Nottingham Trent University

Developing a Conceptual Framework for Adopting Renewable Energy in the Domestic Urban Environment in the UK

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Originality Statement

I hereby declare that this thesis is submitted in partial fulfilment of the requirements for the award of Doctor of Philosophy (PhD) from Nottingham Trent University (NTU) and is entitled "Developing a Conceptual Framework for Adopting Renewable Energy in the UK Domestic Urban Environment". Neither the whole, nor any part of the work, has been submitted before in order to qualify for any other academic degree or award at NTU, or any other university. I further declare that the work is original, except where shown by specific cited reference and acknowledged within the text and represents the efforts of the author alone. The content of the thesis is the result of work that has been carried out since the date of approval of the research programme, and it has been prepared in accordance with the regulations for postgraduate research study set out by NTU. All ethics procedures and guidelines have been duly observed in the preparation of this thesis. Any views expressed in the thesis are those of the author and in no way represent those of the University. The University has permission to keep, lend, or copy this thesis, in whole or in part, on condition that any such use of the material is duly acknowledged.

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List of Publications

Journal Articles

- Al-Habaibeh, A., Yaseen, S. and Nweke, B., 2023. A comparative study of low and high resolution infrared cameras for IoT smart city applications. *Ain Shams Engineering Journal*, p.102108. (Accepted)
- Al-Habaibeh, A., Moh'd, B.A.H., Massoud, H., Nweke, O.B., Al Takrouri, M. and Badr, B.E., 2023. Solar Energy in Jordan: Investigating Challenges and Opportunities of Using Domestic Solar Energy Systems. *World Development Sustainability*, p.100077. (Accepted)
- Nweke, B., Al-Habaibeh, A. and Akib, S., 2023. The Challenges and Opportunities in the Use of Renewable Energy in the Residential Sector: An Analysis from Different Stakeholder Perspectives to Enable the UK Reach NetZero. (Under final editing)
- Nweke, B., Al-Habaibeh, A., Akib, S., and Pokubo, D., 2023. The Importance of Urban Planning in the Implementation of Solar Energy in the Urban Domestic Environment in the UK. (Under final editing)

Conference papers

- Nweke, B. and Al-Habaibeh, A., 2022. Challenges and Opportunities in the implementation of NetZero Strategy: Analysis of Key Issues that Affect the Adoption of Domestic Renewable Energy in the UK from Consumers' Perspective. *ICESF Conference on Energy and Sustainable Futures.* (Accepted)

Abstract

The drive to reduce carbon emissions, address energy poverty and eliminate pollution is critical towards achieving Net Zero. Renewable energy should be utilised in urban environments as well as within large-scale projects to achieve such goals. Distributed solar energy systems, grid-connected or off-grid, could play an important role in addressing the energy challenges in urban environments. Therefore, this research investigated the challenges and opportunities in implementing renewable energy in an urban environment in the UK. Using a concurrent mixed methods approach, qualitative and quantitative data are collected. Qualitative data was collected through interviews with the Nottingham council and residents in the UK. Quantitative data was gathered using structured questionnaires targeting residents in the UK to identify the reasons for overreliance on natural gas and oil, the most important factors hindering their implementation of renewable sources, and their awareness of the climate crisis. Subsequently, using Nottingham as the case study, a roof survey analysis is conducted to investigate the growth of renewables to provide further analysis in this study. Findings in this study show that the key factors to consider in the implementation of renewable energy include financial constraints, lack of information, lack of awareness and urban planning issues. This study also establishes a theoretical and conceptual framework for renewable energy adoption. A preliminary theoretical framework is established after a comprehensive literature review and in the latter stages a comprehensive conceptual framework is developed based on the prior framework and research conducted. Therefore, using behavioural reasoning theory and diffusion of innovation theory, this study suggests that to encourage the adoption of renewable energy, the cost should be subsidised, or addressed via affordable means, and awareness should be increased to enable consumers to adopt clean technologies considering the recent rising costs of electricity. This would involve cooperation between stakeholders through multi-actor partnerships. Furthermore, policies must be developed for implementing sustainability measures as an essential component of urban planning. As a result, houses and cities should be designed to accommodate solar panels in the future instead of having complicated roofs and less-than-optimal orientations.

Table of Contents

List of Abbreviations

UK- United Kingdom

GWh- Gigawatt Hours

TWh- Terawatt Hours

PV- Photovoltaic

EE- Energy Efficiency

RET- Renewable Energy Technology

RE- Renewable Energy

EU- European Union

EHCS- Energy House Condition Survey

List of Figures

List of Tables

Chapter 1: Introduction

Due to the increasing population, there has been a rapid increase in energy production to meet the ever-growing energy consumption. Globally, energy sources consist primarily of fossil fuels and renewable sources. However, fossil fuels are over-relied, which means they will eventually run out.

Despite this, the United Kingdom is overly dependent on fossil fuels, which are depleting. The United Kingdom is bound by regulation and legislation in terms of carbon emissions and green energy. Subsequently, the G8 stated in its declaration that it aims to cut greenhouse gas emissions by 50 percent by 2050 in recognition of the recent international agreements regarding the need to reduce the emission of greenhouse gases. Therefore, prioritising the research and implementation of renewable energy sources is crucial.

1.1 Background

The goal of net zero is to balance the number of greenhouse gases released into the atmosphere and those removed from the environment (Regufe et al., 2021). Therefore, the solution to climate change can be to reach net zero to reduce global warming (Regufe et al., 2021). According to Pandey, Agrawal and Pandey (2010), cutting carbon emissions and reducing carbon footprints are recommended to combat climate change. However, greenhouse gases are not, in their entirety, damaging. On the contrary, they protect the planet's surface from harmful solar radiation. Gases such as these work as a filter to a certain extent, absorbing most excess and toxic energy and returning it to space (Ramanathan and Feng, 2009). McKenzie and Carter (2021) argue that the use of fossil fuels is recognised as one of the critical reasons for the ever-increasing energy crisis and the primary source of greenhouse gas emissions. This has led to the realisation that sustainable improvements are necessary (Shaheen and Lipman, 2007; Byravan et al., 2017) as numerous countries put into effect strategies to reduce the generation of greenhouse gas emissions (Orak, Alshehri and Chen, 2022; Sovacool, Griffiths, Kim and Bazilian, 2021; Monforti-Ferrario and Blanco, 2021). The methods to achieve this involve decreasing environmental pollutants, using resources, and contributing to the welfare of societies through the development of social situations affecting populations (Cioca et al., 2015). However, the successful implementation of sustainable development requires the active involvement of each country globally (Bridgewater, 2021; Leal Filho et al., 2021). This encourages innovative thinking and setting ahead techniques that support the improvement of cities and communities (Cioca et al., 2015).

The benefits of a developed power sector are numerous, including the growth of the economy and the provision of a better standard of living for its vast population (Cerovi and Maradin, 2014). Consequently, power stations utilise substantial amounts of energy to operate their turbines to meet the energy demands of the ever-increasing population (Cioca et al., 2015). Therefore, the United Nations have designed the Sustainable Development Goals (SDGs) as one of its targets to ensure that affordable energy is readily available within an estimated timeframe of 2030. It has also identified other goals, such as switching to more sustainable energy sources and increasing energy efficiency (Acharya and Adhikari, 2021). It aims to achieve this by implementing the appropriate infrastructure to facilitate renewable energy technologies in developing countries (Acharya and Adhikari, 2021). Despite the United Nations' collective goals being accepted by governments worldwide, substituting sustainable energy options for traditional energy methods that have been used globally for many years remains challenging (Acharya and Adhikari, 2021). It requires the combination of effort from the policymakers to collectively create policies that could encourage the facilitation of energy transition, which requires the knowledge of household energy consumption because the total energy consumption is usually characterised by the energy consumption in the residential area (Acharya and Adhikari, 2021). Subsequently, the government in the UK has placed the implementation of renewable energy relatively high on its agenda in hopes of helping promote renewable sources of energy. The country also has the potential to vastly benefit from sustainable energy sources as it could eventually impact the economy and support climate change measures (HM Government, 2020).

The UK's renewable energy program has been promoted since its launch in 1973/1974 following the oil crisis (Haas et al., 2011; Shahzadi et al., 2022; Li and Lee, 2022). As a result, renewables have gained importance over the following years, from being a minimal energy choice to becoming one of the leading choices in the UK and worldwide (Borozan, 2022; Potts, 2022; Akbari, Jones and Arabikhan, 2021). Similarly, the privatisation of electricity in the UK in 1990 led to a boost in renewable energy (Elliot, 1999). However, the recent emergence of Covid-19 may hinder the implementation of renewable energy (Wang, Huang and Li, 2022; Adebayo et al., 2022; Shah, Kirikkaleli and Adedoyin, 2021). In response to the unexpected global crisis, individuals, firms, and states have responded with various economic, social, (Mofijur et al., 2021; Nundy et al., 2021) and political measures (Pu et al., 2021; Aharon and Siev, 2021; Gollakota and Shu, 2022) that are likely to lead to sustainable energy transitions (Kuzemko et al., 2020). The UK has also taken several actions regarding Covid-19's impact on renewable energy. This involves a proposal to implement a scheme under which hundreds of thousands of homeowners will be eligible for vouchers of up to £5000 to make energy-saving home improvements (BBC, 2020). Also, some factors should be considered in implementing renewable energy, such as solar power. For instance, emphasis should be placed on the structural limitations of the existing roof. This factor's importance is due to the significant load that renewable energy systems add to a roof, which can be influenced by the local wind conditions (Mcrma, 2014). Therefore, as the United Kingdom strives to meet its targets, it is essential to investigate the significance of renewable energy (Qin et al., 2021; Azam et al., 2021). This involves analysing the internal and external issues faced by the renewable energy sector (Leonard, Ahsan, Charbonnier and Hirmer, 2022; Fusco, Maggi and Rizzuto, 2022; Funder et al., 2021). Among the internal problems are the investment costs (Leete, Xu and Wheeler, 2013; Essletzbichler, 2012) involved in implementing renewable energy, the lack of requisite infrastructure (Painuly, 2001) and a lack of knowledge about renewable energy (Barnett, Burningham, Walker and Cass, 2010; Mirzania et al., 2019; Goedkoop and Devine-Wright, 2016). The external issues include supplier involvement (Rosenow, Platt and Flanagan, 2013; Keirstead, 2007), governmental policies acceptance (Upreti and van der Horst, 2004; Can Şener, Sharp and Anctil, 2018), and social acceptance (Ruggiero, Onkila and Kuittinen, 2014; Wüstenhagen, Wolsink and Bürer, 2007; Fournis and Fortin, 2016).

1.2 Introducing the Case Study: UK

1.2.1 The Geography and Demographics of the UK

A unitary country consisting of 4 countries, including England, Wales, Scotland and Northern Ireland, the UK is considered one of the largest economies in the world. The government in the UK has constitutional sovereignty based on a parliamentary system, where the parliamentary body has the sole legislative power (Kofler, 2006; McConalogue, 2019). A European country located off the north-western coast, the United Kingdom is surrounded by the Atlantic Ocean, Celtic Sea, Ireland, Irish Sea, North Sea, and the English Channel.

Furthermore, a population density of 281.2 people per square kilometre has been calculated for the United Kingdom, which has a population of 66.8 million (Office for National Statistics, 2021). Additionally, throughout the UK, the eastern part experiences drier weather than the western part, and the Atlantic Ocean also brings along rainy weather to the country's east.

1.2.2 Rationale of The Study

Reducing carbon footprints mitigates the impact of climate change, a factor that positively affects public health and plant and animal biodiversity. Further, this stimulates the global economy and leads to more sustainable and innovative solutions (Perry, Klemeš and Bulatov, 2008; Zhang and Wang, 2017; Chel and Kaushik, 2018). Energy generation, transmission, and distribution contribute to delivering electricity to the United Kingdom's vast population. In this regard, there is a need to focus more attention on the research and implementation of renewable energy sources, especially considering recent international agreements stating the need to reduce greenhouse gases (Shah, Hiles, and Morley, 2018; Weron, 2014; Gholami, Aminifar and Shahidehpour, 2016). This study will examine how renewable energy is implemented in the United Kingdom. It will also discuss how solar energy can be used and implemented as a viable energy alternative in the residential sector in the United Kingdom. Generally, research on this topic will provide an overview of the environmental impact of renewable energy, as well as any issues impeding their general acceptance from different stakeholder perspectives.

1.2.3 Research Problem

Following the oil crisis in 1973/74, the UK launched a renewable energy program that has been ongoing for over 40 years. However, the emergence of Covid-19 could pose a problem in implementing renewable energy (Naderipour et al., 2020; Hoang et al., 2021; Bhuiyan et al., 2021; Kaczmarzewski, Matuszewska and Sołtysik, 2021). The measures adopted by individuals, firms, and states in reaction to the unexpected global crisis have prompted economic, social, and political changes likely to influence sustainable energy transitions (Kuzemko et al., 2020). Concerning Covid-19, the UK has recently taken action to safeguard the renewable energy sector. Through this initiative, hundreds of thousands of homeowners will have the opportunity to receive vouchers of up to £5000 to make energy-efficient home improvements (BBC, 2020). Despite the RHI's contribution to both the UK's renewable energy target and its decarbonisation targets, this reform aims to promote the deployment of the appropriate technologies for the intended purposes (HM Government, 2020). Several measures are available, divided into primary and secondary measures. However, at least one primary measure must be installed with the voucher. For instance, a low carbon heating system such as solar thermal or air source heat pump could be used for low carbon heating and loft or wall insulation for home insulation (HM Government, 2020).

Additionally, some factors must be considered to implement renewable energy sources like solar power. In this regard, the primary structure's existing roof's structural capability is relatively important, and it is critical since renewable energy systems can add considerable loads to a roof. This factor is essential because wind loads, depending on the location, can positively or negatively impact roof loads (Mcrma, 2014).

1.2.4 Research Aim

This project aims to analyse the different perspectives on implementing renewables in the United Kingdom. More importantly, this project will look at the key participants in the renewable energy supply chain going from the decision makers to the end users and their impact on the adoption of renewable energy in a domestic urban environment. It aims to analyse the issues that could be encountered when retrofitting the housing stock, the issues in the urban design of cities, the impact of governmental policies, public acceptance, social change, behavioural change, and the fragmented ownership and management of land and housing.

1.2.5 Research Questions

This study will attempt to answer some central research questions. They include:

- What underlying issues restrict the effective implementation of solar energy in the domestic urban environment in the UK?
- What are the impacts of Covid-19 on renewable energy developments in the UK?
- What are the essential factors in utilising renewable energy in the UK?

1.26 Research Objectives

The essential objectives of this research are to discover the possible challenges that UK energy suppliers and governmental bodies face. Specifically, the research objectives include:

1. To investigate the challenges and opportunities in implementing renewable energy in an urban environment in the UK, using Nottingham as the case study.
2. To understand which renewables are primarily utilised in the residential sector and why?
3. To analyse the different stakeholder perspectives towards implementing renewables in the United Kingdom.
4. To establish the underlying issues that restrict the effective implementation of renewables in the UK.
5. To compare the United Kingdom's acceptance of renewables with a few developed and developing countries to understand the key factors that enable and restrict its effective implementation.
6. To establish ways of improving the issues involved with the stakeholder in the energy sector to provide recommendations to aid the implementation of renewables in the UK.
7. To develop a theoretical and conceptual framework for RE implementation

1.3 Outline of Thesis

Chapter 1 of this thesis explains what this thesis entails and provides an overview of the demographics and geography of the United Kingdom. Furthermore, the problem, objectives, research questions, and methodology are outlined. Chapter 2 of the literature review discusses renewable energy sources and their technologies. In Chapter 3, the researcher examines the challenges and benefits of implementing renewable energy sources. In Chapter 4, the UK's renewable energy development is identified and analysed. An insight into solar energy implementation requirements is provided in Chapter 5. In Chapter 6, a preliminary theoretical framework for renewable energy consumer adoption has been established. The methodology used in this study is described in Chapter 7. In Chapter 8, statistical analysis is provided regarding personal awareness and use of renewable energy sources in the UK, based on data collected from the public through a questionnaire. Using Google Earth and PVGIS, Chapter 9 explores different types of roof orientation in Nottingham, UK, and other factors to investigate the growth of solar panels in the area. A discussion of the results of the interviews conducted with residents in Nottingham, UK is discussed in Chapter 10. By interviewing Nottingham city council, Chapter 11 examines the growth of solar energy in Nottingham from their perspective. Chapter 12 discusses the research questions and objectives in relation to the data gathered for this study. Chapter 13 established a comprehensive conceptual framework developed for the implementation of renewable energy in an urban environment. Based on empirical research and expert opinion, Chapter 14 provides policymakers with actionable recommendations to aid the growth of domestic sustainable energy in the UK. A schematic diagram depicting the thesis structure is provided in Figure 1-1.

