmental impact is crucial as the country aims for net zero emissions by 2050 [3].

Integrating renewable energy in buildings offers environmental and economic benefits. It can lead to long-term cost savings through renewable technologies and energy-efficient designs [4]. However, high upfront costs of renewables, such as wind turbines and solar panels, pose significant barriers, especially for smaller projects [5]. Regulatory challenges also exist, as some building codes and local laws are not designed to accommodate renewable technologies [6]. Additionally, the technical expertise needed to design and build energy-efficient, renewable-powered buildings requires specialized knowledge from architects, engineers, and construction professionals [7].

In the UK, fostering collaboration among architects, professionals, policymakers, and renewable experts will help address supply chain issues. This involves adopting strategies that promote renewable energy use while keeping it affordable. By examining current trends, case studies, and expert insights on the challenges and opportunities, this research aims to understand how renewable energy can advance sustainability in the built environment [8].

1.2. Statement of Research Problem

The primary concern in this research is the absence of integrating renewable energy technologies into sustainable architecture in the UK [5]. Understanding such barriers and finding viable solutions would be critical in achieving sustainability in construction and fulfilling all UK climate change mitigation obligations.

1.3. Rationale

Buildings account for nearly 40% of the UK's energy consumption, making innovative measures to reduce their carbon footprint essential. Integrating renewable energy into building design is a key strategy for lowering energy use [1]. This research examines how diverse renewable technologies—solar panels, wind turbines, and geothermal systems—are incorporated into sustainable architecture, aiding policymakers, architects, and builders in creating more energy-efficient, eco-friendly structures.

Even though most renewable energy systems can save future costs, initial costs, such as those of solar panels and wind turbines, are just too expensive for most developers and property owners [9]. Additionally, many architects and construction professionals lack the expertise and workforce necessary to design and build energy-efficient, renewable-integrated projects [10]. These insights are vital for academics, policymakers, and industry professionals in construction and renewable energy [11].

This study also aims to guide policymakers in reforming regulations to better support renewable energy adoption in construction. The UK government has introduced initiatives like Energy Performance Certificates and the Future Homes Standard to promote energy efficiency.

Renewable energy-efficient buildings offer tangible benefits, including lower energy bills, reduced carbon emissions, and improved air quality [8]. This research explores the potential of renewable energy in advancing sustainable architecture and outlines how the construction sector can develop environmentally friendly, economically viable buildings [5]. The increasing global emphasis on sustainable construction underscores the urgency of adopting these methods.

1.4. Research Aims & Objectives

1.4.1. Research Aim

The crux of this research is to identify contemporary trends, challenges, and prospects to address the environmental impacts that buildings and constructs impose upon nature and make sustainable development a reality in the UK's building and construction sector.

1.4.2. Research Objectives

- The study aims to evaluate the extent and nature of sustainable architecture knowledge and awareness among the country's construction professionals and architects, with a focus on green design and construction processes.
- The study aims to identify the barriers that hinder the implementation of renewable energy technologies in sustainable architecture within the UK.
- We are also examining the role of UK government policies and conventions in promoting the uptake of renewable energy in sustainable construction.
- We aim to ascertain how construction professionals and architects envision the future impact of integrating renewable resources into sustainable architecture in the UK.
- We are also evaluating the involvement of stakeholders in proposing measures to tackle the difficulties associated with the integration of sustainable architecture and renewable energy technologies.

1.5. Research Questions

- What strategies can be adopted to increase the use of renewable energy in architectural practices, and what role might policies and regulations have in this?
- What hampers the employment of renewable energy resources in sustainable architecture, and how can this be reduced?

- Which case studies are perceived as the best in integrating renewable energy into architecture in the UK, and why were they so successful?
- Which renewable energy sources are the most practical for sustainable architecture, and what are their benefits and downsides?
- How does the UK practice sustainable architecture in today's fast, technologically paced society, and what does the future hold for this architecture?

2. Background/Context

2.1. Contextual Discussion of the Situation or Issue

The role of the UK's renewable energy policies, including Building Regulations Part L, Feed-in Tariffs and the Renewable Heat Incentive, in advocating green architecture can neither be overemphasized nor underestimated. The goal of these standard policies rests on reducing carbon emissions in the generation of energy as well as promoting energy efficiency by incorporating renewable technologies in the built environment [1]. According to Allana & Ananias [12], even though these policies are well-meaning, their complicated rules, gaps in regulations, and lack of attention to less common technologies like biomass and tidal energy have made it challenging for architects and developers to fully use these options in their designs.

2.2. Business Environment Overview

The construction industry is often hailed as the bastion of economic development, as it lays the required foundations for a person in terms of housing, commercial, and public infrastructure. Globally, this sector has reportedly been responsible for approximately 38% of all carbon emissions [10], and in the UK, it accounts for around 40% of total energy consumption, as highlighted by the Climate Change Commission.

Awareness of industry-related ecological footprints is currently placing significant demands on the industry regarding sustainability. Among such initiatives is the 2008 Climate Change Act, bindingly draughted to engrave in law the obligation of at least an 80% reduction in emissions of greenhouse gases from 1990 levels by 2050 [3].

The UK government has initiated several regulatory frameworks, such as the Future Homes Standard, which is likely to be implemented in 2025, where new houses will have reduced carbon emissions by about 80% compared to existing standards. Buildings also employ an energy performance certificate to measure and incentivize energy performance. An energy performance certificate is also another measure and incentive tool for energy efficiency in buildings [2].

As a result, this need was met mainly by advances in renewable energy technology in creating systems with increasingly higher efficiencies at lower costs [1]. Incorporating such technologies into building design can result in energy-positive structure buildings that generate more energy than they consume from the grid.

2.3. Contextual Discussion of the Issue in Relation to Business Operations and Market Conditions

Renewable energy in construction offers opportunities and threats from the perspective of business operations. For instance, such buildings could be designed with solar panels, wind turbines, or even other geothermal systems, which have very bright prospects of saving operating expenses in the future and increasing energy efficiency [13]. One of the major obstacles affecting the transition to sustainable architecture is the high upfront investment that these technologies require [4]. Applications of renewable energy systems can save much money over time, but first, they are costly—particularly for smaller firms or developers who operate on very tight budgets.

Obtaining planning permissions for renewable energy installation facilities, large solar farms, or wind farms can be challenging due to local resistance or grid connectivity issues [5]. Moreover, building regulations regarding renewable energy integration still need to mature, which creates uncertainty for developers or architects attempting to incorporate these systems into their designs [5]. Another severe issue is the skill gap in construction. However, there is an alarming shortage of architects, engineers, and construction professionals who are adequately trained in the latest green building technologies [8]. The long-term benefits of such integration with renewable energy include reduced operational expenses, increased self-sufficiency regarding energy, and added value to those properties [14].

3. Literature Review

Literature review is one of the most essential chapters in any research project, systematically comparing available theories, studies, and concepts regarding the research. The primary objective is to situate the existing literature, pinpoint research gaps, and enhance the credibility of upcoming research. The review should provide a clear summary of the key theories and models that support the use of renewable energy in sustainable architecture, like BREEAM (Building Research Establishment Environmental Assessment Method) and LEED (Leadership in Energy and Environmental Design) [15]. It details the evolution of the concepts of sustainable architecture, energy efficiency, and renewable energy sources at a global level and in the UK. Furthermore, this review discusses the significant economic, technical, and regulatory challenges facing the adoption of renewable energy technologies by the UK construction industry.

3.1. Critical Review of Underlying Concepts and Models

This section critically reviews the key theories and models influencing sustainable architecture and the adoption of renewable energy. The bases these models provide suggest an understanding of how energy efficiency and sustainability principles can be successfully inculcated into modern building practices. Sustainable architectural design minimizes the environmental impact of buildings through efficient use of resources, waste minimization, and optimization of energy performance [5].

The LCA (life cycle assessment) model allows architects and construction professionals to appreciate the long-term sustainability of their work and consider those areas where renewable energy technologies can be integrated to reduce the overall carbon footprint of the building [15]. The ZEB (zero energy building) model ensures that a building generates as much energy from renewable sources as it consumes.