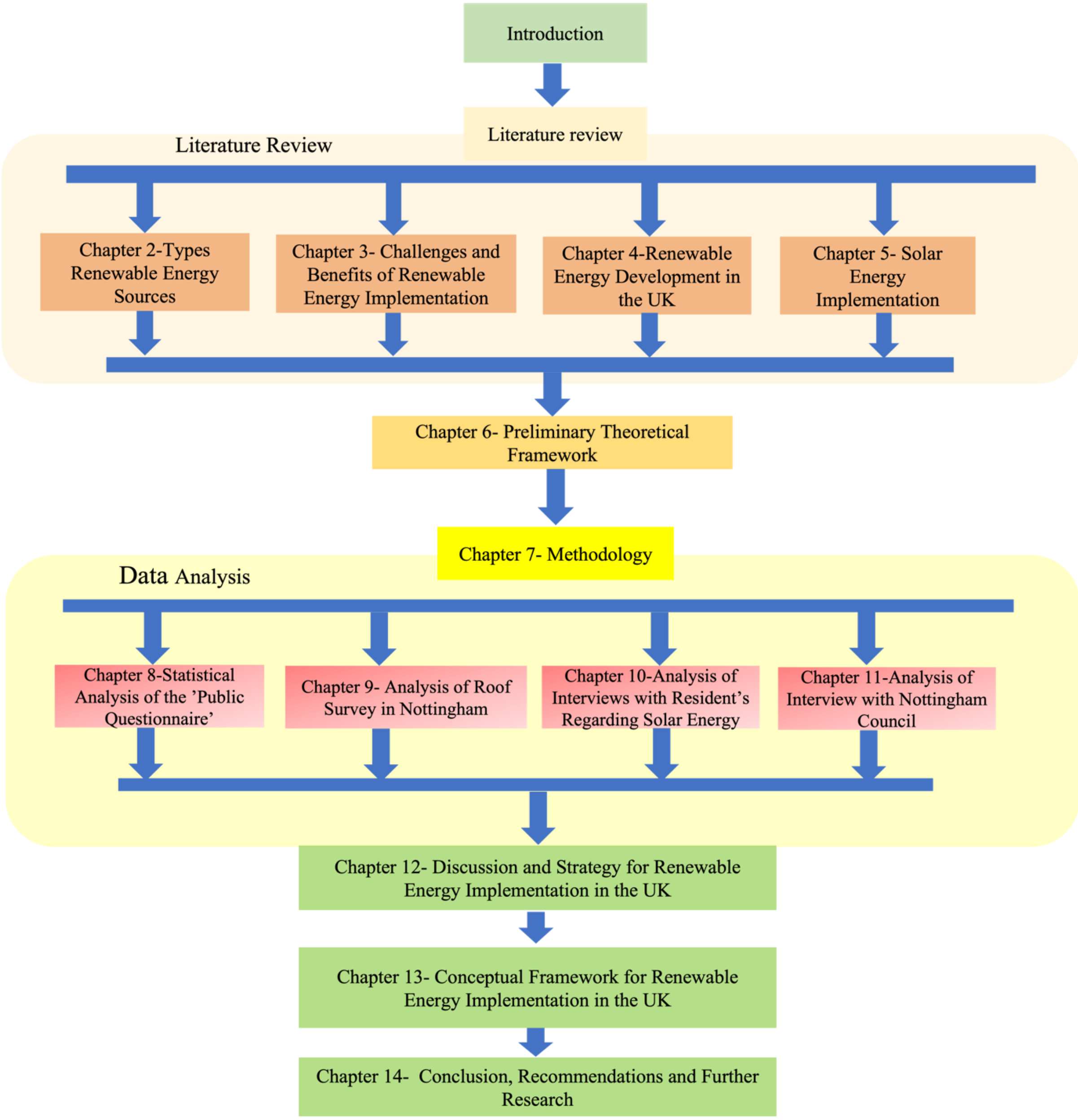

Figure1-1: Outline of Thesis (Source: Author's Own)

1.4 Research Methodology Design

The previous sections involved the discussion of the ideas and investigated literature which will be useful during the time spent understanding the issues influencing the implementation of renewable sources in the UK. Subsequently, the research methodology and design used in this study are described in this chapter. It will explore the procedure for conducting this research, the method of gathering data, and the approach adopted. The data reduction technique that will be utilised in this examination is Primary data. The results of this study will also clarify the methodology used in this study. Participants in this research were anonymous, and no names were given to organisations, nor were the identities of those interviewed. Interview questions were used only after permission had been granted. Respondents are informed before taking the survey that survey information is strictly confidential. As this research progresses, it will include qualitative and quantitative research, as a primary dataset will be gathered.

Identifying possible trends and drawing valuable conclusions from this information will give the researcher a deeper understanding of this research. Questionnaires and interviews will form the basis of the primary research. The primary research will be collected from the questionnaire targeting the current users of renewable energy and potential users and interviews targeting the energy providers, governmental bodies, current users of solar energy and potential users of solar energy. Furthermore, a roof survey will be utilised to investigate the growth of solar energy in Nottingham. The qualitative research strategy includes conclusions and thoughts regarding this study. As part of this study, the research questions will be examined using the data and information collected from the analysis of the questionnaire, roof survey and during interviews. A conclusion from this investigation from the questionnaire will be drawn using SPSS to analyse and evaluate the figures. This will either provide answers to the research questions or enable the researcher to understand the research questions further to recommend viable solutions. Then again, both methods are not opposed concepts in this study, but both have the same goal of answering the research questions, which is why they should not be viewed as such, as a general overview of the literature is first gathered. It is then necessary to gain a deeper understanding of the literature to narrow down the research question. The research methodology utilised for this study is depicted in Figure 1-2.

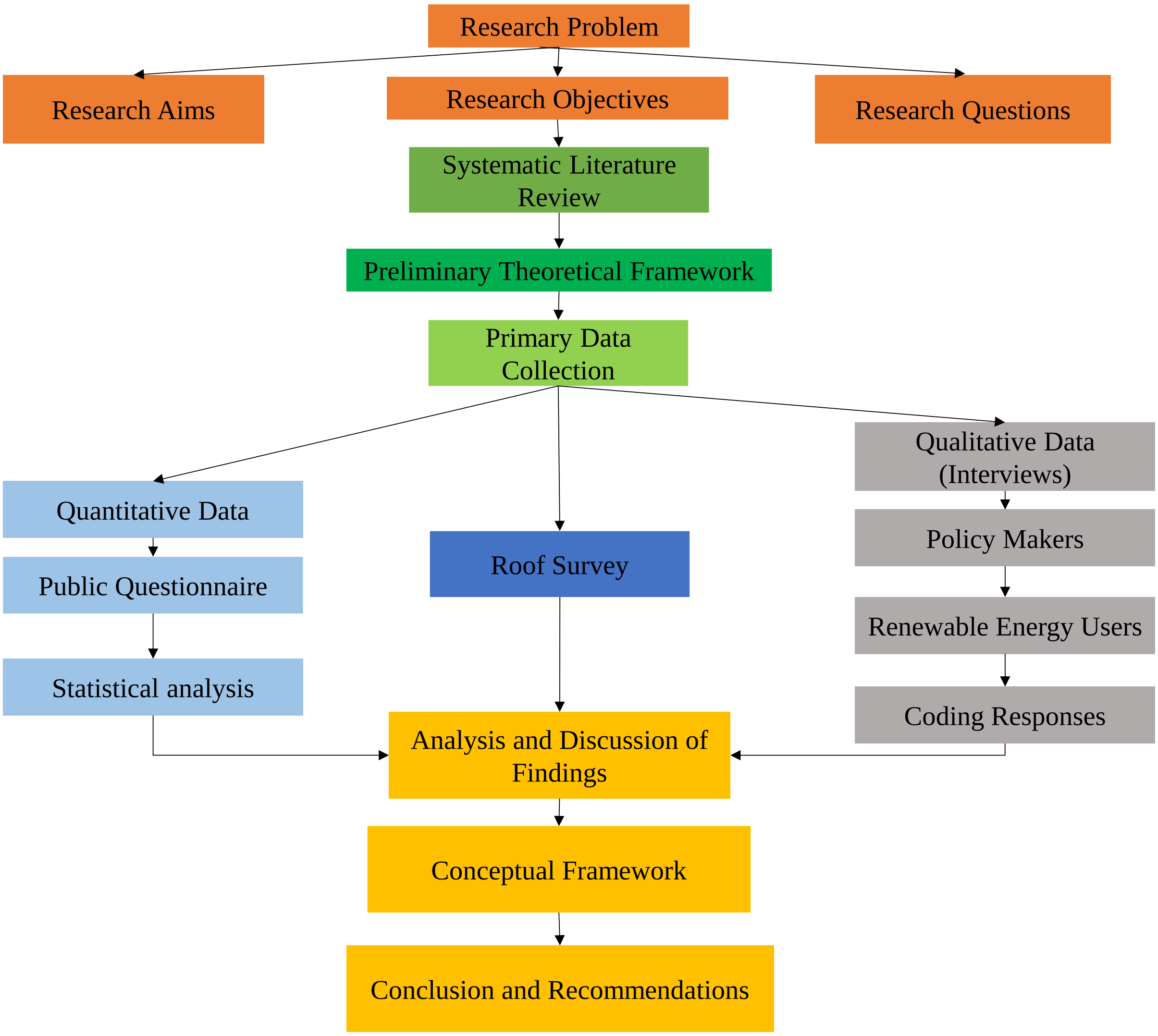

Figure 1-2: Research Methodology (Source: Author's Own)

1.5 Summary

This chapter has outlined this thesis's contents and provided demographic and geographical information about the United Kingdom, where the study is conducted. It has also identified the research motivation and problem, outlined the research aim and objectives, and introduced the corresponding research questions. Additionally, this study provides information about the importance of this study in understanding the energy landscape in the United Kingdom. Subsequently, the methodology used in this study, the key elements, the structure, and the contents of each chapter are outlined. Within the next chapter, renewable energy sources and related technologies will be examined as the initial phase of the literature review.

Chapter 2: Types of Renewable Energy Sources

2.1 Introduction

This chapter outlines the several types of renewable energy sources available and their technological applications. The historical overview will be addressed with emphasis on the renewable energy source most applicable to this study. Furthermore, each energy source's characteristics, advantages and disadvantages will be identified. These factors are considered essential because renewable energy systems differ regarding their corresponding cost and life cycle assessment, which impacts the revenue and capital cost of renewable energy investments.

2.2 Importance of Renewable Energy

According to Bowden and Payne (2009), the current climate of insecurities over the instability of oil costs, the natural consequence of fossil fuel by-products, and the over-dependence on traditional energy sources are generally contributing factors to the growing interest in sustainable energy sources. Nevertheless, it has been paramount for governmental bodies to implement policies promoting sustainability. These include sustainable energy tax reductions based on production, installation discounts for renewable energy, renewable energy portfolios and establishing markets to manage renewable energy certificates effectively (Bowden and Payne (2009). Zerrahn (2017) emphasises that gradual progress to renewable sources is essential to detoxify the environment. Several authors support this by suggesting that the release of carcinogenic compounds into the atmosphere from burning fossil fuels has been increasing at an unacceptable rate. Therefore, this requires the urgent development of strategies to protect the deteriorating state of the environment by moving to more alternative sources of energy (Kothiyal et al., 2022; Claxton, 2015; Chen, Cheng, He and Wang, 2022; Yıldız, 2018).

2.3 Types of Renewable Energy Sources

According to Moriaty and Honey (2020), technological advancements are driving down the cost of renewable energy, providing a glimpse of a greener future. However, although most types of renewable energy technologies have experienced rapid growth, their growth rate depends on numerous factors, which differ across sources. The types of renewables are shown in Figure 2-1.

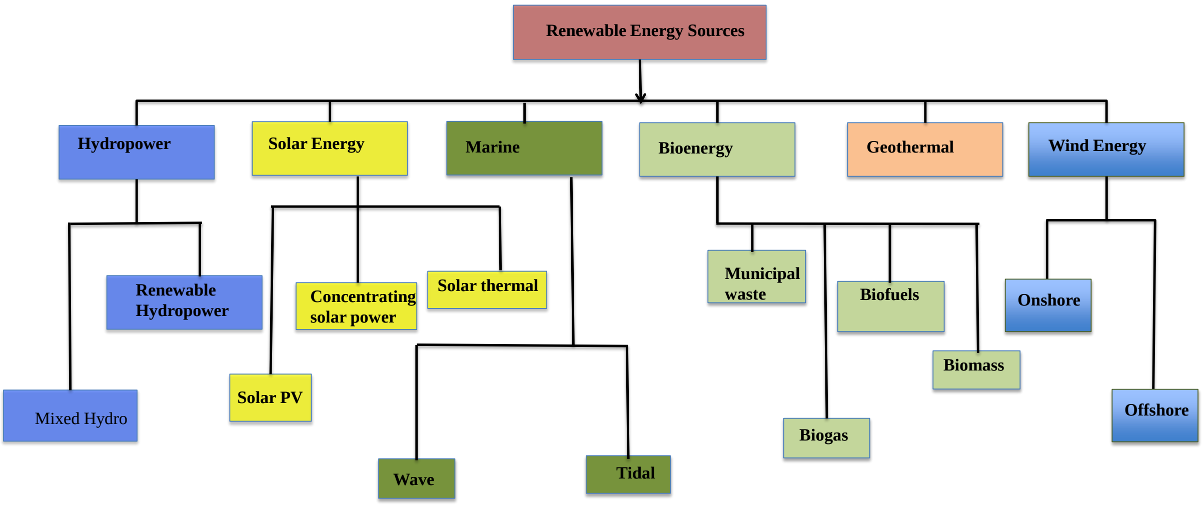

Figure 2-1: Types of Renewable Energy Sources

Source: Reproduced from (Chen, Cheng, He and Wang, 2022)

2.3.1 Solar Energy

Solar energy is widely regarded as one of the most reliable (Amin et al., 2017) and effective renewable energy sources (Lewis, 2007). One of the key advantages of this energy source is its applicability in various parts of the world because of direct solar radiation (Banos et al., 2011). Solar radiation is mainly converted into energy through active and passive solar designs. Fundamentally, active solar design is based on capturing solar energy using photovoltaic panels to convert that energy into heat. According to Banos et al. (2011), PV cells and batteries cannot be used all year round in regions far from the equator to provide street lighting for commercial purposes. Boyle (2012) asserts that there is a misconception about solar energy with the idea that solar PV cells consume as much electricity as they produce during their life during the production phase. The possibility exists that this may have occurred at the beginning of the PV era when refining monocrystalline silicon required a considerable amount of energy, and cell productivity was comparatively low. Despite this, the latest PV technologies utilise thinner cells (Wohlgemuth et al., 2006), thereby reducing the payback period (Wijesuriya et al., 2017).

Similarly, PV systems do not have moving parts and do not emit noise (Meah, Fletcher and Ula, 2008; Spertino et al., 2021; Suarez et al., 2018). According to Kannan and Vakeesan (2016), in recent years, solar energy has gained rapid growth globally, and this has led to an increase in the use and installations of solar photovoltaic systems (PV) (Huijben, Verbong and Podoynitsyna, 2016). Şen (2004) suggest that in addition to being renewable, solar energy is sustainable as it is derived from electromagnetic radiation. China is widely regarded as the largest installer of renewable energy sources. Its implementation of this energy source ranges in different uses such as heating, road lighting, and water heating (Liu, Wang, Zhang and Xue, 2010; Li and Huang, 2020). Pandey et al. (2016) suggest that the main technological components such as inverters, batteries, and PV panels are easily accessible for harnessing solar power.

Furthermore, other components such as PV panels, batteries, inverters, and charge-regulating components are inexpensive, easy to install, and require little maintenance. Subsequently, according to Fu, Feldman and Margolis (2018), PV system prices declined significantly between 2014 and 2016, resulting in a scheme known as rent-a-roof packages that could earn people money (Inderberg, Tews and Turner, 2018; Richter, 2013). The scheme involved paying customers to use their roofs for PV installation. This had a positive impact, with Baborska-Narozny, Stevenson and Ziyad (2016) stating that over 5000 UK households had installed solar panels. Hence, the UK government deserves acknowledgement for incentivising the uptake of solar energy systems on an industrial scale. Lewis and Nocera (2006) suggest that the developments in solar energy have provided additional benefits, such as the steady availability of electricity and a noticeable improvement in lighting quality. On the contrary, several studies found that in the UK, there is a tendency of smaller energy suppliers who are reliant on purchasing wholesale energy from larger companies at uncompetitive prices to resell to the consumers at inflated prices (von der Fehr and Harbord, 1993; Bradley, Leach and Torriti, 2013; Bunn and Yusupov, 2015).

Solar PV panels can only produce electricity during the day, and the energy produced is higher in summer than in winter. Boyle (2004) claims that there is a peak in the electricity demand in the UK during the summer rather than the winter. The reason is that buildings in the UK are relatively small, which, when combined with heavy insulation, allows them to retain heat quite effectively, thus keeping residents warm (Lomas and Porritt, 2016). Therefore, there is an increase in the use of cooling systems, which eventually contributes to the rise in the consumption of energy during the summer (Gupta et al., 2021, Alfakara and Croxford, 2014). Despite this, the information provided indicates that solar system implementations in the UK will be the country's most viable renewable energy source.

2.3.2 Wind Energy

Wind energy is regarded as one of the most viable alternative energy sources. Prior research in the development of wind energy showed that the use of larger turbines increases the output of the wind turbines by capturing more wind and producing more electricity whilst lowering the cost per installed unit of production (Banos et al., 2011). Subsequently, there are some benefits associated with wind turbines. According to Breeze (2016), the growth of wind power has led to the increased distribution of small-scale turbines with grid connections, along with creating development opportunities in offshore energy production. However, as wind energy is a viable alternative to fossil fuels, environmentally, it constitutes some negative impacts. The adverse effects include low wind speed and unpredictability (Keyaerts, et al., 2014). Therefore, offshore (Kalvig, Gudmestad and Winther, 2013) and high altitudes (Valsaraj et al., 2020) are best suited for wind farms because wind conditions because they are more constant. A positive impact of this energy source is that it does not generate carbon dioxide (CO2), radioactive substances, or pollutants that have the potential to contaminate land or sea in the latter stages.

Unlike other renewable energy sources, wind turbines do not require water consumption. Assuming the future is one of water scarcity, this could become a crucial factor (Boyle, 2012). Furthermore, wind energy has adverse environmental effects, including noise production, wildlife impact, and aviation disruptions (Boyle, 2012). According to Hammar, Perry, and Gullström (2022) and Maxwell et al. (2022), research findings showed that offshore wind turbines could negatively impact fish and marine life. Despite this, there are guidelines established by the United States Fish and Wildlife Service (USFWS), which are to provide helpful information to wind energy project developers (Boyle, 2012).

Nonetheless, despite the adverse effects of wind power, it is still one of the fastest-growing technologies. Therefore, it will become a vital part of the global reduction of carbon dioxide emissions. In the UK, the wind energy market is rapidly making a significant contribution and is gradually becoming a prominent source of energy in the country. According to Millward -Hopkins et al. (2013), the UK has the highest wind speeds in Europe, and if fully harnessed, it could provide its entire electricity needs. Several sources have identified that most wind energy installations in the UK are onshore, with a few offshore installations emerging gradually (Bassi, Bowen and Fankhauser, 2012; Kota, Bayne and Nimmagadda, 2015; Enevoldsen, 2016). Among the developments in recent years, the growth of onshore wind power, which is considered a cost-effective source of energy, has been evident.

Besides contributing to economic growth, it also promotes diversity in the categories of its developers. According to figures from the UK wind industry trade association, by the end of the second quarter of 2016, approximately 35TWh of electricity was generated, enough to power 8 million homes. Subsequently, an analysis from Wind Energy Statistics (2016) indicated that an estimated 44.23% of the onshore wind energy projects are in England, while the projects in Scotland, Northern Ireland and Wales are 39.58%, 6.67%, and 9.62 percent, respectively.

2.3.3 Hydro-energy

Hydropower is a form of energy that uses kinetic energy in the movement of water to produce electricity (Egré and Milewski, 2002). Water is denser than air, making it possible to produce significant amounts of energy even in a slow-moving stream (Kumar, Majumdar and Babu, 2012). There are several types of hydropower systems that exist today. A few examples are hydroelectricity, which produces electrical energy by using the gravitational force of moving water, and ocean energy, which is provided by tides, ocean waves, and average temperatures of the ocean (Pal and Khan, 2021). Kothari, Buddhi, and Sawhney (2008) report that hydropower can produce hydrogen. According to Banos et al. (2011), increasing interest has been expressed in developing and controlling hydropower plants in recent years. Several authors claim that in many countries, hydropower is the most developed renewable energy technology (Yuksel, 2007; Pandey and Karki, 2016; Bahadori, Zahedi and Zendehboudi, 2013). Furthermore, it does not consume or contaminate the water it uses to generate electricity so that it could be utilised for other purposes (Bahadori, Zahedi and Zendehboudi, 2013). The UK generates a substantial amount of renewable energy from hydropower. According to Ferreira et al. (2013), Dinorwig Hydro Power Station in Wales, UK, is the country's largest hydropower station located in Wales and generates 5,885 GWh of electricity per year. Furthermore, there are several hydropower projects spread throughout the UK, with many in Scotland due to the water flow requirements of the project (Sample et al., 2015). Nevertheless, recently, turbines that can produce water at small flows have been developed for various applications. According to World Energy Council (2016), hydropower accounted for 71% of the electricity production globally. Despite this, there is estimated to be approximately 10,000TWh/year of untapped hydropower globally (World Energy Council, 2016). Several authors suggest that before hydropower is implemented, essential aspects such as social impacts, economic impacts, and environmental impacts should be critically analysed (Aßmann, Laumanns and Uh, 2006; Boyle, 2012; Charlier, 2009). According to Boyle (2012), since 1990, approximately 35 major dam failures have resulted in catastrophic damage or fatalities. The study also stated some crucial findings. It suggests that carbon emissions could be emitted in tropical reservoirs under specific circumstances; likewise, waterborne diseases can occur. Lastly, embarking on this type of project usually requires a high level of up-front investment (Boyle, 2012). Despite this, its benefits outweigh its disadvantages. In addition to providing flood protection, it has a lifespan of 50 to 100 years. It contributes by helping preserve the environment from depleting non-renewable resources like coal, gas, and petroleum (Boyle, 2012).

2.3.4 Bioenergy

Bioenergy is a source of renewable energy derived from biological materials such as plants, animals, and living organisms. Biomass is generally regarded as one of the most promising renewable sources. However, more research is needed to establish the efficiency of biomass production as an economically and technically feasible source. The are several benefits of bioenergy. For instance, the steam, which is produced due to the burning of biomass, is used for making electricity and providing heat and steam for industry and homes (Balat, 2009; Campoy et al., 2009; Deshmukh et al., 2013; Gebreegziabher et al., 2014). Furthermore, biomass can be converted into various useful fuels, including biodiesel fuel, ethanol fuel and methane gas (Banos et al., 2011).

In contrast, Boyle (2012) contends that bioenergy is environmentally beneficial and harmful. The study stated that biomass production requires a vast amount of land, but the resulting impacts on the soil are of significant concern. The reason is that humus or organic materials are present in the soil (Boyle, 2012). Furthermore, healthy soil contains an abundance of humus, which acts as a carbon storage mechanism, able to hold immense amounts of carbon over an extended period (Boyle, 2012). Therefore, biomass production would involve cultivating the soil, which, when inevitably exposed to the atmosphere, releases carbon dioxide when broken down. There are also many questions regarding the benefits of bioenergy and the impact of its implementation.

In contrast, bioenergy is becoming increasingly popular as a renewable energy source, with the UK's government establishing a framework for promoting the technology (Bakar and Anandarajah, 2015; De Laurentis, 2015). It is also becoming a viable source in other globally. According to Azad et al. (2015), Australia is fast embracing biofuel as a reliable source of transportation fuel. In contrast, biomass boilers in the UK are widely used for generating heat (Eyre and Baruah, 2015). Despite this, a lot of research is needed before implementing bioenergy.

2.3.5 Geothermal Energy

Energy stored inside the earth as heat is referred to as geothermal energy. According to Banos et al. (2011), geothermal heat pumps have an enormous capacity that can be used for both heating and cooling. The earth's depth plays an essential role in this technology since its temperature is relatively constant and warmer in winter and cooler in summer compared to the air during the same period (Omer, 2008). Due to its constant energy source and lack of intermittence, geothermal energy can provide power 24 hours a day, unlike other renewable resources such as wind and solar (Tousif and Taslim, 2011). Although erecting a power station is quite costly, operating costs are relatively low, which results in low energy costs. According to Bertani (2005), 19 countries annually construct and install geothermal power plants.

Furthermore, geothermal energy has been developed to a relatively small extent despite its many advantages and potential in terms of contributing substantially to environmental protection by reducing greenhouse gas emissions (Karytsas and Choropanitis, 2017). Furthermore, besides the development of standalone hybrid power generation systems, it has also seen a remarkable increase in interest to optimise energy conservation and consumption (Moya et al., 2018). Compared to traditional renewable energy systems, these systems can be more reliable and cost-effective when designed optimally (Mahbaz, Dehghani-Sanij, Dusseault and Nathwani, 2020). Consequently, it is crucial to identify the factors that are crucial during the planning, design, construction, and operation of a hybrid power plant to maximise its operational and economic benefits, which are often in conflict (Banos et al., 2011). Among the environmental concerns associated with geothermal energy are noise pollution from drilling wells (Kagel, Bates and Gawell, 2005), disposal of drilling fluids (Paulillo et al., 2020), and gaseous pollution (Boyle, 2004). In contrast, geothermal energy is widely recognised as one of the most important renewable energy sources. Although geothermal energy poses many environmental concerns, extensive research is necessary to address them.

2.4 Summary

This chapter has outlined the renewable energy sources available, and the technological operations involved. Furthermore, it provided some advantages in contrast with the disadvantages associated with an emphasis on the renewable energy source pertinent to this study. The next chapter will investigate the challenges and benefits of implementing renewable energy.

Chapter 3: Key Factors of Renewable Energy Implementation

3.1 Introduction

Frameworks have been implemented in different parts of the world to promote renewable energy, each implementing effective mechanisms. This illustrates that developed and developing countries are shifting from over-reliance on fossil fuels to renewable energy to fulfil their energy needs (Wüstenhagen, Wolsink and Bürer, 2007). For instance, energy shortages are prevalent in Pakistan, where less than half of the resident population has access to electricity (Zafar et al., 2018). As part of its effort to reduce fossil fuel dependence, the government implemented renewable energy policies. Although this policy had its challenges, it did achieve some success (Zafar et al., 2018). Some of the reasons could include inadequate infrastructure, limited collaboration between organisations, limited access to technology, and lack of a skill-based workforce and training facilities (Zafar et al., 2018). Furthermore, several nations have also adopted policies promoting the use of renewable energy. This includes Germany, Italy, Denmark, Spain, France, the Netherlands, and Sweden. Their initiatives included Feed-in-Tariffs, green certificates, and competitive bidding processes (Zafar et al., 2018).

3.2 Renewable Energy Policies

Due to the growing number of net-zero reduction targets at the public, sub-national, and organisational levels, understanding the financial and technical aspects of net-zero emissions energy frameworks is essential. Consequently, Bistline (2021) reports that the number of studies examining net-zero objectives has increased. However, they are difficult to clarify because of contradictions across countries, differences in model constructions, and assumptions concerning inputs (Bistline, 2021). Approximately 164 nations have developed sustainable power strategy targets, and specified measures are required to achieve these targets (Donastorg, Renukappa, & Suresh, 2017).

According to Lund (2009), there are mainly three factors that influence energy strategies. They include security of supply, natural effects, and prices. However, there is another part of energy strategy, specifically the immediate opportunities for work that come from energy, specifically energy advancements (Lund, 2009). Therefore, there are various methods to support the advancement of energy technologies. An array of internal and external factors can affect the selection of a particular technique, such as the availability of assets, the development framework, and the status of the business (Lund, 2009). As component prices and installation and operational costs have decreased drastically, solar energy has become increasingly affordable (Leaman, 2015). Despite the relatively high upfront costs associated with solar and other renewable energies, governments are still responsible for monitoring and guiding solar energy applications worldwide, utilising a wide range of currently available policy tools (Lo, 2014; Solangi et al., 2011). Therefore, a practical policy framework is crucial to minimising capital costs for developers and reducing regulatory risks for investors (De Jager et al., 2008). According to Painuly (2001), the number of government targets and policies is increasing as countries recognise solar energy's potential for providing sustainable energy.

According to World Energy Council (2016), there were 164 renewable energy targets in place by 2015; 45 had solar energy targets covering both power generation and heating and cooling. This indicates that the expansion of policy targets has been primarily driven by emerging and developing economies (World Energy Council, 2016). Supply-side and demand-side drivers have benefited or are currently benefiting the world's most established solar markets. Feed-in tariffs and premiums have proven particularly effective for utility-scale solar in Europe, Australia, and the United States (World Energy Council, 2016). Utility companies in the United States sign long-term power purchase agreements (PPAs) with developers to secure revenue streams for power plants during the agreement (World Energy Council, 2016).

Furthermore, solar development is also boosted by government investment and production tax credits (Solangi et al., 2011). Furthermore, FiT and net metering have proven effective in addressing distributed systems. Table 3-1 illustrates policies that are promoting the development of solar PV in these markets.

Table 3-1: Key Drivers for the Growth of Solar PV globally

Country	**Policy / Regulatory Target**	**Supply Side Drivers**	**Demand Side Drivers**	**Fiscal Incentives Remark**	**Remark**
Germany	Yes	Feed-in tariff; Competitive bidding	Mandatory interconnection	Capital subsidy	Grid parity achieved; capital subsidy now provided for energy storage.
China	Yes	Feed-in tariff; Competitive bidding		Capital subsidy	
Japan	Yes	Feed-in tariff	Net metering	Capital subsidy	Shifted from net to gross metering in 2009.
Italy	Yes	Feed-in tariff			
United States	Yes	Investment tax credit (ITC)	Renewable Portfolio Standards (RPS); Net metering	Capital subsidy; Tax credits	A few states have gross metering in place
France	Yes	Feed-in tariff			
Spain	Yes	Feed-in tariff		Capital subsidy	New projects not eligible for FiT from 2012, additional 6% on participating projects.
United Kingdom	Yes	Feed-in tariff	Net metering; Renewable Obligation (RO)	Capital subsidy	
Australia	Yes	Feed-in tariff	Net metering	Capital subsidy	
India	Yes	Feed-in tariff; Competitive bidding	Renewable Portfolio Obligation (RPO); Renewable Energy Credits (REC)	Capital subsidy; Viability gap funding; Accelerated depreciation; Tax holidays; Priority Sector Lending; Concessional Duties	Competitive bidding on tariff is preferred instrument rather than FiT.

Source: Reproduced from (World Energy Council, 2016)

3.3 Legal Issues in the Renewable Energy Sector

Mauger (2018) argues that to achieve a national-scale energy transition, it is essential to have an appropriate and stable legal framework that enforces a clear and focused energy policy. Therefore, as the world's largest emerging nation, China fully recognises the importance of addressing environmental change issues and has made considerable efforts toward this target. The Chinese government has promoted the development of a sustainable power industry through various initiatives (Chang and Wang, 2017). This involves setting clear policies, facilitating guidelines and technical assistance, subsidising power costs, proposing financial incentives, and providing various institutional service (Chang and Wang, 2017). Additionally, Australia established a comprehensive legal and strategy framework for developing renewable energy by being aware of the importance of environmentally friendly energy to its people and economy. According to Buckman and Diesendorf (2010), Australia established the Renewable Energy Target (RET) in 2001, thus becoming the world's first nation to legally adopt environmentally friendly development objectives. Subsequently, Australia has extensively applied incentive approaches such as financial aid, tax deductions and credit advances in various fields that utilise sustainable energy, which has proven highly effective especially in transportation where there is a high energy requirement (Nelson, Nelson, Ariyaratnam, and Camroux, 2013).

France is also one of the nations that have implemented legislation for its renewable energy agenda (Wüstenhagen, Wolsink and Bürer, 2007). It is recognised as a leader in the European Union concerning the improvement and use of environmentally friendly energy sources. According to Liu (2019), the 2005 Energy Law established that least 10% of all energy consumption in 2010 would be from sustainable sources. Therefore, as the UK is embracing sustainable energy, decentralised generation has been proposed as an opportunity for government to respond to the developments in power generation, rather than swapping the unified framework for another similar (Markides, 2013). This means a chance exists to consolidate a decentralised organisation with huge advantages. In addition, Raybould, Cheung, Connor, and Butcher (2019) claim that up to 50 billion could be invested into the UK energy organisation to guarantee its energy security.

3.4 Insurance Issues in the Renewable Energy Sector

Insurance is regarded as one of the critical factors in the renewable energy industry because it provides financial security from damages to renewable energy projects. This includes damages during transportation, manufacturing, technical difficulties, and by unexpected forces of nature (Kirillova, Pukala and Janowicz-Lomott, 2021). However, the insurer of any renewable energy resources must provide adequate and reliable information of the potential severity of losses from all the damages covered (Kirillova, Pukala and Janowicz-Lomott, 2021). Regardless of how a given insurance provider interprets the study of environmental change, energy insurers are progressively mindful that the business climate is changing around them. Specifically, financial institutions, credit rating agencies, banks, clients, risk managers, and executives perceive environmental change as a danger and strive to include back-up plans to respond to it (Kirillova, Pukala and Janowicz-Lomott, 2021). According to Mills (2009), it is expected that insurance providers will devote more resources and consideration to environmental change as its consequences are further explored. However, the issue of accessibility and adaptability will continue to be raised, and agencies will continue to provide environmental risk information on both the assurance and resource management aspects.

3.5 Market Drivers of Renewable Energy

Over the last two decades, the electricity industry has witnessed two major transforming events that have profoundly impacted it. In this context, wholesale market competition has been introduced to markets in Australia, New Zealand, North and South America, and Europe (Woo, Lloyd and Tishler, 2003; Alagappan, Orans and Woo, 2011). As an investor, imploring a developer's perspective of renewable energy systems is crucial. The return on an investor's investment in a renewable energy source should be commensurate with the risk associated with its business (Tang, Chiara and Taylor, 2012; Sen and Ganguly, 2017). These characteristics are typically found in financially successful projects. For instance, a wind farm near a grid and with consistently high wind speed is well suited to the technology chosen.