3.1.1. Sustainable Architecture: Key Concepts and Definitions

According to UNEP, sustainable architecture refers to designing buildings harmoniously with the natural environment, using resources efficiently, and minimizing pollution [16]. The approach has been directed toward creating functional, pleasing structures that contribute positively to environmental sustainability through reduced energy use, minimizing waste, and encouraging the use of renewable resources.

Key Principles of Sustainable Architecture

Energy-efficient buildings save resources in operational costs and reduce dependence on non-renewable energy sources, which is an urgent necessity to address climate change. According to the statistics from the International Energy Agency, nearly 40% of all energy consumed on Earth and one-third of carbon emissions come from the building sector. Over the last few decades, the focus has shifted from pure energy efficiency to integrating renewable energy technologies like geothermal power, wind turbines, and solar panels into building design.

The governments of the UK are encouraged, through the Feed-in Tariff and the Renewable Heat Incentive, to promote the uptake of solar and other renewable technologies to create energy-positive buildings that consume less than they generate. Equally, a giant percentage of projects, both in the public and private sectors, in the UK aim for high BREEAM ratings to demonstrate sustainability and thereby secure environmentally conscious tenants and buyers [17]. The development and existence of green building certification systems help architects and builders during the design and building process. They act as a marketing tool that allows projects to demonstrate their commitment to sustainability.

The Role of Material Selection in Sustainable Architecture

An important dimension of sustainable architecture embraces using renewable, locally sourced materials with low embodied energy and minimum environmental impact. Architects can reduce waste and enhance resource efficiency in making choices concerning materials with minimal environmental impact. The use of the cradle-to-cradle principles enables the architect and designer to construct buildings that meet the needs of the present with considerations for the future.

Indoor Environmental Quality and Health Considerations

Sustainable architecture emphasizes interior environmental qualities, including air quality, natural lighting, thermal comfort, and acoustics. Research indicates that improving indoor environmental quality can enhance productivity and reduce absenteeism in commercial settings. Incorporating natural materials, greenery, and exposure to nature can also significantly boost occupants' psychological and emotional well-being [18]. Biophilic design, which integrates natural elements into building architecture, aligns with sustainability goals by enhancing indoor environmental quality and fostering a connection with nature.

Policy Frameworks and Government Initiatives

The UK government's commitment to achieving net-zero carbon emissions by 2050 has led to the implementation of stringent building regulations that promote energy efficiency and renewable energy integration. For example, the Future Homes Standard, set to be enforced from 2025, requires new homes to emit 75% - 80% less carbon dioxide compared to current standards. The UK Green Building Council (UK GBC) plays a vital role in advocating for sustainable building practices by fostering collaboration among stakeholders and promoting green building initiatives.

Challenges in Sustainable Architecture

A primary obstacle is the high initial cost of renewable energy technologies and sustainable materials, which discourages many developers and property owners from pursuing green building projects [18]. Although long-term savings from energy-efficient designs can outweigh these upfront expenses, the initial financial barrier remains significant. Additionally, limited technical expertise and skills hinder the adoption of sustainable architecture. Addressing these challenges offers an opportunity for stakeholders to collaborate and promote a more sustainable built environment [17] [19].

3.1.2. Renewable Energy in Sustainable Architecture

Renewable energy empowers global initiatives on climate change to develop efficient solar photovoltaic panels, wind turbines, geothermal heat pumps, biomass systems, and several others that can dramatically alter the carbon footprint of any structure and enhance energy security and resilience [16].

Biomass Systems in Sustainable Architecture

Biomass energy from organic sources, including wood, agricultural waste and algae, offers a renewable way to generate power and increase heat. Despite the vast array of solar, wind, and geothermal energy sources leading the way for sustainable architecture in the UK, there is an opportunity to utilize biomass in rural or agricultural areas. It significantly contributes to waste reduction and generates significant sustainable energy for residential and commercial heating applications, thereby improving the overall energy balance of the UK [20]. According to Allana and Ananias [12], this system stands out among the unique considerations of sustainable architecture, particularly in locations with flourishing agricultural activity, such as remote sites. Biomass is challenging relative to solar and wind in terms of emissions and feedstock availability [20]. Nevertheless, the use of biomass can help to diversify energy, especially when combined with combined heat and power (CHP) systems in sustainable developments.

Geothermal Energy in Sustainable Architecture

Geothermal energy harnesses the heat from the ground for heating and cooling purposes. Large establishments or constructions in the United Kingdom, where there is a constant need for a steady energy supply, have widely used it. As Mali [21] highlight, in winter, the system captures heat from the ground, while in summer; it releases it, lowering the energy intake for heating and cooling by up to 70%. Since it has more than 25 years of durability, it can be regarded in the long run as a capital investment by the property owner, especially in reducing carbon emissions from buildings and contributing to national and global sustainability goals [22].

Wind Energy in Sustainable Architecture

Due to space and aesthetic issues, more wind energy must be used, creating a niche for different building designs. Smaller wind turbines, situated atop or within more substantial developments, could harness wind energy to provide electrical energy supplements. Although most cities have restrictions on tapping energy from wind, such technology is increasingly applicable in rural or coastal areas where wind currents flow at higher velocities [23]. Micro-wind turbines produce pure, renewable energy and are therefore worth considering for inclusion in green architecture, especially where not many renewable energy sources are available.

For example, when a building is constructed on a site with very high wind potential, the energy produced using micro-wind turbines would suffice to meet the entire energy-operating requirement of the building, thereby contributing to energy self-sufficiency [24]. Furthermore, integrating wind into solar PV systems and other renewable technologies can go a long way toward building a more secure and reliable energy system.

Solar Energy in Sustainable Architecture

Solar energy has extensive applications in the UK, mainly because of technological advancements, government subsidies, and reductions in the prices of solar PV systems. According to the UK Department for Business, Energy & Industrial Strategy (2020), by 2019, solar PV installations had reached an installed capacity of nearly 13.5 GW, positioning it as one of the country's most emerging renewable energy segments. They can be integrated into building designs innovatively: rooftop installations, solar awnings, and building parts are covered by solar facades [25]. Other significant financial benefits include reduced utility bills and insulation against energy price fluctuations.

Challenges in Integrating Renewable Energy

Although renewable energy technologies have many good points for building sustainably, it is still really hard for them to be used by the construction industry a lot [26]. A 2020 report by the International Renewable Energy Agency (IRENA) says that while solar panels have gotten much less expensive in the last decade, installing them is still costly, and owners may be hesitant due to inadequate technical skills in the construction industry [27]. Collaboration between schools, industry, and government is needed to bridge this skills gap and share best practices [28]. Regulatory barriers hinder the large-scale use of renewable energy in building design [29]. UK government schemes like the Feed-in Tariff and Renewable Heat Incentive have promoted renewable energy installations. Integrating renewable energies is essential for sustainable architecture [26]. Technologies related to renewable energies provide opportunities for reducing carbon footprints and achieving energy independence in buildings [27].

3.1.3. Policy and Regulatory Frameworks Supporting Sustainable Architecture

Government policies and regulations greatly facilitate the emergence of sustainable architecture, with increasing conversion to renewable energy [30]. The UK's Future Homes Standard would ensure that by 2025, all new homes built in the UK are energy-efficient and can be heated with low-carbon heat sources [31]. Apart from national policies, the UK also uses international frameworks implemented for carbon emissions reduction and sustainability. The Paris Agreement commits countries to a rise in global warming below 2˚, which was signed in 2016, and the UK is committed to reducing carbon emissions by at least 68% by 2030 on 1990 levels. A report by the UK Green Building Council showed that even though many developers and contractors realize the importance of sustainability, a lack of clear guidelines and financial incentives usually presents difficulties in practicing it on a larger scale [31].

3.1.4. Literature Gaps

Incorporating aesthetic and functional features

In all forms of integration, aesthetic concerns receive the least attention regarding renewable energy technologies [10]. Most homeowners and developers tend to evade such renewable energies because they make their houses 'ugly' and compromise the architectural integrity of the building [3]. These issues need to be fixed by thinking about how city planning can help people accept renewable energy systems more easily, like creating specific areas for them or providing rewards for making these technologies look good in new city projects.