Additionally, it is essential that successful projects choose sites that are readily interconnected to existing grid infrastructures (Alsayegh, Alhajraf and Albusairi, 2010; Kaundinya, Balachandra and Ravindranath, 2009). However, the development of a project can be hindered by excessive costs or obstacles, regardless of whether interconnection is possible. Therefore, the project must be completed with timely and cost-effective interconnections. It is also critical that a project investor be willing and equipped to pay a premium to succeed (Wu, Yang and Tan, 2020; Marcus et al., 2013). Due to the higher costs of renewable energy, it is crucial for an investor to accommodate the possibility of this. Most likely, this buyer is a load serving entity (LSE) whose retail customers can benefit from its cost savings from acquiring renewable energy (Tang and Zhang, 2019). More importantly, it is imperative for the successful developer to generate long-term revenue streams to cover expenses and provide a return on investment. A long-term power purchase agreement (PPA) is most likely to be the source of this revenue stream for the company (Tang and Zhang, 2019). Since renewable energy projects are very capital-intensive, investing in them entails a high level of risk, so a PPA is necessary (Tietjen, Pahle and Fuss, 2016). Furthermore, for a project to be successful, it is essential to have a transmission tariff that supports renewable energy generation such as solar and wind since many renewable generation technologies experience intermittent output profiles (Karatayev, Hall, Kalyuzhnova and Clarke, 2016; Shyam and Kanakasabapathy, 2017).

3.6 Commonly used Renewable Energy Technology in an Urban Environment

According to Neves, Salgado and Beijo (2017), United Nations statistics show that 78% of Latin American citizens resided in urban areas in 2007. This percentage is expected to raise to 89% by 2050 because of increasing urbanisation (Neves, Salgado and Beijo, 2017). As the urban population grows rapidly, it will reach 62% by 2050 in less urbanised regions of Asia and Africa, where 40% live in cities. Hence, the move to a 100% renewable model has already been embraced by many cities. Currently, solar energy and wind energy are the most popular sources of renewable energy in cities (Liu and Wang, 2009; Dehghan, 2011; Liu, Wang, Zhang and Xue, 2010).

Furthermore, fuel costs are covered by kilowatt-hour charges per kilowatt-hour of electricity consumed, thus resulting in a slight regressive effect in the price of electricity. This regressive pricing structure has been exacerbated mainly because of the recent, rapid growth in RETs such as wind turbines and solar panels. As a result, some governments have supported renewable energy through direct subsidies and support for consumers (Haar, 2020). Nevertheless, there is much more to the problem. For every extra kilowatt-hour generated by solar and wind, the cost of producing it is virtually zero, since the cost of generators and networks almost entirely covers the costs (Haar, 2020). Increasing fixed charges and reducing per-kilowatt-hour charges are the producers' ways of recouping their investments. In this regard, poorer, low-consumption households are penalised more for their electricity usage as they effectively pay more per kilowatt-hour (Haar, 2020). This results in families with low incomes having higher electricity prices per kilowatt-hour (kWh) than those with higher incomes. Electricity still costs less for many large companies (Haar, 2020).

Over 50% of global final energy consumption is attributed to heat, the most significant energy end-use (IRENA, 2018). Approximately half of this heat is consumed by industry, for example, steam production for industrial processes. At the same time, the remaining part is used for heating buildings and water, cooking, and agriculture (IRENA, 2018). As a result, there has been a rapid growth in energy consumption for cooling, space cooling and refrigeration accounts. This also accounts for about 2% of final energy consumption worldwide (IRENA, 2018).

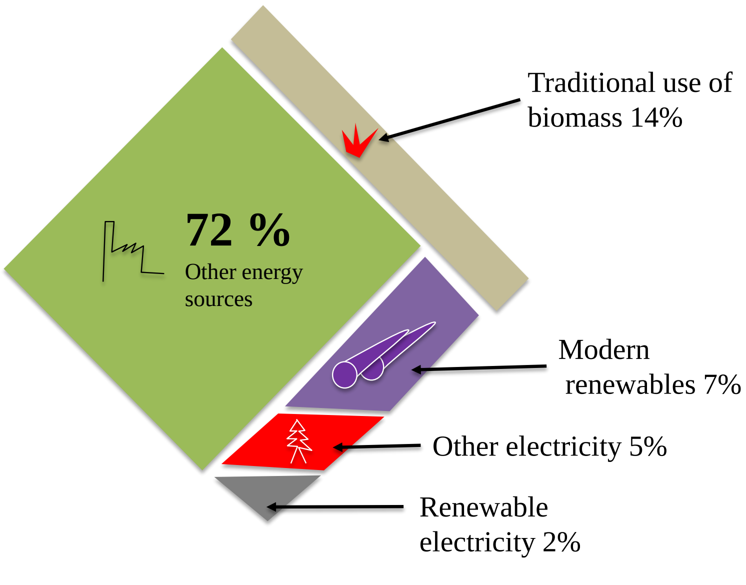

Figure 3-1: Total Energy Consumption for Heat in 2015

Source: Reproduced from (IRENA, 2018)

Based on its relative importance, the study established by IRENA (2018) concentrates on heat, with some consideration of cooling. It shows that a large portion of heat is still produced by fossil fuels, with over 70% coming from natural gas, oil, or coal (Figure 3-1). This contributes significantly to carbon dioxide (CO2) emissions. In 2015, around 12.5 gigatons of CO2 were emitted, representing 39% of total annual emissions from energy sources. In the energy transition, the Energy Transition Commission, a consortium of influential stakeholders, describes decarbonisation of heating, cooling, and cooking as a critical prize (IRENA, 2018). Around 14% of global heat is traditionally generated from solid biomass and the percentage is higher in some areas (IRENA, 2018).

Furthermore, the use of biomass for cooking is widespread in rural areas of sub-Saharan Africa and parts of Asia, usually with inefficient open fires or cookstoves, causing severe environmental and health problems such as air pollution. However, this study discusses how renewable energy can be used efficiently and using a modern approach. The electricity generated by modern renewable heat sources accounted for 9% of the total energy consumed in 2015 (IRENA, 2018). Currently, biomass dominates renewable heat consumption. Other options include solid biomass boilers and biomass, or biogas cogeneration systems linked to district heating, biomethane injection into natural gas grids, and direct use of biogas in cooking (IRENA, 2018). Subsequently, some industrial applications use solar thermal for supplying district heating systems, while solar thermal is increasingly used in large-scale applications to heat water (Rezaie and Rosen, 2012).

Geothermal energy has also been described as a potential source for heating homes. There are many uses for geothermal energy, including district heating, heating buildings, swimming pools, and industrial applications (IRENA, 2018). Hydrogen can also be produced with renewable electricity long-term (Carmo and Stolten, 2019). Natural gas can produce hydrogen, which can be used as a low-carbon heating source in countries with extensive gas grids, such as the Netherlands and the United Kingdom (IRENA, 2018). To decarbonise, industrial waste heat, among other sources, must be better utilised. Subsequently, there could be a potential for cooling systems. Distributed solar PV generation and self-consumption with some cold storage (e.g., ice storage) could meet cooling demand and solar availability (IRENA, 2018).

Solar absorption chilling and ground source cooling are direct renewable cooling options (IRENA, 2018). District energy networks can provide heating and cooling solutions by integrating renewable heating and cooling solutions with efficient options such as reusing excess heat (Rezaie and Rosen, 2012). District energy can also offer flexibility within the system by integrating power-to-gas, large-scale heat pumps, electric boilers, and thermal storage (Averfalk et al., 2017). Furthermore, heating, and cooling demand is influenced by energy-efficient buildings (Pacheco, Ordóñez and Martínez, 2012), appliances (Hart and De Dear, 2012), and industrial processes (Lake, Rezaie and Beyerlein, 2017). Therefore, energy efficiency is a fundamental and cost-effective first step to shift to renewable heating and cooling. Increasing energy efficiency can reduce heat demand and make biomass boilers more cost-effective. For example, the efficiency of heat pumps can be improved by adequately insulating buildings (Arteconi, Hewitt and Polonara, 2013). Several factors are responsible for encouraging renewable energy use in an urban environment. This involves the availability of subsidies for installing renewable energy systems such as photovoltaic and wind turbines (Gonzalez, et al., 2015). Another benefit is that the producer does not incur extra costs for each additional kWh of electricity generated by wind turbines and solar panels. Therefore, a greater wind or brighter sun today doesn't cost anything more to produce (Gonzalez, et al., 2015). Furthermore, several factors determine the cost of power production. However, most of the expenses are related to the construction of the power plants, wind turbines or solar panels, and the distribution lines, transformers, and regulators associated with these (Kalantar, 2010).

3.7 Use of Feed-in-Tariff (FiT)

A vital incentive scheme to encourage economic growth is the Feed-in-Tariff (FiT) applied to solar and wind technologies. FiTs schemes, essentially, pay sustainable energy producers a fixed rate (tax) for each kWh of power created and the power generation sold to the grid. Therefore, this obliges the energy organisations to buy all the power from qualified producers in their administration region for a period of 15 to 20 years (Muhammad-Sukki et al., 2013). There are generally three components to Feed-in-Tariffs provisions that are crucial to their success (Lu et al., 2020). They include access to the grid, long-term contracts, and price provisions that are based on the cost associated with the energy source (Lu et al., 2020). Those who generate excess renewable electricity and send it to the grid, such as homeowners, farmers and businesses will be paid according to the cost of the electricity generated (Lu et al., 2020). As a result, investors can earn a reasonable investment return, thus encouraging the development of an array of technologies such as wind and solar.

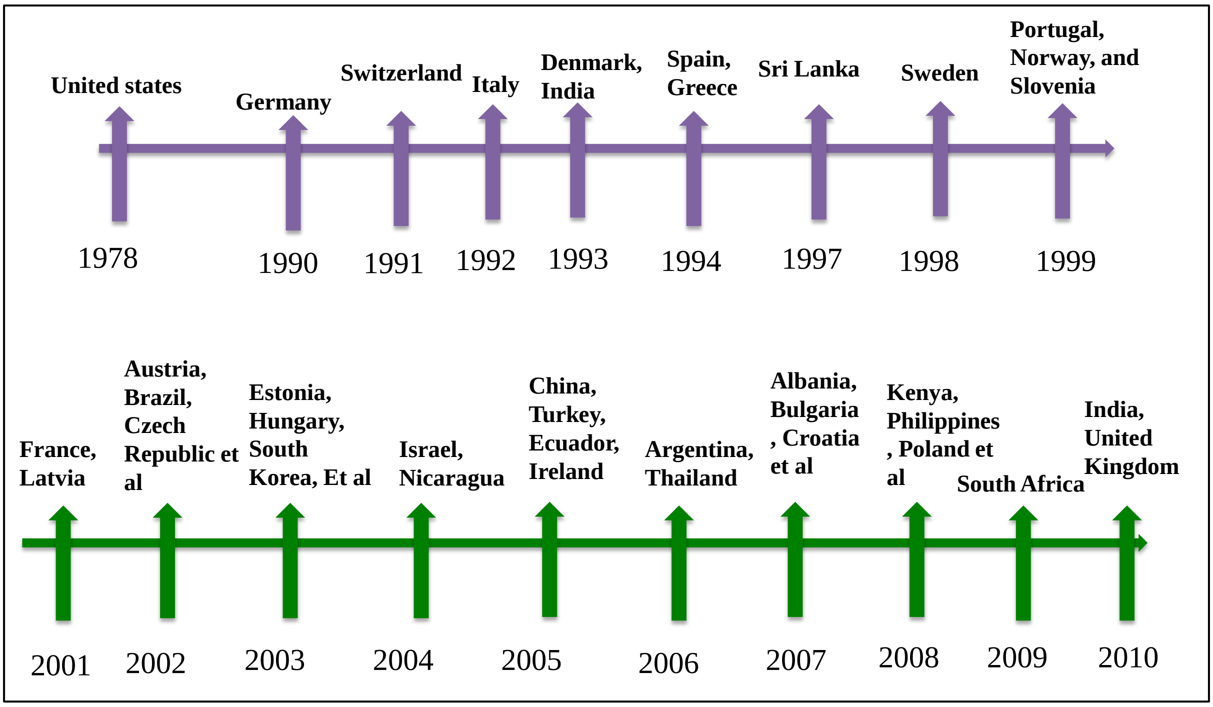

Figure 3-2 : History of the International Adoption of Feed-in-Tariff

Source: Reproduced from (Lu et al., 2020)

Depicted in Figure 3-2 is the history of the international adoption of feed-on-tariff (FiT). The FiT program has been implemented in more than 45 countries over the past two decades. As part of the National Energy Act (NEA), signed by President Jimmy Carter in 1978, Feed-in-Tariffs were implemented in the US under President Jimmy Carter to promote the development of renewable resources, such as solar, geothermal and wind energy (Lu et al., 2020).

As early as 1990, Germany introduced a FiT program based on the premise that these payments were based on a percentage of retail electricity rates (Lu et al., 2020). Furthermore, FiT programs were implemented in Denmark and Spain in 1993 and 1994, respectively (Couture, Cory, Kreycik and Williams, 2010; Mendonça, 2012; Hirsh, 1999; Lu et al., 2020). The rate of FiT payments depends on a few factors such as technology size, the location of its operation, and its region (Ramil and Twaha, 2015). To elaborate, it involves analysing its application in residential or commercial scale and understanding its location, which could include rooftop solar PV or ground-mounted projects (Ramil and Twaha, 2015). In the UK, homeowners and businesses were encouraged to invest in renewable energy through the FiT scheme, which was introduced in April 2010. The law required that energy suppliers compensate owners of renewable energy generation systems for any electricity they generated and contributed to the National Grid due to their installation (Ofgem, 2019). The FiT scheme was a huge success, with more people installing solar panels than expected. As a result, the government had to reduce the tariff over 9 years until it finally closed the program to new applicants in March 2019 (Ofgem, 2019). Depicted in Table 3-2 and Figure 3-3 is the rate of installed capacity of solar PV from 2010 to 2020. This shows that despite the closing of the FiT in 2019, the number of new installations grew further in the UK.

Table 3-2: Microgeneration capacity of Photovoltaic from 2010 to 2020

Year	Microgeneration capacity from 2010 to 2020 (MW)
2010	79
2012	1728
2014	2928
2016	4896
2018	5213
2019	5403
2020	5532

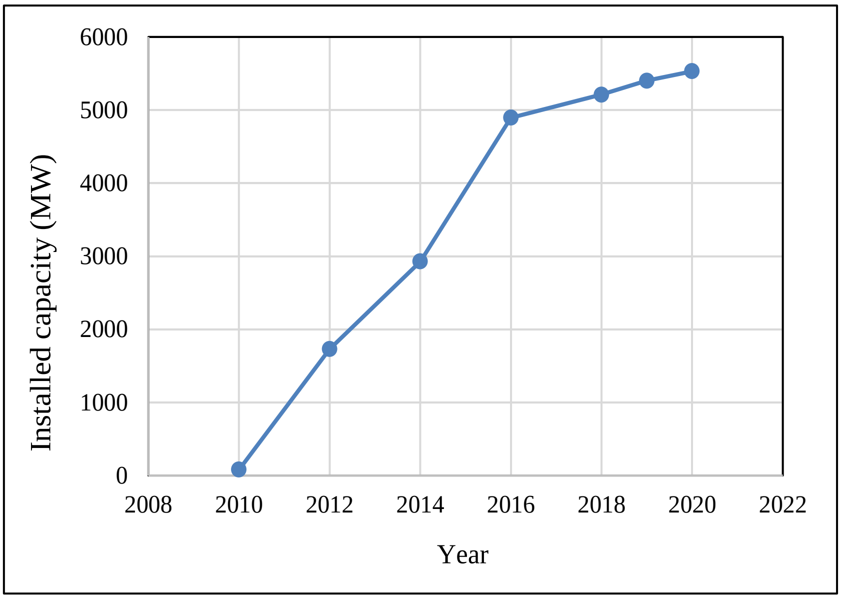

Figure 3-3: Microgeneration Capacity of Solar PV from 2010 to 2020

Source: Adapted from (Department for Business, Energy and Industrial Strategy, 2021)

Subsequently, the UK has made strides to ensure the continuous development of sustainable energy. To achieve net zero carbon emissions in the UK by 2050, the Smart Export Guarantee SEG scheme has been introduced as a replacement for the FiT scheme (Ofgem, 2020). Using renewable electricity will help consumers save money over time if they sign up for an SEG tariff and install renewable generation technology (Ofgem, 2020). SEGs can still be profitable, even though they are not as profitable as FITs initially were. Due to SEG's energy policy, renewable energy users are only paid for excess electricity put into the grid, rather than all the electricity generated (Ofgem, 2020). Table 3.3 depicts the difference between SEG and Feed-in-Tariff in the UK.

Table 3-3: Difference between SEG and Feed-in-Tariff in the UK

	Smart Export Guarantee	Feed-in-Tariff
Tariff rate	Electricity suppliers offer different tariffs.	Ofgem regulations stipulate that all applicants pay the same tariff.
Amounts payable	There are multiple tariff options, such as fixed tariffs and flexible tariffs, that suppliers can offer.	After installation, the tariff remains fixed for 20-25 years.
Scheme-purchased electricity	Export electricity is only subject to a single payment.	Electricity generated and estimated electricity exported are the two types of payments.
Calculation of payments	Smart meter that measures exported electricity every 30 minutes.	Usually, 50 percent of the electricity generated is exported. Meters are used to record generation.
Certification required for solar panels	It should be MCS or the equivalent.	It is necessary to have MCS certification
Planned funding	Companies that purchase energy pay the SEG.	Energy bills were levied to pay for the FIT.

Source: Adapted from (Ofgem 2019; 2020)

This indicates that despite the loss of the FiT scheme for new customers, there are still savings to be made by installing renewable energy sources with SEG. One benefit is the possibility of reducing energy bills, regardless of what was earned previously through the Feed-in Tariff program.

3.8 Impacts of Covid-19 on Renewable Energy Generation

In March of 2020, after it had been confirmed that COVID 19 was spreading across the globe, the World Health Organization officially declared the outbreak a pandemic, just three months after it had been registered as a global outbreak (Shultz et al., 2020). At the time of the first reports of Covid-19 spread to Wuhan, China, approximately 0.118 million people had already contracted the disease. A total of 26 countries had not reported any cases of Covid 19, while 57 countries had reported ten or fewer cases of the virus (Shultz et al., 2020). Historically, no other event has caused more disruption to the energy sector than the Covid-19 pandemic, with its effects expected to last for decades (Hoang et al., 2021). Subsequently, depending on the fuel, the impact of the pandemic varies. However, it is too early to determine whether the pandemic will be a setback or a catalyst for change (Hoang et al., 2021). There are still many uncertainties to be resolved, and key decisions concerning energy policies need to be made. It is predicted that while oil demand is expected to fall by 8% and coal use by 7%, renewable energy is expected to significantly increase. It is estimated that 3% of natural gas supply will be reduced, while only 2% of its electricity supply will decline (Das, 2020; Tian et al., 2022; Hosseini, 2020; IEA, 2020). An uncertain future for energy development is created by the uncertainty surrounding the duration and economic and social consequences of the pandemic (Das, 2020; Tian et al., 2022; Hosseini, 2020; IEA, 2020). IEA (2020) suggested that Sub-Saharan Africa is expected to experience a decline in access to electricity, reversing several years of progress. In Sub-Saharan Africa, it is estimated that there are there are 580 million people who lack access to electricity, which accounts for roughly three quarters of the total worldwide. Therefore, incentives must be created to improve this situation (IEA, 2020).

Furthermore, in reaction to the impacts of the pandemic, government's attention has been drawn to public health and economic crises in countries with a high access deficit, which has led to substantial borrowing costs (IEA, 2020). Nonetheless, the resilience of renewable energy will be impactful for the next decade and beyond since renewables are the only major energy source to grow in 2020. According to IEA (2020), a well-designed electricity network would be crucial, as solar PV and wind together will generate almost 30% of global energy by 2030.

3.9 Benefits of Renewable Energy Implementation

Several benefits are associated with renewable energy, including environmental values and the reduction of greenhouse gases polluting the environment. This is further elaborated in Figure 3-4.

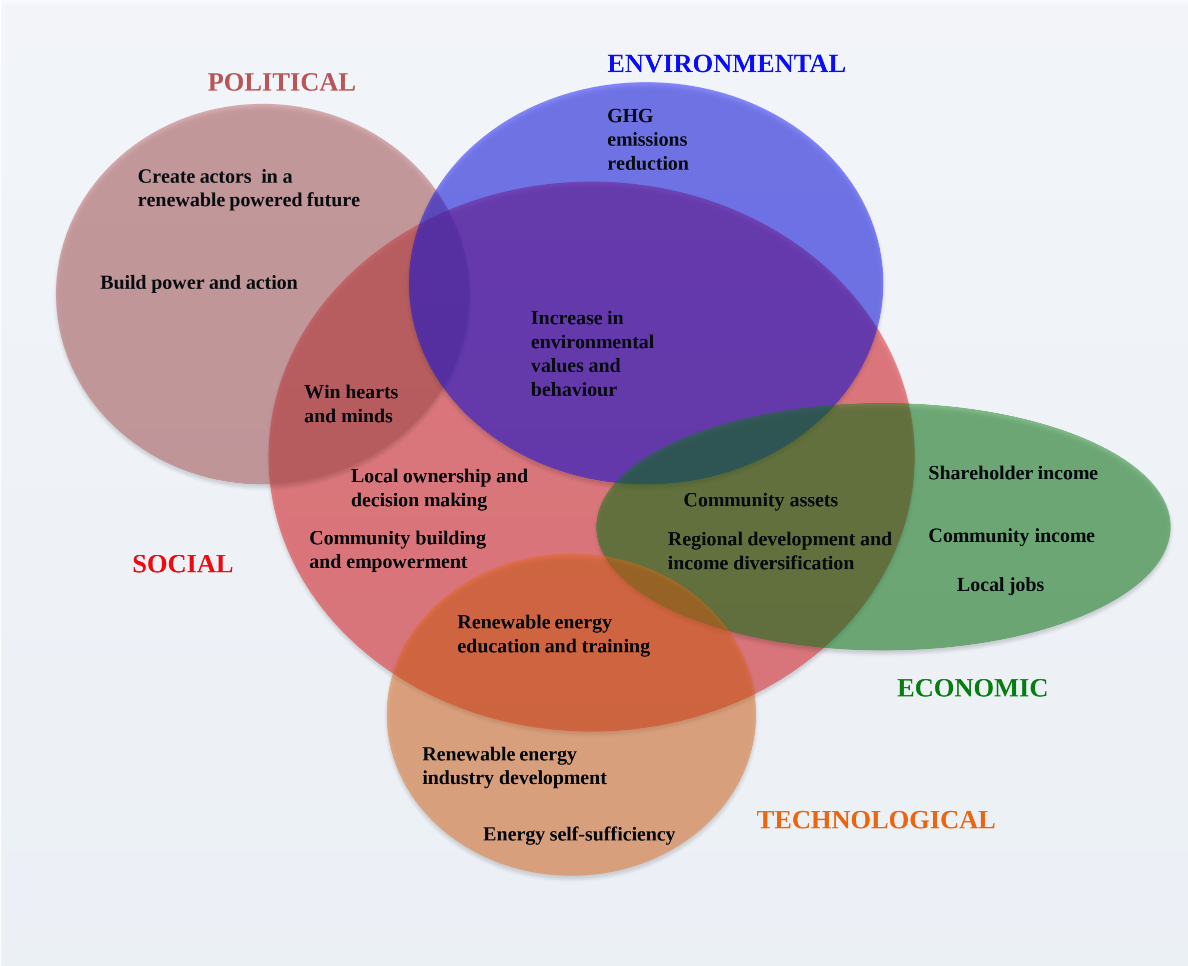

Figure 3-4: Global Benefits of the Production of Renewable Technologies

Source: Reproduced from (Ellabban et al., 2014)

It is apparent from Figure 3-4 that renewable energy can contribute to a society's environmental values, promote environmental sustainability, and reduce carbon dioxide emissions. In addition, it offers potential employment opportunities that contribute to the social and economic development of the area. This therefore implies that for long-term acceptance and support of renewable energy, society needs to be oriented towards its relationship with the energy source (Wüstenhagen et al., 2007). The analysis of a social perspective is also an essential requirement for the growth of renewables. It involves examining the interactions between individuals, groups, and social organisations, as well as behavioural patterns exhibited by individuals, groups, and organisations (Sheikh et al., 2016; Simas and Pacca, 2014; Amer and Daim, 2011). According to Sheikh, Kocaoglu and Lutzenhiser (2016), renewable energy needs to be assessed from a social perspective to establish a sustainable approach aligned with social constructs. It has also identified that there are times when the impact on human beings can take precedence over any other consideration. Therefore, a comprehensive assessment framework should include a social impact evaluation for significant studies (Soltani et al., 2021; Rae and Bradley, 2012; Naicker and Thopil, 2019). A social perspective can be analysed using a number of constructs. This includes employers, health and safety officials, public perception, and local infrastructure development. However, an essential consideration for any government or society is the issue of employment. Economic well-being is associated with employment for individuals and society (Diener and Seligman, 2004). Governments and politicians recognise that sustained employment leads to a happy voter base, while a lack of employment produces demands for reform among the population (Alt and Lassen, 2006).

Therefore, it is crucial to the country's economic stability because manufacturing creates jobs, provides growth, and increases productivity (Obschonka and Silbereisen, 2015; Pagés, 2010). Subsequently, technological changes play a significant role in renewable energy development. Developments such as these determine the cost and maturity of specific technologies and the efficiency and effectiveness of investments (Pagés, 2010).Furthermore, as technology develops and time elapses, costs decrease as well. Consequently, the government plays a vital role in the process of promoting the use of renewable energy worldwide. This is achieved by establishing customer benefits such as short returns on investment, raising public awareness about renewable energy, and promoting the use of efficient technologies (Lund, 2010). This eventually has a considerable impact on renewable energy suppliers also affected by market and customer satisfaction (Lund, 2010).

3.10 Models of RE implementation

The developments of sustainable business models within the built environment can play a vital role in promoting RET deployment (Iea-Retd, 2013). Building owners can leverage them for access to capital, risk outsourcing, and further energy services, including financing up-front costs (Hannon, Foxton and Gale, 2015). When the government modifies existing legislation to promote business, a business model becomes viable (Dóci, Vasileiadou and Peterson, 2015). However, business models alone will not significantly increase RET deployment. A study by the International Energy Agency and other organisations indicates that despite its benefits, RET and energy efficiency measures are still not widely adopted in the built environment (IEA, 2007; Houser, 2009; Bertoldi and Boza-Kiss, 2017; Kephalopoulos et al., 2016). As a result of the development of innovative and new business models, one or more of these barriers could be overcome, leading to sustainable energy development in the built environment. Business models have been studied extensively, but a general definition is not yet agreed upon, despite definitions generally stating that a business model describes the process by which it creates value for customers or shareholders (Osterwalder, 2005, Osterwalder et al 2005, Shafer, Smith and Linder, 2005). Subsequently, there are different aspects involved in the process of creating value. Weill and Vitale (2001) suggest that this analysis has many aspects. It indicates that strategic objectives, value propositions, revenue sources, critical success factors, core competencies, customer segments, sales channels, and key activities and resources are crucial.

Alternatively, a business model could simply be viewed as how a company generates revenue to survive (Rappa, 2001). Business models are often researched at the company level, focusing on the strategy. However, it is paramount to include non-corporate strategies in the definition of a business model, despite the concrete case of the deployment of RET in the built environment. Multifaceted in nature, the built environment encompasses many market segments and participants. According to the World Business Council for Sustainable Development (2009), several stakeholders are identified in its ‘Roadmap for a Transformation of Energy Use in Buildings’. They include investors, manufacturers, governments, developers of RE, occupiers, suppliers, architects, engineers, contractors, builders and utilities. There may also be an involvement of energy service companies in this process. In the built environment, at least five entities can directly invest in RET, including the investor, the energy service company, the utility, building developer, and the occupier (Eiffert, 2000). The result is that value can be created as a by-product of the entire process. Various barriers can impede the development of RE. These include market and social barriers, information failures, regulatory, and financial barriers (Painuly, 2001; Brown, 2001; Reddy and Painuly, 2004). It is often the case that energy costs in buildings are relatively low compared to other costs (IEA, 2007).

However, building owners lack motivation to improve their buildings' energy efficiency. Consumers are more likely to buy building upgrades for various reasons, such as comfort, aesthetics, reliability, convenience, and/or status. According to the IEA (2007), companies prioritise investments in core business assets. Likewise, the market price of energy does not consider externalities, such as the cost associated with depleting natural resources, pollution, and climate change, since these costs are not accounted for in the market price (Wuertenberger et al., 2011). Therefore, energy is too cheap from a societal perspective. There is therefore a lack of accurate price signals available to consumers and project developers that reflect the true marginal cost of energy use (Wuertenberger et al., 2011). Then again, a building's perceived inconvenience and the transaction costs associated with installing new equipment in an unoccupied building may outweigh any benefits from implementing RET and EE measures (Wuertenberger et al., 2011). There are also issues regarding split incentives. In a split incentive, as the name implies, the person who pays the upfront costs for a measure such as a renewable energy or energy efficiency incentive is not the same person who benefits from lower energy costs (Wuertenberger et al., 2011). A split incentive occurs for example in rental properties when the owner of the property has little incentive to invest when the tenant pays the energy bills. Also, the tenant may be less inclined to invest in RET given the possibility of moving out before the repayment period. However, a split incentive may also be offered between the building-owner, user, and the project developer in new buildings, where there may be no or little benefit to incorporating RET. This is crucial in situations whereby the developer is unlikely to fully recover the higher initial costs from the building owner (IEA, 2007). In addition, some people are elderly or will move within the next few years and are not prepared to invest further in their homes. In rented apartments where heating costs are shared equally, there are fewer incentives to conserve energy (Wuertenberger et al., 2011).

Furthermore, researchers have discovered a general lack of awareness about RET and EE (Wuertenberger et al., 2011). Investments in buildings do not consider RET alternatives if they aren't proven to be viable. Furthermore, individuals investing in EE or RET are not adequately informed about financing options (Wuertenberger et al., 2011). Despite their willingness to adopt EE or RET, building owners often have difficulty finding independent and objective advice from financial experts, even if they are motivated to do so. RET can be limited to a few institutions or professional groups due to a lack of knowledge or competence of those involved in installation and maintenance (Wuertenberger et al., 2011). This may therefore result in poor equipment installation (Wuertenberger et al., 2011).

Furthermore, the deployment of RET may be hindered by procurement rules prohibiting building management outsourcing to private companies (Wuertenberger et al., 2011). In most cases, renewable energy or energy-saving technologies are not invested in due to the long payback periods and long economic lifespans they require, as well as the fact that they are not meeting people's expectations (Wuertenberger et al., 2011). Compared to conventional technologies, renewable energy technologies require a higher up-front investment (Wuertenberger et al., 2011). As a result, investments may be hindered as decision makers, particularly private homeowners, may be unwilling to spend a large sum of money up front. For example, Fuller (2009) suggests that it is estimated that private consumers' implicit discount rates for investment decisions range from 25% to 75%. This therefore greatly raises the hurdles for upfront investments.

Furthermore, RET or EE programs are particularly challenging for low-income homeowners and small business owners (Wuertenberger et al., 2011). Additionally, because of high technology or regulatory risk, EE and RET projects can be risky investments (Wuertenberger et al., 2011). A high discount rate is applied for projects with higher risks, or a higher return is required to compensate for it. Therefore, because of the lack of investor attention, EE and RE projects are often unattractive for investors (Wuertenberger et al., 2011). There is also the possibility that RETs are perceived as being riskier than they are. However, when EE measures or RET are implemented, credit capacity and risk profile should improve for mortgage customers, since more income will be available to pay interest and down payments (Wuertenberger et al., 2011). Nevertheless, financiers do not usually recognise this increased credit capacity due to mortgage criteria.

There are several business models used to promote and implement RE sources. They include product service systems, energy contracting models, business models based on new revenue models, and business models based on financing schemes (Wuertenberger et al., 2011). An example of a product-service system business model in sustainable energy is Energy Service Companies (ESCOs). Energy Supply Contracting (ESC) and Energy Performance Contracting (EPC) are fundamentally different business models in the ESCO sector, which provide either useful energy or energy savings to the end user (Wuertenberger et al., 2011). The Energy Supply Contracting model is a business model in which an energy service provider (ESCO) provides useful energy to an owner or user of a building under a long-term contract, such as electricity, heat, or steam. The EPC model averages energy savings over a baseline (Wuertenberger et al., 2011).

Additionally, ESCs and EPCs have a wide range of variations in practice. Mostly, they relate to how the investments are financed and the services provided under the contracts

(Wuertenberger et al., 2011). It is pertinent to note that in Anglo-Saxon markets, for example, there are two types of EPC models, wherein one involves the ESCO deciding on the financing, and the other does not. In terms of service products, one of the services offered by the ESCO is Guaranteed Savings, which can be purchased without financing. In contrast, shared savings can be purchased with financing included (Wuertenberger et al., 2011).

Additionally, a third, innovative model, Integrated Energy Contracting (IEC), is under trial in Austria and Germany. It is a methodological framework that uses the ESC model in calculating energy savings and expands upon it by adding an approach that identifies deemed savings for energy efficiency measures (Wuertenberger et al., 2011). Compared to conventional ESCs, the IEC provides far greater energy and emissions savings by extending its services to the entire building (Wuertenberger et al., 2011). Among the most common and successful incentive schemes for RET deployment, feed-in schemes compensate the owners of RET installations by charging a higher price for renewable energy to cover RET's higher cost than conventional technologies (Wuertenberger et al., 2011). Therefore, RET and conventional technologies have a financial gap that feed-in remuneration schemes can bridge. These are the characteristics, which are important for the development of a business model bases on revenue. Electricity from renewable sources is typically fed into the electric grid through Feed-in-Tariffs or feed-in premiums (Wuertenberger et al., 2011). Buildings certified by voluntary 'green' building labels also offer a business case independent of policy incentives for building developers (Wuertenberger et al., 2011). The opportunity to earn more revenue from an investment in energy efficiency arises for building owners whose tenants don't occupy the property and for housing corporations whose tenants can charge a higher rent after the renovation has been completed (Wuertenberger et al., 2011). Therefore, the tenant will have to pay a higher rent to offset the energy savings (Wuertenberger et al., 2011).