Policy implementation

Policies encouraging sustainable design and how to consider them when implementing renewable energy sources are proliferating in the UK. However, a considerable gap remains between the policy statements and pragmatic ground realities regarding actual implementation [30]. For instance, Building Regulations Part L lays down minimum requirements for energy performance in new buildings. However, the extent to which SMEs in the building sector can comply with these regulations remains unexplored [28].

Policies and barriers to applying regulations, particularly in small companies with few resources or skills to work out compliance requirements, must be examined [30]. The challenges small and medium-sized enterprises (SMEs) face in developing countries for using renewable energy technologies, like high initial costs, difficulty getting funding, and lack of technical skills, can help identify ways to overcome these challenges and improve compliance. Regional authorities may adopt or apply national policies differently; such disparities in the regional implementation of policies can worsen these barriers even more [1]. There is a need for further study to understand these regional differences in implementing policies fully and their consequences for the success of different projects in sustainable architecture.

Urban settings

In the UK, renewable energy systems needing large tracts of land are not feasible in a densely populated city. Building, regulatory, and space restrictions further hinder the expansion of such systems [15]. Urban areas have limited rooftop space available for solar panel installation. Local resistance to changes in urban aesthetics, along with existing zoning regulations, prevents the integration of these systems [14]. It has spurred scholarly interest in retrofitting old buildings to achieve energy efficiency without compromising their efficiency or visual aesthetics [8]. Future studies will explore the introduction of sustainable architecture in the densest urban environments.

Social and economic factors

In the UK, factors hindering these systems' integration include income differences, regional inequality in access to technology, and the varying effectiveness of government schemes that have yet to be investigated [7]. Incentives like tax credits or grants to encourage renewable energy development may be more available to higher-income households and commercial developers than low-income communities [10]. Assessing green mortgage programs, feed-in tariff schemes, local tax deductions, and government grants would be required to drive uptake [7]. The value of public education campaigns in conveying such constructions' environmental and economic advantages should be accounted for.

Long-term empirical data on the reduction of carbon emissions needs to be collected.

Energy-efficient technologies and renewable energy systems in buildings have been a topic of substantial research, ranging from passive design geothermal energies to photovoltaic solar energy systems [19]. There is, however, minimal empirical long-term data on the efficacy of such alternatives concerning carbon emission reductions [30]. Most of the reviewed literature has not included long-term empirical evidence for reductions in carbon emissions and energy savings over long periods [5].

Contemporary research should consider that these energy systems, like solar or wind turbines, tend to deteriorate in performance after 20 or 30 years, eventually affecting their efficiencies and, hence, their capacities to produce energy and carbon savings [32]. Technological advances further determine the performance of the systems, changes in climate patterns, and various shifts in government policies [19]. Long-term studies are essential in providing empirical evidence on how renewable energy systems continue operating in actual situations.

4. Methodology

The methodology chapter is the foundation of any research, outlining the systematic approach used to address the research questions. It details research design, data collection methods, and strategies for data analysis. As Pandey [33] emphasize, methodology defines the theoretical framework within which the research is conducted, guiding the selection of appropriate techniques to ensure the findings are reliable and valid.

This chapter critically justifies the chosen research philosophy, including ontological, epistemological, and axiological perspectives that underpin the study. It specifies whether the research is exploratory, explanatory, or descriptive, and whether the approach is inductive, deductive, or abductive. Additionally, it explains the data collection methods—such as interviews and surveys—along with the rationale for their selection. The chapter describes the target population, sampling process, and data analysis procedures. Ethical considerations, potential limitations, and measures taken to ensure the credibility and validity of the findings are also addressed.

4.1. Critical Discussion of Research Design

4.1.1. Research Philosophy-Ontology, Epistemology, Axiology

The researcher's philosophical stance influences both the approach to and interpretation of the study [34]. Axiology pertains to the role of values in research, which is particularly significant in sustainability studies, given the ethical considerations related to environmental stewardship. Epistemology concerns the nature and scope of knowledge; in this context, it facilitates the exploration of perceptions, experiences, and policies influencing stakeholder decisions regarding sustainable practices—especially within the economic, environmental, and social dimensions of sustainability and renewable energy. Ontology relates to the nature of reality and is pertinent to understanding perceptions about the growth and adoption of renewable energy practices, as perceived by architects, policymakers, and users.

4.1.2. Research Approach-Inductive, Deductive, Abductive

The three primary research approaches—inductive, deductive, and abductive—are selected based on the nature of the research questions and their relationship with theory and empirical evidence. This study adopts an inductive approach, developing new theoretical insights from field observations. An inductive approach is suitable for exploring the adoption of renewable energy, as it provides flexibility in data collection, pattern recognition, and the formulation of models or theories relevant to sustainable architecture. According to Heit [35], inductive reasoning involves moving from specific observations to broader generalizations and theories. Specifically, this approach enabled an examination of how engineers, policymakers, and architects interact with renewable energy solutions, allowing the researcher to identify factors that may hinder or facilitate the integration of sustainable practices [36].

4.1.3. Research Design-Exploratory, Explanatory, Descriptive

This study adopts an exploratory research design, suitable for investigating an under-researched area or a multifaceted phenomenon. According to Žukauskas [37], exploratory research is appropriate when there is a need to clarify understanding of an issue, especially in the absence of definitive answers. Sustainable architecture integrated with renewable energy is an evolving field; thus, exploratory design offers flexibility in examining various factors and stakeholder perspectives.

The exploratory approach aligns well with the inductive methodology, as it focuses on identifying patterns and relationships rather than testing existing theories. It allows for an in-depth investigation of how sustainable architecture is implemented in the UK, the integration of renewable energy technologies, and the opportunities and challenges associated with these processes. Additionally, a descriptive design complements this by documenting the current state and emerging trends in renewable energy adoption within UK architecture.

4.2. Methods

4.2.1. Explanation and Justification of the Methods

A qualitative approach was chosen to explore stakeholders' motivations, perspectives, and experiences in implementing renewable energy technologies. Gerring [38] highlights that qualitative methods are ideal for studying complex social phenomena where context and participant viewpoints are essential.

Data collection involved surveys and semi-structured interviews. Surveys provided standardized data across a broader population, revealing general trends in renewable energy adoption in UK architecture [39]. Semi-structured interviews offered in-depth insights into decision-making processes and challenges faced by stakeholders [40]. Together, these methods support the study's aim of generating new understanding and detailed perspectives.

4.2.2. Explanation of the Construction of the Method

Interview and survey methods were carefully constructed to ensure they adequately addressed the research questions. We designed semi-structured interviews to explore the research's central themes of integrating renewable energy technologies into architectural designs. Each interview started with some general questions about the experience of participants and their role in the sustainable architecture field and then moved to specific questions concerning participants' experiences with renewable energy technologies. For surveys, the combination of closed-ended and open-ended questions guaranteed that the surveys captured both quantitative and qualitative data.

4.2.3. Delivery Plan of the Research Method

The researcher conducted face-to-face or virtual interviews with UK-based engineers and architects involved in sustainable building projects. These interviews were scheduled over six weeks, each lasting approximately 45 minutes to an hour. Participants received briefing sheets outlining the research purpose and topics beforehand.

Additionally, questionnaires were distributed via email to a broader sample of policymakers, engineers, and architects identified through professional associations, industry networks, and government agencies. Online tools such as Google Forms and SurveyMonkey facilitated data collection over four weeks, with follow-up reminders sent to improve response rates. The entire data collection process lasted approximately eight weeks, providing sufficient time for analysis and interpretation.

4.2.4. Piloting

A pilot study was conducted beforehand on a small group of participants, testing the research methods and refining the questions and survey design to ensure they were reliable and valid.

4.3. Population & Sample

4.3.1. Population

The population of this research included professionals actively involved in integrating renewable energy systems and sustainable architecture in the UK. They included renewable energy experts, policymakers, architects, and construction professionals who were stakeholders or had direct experience in implementing, constructing, and designing buildings using renewable energy technologies. In a UK context where the renewable energy markets are experiencing tremendous growth, professionals in this category would have been familiar with the best practices, challenges, and current trends [19]. Similarly, these professionals drive sustainability goals within the sector, making them suitable candidates for this research.