Furthermore, split incentives need to be addressed by legal changes. Innovative financing schemes can therefore assist in developing business cases, provided that these financing schemes minimise the high upfront costs associated with such schemes (Wuertenberger et al., 2011). These are characteristics of the business model developed on financing schemes in a world with limited government budgets. However, new and innovative financing methods are being developed that don't have a detrimental impact on the public budget (Wuertenberger et al., 2011).

For instance, several pilot projects have been conducted in the US regarding Property Assessed Clean Energy (PACE) (Wuertenberger et al., 2011). This involves having RET projects to be financed by bonds issued by local governments. A special assessment payment is made on the building owner's property tax bill for a specified time to repay the loan (Mathews and Kidney, 2012). When the property changes ownership, the remaining debt is transferred with the property to the new owner (Wuertenberger et al., 2011). A utility can provide funding for installing RET or EE measures through its on-bill financing program, which addresses barriers such as high up-front costs and access to funds. As a result of the investment, the homeowner pays for it through the energy bill. Leasing of RET offers another opportunity for building owners to use RET without making an upfront investment (Wuertenberger et al., 2011). Therefore, the owners of buildings can benefit from the incentives offered by these programs.

3.11 Payback Period for Renewable Energy Sources

The use of payback is a concept which is extensively used in any business venture (Brownson, Gardner and Nieto, 2015). Energy payback period is defined as the specific period or duration which is required to recover all investment costs incurred during the implementation of a project (Kumar and Tiwari, 2009). According to Wilson and Dowlatabadi (2007), logic and utility preferences are expected to drive consumer decisions. Most current policy measures, including tax credits, incentives, and rebates, are inferred from assumption that consumers behave rationally and that reducing the up-front investment costs will encourage them to purchase. Nevertheless, studies had also shown that discount rates are more effective when applied contextually, according to the type of purchase, the perceived risks, and the length of the payback period (Loewenstein and Prelec, 1992). In a study about renewable energy consumer adoption, the findings showed that approximately one-third of consumers surveyed by Potomac Electric Company could not answer the question about the payback time for investment in energy technologies (Koomey, 1990). According to the survey, over three-fourths reported a payback period of three years or less. However, renewable energy systems have substantially more extended payback periods than are commonly assumed. Solar energy one of the most prominent examples.

In contrast to business energy investments with a two-to-three-year payback period, commercial solar power installations pay for themselves in five to nine years (Rendon, 2003). It is also essential for electric utilities to maintain low costs and quickly pay back their investments. A payback period of less than 5 years is also helpful to consumers when investing in renewable energy systems (Fouad et al., 2022). In order to accept new services, consumers are mainly motivated by financial rewards and reductions in bills. As a reason for choosing less than 5 years of payback time, some respondents expressed concern about the guarantee of renewable energy sources and the after-sale services (Fouad, Kanarachos and Allam, 2022). This is partly because most people desire their money back as soon as possible after investing. They also believe that investing will be worthwhile if the return on investment is less than five years; otherwise, they consider that the investment will not be worthwhile (Fouad, Kanarachos and Allam, 2022).

3.12 Summary

This chapter highlighted the issues and benefits associated with renewable energy implementation. It identified frameworks implemented by various countries to promote renewable technologies and some hindrances impacting their growth. It also identified the RET models of implementation and levelized cost of electricity for solar energy. To address the challenges involved with renewable energy implementation; renewable energy policies, legal issues, insurance issues, market drivers of renewable energy, commonly used technology in an urban environment and feed-in-tariff should be critically analysed. Also, the impact of Covid should be regarded as an important factor that could either present a scenario for the development of renewable energy or impede the development shown in that sector. Concerning the benefits associated with renewable energy sources, it is imperative to observe and adhere to the social perspective, as this could be the most important aspect of enabling the growth of these technologies.

Chapter 4: Renewable Energy Development in the UK

4.1 Introduction

In terms of energy security, the UK is ranked as the most energy secure country in the EU and the fourth most secure country overall. Although the government inherited a huge investment challenge in all energy sectors in the form of a huge financial challenge, the government remains committed to providing reliable, secure, and cost-effective energy supplies in the future. This is evident in the laid-out Climate Change Act 2008, therefore meeting the climate change targets (HM Government, 2009).

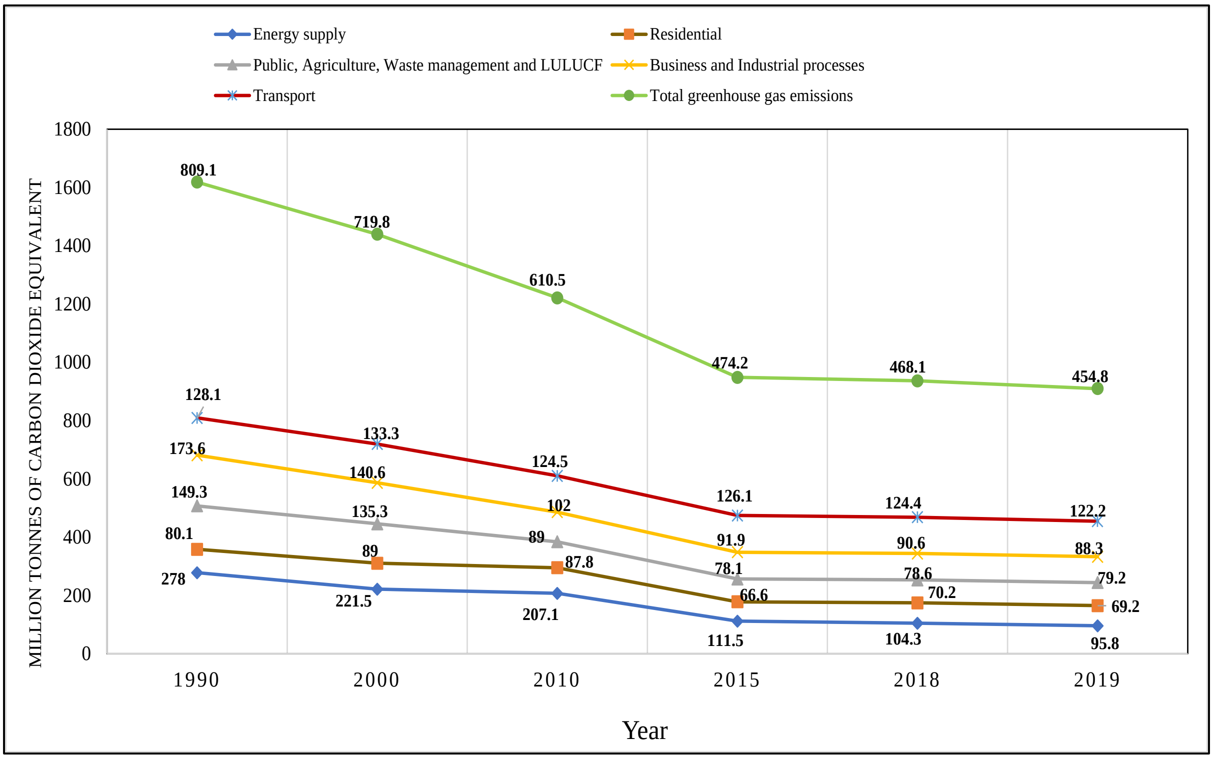

Figure 4-1: Total Greenhouse Gas Emissions in the UK from 1990 - 2019

Source: Reproduced from (Department for Business, Energy and Industrial Strategy, 2021)

Depicted in Figure 4-1 are the territorial greenhouse gas emissions from the various sectors in the UK. The UK emissions of carbon dioxide equivalent (MtCO2e) in 2019 were estimated to be 454.8 million tonnes, a 44% decline from 1990.

Transportation accounted for 27% of total greenhouse gas emissions in 2019, and emissions decreased 5% between 1990 and 2019. A change in the electricity mix has resulted in a 66% reduction in GHG emissions from the energy supply sector since 1990, accounting for 21% of emissions in 2019. Residential emissions made up 15% of emissions in 2019; however, they have decreased by 14% since 1990. The UK became the first nation to have a legally binding carbon budget by passing the Climate Change Act 2008 (HM Government, 2009).

Additionally, the Department of Energy and Climate Change (DECC), in conjunction with the long-term carbon reduction target mandated by law, adopted five-year carbon budgets based on the recommendations of the Committee on Climate Change. Furthermore, DECC must regularly report to parliament on its progress toward these targets. To reduce carbon dioxide emissions, the UK energy sector's low-carbon electricity strategy aims to replace large, centralised, fossil-fuelled plants with low- or zero-carbon plants (Department of Energy & Climate Change, 2013; HM Government, 2009). Therefore, the UK needs to further its efforts to implement renewable energy and achieve set targets successfully.

In March 2020, the UK government announced its budget for 2020. The outlined budget was expected to accommodate issues faced by the impact of Covid 19 on people, businesses, and security measures (HM Government, 2020). However, the government also allocated £500 million to support the deployment of electric cars, £100 million to effectively implement a scheme to help households and small businesses to invest in low carbon heating systems, and £270 million to encourage existing new and green heat network schemes. This showed that the government prioritises sustainability development in the UK, aiming to further reduce its carbon emissions from its various sectors (HM Government, 2020).

4.2 Use of District Heating in the UK

In district heating, local fuel and heat resources that would otherwise be wasted are efficiently utilized to satisfy the heat demands of local consumers. Through a local pipe distribution system, the local heating market can be reached efficiently and effectively (Werner, 2017). District heating systems worldwide have incorporated several renewable methods to generate heat, including geothermal wells, solar collectors, and biomass fuels (Østergaard et al., 2020). As a result, societal heat demands can be met without using conventional primary energy without negatively impacting the environment. This gives district heating a fundamentally different business situation compared to other sectors in which economy-of-scale is characterised instead of economy-of-size. According to Rezaie and Rosen (2012), district heating systems have achieved this globally based on market penetration, local resource usage, network size, and environmental impacts. District heating provides most of the energy in some European countries. Increasingly, district heating is being installed in new homes in the UK because of new housing developments. According to Cooper, Hammond and Norman (2016), about 200,000 homes benefit from district heating networks in the UK. In addition, London is planning on using waste heat from its tube stations for electric heating (Wegner et al., 2021).

Despite its advantages, district heating has one major disadvantage: planning it before construction is much easier than retrofitting it (Brand and Svendsen, 2013). It also requires convincing many residents that the project will be beneficial and that they will not be held liable for the installation costs. There are also other issues associated with this type of heating. For instance, the control of heat is deemed to be a more significant issue than the heating itself. People who pay for their heating at a flat rate tend to open windows instead of turning the thermostat down, which causes the rooms to be heated much higher than they would if they paid a monthly bill (Langevin, Gurian and Wen, 2013).

Additionally, old systems often have inadequate control over the heating, especially in the winter (Elsharkawy and Rutherford, 2018). In a building with communal heating, some flats have only one or two programmers, thermostats, and thermostatic values, while many homes nowadays have all three (Urquizo, Calderón and James, 2018). This can lead to overheating and energy waste (Li, Sun, Zhang and Wallin, 2015). Therefore, a district heating system with metering would be ideal so ustomers can be charged based on how much energy they consume (Darby, 2010; Burak Gunay, O'Brien, Beausoleil-Morrison and Perna, 2014). However, customers who currently have flat rate charging and do not want their bills to increase are unlikely to agree to this, primarily due to customer pushback. The UK is, however, moving towards a low-carbon and digitalised future that offers opportunities to transform how it will heat homes and buildings (HM Government, 2020). The UK is also making strides to grow the market for heat networks. The government has allocated £320m of funding through 2021 (Chauvaud de Rochefort, 2018). Hundreds of heat networks will be constructed in

England and Wales because of this funding, which is expected to attract up to £2 billion additional capital investment (Chauvaud de Rochefort, 2018).

4.3 Impacts of Covid-19 on Energy Generation in the UK

Covid-19 has had some impacts on the generation of energy in the UK. The efforts to comply with Covid-19 restrictions hit energy demand in 2020 from the economy, work, and leisure (Department for Business, Energy and Industrial Strategy, 2021). Despite the decline in oil and gas extraction in 1986, the UK economy generates substantial revenue from these sources. Since the UK's oil and gas production fell below the UK's electricity production until 2014, its value is also affected by demand and production reductions (Department for Business, Energy and Industrial Strategy, 2021). However, production and prices dropped because of Covid-19's impact on supply and demand by 2020.

Table 4-1: Production of primary fuels - UK

	1990	2000	2010	2018	2019	2020
Primary oil	100.1	138.3	69	56	57.4	53.6
Natural gas	45.5	108.4	55.3	38.8	37.4	37.7
Coal	56.4	19.6	11.4	1.9	1.8	1.2
Primary electricity	16.7	20.2	151	20.5	19.2	18.9
Bioenergy & waste	0.7	2.3	5.8	12	12.3	12.7

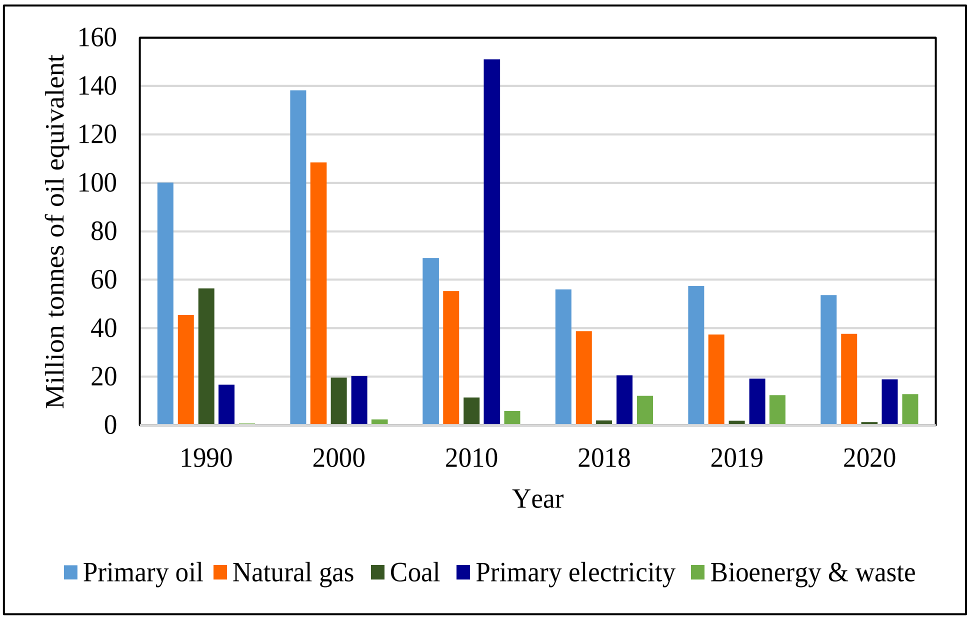

Figure 4-2: Production of Primary Fuels in the UK

Source: Reproduced from (Department for Business, Energy and Industrial Strategy, 2021)

Depicted in Figure 4-2 is the production of primary fuels in terms of energy content. It is estimated that the total production of primary fuels in 2020 decreased by 3.1% compared to the same period in 2019. Due to the delay in maintenance activities at the North Sea, impacted by the pandemic, renewable energy sources such as bioenergy and waste, wind and solar power have been offset by reductions in fossil fuel and nuclear output (Department for Business, Energy and Industrial Strategy, 2021). Subsequently, several nuclear power station outages were reported in the UK. Production of coal reached an all-time low in 2020. Among the total energy production, crude oil and natural gas liquids accounted for 43%, natural gas 30%, nuclear, wind and solar energy 15%, bioenergy and waste 10%, and coal 1%. During the 1990s and 2000s, oil and gas production grew rapidly. Natural gas production reached record levels in 2000, while petroleum production reached record levels in 1999. Due to the opening of new oil fields, bioenergy and waste production growth, and increased wind and solar production, production levels have increased since 2014 despite general declines (Department for Business, Energy and Industrial Strategy, 2021). The production level in 1999 has fallen by 58%, while there has been a 5.1% decline in oil and gas production since 2000 (Department for Business, Energy and Industrial Strategy, 2021).

Furthermore, due to the Covid-19 pandemic lockdowns imposed from 2020 to 2021, consumption levels were severely impacted in the UK starting in March 2020. Warmer temperatures also contributed to a reduction in consumption in 2020, with the average consumption falling by 2.8%, resulting in a reduction in heating degree-days to 5.1 from 5.4 (Department for Business, Energy and Industrial Strategy, 2021). There was an increase in consumption from working from home of 2.3%, but there was a decrease in transportation-related consumption. Since travel restrictions were introduced during the lockdown, transportation-related consumption fell by 29% (Department for Business, Energy and Industrial Strategy, 2021). During the same period, transport consumption dropped by 18%, and air consumption dropped by 60%. There were also declines in the different industries in the UK. Due to the closure of factories, shops, offices and schools during the lockdown, the energy consumption in the service sector declined by 5.6% (Department for Business, Energy and Industrial Strategy, 2021). The impact of the pandemic on energy generation and consumption is evident in the UK, and the impacts will be analysed in the years to come. Still, it would require the attention of governmental bodies and energy providers to provide swift action to tackle any issues that may arise (Harris, 2021).