4.3.2. Sample Size

The sample size of approximately 45 participants was chosen to allow sufficient diversity of perspectives for the qualitative data collection and analysis while ensuring they are well managed. The participants were selected based on their willingness to participate in an interview or survey, their involvement in projects prioritizing renewable energy integration, and their experiences in the field. The sample size and scope were selected as representative and focused for in-depth insight. According to Subedi [41], this sample size was reasonable for qualitative research as it permitted comprehensive thematic analysis while guaranteeing diversity in perspective.

4.3.3. Sampling Techniques

We employed the purposive sampling technique in this research, a nonprobability approach commonly used in qualitative studies [42]. It enabled the researcher to obtain valuable information regarding the topic. Equally, snowball sampling allowed initial participants to recommend other professionals in their networks who would meet the research criteria [43].

4.3.4. Data Analysis

Thematic analysis was used to interpret the data. Initially, data was transcribed and organized into systematic categories to facilitate coding. NVivo software supported the analysis by enabling coding, categorization, and segment retrieval. The process began with open coding to identify key ideas and statements, followed by axial coding to establish relationships among codes and expand themes. The final step involved developing narratives that linked the identified themes to the research questions and theoretical framework.

4.3.5. Validity and Reliability

We applied triangulation to enhance validity by using multiple data sources, interviews, and questionnaires [44]. It guaranteed the consistency of the conclusion across various data sources and the accurate representation of stakeholders' viewpoints. A straightforward, systematic approach to collecting and analyzing data ensures reliability [45]. We refined survey instruments and structured interviews based on pilot feedback to minimize research inconsistencies in participant interpretation of questions [44].

4.3.6. Limitations of the Research Design

Some professionals declined participation due to personal reasons. The reliance on self-reported data may have introduced bias, with some participants providing less than fully candid responses. The sample's representativeness might not capture the full range of views across all professionals. Additionally, the qualitative nature of the study limits the generalizability of its findings.

4.3.7. Research Ethics

The University of Gloucestershire adhered to ethical guidelines to ensure respect for participant rights and dignity. The university's ethics committee approved the research prior to data collection. Participants received full information about the study's purpose, procedures, and potential risks, and their informed consent was obtained. They were also informed of their right to withdraw at any time. Confidentiality and anonymity were strictly maintained throughout the research.

5. Findings

5.1. Presentation of the Findings

The findings presented in this chapter are based on data gathered from two key participant groups: architects and construction professionals and renewable energy experts and policymakers.

5.1.1. Findings from Architects and Construction Professionals

Sample Overview

20 participants were surveyed and interviewed from a diverse range of companies, the majority of which are involved in green architecture initiatives and sustainable building practices.

Thematic Areas Identified

Thematic Area 1: Perceptions of Sustainable Architecture

Most architects and construction professionals generally view sustainable architecture in a positive light. Regarding understanding the principles of sustainable architecture, 80% of the respondents rated their knowledge "high" on the Likert scale, 4 - 5, indicating high expertise and adherence to sustainability in design practices. A further 15% described their understanding as "moderate" (3), suggesting that, while they recognize the importance of sustainability, their depth of knowledge may be more limited. Only 5% rated their understanding as "low" (1 - 2), highlighting a small minority that may need additional training or resources.

Table 1: Perception of Sustainable Architecture, illustrates that most respondents are aware of sustainable architecture and find it relevant to the future of the construction business. Most professionals shared increased awareness of the importance of lessening environmental impact with building design.

Table 1. Perception of sustainable architecture.

Understanding Level	Percentage of Respondents
High Understanding (4 - 5)	80%
Moderate Understanding (3)	15%
Low Understanding (1 - 2)	5%

Thematic Area 2: Integration of Renewable Energy Technologies

An overwhelming number identified solar energy as the most adopted technology, with many respondents integrating it into their design practices. Other technologies that were mentioned included wind and geothermal systems, but they were adapted to a lesser extent than solar energy. Cost-effectiveness and ease of installation were the primary justifications for choosing solar technology.

Table 2: Frequency of Renewable Energy Technology Integration and Figure 1: Frequency of Renewable Energy Technology Integration As shown on the bar graph, solar energy was the first choice, which reflects the trend in the industry where photoelectric systems have become more available at reasonable prices. Wind and geothermal systems were less utilized but were specified for specific projects that required such systems.

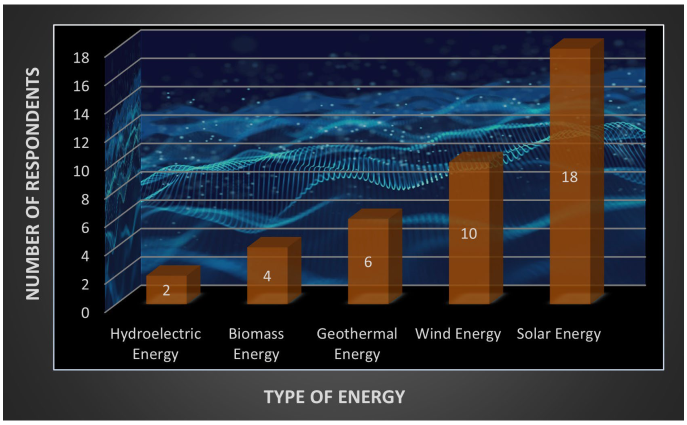

Figure 1. Frequency of renewable energy technology integration.

Table 2. Frequency of renewable energy technology integration.

Renewable Energy Technology	Number of Respondents Using Technology	Percentage of Total Respondents
Hydroelectric Energy	2	10%
Biomass Energy	4	20%
Geothermal Energy	6	30%
Wind Energy	10	50%
Solar Energy	18	90%

Thematic Area 3: Barriers to Implementation

Key barriers frequently cited include high initial costs, limited technical expertise in renewable technologies, and regulatory challenges. The high upfront expense is especially burdensome for smaller firms and projects with tighter budgets. Many professionals emphasized the need for increased training and skill development in renewable energy systems. Additionally, complex and outdated regulations were identified as significant deterrents to adopting innovative, sustainable solutions.

Table 3: Barrier for Implementation and Figure 2: Percentage of Respondents indicate that, at least for smaller projects, cost is the biggest hurdle to integrating renewable energy technologies. The respondents pointed out that even if long-term savings are foreseen, often high expenses, in the beginning, stand in the way of persuading clients to go on with such investments. Some professionals complained about the inadequacy of skills, especially in newer technologies, which delay project implementation.

Table 3. Barrier for implementation.

Barrier for Implementation	Percentage of Answers
Regulatory and Approval Challenges	20%
Lack of Technical Expertise	35%
High Initial Costs	45%

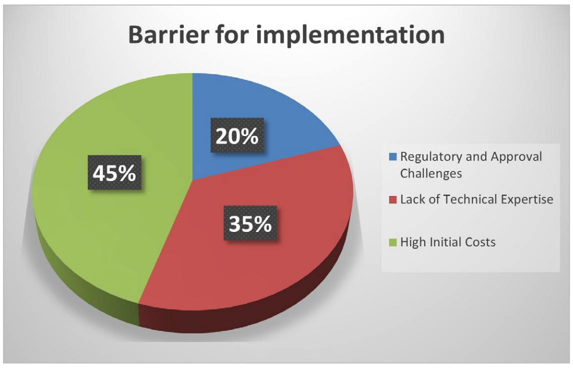

Figure 2. Percentage of respondents.

Thematic Area 4: Future Trends and Expectations

90% of respondents believed there would be a greater presence of renewable energy in architectural designs over the next decade due to energy-efficient materials and growing regulatory pressure to reduce carbon footprints. Many professionals highlighted the shift in public awareness and increasing demand for more environmentally responsible buildings as furthering this change. Furthermore, 75% of respondents predict that changes in legislation and government incentives will be one of the most decisive factors, speeding up the integration of renewable energy technologies and further assisting sustainable architecture.

Table 4: Expectations of Renewable Energy Adoption in Architecture and Figure 3: Expectations of Renewable Energy Adoption in Architecture show that the respondents believed that the adoption of renewable energy would increase in the following 10 years. The optimistic projection underlines the fact that there is an industrial consensus to move towards more sustainable designs with continuous technological advancement and policy initiatives.

Table 4. Expectations of renewable energy adoption in architecture.

Importance of Sustainability	Number of Respondents	Percentage of Total Respondents
Very Important	24	80%
Important	4	13.3%
Neutral	2	6.7%
Not Important	0	0%
Not at all Important	0	0%

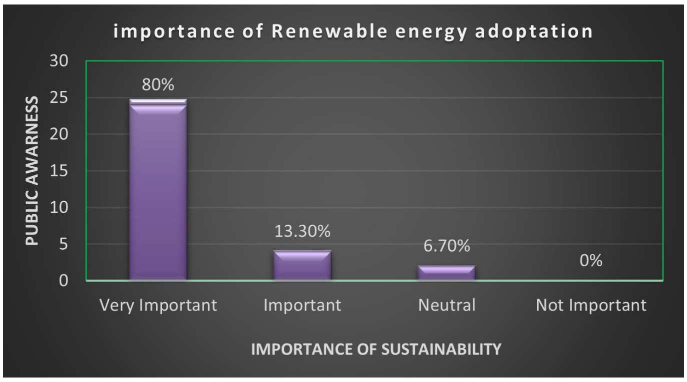

Figure 3. Expectations of renewable energy adoption in architecture.

5.1.2. Findings from Renewable Energy Experts and Policymakers

Sample Overview

15 participated, and the questions they answered focused on the policy and regulatory mechanisms of integrating renewable energies into building designs throughout the UK. They explained how policy has affected industrial practices and the barriers in national-level initiatives promoting renewable energies.

Thematic Areas Identified

Thematic Area 1: Policy Impact on Sustainable Architecture

Renewable energy experts identified government policies as a key driver. For example, 70% of panelists rated UK building regulations as highly influential. They noted that incentives such as tax breaks and funding programs, along with updated standards emphasizing energy efficiency and sustainability, have significantly encouraged the adoption of green technologies in building design. Experts also emphasized the need for policies to be regularly revised to keep pace with technological advances in renewable energy, ensuring continued support for sustainable architecture.

Table 5: Perceived Policy Impact on Sustainable Architecture and Figure 4: Perceived Policy Impact on Sustainable Architecture illustrate that policy continues to be a major driving force for green construction, with renewed regulations pushing the industry towards sustainability.

Table 5. Perceived policy impact on sustainable architecture.

Policy Impact Rating	Percentage of Respondents
Low Impact (1 - 2)	10%
Moderate Impact (3)	20%
High Impact (4 - 5)	70%

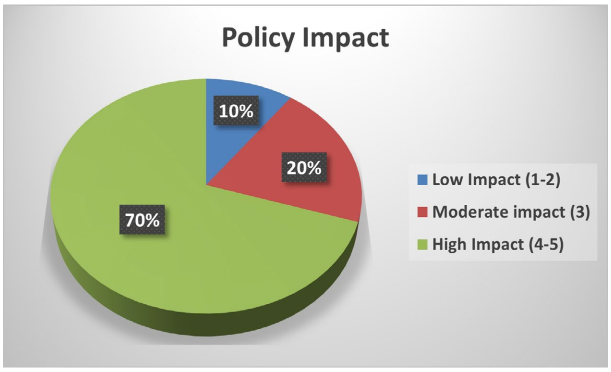

Figure 4. Perceived policy impact on sustainable architecture.

Thematic Area 2: Challenges in Renewable Energy Regulation

Experts highlighted regulatory inflexibility as a significant barrier to wider adoption of renewable energy in architecture. They expressed concern that current policies are not keeping pace with technological advancements, thereby impeding innovation. One respondent noted that existing regulatory frameworks lag behind the development trajectory of emerging technologies, limiting deployment. Additionally, complex and lengthy approval processes increase project costs and discourage stakeholders from adopting newer, more efficient solutions.

Thematic Area 3: Importance of Stakeholder Collaboration

Eighty-five percent of respondents emphasized that effective cross-sector communication and partnerships are essential for successfully integrating renewable energy technologies into building design. They highlighted the importance of ongoing dialogue between technical experts and regulatory bodies to address challenges such as evolving standards and the practical deployment of new technologies. Such collaboration fosters innovative solutions to sustainability and regulatory demands, facilitating smoother installation processes for renewable energy systems.

Thematic Area 4: Recommendations for Future Policy

Most experts agree that enhancing economic incentives, such as tax breaks and grants, is crucial for promoting green building projects. They also advocate for streamlining approval processes to accelerate renewable energy installations and increasing government investment in research and innovation for sustainable technologies. Many believe the current policy framework is insufficient to meet the rising demand for sustainable architecture, emphasizing the need for significant policy reforms to further advance renewable energy integration in building construction.

Participants Overall Perspectives on Biomass and Other Less Common Methods

While stakeholders discussed solar, wind, and geothermal energy primarily, biomass was not at the forefront of their discussion as a priority focus within their answers. This aligns with current trends in UK architectural practices, which do not heavily utilize biomass. Nevertheless, the literature indicates that biomass, especially for rural and off-grid contexts, has vast potential to enable the incorporation of renewable energy in sustainable architecture.

6. Discussion

6.1. Critical Research Objectives and Discussion of the Findings in Contrast to the Models and Concepts Discussed in 3.2

6.1.1. Overview of Research Objectives

Objective 1: To assess the level of knowledge and awareness of sustainable architecture among construction professionals and architects regarding green design and construction processes.

Findings indicate that most professionals have a high level of awareness and understanding of sustainable architecture principles and technologies [26]. The sector has moved beyond early adoption, with sustainable architecture now in the early majority stage of integration [16]. This reflects widespread acceptance of theoretical principles and recognition of sustainability's importance [32]. However, as discussed later, practical implementation remains hindered by financial and regulatory barriers despite this awareness.

Objective 2: Determining the factors that impede the adoption of renewable energy technologies for sustainable architecture in the UK.

The study identified key barriers, including high initial costs, limited technical expertise, and regulatory challenges, evaluated through the Triple Bottom Line framework. Despite industry awareness of their benefits [31], these barriers restrict full deployment of renewable technologies. While professionals recognize the long-term advantages, short-term financial and technical hurdles often overshadow these benefits [29]. Consequently, immediate economic interests tend to oppose a long-term sustainability agenda

Objective 3: Examining the role of UK government policy and conventions in terms of renewable energy uptake in promoting sustainable construction

Several respondents acknowledged the significant role of policies and regulations in adopting renewable energy in building construction. Moreover, the survey indicated that regulatory frameworks are usually inflexible and need help to keep up with emerging technologies [26]. In turn, it leads to institutional isomorphism, in which the regulatory environment is important but sometimes gets in the way because it is rigid [16]. Therefore, the achievement of this objective necessitates the development of more dynamic and flexible policies to enhance the integration of renewable energy sources.

Objective 4: Determining how construction professionals and architects envision the future influence of incorporating renewable resources in sustainable architecture in the UK.

Field survey data indicate that perceived usefulness and ease of use significantly influence acceptance of new technologies [19]. Respondents expressed confidence that improved technology, coupled with more favorable government regulations, will promote wider adoption of renewable energy in architectural design [9]. Most believed that, due to increasing efficiency and regulatory pressures to cut carbon footprints, renewable technologies will see expanded use in the next decade. Despite current challenges, there is a strong optimistic outlook among professionals regarding the future integration of renewable energy in architecture [31], reflecting a positive future trajectory based on professional expectations.

Objective 5: Assessing stakeholder participation in recommending action to address the challenges of integrating sustainable architecture and renewable energy technologies.

The results have eminently shown that barriers to integrating renewable energy—both technical and financial—can only be overcome by the collaboration of stakeholders such as architects, construction professionals, and policymakers [19]. The findings also resonate well with the Collaborative Planning Model, which stipulates that there is a need for cooperation among diverse actors. Specifically, most respondents supported the idea that collaboration can enable the integration of renewable energy through the pooling of expertise and addressing the prohibitive financial costs [9]. Therefore, it pinpoints the imperative of multi-stakeholder collaboration as key to the future success of sustainable architecture.