4.4 Impacts of Brexit on the Energy Sector

The British people voted during a historic referendum on 23 June 2016 to leave the EU; an event commonly referred to as "Brexit" (McCann and Hainsworth, 2017). It was also assumed that a member state leaving the EU was a new phenomenon. Article 50 of the Treaty of the European Union (TEU) lays out the steps to declare a member state's intention to leave the Union. During the post notification of intent by the exiting party, two years will be available for negotiations regarding, among other things, energy and trade regimes (Ifelebuegu, Aidelojie and Acquah-Andoh, 2017). Therefore, before and during the dialogue, different stakeholders are involved at different levels in determining the strategic direction of the divorce (Ifelebuegu, Aidelojie and Acquah-Andoh, 2017). However, a vote to leave the EU could lead to significant long-term damage to the economy of the UK, according to major multinational energy companies, including BP, Centrica, and Shell, in the weeks leading up to the Brexit referendum.

Additionally, the UK Treasury stated that leaving the EU would be better for the UK than staying in it as it published a report on the implications of Brexit (Ifelebuegu, Aidelojie and Acquah-Andoh, 2017). Among the benefits of leaving the EU, several reports argue that there would be an increase in economic activity of 6.2%, an increase in household income of £4300, and a reduction in tax payments. The EU made a major proposal in November 2016 that included new regulations as part of a "winter package" designed to promote greater cooperation between the EU and the member states, along with transmission operators (Ifelebuegu, Aidelojie and Acquah-Andoh, 2017). The UK's electricity framework incorporates most of these regulations post-Brexit. However, the UK will still need to reassess the energy regulatory framework post-Brexit, which will require some form of EU agreement. Additionally, by 2030, the UK government estimates that £140 billion will be needed for investment, while some observers believe even more will be required (Ifelebuegu, Aidelojie and Acquah-Andoh, 2017). However, considering that four of the top six energy suppliers in the UK are owned by EU companies, attracting such a huge investment will be more complicated in the current economic climate and post-Brexit uncertainty.

However, the impact of Brexit on solar energy providers should also be considered. The resulting impact on free trade and the delays in import and export were also evident with the lack of lorries for the transportation of solar panels. The effect was also kept minimal, as wholesalers had predicted a 'no-deal' decision hence implementing procedures to mitigate the impact through stockpiling (Lempriere, 2022). Regardless, there is optimism that the industry will soar and flourish in the forthcoming years as solar energy continues to grow in the UK (Cox, 2016; Djankov, 2017; Greenhalgh and Azapagic, 2009; Herranz-Surrallés, 2016; Leal-Arcas, Grasso and Alemany Ríos, 2018).

4.5 Impacts of Inflation and Rising Energy Prices

In recent years, oil price volatility has exhibited an unprecedented increase in the controversy surrounding its causes (Cavallo, 2008). Studies show that the sharp movements in fundamental supply and demand of oil are widely attributed to the stronger oil price fluctuations. It is claimed that fundamental changes cannot fully explain oil price fluctuations and that financial speculation also contributed (Anton Mork and Hall, 1980). Despite substantial volatility in oil prices and a strong macro economy, there is little discussion of oil price uncertainty in this debate. When there is more uncertainty, the decision to produce or consume is delayed, resulting in a decrease in quantity and an increase in shock impacts on prices. Subsequently, Covid-19, the Russian-Ukrainian conflict, and global warming pose uncertainties, highlighting the importance of renewable energy sources (Liedtke, 2022). Central banks are also under increasing pressure to maintain inflation expectations in the face of the energy transition to renewables and the rise in energy prices (Cecrdlova, 2021). Despite this, electricity consumption in the overall energy sector is steadily increasing (Bednář, Čečrdlová, Kadeřábková and Řežábek, 2022).

Subsequently, there are significant macroeconomic effects associated with energy price increases. Hence, increasing energy prices is largely a result of inflation. As oil prices rise, they drive up the energy component of the consumer price index (CPI), which includes items related to energy fuels for cars, homes, and motors, among others (Bednář, Čečrdlová, Kadeřábková and Řežábek, 2022). Furthermore, the economy's recovery is likely to be slowed by higher energy prices. In recent volatility in energy prices, electricity and gas assumptions are critical to budgeting. Furthermore, it can be of considerable value to examine the scenarios associated with energy price developments as they relate to the implications for growth and fiscal aggregates since they are likely to be highly consequential (Robert and Lennert, 2010).

4.6 Fuel Poverty

According to Boardman (1991), a household that spends more than 10% of its income on fuel services is classified as living in fuel poverty. The 1991 EHCS Energy Report adopted a 10% of the income threshold for fuel to determine the scale of the issue of heat affordability. Furthermore, the 1996 Energy Report introduced the concept of thermal comfort. As determined by the household type and occupancy level, three heating systems were classified as full, standard, and partial. Furthermore, the Fuel Poverty Survey of 1991 included a measurement of basic income and a full income, in addition to other parameters such as Housing benefits, Mortgage Interest, and Income Support (Boardman, 1991).

Nonetheless, net disposable income is measured before or after housing costs are deducted when calculating poverty statistics (Moore, 2012). Therefore, government statistics on fuel poverty have been published annually using full and basic income definitions since the UK Fuel Poverty Strategy was implemented. The use of budget standards can provide more accurate and consistent measurements of households' ability to afford fuel costs. In this context, households are said to be in fuel poverty if, after deducting their actual housing costs, their residual net income cannot cover all their needed fuel expenses (Moore, 2012).

In England, Low Income Low Energy Efficiency (LILEE) is now considered a more reliable measure of fuel poverty than Low Income High Costs (LIHC). The LILEE classifies a household as fuel poor if it spends most of its income on energy costs, leaving them with a residual income below what is required to heat their home (Department for Business, Energy and Industrial Strategy, 2021). In England, many households were estimated to be living in fuel poverty. Furthermore, the fuel poverty gap in 2019, which is the average reduced fuel bill needed for poor households not to be classed as fuel poor, is estimated at £216, down slightly from £225 in 2018 following a steady decline starting in 2014 (Department for Business, Energy and Industrial Strategy, 2021). Despite this, the key factors driving fuel poverty in 2018 and 2019 include energy efficiency improvements, which have decreased fuel poverty. It increased the number of low-income households in band C, thus removing them from fuel poverty.

Additionally, a median income growth rate was observed among households near the poverty line because of the low-income threshold increase. However, the UK has been supporting home improvement directly and indirectly for many years, especially for low-income families living in fuel poverty. This has been accomplished primarily through suppliers' obligations, grants, and discounts on heating bills (Department for Business, Energy and Industrial Strategy, 2021).

4.7 The prime minister's 10-point plan regarding greener buildings

As a leader in sustainability, the UK has already made significant progress in meeting its targets for greenhouse reductions. It has also shown that it is possible to achieve economic success and environmental responsibility (HM Government, 2020). In November 2020, the prime minister of the UK announced a ten-point plan to establish a Green Industrial revolution and provide a foundation for immense economic growth. The plan included green public transportation, hydrogen heating, green finance, offshore wind, carbon capture, use and storage (CCUS), and environmental protection to promote biodiversity growth and job creation. It also aimed to end the sale of petrol and diesel cars and encourage zero-emission and greener buildings by making buildings more energy efficient (HM Government, 2020). The UK government vows to avoid costly retrofits and ensure future-proof buildings by implementing a system known as Future Home Standard. Also involved would be consultation with stakeholders about making non-domestic buildings more energy efficient and environmentally friendly (HM Government, 2020).

Additionally, manufacturing and investments are strongly emphasised. To accomplish this objective in a cost-effective and timely manner, the government aims to install 600,000 heat pumps a year by 2028 by introducing market-driven incentive frameworks for growth and implementing necessary regulations to encourage this growth, especially in off-gas grid properties (HM Government, 2020). The Chancellor announced several schemes to support this growth and provide $1 billion. The government is extending the Green Homes Grant for another year to improve homes' energy efficiency and replace fossil fuel heating. Public Sector Decarbonisation Scheme will reduce emissions in schools, hospitals, and public buildings. The Homes Upgrade Grant will upgrade the heating systems of more off-the-grid homeowners, especially those living in rural areas (HM Government, 2020). The Social Housing Decarbonisation Fund will also receive further funding to continue upgrading the most inefficient social housing in the country. As a result of strengthening landlord energy efficiency requirements in the private sector, private renters will also benefit. Subsequently, the Energy Company Obligation will be extended to 2026 to ensure suppliers can improve draughty, cold homes for those least able to pay (HM Government, 2020). It is apparent that to reduce energy and material consumption in household products; the UK needs to improve energy efficiency standards, resulting in lowered bills for households and businesses (HM Government, 2020). It is nevertheless difficult to implement energy retrofit schemes due to the numerous obstacles they face. The obstacles can mostly be categorised into four categories: financial, technical, information, and management (Zhang et al., 2021). However, the steps outlined by the government are well thought out, and with the policies set in place, the goals set are quite realistic in the set timeframe.

4.8 Use of Smart Meters

A key component of smart cities is smart meters, which are Internet of Things devices. A smart meter measures the energy consumption by end users based on information provided by the load devices they are connected to, and they provide utilities and system operators with additional information regarding consumption (March, Morote, Rico and Saurí, 2017; Fettermann et al., 2020). Several benefits are associated with the Internet of Things (IoT) for industries, services, and users (Porter and Heppelman, 2014). Aside from these benefits, these tools also improve monitoring, control, customisation, and prediction. Smart meters are one of the most successful IoT-connected devices organisations use to integrate value-added services to their stakeholders. However, consumers' acceptance of the smart meters is crucial for the smart meter to be implemented and for sustainable resource use. The devices of this type are not only capable of providing continuous and automated measurement of energy consumption. Still, they can also be used to store and transmit the information they collect in real-time with other devices on the household smart network they are part of and with other devices throughout the household (Ahmad and Zhang, 2021; Boyle et al., 2013; Hobbs, Anda and Bahri, 2019; Kumar, Chauhan, Singh and Sharma, 2021). A smart meter is an indispensable component of a smart city's information technology system. As such, smart metering is an essential part of the smart water and electricity networks for developing smart cities. Despite smart meters' apparent benefits, they will not guarantee that natural resources will be used more rationally. It is necessary for smart meters to be interacted with by consumers. Subsequently, smart meters can reduce energy consumption. It is also worth considering the impact of consumer groups. The reason is that consumer groups can create resistance groups and delay the implementation of smart meters if smart meters are implemented without consumer consideration (Hess and Coley, 2012; Jegen and Philion, 2017; Yang, Liu, Gaterell and Wang, 2017).

Smart meters in the UK are replacing gas and electricity meters, which have been around for many decades (HM Government, 2020). As a result, consumers can track their consumption with smart meters, top-up credit remotely from home, and receive automatic meter readings. It also helps develop an accurate billing system and integrate renewable energy sources and electric vehicles effectively and cost-effectively (HM Government, 2020).

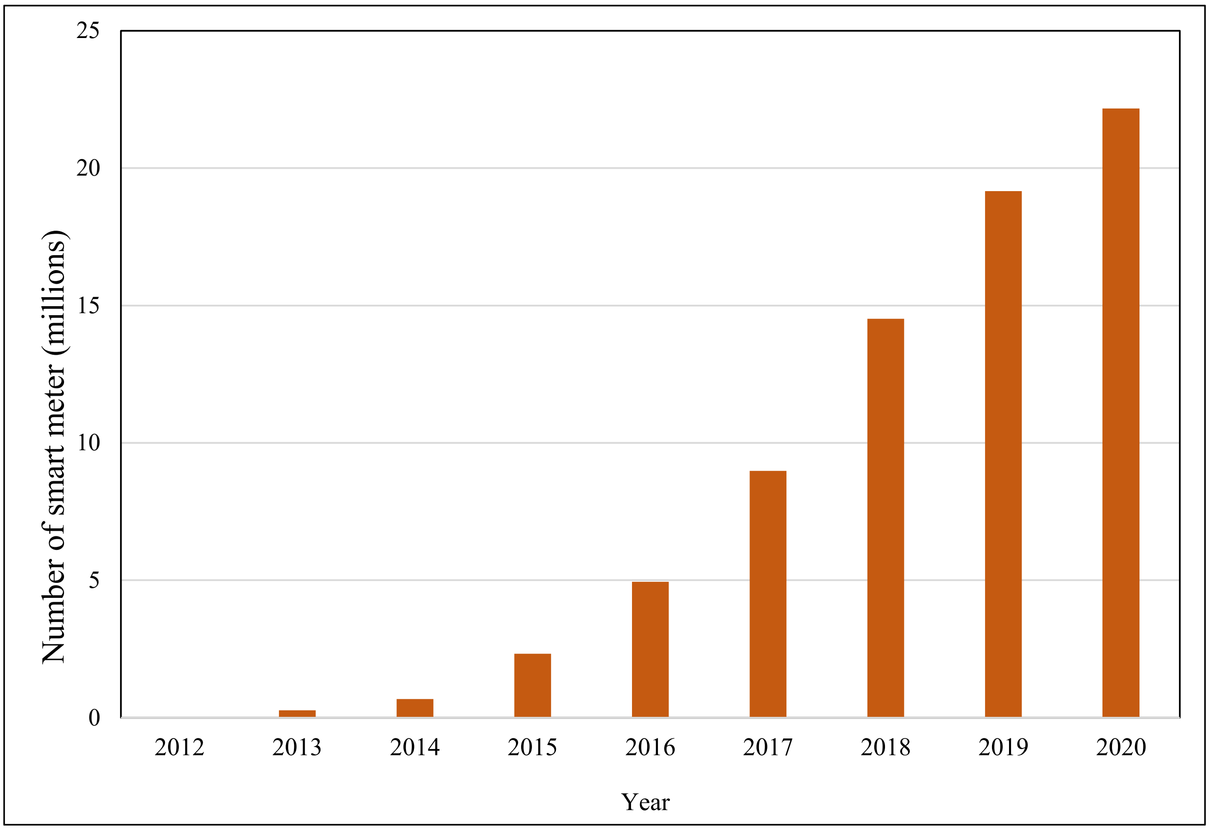

Figure 4-3: Number of Smart Meters Installed in the UK from 2012 – 2020

Source: Adapted from (HM Government, 2020).

Depicted in figure 4-3 is the growth of smart meters in the UK between 2012 and 2020. It shows that at the end of 2020, over 20 million smart meters had been installed in the UK. This suggests that the government is embarking on its agenda appropriately whilst highlighting the increasing awareness of energy use (Chou and Gusti Ayu Novi Yutami, 2014; Venkatesh, Morris, Davis and Davis, 2003).

4.9 Energy Efficiency in Homes

The United States and Europe consume almost 40% of the primary energy in commercial and residential buildings, while China consumes nearly 30% (Cao, Dai and Liu, 2016). Thus, numerous energy-saving technologies have been studied worldwide to reduce the building's reliance on primary energy. As an alternative, renewable energy was considered the best solution to global warming, air pollution, and energy security. Furthermore, studies stated that energy efficiency and renewable energy could be achieved by integrating these technologies into building construction (Aste, Adhikari and Del Pero, 2011; Crawley, Pless, and Torcellini, 2009; Garg, 2009). A building's energy efficiency can be improved to increase thermal comfort and reduce the energy consumed (Mirrahimi et al., 2016; Martínez-Molina, Tort-Ausina, Cho and Vivancos, 2016).

Consequently, this translates into lower energy bills and a smaller and less expensive energy system by reducing energy demand. As a result, consumers' overall costs will be reduced due to the transition to Net Zero. Furthermore, energy efficiency reduces carbon emissions and shifts heat demand (National Statistics, 2008). Insulation, controls, energy-related products, and heating and cooling systems are among buildings' most common energy efficiency measures. Buildings can be insulated in many simple yet effective ways, reducing energy costs, heating bills and heat loss (National Statistics, 2008). There are several insulation options available. Due to the huge population density, the building stock is undoubtedly the largest consumer of electricity and many other resources, as well, and must also be considered (National Statistics, 2008).

However, compared with other sectors, especially manufacturing and transportation, buildings offer more potential for reductions. It is estimated that in 2010, 45% of the carbon dioxide (CO2) emissions in the UK were generated using energy for the operation of buildings on a day-to-day basis and the powering of a wide range of electrical equipment both in residential and non-residential buildings (National Statistics, 2008). Approximately 10% of emissions were related to building construction and maintenance; they involved gathering, processing, and transporting raw materials, making and transporting building products, and then constructing and controlling the building (National Statistics, 2008). Additionally, around 4 million residential buildings in the UK were built before 1919, which accounts for about 20% of all residences. Between 1920 and 1939, a further 20% of the buildings were constructed (National Statistics, 2008). According to the Department of Energy & Climate change (2013), the government estimates that among the total energy consumed by the average UK household, 60% was consumed for heating, 21% for hot water, 14% for electric appliances, 3% for lighting and 3% for cooking.

Furthermore, heating accounted for almost 50% of carbon dioxide emissions. One of the most significant factors that influence a building's energy use in operation, according to the site and context, is its building fabric. As well as providing natural ventilation and lighting, building envelopes buffer heat and humidity and reduce solar gain to provide a comfortable indoor environment (Posani, Veiga and de Freitas, 2019). It is also worth identifying that energy is consumed by building services and equipment.