6.1.2. Research Themes

Theme 1: Perceptions of Sustainable Architecture

Awareness and understanding of sustainable architecture among professionals are high, with 80% indicating strong comprehension, aligning with Rogers' Diffusion of Innovation Theory that emphasizes awareness as a precursor to adoption. The industry has moved beyond early adopters, now in the early majority phase [5]. Despite this progress, practical implementation remains hindered by financial and regulatory barriers. While environmental concerns are prominent, decision-making is largely driven by economic factors, with cost-efficiency often taking precedence over environmental goals [19].

Theme 2: Integration of Renewable Energy Technologies

Solar energy dominates adoption due to cost advantages and ease of installation, reflecting Porter's Five Forces—substitutes threat and supplier power. This reliance indicates a focus on economically viable solutions, often at the expense of exploring other renewable options. The Sustainable Architecture Model advocates for integrating sustainability principles from the start of design, but barriers such as high initial costs and lack of expertise hinder full realization, emphasizing the short-term focus despite awareness of long-term benefits.

Theme 3: Policy Impact and Regulatory Challenges

Government policies play a crucial role in shaping renewable energy adoption, with 70% of respondents noting the significant influence of UK regulations. However, many highlighted that existing policies are often rigid, outdated, and slow to adapt to technological advancements. This creates a paradox where policies both promote and hinder progress. Additionally, lengthy approval processes and bureaucratic delays further obstruct timely implementation, illustrating how institutional inertia can stifle innovation.

Theme 4: Stakeholder Collaboration and Future Outlook

Effective collaboration among architects, professionals, and policymakers is essential, with 85% of respondents emphasizing the importance of cross-sector partnerships to address cost and expertise challenges. Looking ahead, 90% of participants are optimistic about the expanded adoption of renewable technologies over the next decade, driven by advancements in materials and growing regulatory pressures to reduce carbon footprints. This aligns with the Technology Acceptance Model, where perceived ease of use and perceived usefulness are key factors influencing technology adoption.

Biomass and other renewables like hydro and tidal remain less prevalent in UK green architecture due to technical challenges, limited market incentives, and policy gaps in their integration into building structures [12]. Future chances lie in overcoming technology problems, creating supportive policies, and diversifying energy sources to boost the use of less common renewable energy options in buildings.

6.2. Policy Landscape and Its Impact on Architectural Practices

Current UK policies, such as the Building Regulations Part L, Feed-in Tariffs, and Renewable Heat Incentive, stipulate incorporating renewable energy into architecture. Even though these regulations encourage take-up, they are often vague, creating design uncertainties [29]. For example, grid access issues undermine small-scale wind projects, while strict planning permissions delay solar installations. Analyzing these policies highlights the need for streamlined facilitation policies to accelerate innovation in sustainable architecture.

Respondents indicated that revised legislation and increased government incentives could significantly support the further integration of renewable energy technologies, as suggested by the Sustainable Development Model. This model advocates for policies that balance economic growth with environmental protection. Moving forward, such policy changes are expected to be essential for the broader dissemination of renewable technologies, including increased financial incentives for green buildings and streamlined approval processes.

7. Conclusion & Recommendations

7.1. Conclusion

Addressing research questions

What are strategies to improve the uptake of renewable energy in architectural practices, and what might be the role of policies and regulations?

Participants stressed that there is a need for government incentives, including tax rebates for green buildings and grants for systems producing renewable energy. Realistically, the UK Building Regulations did push the bar higher for greener practices. However, we need to expedite their update to keep up with rapidly evolving technologies. Thus, accelerating the approval processes for renewable energy projects and increasing government investment in innovation could further encourage the diffused use of renewable technologies in architecture.

How can we minimize the obstacles to using renewable energy sources in sustainable architecture?

According to the respondents, governments reduce the identified obstacles by increasing financial incentives and providing more explicit regulatory guidance. The respondents also emphasize the importance of education and training in enhancing the technical expertise of professionals in various industries. Therefore, this study addresses the research question by identifying obstacles and providing practical solutions.

What case studies are considered the most successful integration of renewable energy into UK architecture, and what factors contributed to their success?

Case studies identified include BedZED and Kingspan Lighthouse as examples of best practices in integrating renewable energy into designs. The success of these projects can be attributed to a combination of factors, including the use of highly advanced technology, a collaboration between architects and renewable energy experts and architects, and solid governmental support. Furthermore, this research demonstrated how often successful integration is based on synergy between policy, technology, and professional collaboration.

What is the most practical renewable energy sources used in sustainable architecture, and what are their respective advantages and disadvantages?

The findings show that UK architecture primarily uses solar energy due to its affordability and ease of installation. It uses wind energy and geothermal systems, albeit less frequently, due to their higher costs and more complex installation processes. Solar energy offers substantial advantages such as scalability and falling panel costs, but its major drawback is its dependence on meteorological conditions. Wind energy provides higher output, but its installation could not be more manageable in an urban environment. Despite its high efficiency, geothermal energy necessitates a substantial initial investment, making it most suitable for large-scale projects.

What is the current practice of sustainable architecture in the UK, and where is it heading?

The research results revealed that the UK has increasingly integrated renewable energy technologies into sustainable architecture to increase energy efficiency and decrease carbon footprints. Despite technological advancement, the study reveals that mainstream adoption remains elusive, necessitating a review of policies and programs supporting such technology. Renewable energy will be at the core of sustainable architecture's growth when a friendlier regulatory environment and continued technological innovations emerge. Market demand and regulatory pressures, respectively, will drive increased use of energy-efficient materials and renewable energy systems in sustainable architecture in the UK in the future. Many respondents expected renewable energy to become a dominant feature in architectural designs over the next decade.

Addressing the Research Aim and Objectives

The research investigated the integration of renewable energy technologies in variations of sustainable architecture in the UK. We have addressed the issue by measuring participants' perceptions, analyzing the barriers, evaluating the role of government policies, and reviewing successful case studies. For instance, it is evident that while architects are becoming increasingly aware of integrating those technologies, the main challenges they face are cost and regulations. Moreover, depending on its scope and adaptability, government policy has been acting as both an enabler and a hindrance.

The potential impact of the findings

The results of this research have widespread ramifications both for policy and practice. To policymakers, it underlines the importance of regulatory frameworks that are flexible and supportive enough to adapt to rapid changes in technology. For architects and construction professionals, the findings point out that it requires continuous education and collaboration across professions to further the integration of renewable energy into their architectural practices. The study suggests that innovations in renewable energies and materials, along with stronger governmental policies on reduced carbon emissions, will shape the future of sustainable architecture in the UK.

7.2. Limitations

A key limitation relates to sample size and representativeness. The study primarily focused on architects, construction professionals, renewable energy experts, and policymakers in the UK, which may limit the diversity of perspectives. Additionally, the rapid evolution of renewable energy technologies restricts the generalizability of findings. Increasing the sample size could offer deeper insights, especially regarding experience levels within each sector.

Another limitation stems from the qualitative methodology. While it provided rich, detailed data, it also introduced potential biases, as responses may reflect personal experiences and backgrounds. Despite efforts to ensure objectivity, self-reported data might be inaccurate or biased, with participants potentially emphasizing successes or challenges based on their roles.

Time constraints also affected the depth of results. Given the ongoing developments in the field, a longitudinal approach might better capture long-term trends —something a cross-sectional design cannot provide. Finally, issues of validity and reliability inherent in qualitative research limit the extent to which findings reflect broader industry sentiments. These limitations should be considered when interpreting the results, and future studies could address them to enhance robustness and applicability.

7.3. Recommendations

7.3.1. For Further Research

First, a geographic expansion into an international scope would provide a comparative overview of trends in adopting and regulating renewable energy technologies in architecture. It will help explore differing regulatory frameworks, technological advancements, and cultural attitudes toward sustainability across regions. A longitudinal study of changes in the application of renewable energy over time in architectural practices would bring into much sharper focus any trends, obstacles, and successes. People are achieving specific technological innovations, like improving solar panels or developing geothermal systems. How such innovations can reduce or master specific barriers—such as those of cost or expertise—is a matter for direct investigation. Lastly, incorporating quantitative research into qualitative studies would enable the establishment of more generalizable conclusions. Surveys with more extensive and diverse samples complemented with statistical analysis may provide robust data on the adoption, perceptions, and financial impacts of renewable energy technologies in architecture.

Future research will investigate incorporating less popular technologies such as biomass, tidal, and hydro in green architecture. They have yet to realize their potential for renewable energy source diversification [20]. Market readiness, policy contexts, and technical viability will inform perspectives on surmounting current adoption challenges in the UK context.

7.3.2. For the Industry

Several recommendations arise from the research findings for architectural firms and renewable energy stakeholders in the UK: Cooperation between architects, construction professionals, and policymakers is required to break down regulatory and technical barriers. An industry-wide approach like this might ensure a more seamless integration of renewable technologies at the design level. Second, investing in training to enhance technical expertise will give architects and construction teams the confidence to apply renewable energy solutions comprehensively. Active advocacy for policy reforms could greatly enhance the implementation efforts by making the approval processes for renewable energy projects swifter and more flexible.

Industry stakeholders, such as policymakers and architects, should explore new renewable energy technologies like tidal, biomass, and hydro. They will invest in trial projects and work together across different sectors to prove their effectiveness, lower costs, and check if they are practical. This will help diversify the energy sources and make the UK's buildings more resilient in sustainable architecture.

7.3.3. Policy Recommendations

The UK's policymakers must update building codes to encompass renewable energy, redefine subsidies to support non-conventional technologies like biomass, hydro or tidal, and demystify the approvals of renewable installations. Current policies ignore innovative solutions, creating market and regulatory gaps that hinder development. A more expansive policy will promote heterogeneity and sustainable energy adoption, enabling architecture to meet challenging climate targets.

Acknowledgements

This dissertation would not have been possible without the support of many individuals and organizations. I sincerely thank my supervisors, Dr. Amandi Kulasinghe and Dr. Rishard Hussain, for their guidance and inspiration throughout this journey. I am also grateful to the staff at the University of Gloucestershire for providing essential resources and facilities.

My appreciation goes to my classmates for their encouragement, ideas, and discourse. I am deeply grateful to my family for their unwavering support and encouragement.

Dedication to My Daughter

To my beloved daughter, Serena Berro, I dedicate this research and work to you. Your presence and love inspire me to persevere and strive for my best. This dedication reflects how much you mean to me, and I am forever grateful to have you in my life.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

References

[1] Potrč, S., Čuček, L., Martin, M. and Kravanja, Z. (2021) Sustainable Renewable En-

ergy Supply Networks Optimization—The Gradual Transition to a Renewable Energy System within the European Union by 2050. *Renewable and Sustainable Energy Reviews*, **146**, Article 111186.
https://www.sciencedirect.com/science/article/pii/S1364032121004743

[2] Sagel, V.N., Rouwenhorst, K.H.R. and Faria, J.A. (2022) Green Ammonia Enables Sustainable Energy Production in Small Island Developing States: A Case Study on the Island of Curaçao. *Renewable and Sustainable Energy Reviews*, **161**, Article 112381.
https://research.utwente.nl/en/publications/green-ammonia-enables-sustainable-energy-production-in-small-isla

[3] Yang, N., Shi, W. and Zhou, Z. (2023) Research on Application and International Policy of Renewable Energy in Buildings. *Sustainability*, **15**, Article 5118.
https://ideas.repec.org/a/gam/jsusta/v15y2023i6p5118-d1096666.html

[4] Obaideen, K., Nooman AlMallahi, M., Alami, A.H., Ramadan, M., Abdelkareem, M.A., Shehata, N., *et al.* (2021) On the Contribution of Solar Energy to Sustainable Developments Goals: Case Study on Mohammed Bin Rashid Al Maktoum Solar Park. *International Journal of Thermofluids*, **12**, Article 100123.
https://www.sciencedirect.com/science/article/pii/S2666202721000604

[5] Norouzi, M., Haddad, A.N., Jiménez, L., Hoseinzadeh, S. and Boer, D. (2023) Carbon Footprint of Low-Energy Buildings in the United Kingdom: Effects of Mitigating Technological Pathways and Decarbonization Strategies. *Science of The Total Environment*, **882**, Article 163490.
https://www.sciencedirect.com/science/article/pii/S0048969723021095

[6] Lu, Y., Khan, Z.A., Alvarez-Alvarado, M.S., Zhang, Y., Huang, Z. and Imran, M. (2020) A Critical Review of Sustainable Energy Policies for the Promotion of Renewable Energy Sources. *Sustainability*, **12**, Article 5078.
https://www.mdpi.com/2071-1050/12/12/5078

[7] Hafez, F.S., Sa'di, B., Safa-Gamal, M., Taufiq-Yap, Y.H., Alrifaey, M., Seyedmahmoudian, M., *et al.* (2023) Energy Efficiency in Sustainable Buildings: A Systematic Review with Taxonomy, Challenges, Motivations, Methodological Aspects, Recommendations, and Pathways for Future Research. *Energy Strategy Reviews*, **45**, Article 101013. https://ui.adsabs.harvard.edu/abs/2023EneSR..4501013H/abstract

[8] Lucchi, E. (2023) Renewable Energies and Architectural Heritage: Advanced Solutions and Future Perspectives. *Buildings*, **13**, Article 631.
https://www.mdpi.com/2075-5309/13/3/631

[9] Al Naimat, A. and Liang, D. (2023) Substantial Gains of Renewable Energy Adoption and Implementation in Maan, Jordan: A Critical Review. *Results in Engineering*, **19**, Article 101367. https://doi.org/10.1016/j.rineng.2023.101367

[10] Hunter, G.W., Vettorato, D. and Sagoe, G. (2018) Creating Smart Energy Cities for Sustainability through Project Implementation: A Case Study of Bolzano, Italy. *Sustainability*, **10**, Article 2167. https://www.mdpi.com/2071-1050/10/7/2167

[11] Zhang, S., Yang, X., Xu, W. and Fu, Y. (2021) Contribution of Nearly-Zero Energy Buildings Standards Enforcement to Achieve Carbon Neutral in Urban Area by 2060. *Advances in Climate Change Research*, **12**, 734-743.
https://ui.adsabs.harvard.edu/abs/2021ACCR...12..734Z/abstract

[12] Allana, K.S.P. and Ananias, F.D.J. (2023) Impacts of Using Biomass as an Energy Source in Homes. Springer International Publishing.
https://doi.org/10.1007/978-3-031-01477-8

[13] Olabi, A.G., Obaideen, K., Abdelkareem, M.A., AlMallahi, M.N., Shehata, N., Alami,

A.H., *et al.* (2023) Wind Energy Contribution to the Sustainable Development Goals: Case Study on London Array. *Sustainability*, **15**, Article 4641. https://www.mdpi.com/2071-1050/15/5/4641

[14] Li, L., Lin, J., Wu, N., Xie, S., Meng, C., Zheng, Y., *et al.* (2022) Review and Outlook on the International Renewable Energy Development. *Energy and Built Environment*, **3**, 139-157. https://www.sciencedirect.com/science/article/pii/S2666123320301148

[15] Norouzi, M., Chàfer, M., Cabeza, L.F., Jiménez, L. and Boer, D. (2021) Circular Economy in the Building and Construction Sector: A Scientific Evolution Analysis. *Journal of Building Engineering*, **44**, Article 102704. https://doi.org/10.1016/j.jobe.2021.102704

[16] Chel, A. and Kaushik, G. (2018) Renewable Energy Technologies for Sustainable Development of Energy Efficient Building. *Alexandria Engineering Journal*, **57**, 655-669. https://www.sciencedirect.com/science/article/pii/S1110016817300911

[17] Durnova, I., Klein, K., Krenzer, J. and Wetzel, T. (2022) Differences of the Green Building Certification Systems BREEAM, LEED and DGNB. https://www.researchgate.net/figure/The-most-impactful-green-building-benefits-across-a-variety-of-areas-Source_fig2_382919668

[18] Zhong, W., Schröder, T. and Bekkering, J. (2022) Biophilic Design in Architecture and Its Contributions to Health, Well-Being, and Sustainability: A Critical Review. *Frontiers of Architectural Research*, **11**, 114-141. https://www.sciencedirect.com/science/article/pii/S2095263521000479

[19] Grover, R., Emmitt, S. and Copping, A. (2018) Sustainable Development and Architectural Practice: Framing Strategic Approaches in the United Kingdom. *Sustainable Development*, **27**, 377-387. https://doi.org/10.1002/sd.1910

[20] Panepinto, D., Zanetti, M.C., Gitelman, L., Kozhevnikov, M., Magaril, E. and Magaril, R. (2017) Energy from Biomass for Sustainable Cities. *IOP Conference Series: Earth and Environmental Science*, **72**, Article 012021. https://iopscience.iop.org/article/10.1088/1755-1315/72/1/012021/pdf

[21] Mali, N., Abhijit, A.S.D.K.Y. and Bist, N.N. (2021) Design Architecture for Direct Application of Geothermal ENERGY. https://www.researchgate.net/profile/Kriti-Yadav-10/publication/348704443_Design_architecture_for_direct_application_of_geothermal_energy/links/600be86d92851c13fe2dffbb/Design-architecture-for-direct-application-ofgeothermal-energy.pdf

[22] Abddeelaziz Farid, M.M. and Radwan, A.O. (2020) Buildings Design Integration with Geothermal Energy System Technologies and Air Conditioning Applications. *Journal of Arts & Architecture Research Studies*, **1**, 33-46. https://journals.ekb.eg/article_153846_c79bd14ed30a2f9d4df58c292cc5dc7a.pdf

[23] Cacciuttolo, C., Navarrete, M. and Atencio, E. (2024) Renewable Wind Energy Implementation in South America: A Comprehensive Review and Sustainable Prospects. *Sustainability*, **16**, Article 6082. https://doi.org/10.3390/su16146082

[24] Noori, M. (2013) Sustainability Assessment of Wind Energy for Buildings. https://stars.library.ucf.edu/cgi/viewcontent.cgi?article=3872&context=etd

[25] López, C.S.P. and Frontini, F. (2014) Energy Efficiency and Renewable Solar Energy Integration in Heritage Historic Buildings. *Energy Procedia*, **48**, 1493-1502. https://www.sciencedirect.com/science/article/pii/S1876610214004317

[26] Canale, L., Di Fazio, A.R., Russo, M., Frattolillo, A. and Dell'Isola, M. (2021) An

Overview on Functional Integration of Hybrid Renewable Energy Systems in Multi-Energy Buildings. *Energies*, **14**, Article 1078. https://www.mdpi.com/1996-1073/14/4/1078

[27] Kalogirou, S.A. (2013) Building Integration of Solar Renewable Energy Systems Towards Zero or Nearly Zero Energy Buildings. *International Journal of Low-Carbon Technologies*, **10**, 379-385. https://ideas.repec.org/a/oup/ijlctc/v10y2015i4p379-385..html

[28] Vagtholm, R., Matteo, A., Vand, B. and Tupenaite, L. (2023) Evolution and Current State of Building Materials, Construction Methods, and Building Regulations in the U.K.: Implications for Sustainable Building Practices. *Buildings*, **13**, Article 1480. https://www.mdpi.com/2075-5309/13/6/1480

[29] Alzaatreh, A., Mahdjoubi, L., Gething, B. and Sierra, F. (2018) Disaggregating High-Resolution Gas Metering Data Using Pattern Recognition. *Energy and Buildings*, **176**, 17-32. https://doi.org/10.1016/j.enbuild.2018.07.011

[30] Sharp, J., Hobbs, G., Henrotay, C., Steinlage, M., Debacker, W., De Regel, S. and Sjögren, C. (2019) Framework for Policies, Regulations and Standards. BAMB-Buildings as Material Banks. https://www.bamb2020.eu/wp-content/uploads/2019/07/BAMB-Framework-for-Policies-Regulations-and-Standards-web.pdf

[31] Alsaeed, M., Hadjri, K., Nawratek, K., Tower, S. and Tower, A. (2024) A Comparative Analysis of UK Sustainable Housing Standards. ResearchGate. https://www.researchgate.net/publication/381407618_A_Comparative_Analysis_of_UK_Sustainable_Housing_Standards

[32] Donovan, E. (2020) Explaining Sustainable Architecture. *IOP Conference Series: Earth and Environmental Science*, **588**, Article 032086. https://iopscience.iop.org/article/10.1088/1755-1315/588/3/032086/pdf

[33] Pandey, P., and Pandey, M.M. (2015) Research Methodology: Tools and Techniques. Bridge Center. https://www.euacademic.org/BookUpload/9.pdf

[34] Kirongo, A. and Odoyo, C. (2020) Research Philosophy Design and Methodologies: A Systematic Review of Research Paradigms in Information Technology. https://www.globalscientificjournal.com/researchpaper/Research_Philosophy_Design_and_Methodologies_A_Systematic_Review_of_Research_Paradigms_in_Information_Technology_.pdf

[35] Heit, E. (2001) Models of Inductive Reasoning. In: Sun, R., Ed., *The Cambridge Handbook of Computational Psychology*, Cambridge University Press, 322-338. https://faculty.ucmerced.edu/eheit/computational.pdf

[36] Zalaghi, H. and Khazaei, M. (2016) The Role of Deductive and Inductive Reasoning in Accounting Research and Standard Setting. *Asian Journal of Finance & Accounting*, **8**, 23-37. https://www.researchgate.net/profile/MahdiKhazaei/publication/294872064_The_Role_of_Deductive_and_Inductive_Reasoning_in_Accounting_Research_and_Standard_Setting/links/58fc99c30f7e9ba3ba557612/The-Role-of-Deductive-and-Inductive-Reasoning-in-Accounting-Research-and-Standard-Setting.pdf

[37] Žukauskas, P., Vveinhardt, J. and Andriukaitienė, R. (2018) Sociodemographic Indicators: Employee Attitude. In: Žukauskas, P., et al., Eds., *Management Culture and Corporate Social Responsibility*, InTech, 5. https://www.intechopen.com/chapters/59023

[38] Gerring, J. (2017) Qualitative Methods. *Annual Review of Political Science*, **20**, 15-

36. https://www.researchgate.net/publication/312479346_Qualitative_Methods

[39] Jain, N. (2021) Survey Versus Interviews: Comparing Data Collection Tools for Exploratory Research. *The Qualitative Report*, **26**, 541-554. https://nsuworks.nova.edu/tqr/vol26/iss2/12/

[40] Naz, N., Gulab, F. and Aslam, M. (2022) Development of Qualitative Semi-Structured Interview Guide for Case Study Research. *Competitive Social Science Research Journal*, **3**, 42-52. https://cssrjournal.com/index.php/cssrjournal/article/view/170/72

[41] Subedi, K.R. (2021) Determining the Sample in Qualitative Research. *Scholars' Journal*, **4**, 1-13. https://files.eric.ed.gov/fulltext/ED618228.pdf

[42] Rai, N. and Thapa, B. (2015) A study on Purposive Sampling Method in Research. *Kathmandu*: *Kathmandu School of Law*, **5**, 8-15. https://www.scirp.org/reference/referencespapers?referenceid=3433795

[43] Parker, C., Scott, S. and Geddes, A. (2019) Snowball Sampling. SAGE Research Methods Foundations. https://eprints.glos.ac.uk/6781/1/6781%20Parker%20and%20Scott%20%282019%29%20Snowball%20Sampling_Peer%20reviewed%20pre-copy%20edited%20version.pdf

[44] Noble, H. and Smith, J. (2015) Issues of Validity and Reliability in Qualitative Research. *Evidence Based Nursing*, **18**, 34-35. https://doi.org/10.1136/eb-2015-102054

[45] Quintão, C., Andrade, P. and Almeida, F. (2020) How to Improve the Validity and Reliability of a Case Study Approach? *Journal of Interdisciplinary Studies in Education*, **9**, 273-284. https://www.ojed.org/jise/article/view/2026/1145