There are other aspects of energy consumption within a building that need to be considered, such as computer equipment and appliances that are used for business or recreation, as well as the fixed building services, which include heating, cooling, ventilation, hot water, and lighting (Gillott et al., 2016). It is imperative that all aspects of the building, including the degree to which the occupants maintain their buildings and the level of standards they consider appropriate for the internal environment, as well as the equipment and technology they bring into the building, and the way they occupy the spaces, be considered (Xing, Hewitt and Griffiths, 2011). There is a high degree of interdependence between all these factors. Similarly, the efficiency of a building envelope depends heavily on its maintenance and operation. When understanding and reducing energy use in a building, it is necessary to consider the complex system of structure, equipment, and people from a holistic perspective (Tsagarakis, Karyotakis, and Zografakis, 2012). Additionally, some methods could be implemented to reduce energy usage and improve thermal efficiency. They include draught-proofing, loft, and floor insulation, insulating heating systems, insulating walls, and double or triple glazing for windows (Department of Energy & Climate Change, 2013).

Over time, various building components move and distort, resulting in gaps and cracks, which are prone to allowing heat to escape (Department of Energy & Climate Change, 2013). A similar circumstance frequently occurs with windows and doors, which can be major sources of heat loss (Department of Energy & Climate Change, 2013). There are various types of insulation, including but not limited to loft insulation, cavity wall insulation, and solid wall insulation. The utilisation of insulation materials derived from natural fibres can significantly improve the efficiency of buildings (Department of Energy & Climate Change, 2013). The most used fibres include flax, wool, cellulose, and hemp. In addition to allowing moisture to transpire through their air spaces, these fibres can absorb and then release moisture as evaporation occurs. These characteristics are absent in synthetic insulation materials (Department of Energy & Climate Change, 2013). Depending on the context, opportunities and constraints vary greatly.

For instance, fabric improvements, such as internal wall insulation, are relatively easy to install when a building is being repaired, altered, or extended (Robert, 2008). However, there would probably be a high level of disruption and relative costs if the building were occupied. Additionally, many factors can influence energy use in a building as well as potential improvements. The elements of wind, rain, and sun contribute to these effects (Omer, 2008). Buildings subjected to driving rain and wet walls for an extended period may have limited options for wall insulation (Omer, 2008). There is also a risk associated with energy efficiency measures that can be exacerbated by defects or dampness in the building elements, in addition to lowering their energy efficiency. Therefore, maintenance and repairs should be prioritised (Balaras and Argiriou, 2002).

Table 4-2: Homes in the UK with Energy Efficiency Measures from 2015 – 2020

End of year	Cavity wall insulation	Loft insulation >= 125mm
2015	13320	15890
2016	13560	16060
2017	13820	16250
2018	14090	16470
2019	14350	16680
2020	14560	16860

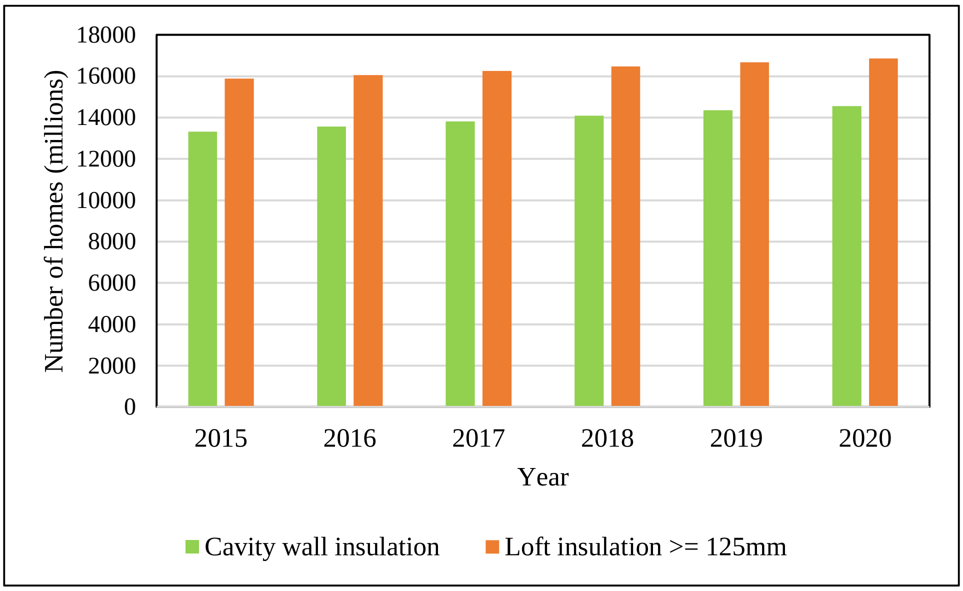

Figure 4-4: Number of UK Homes with Energy Efficiency Measures from 2015 – 2020

Source: Reproduced from (HM Government, 2020)

Insulating cavity walls and lofts can improve energy efficiency in homes at a low cost (Brechling and Smith, 1994). Thermal efficiency standards are mandated in Building Regulations for new homes and can usually be met by implementing these measures. Furthermore, these measures have been retrofitted into existing homes through government programs or DIY (Do It Yourself) loft insulation (HM Government, 2020). As a result of new construction and retrofitting insulation, the number of insulated homes has increased. As depicted in Figure 4-4 and Table 4-2, there are now 14.6 million insulated homes out of 20.8 million homes with cavities, up by 9% between December 2015 and December 2020. As a result, 16.9 million of the 25.4 million homes with lofts are insulated to a depth of at least 125mm, an increase of 6% between December 2015 and December 2020 (HM Government, 2020).

4.10 The use of Built Environment Wind Turbines (BEWT)

Depending on the application, wind turbines may be grid-connected or off-grid (Bhuiyan and Yazdani, 2012). A battery storage facility is required for off-grid systems to store surplus electricity, thus ensuring a steady supply of electricity (Gupta, Saini and Sharma, 2010). Generally, these applications best suit rural, remote, and isolated areas, including small islands and remote villages. Wind turbines installed in built environments are termed built-environment wind turbines (BEWTs), and usually, they are found in urban and suburban areas (Fields et al., 2016). Depending on the building, BEWTs can be mounted on the building or among the buildings (Dutton, Halliday and Blanch, 2005). It is also possible to integrate them into a building and include them in the design from a structural, architectural, and economic perspective as part of the building process (Dutton, Halliday and Blanch, 2005). Similar to a solar photovoltaic system, a BEWT attached to a building may attract project developers because it provides local energy. There are, however, additional challenges associated with BEWTs that differ from solar photovoltaics.

Several factors need to be considered before installing a wind turbine in an urban environment, including the site, the turbine, and its long-term operation. Furthermore, each turbine's electricity production, loads, and reliability will vary according to the wind (Anup, Whale and Urmee, 2019). BEWT project developers must also set clear objectives, understand the structure, and prepare long-term maintenance and operation plans. Projects involving BEWT are rarely ground-mounted. This necessitates special considerations that can increase the cost of a project. Depending on how much wind powers the turbines, wind turbines experience dynamic loads (Whale and Urmee, 2019). Building designs and installation retrofits may require specialised foundations to support these loads (Dutton, Halliday and Blanch, 2005; Škvorc and Kozmar, 2021). Thus, engineering, permitting, materials, and labour costs may increase, resulting in higher total installed costs and levelized costs of energy. It is imperative that a long-term maintenance plan is developed, which includes a method with the possibility of accessing the turbine safely and cost-effectively in the future. A detailed plan should also be made for the logistics of providing service support if the installation is mounted on a building (Dutton, Halliday and Blanch, 2005). The structure's access requirements and access methods determine the exact additional time and cost. It is also important to consider productivity, visibility, and other factors when setting up maintenance access (Dutton, Halliday and Blanch, 2005). BEWT should also consider the safety and comfort of the people in the vicinity. BEWTs emit sound and vibration, which can be transmitted throughout buildings (Mertens, 2006). As part of their research and development process, developers should inquire with prospective turbine manufacturers about the certified sound level of the turbine, its dynamic motion, and any sound/vibration mitigation options that might exist for mounting or operation. During the structural engineering analysis, vibration and sound should be considered (Bianchi, Bianchini, Ferrara and Ferrari, 2013; Hamza and Dudek, 2011).

Case Study 1

Depicted in the Figure below is a 500W BEWT installed in a house in Nottingham, UK, but it is facing vibration and noise during operation. It is connected to a battery to power the external lights of the house.

Figure 4-5: Built Environment Wind Turbine System

BEWTs or their installation are not currently covered by any accepted design methodologies or standards, which means there is no available means for assuring the safety and suitability of the design of BEWTs or their installation (Fields, Oteri, Preus and Baring-Gould, 2016). Furthermore, a qualified third party should evaluate the turbine and the installation against site-specific resources to reduce the likelihood of premature turbine failure for BEWT project developers (Fields, Oteri, Preus and Baring-Gould, 2016). An analysis of BEWT projects should include an analysis of where components may land if dislodged. In evaluating the feasibility of a BEWT project, stakeholders often use project economics as one of many factors (Fields, Oteri, Preus and Baring-Gould, 2016). It is important for the project stakeholders to evaluate the total project cost and energy output. Based on that information, other renewable energy or energy efficiency solutions can be considered based on the onsite electric loads and power costs. The viability of a BEWT project should also be assessed in terms of marketing, education, and carbon reduction (Fields et al., 2016).

4.11 Summary

This chapter identified renewable energy development in the UK. It also analysed the growth of district heating, the impacts of Covid-19 on energy generation, the impacts of Brexit, the impacts of inflation and rising energy prices, fuel poverty, the use of smart meters, the prime minister's 10-point plan, energy efficiency in homes, and the potential use of BEWT in the residential area to supplement renewable energy production. The next chapter will discuss the implementation of solar energy.

Chapter 5: Solar Energy Implementation

5.1 Introduction

The advantages of PV technology over conventional energy converters have been demonstrated in numerous studies (Dornan, 2011; Svantesson and Linder, 2012). Typically, PV systems can be installed on roofs, or they can be mounted on posts. A PV cell is stimulated through a layer designed to give up electrons easily by sunlight/photons striking it. During the production of current in a cell, electrons that carry negative charges are stimulated to produce current by converting them into electricity. These electrons are pulled to another layer by the electrical field in the solar cell. The movement of charges in the cell can then be used to power an external load by the connection of the cell to that external load (Grätzel, 2005).

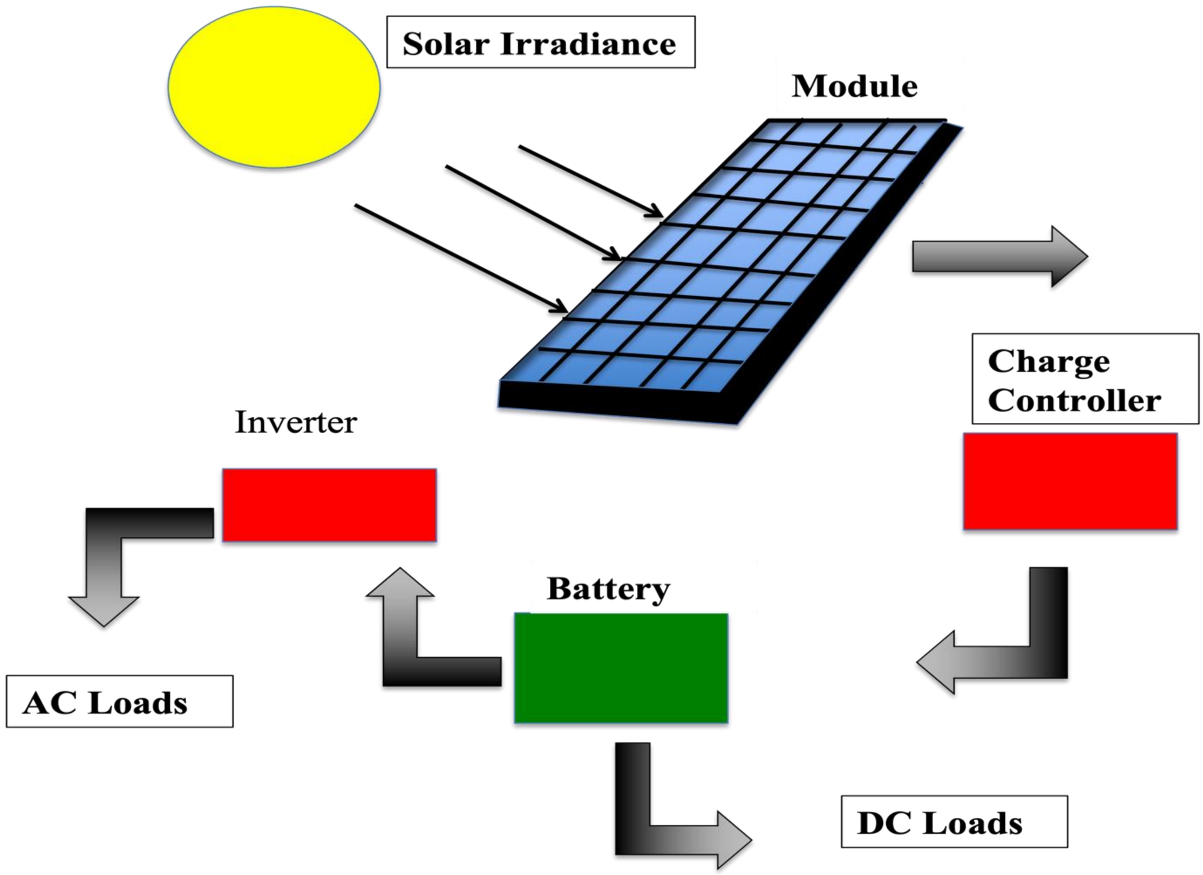

Figure 5-1: Components of a Solar PV System

Source: Reproduced from (Al-Mamun et al., 2013)

In most cases, a PV system includes collector panels, batteries, and components that convert electricity into alternating current (AC) so that household appliances and lights can be powered (See Figure 5-1). According to several authors, PV cells are simple and robustly designed, which makes them a low-maintenance solution since they are solid-state devices with no moving parts (Foster et al., 2010; Svantesson and Linder, 2012). Additionally, less transportation is required due to the absence of a fuel source to operate PV panels (Svantesson and Linder, 2012). Thus, PV technology is especially practical in remote areas since it requires less transportation of fuel and technicians. Furthermore, PV systems can be scalable, which means that the system can be expanded if enough space is available as demand increases (Svantesson and Linder, 2012). Subsequently, life cycle costs in developing and remote regions are generally lower than conventional lighting sources (Svantesson and Linder, 2012).

Consequently, as a sustainable energy source, PV has considerable advantages over conventional energy sources, particularly in terms of quality, efficiency, and cost. However, there are various drawbacks associated with different PV systems. There are many differences between off-grid and on-grid PV systems regarding service costs and lifetimes. According to Misak and Prokop (2010), battery problems are particularly prevalent in off-grid systems. Furthermore, batteries can be environmentally harmful and expensive and inefficient. For example, if lead batteries are not properly protected from the elements, their electrolyte may evaporate in hot climates (Svantesson and Linder, 2012). In addition, improper use or maintenance may unnecessarily shorten a battery's lifespan (Svantesson and Linder, 2012). Svantesson and Linder (2012) also state that batteries risk ending up in the backyards of rural homes, where they may contaminate the ambient environment.

Consequently, to maximise PV systems' efficiency, they should be used as soon as they are generated. Svantesson and Linder (2012) also point out that the physical conditions of the installation site may also determine the lifetime and cost of the system. For instance, a hot and humid environment will require half of the service cost to cover operational and maintenance costs (Aydin, 2009). It is also worth noting that PV systems may damage surrounding landscapes during construction. Furthermore, installing solar panels may create problems for nearby residents regarding aesthetics and visibility (Aydin, 2009).

Table 5-1: Advantages and disadvantages of solar PV

Advantages	**Disadvantages**
It has a 25-year life span	It requires a substantial upfront cost
It is scalable depending on required expansion	It utilises a large area for installation
It is a clean and sustainable source of energy	It is dependent on the weather
It can be implemented in remote areas	The installation and yearly maintenance require technical knowledge and expertise
The operating costs are limited due to the no additional costs from fuel	Pollution issues from the manufacturing, installation, and transportation of the equipment

Source: Adapted from (Abdul-Ganiyu et al., 2021; Hosenuzzaman et al., 2015; Kim et al., 2017; Nasir, Zaffar and Khan, 2016; Tawalbeh et al., 2021; Wazed, Hughes, O'Connor and Calautit, 2017)

Depicted in Table 5-1 is the advantages and disadvantages of solar PV systems. A wide range of solar energy systems can be used for various applications, including small stand-alone devices and large grid-connected systems (Foster et al., 2010). Stand-alone systems are commonly used in remote locations without easy access to an electric grid (Kalogirou, 2013). In such systems, energy is normally stored in batteries. Usually, a stand-alone system will consist of a set of PV modules, a set of charge controllers, and an array of batteries that will provide power to the system. A charge controller administers the power from the PV modules to the charge controller to produce DC electricity for storage. It is provided with an inverter, which converts DC electricity into the AC form required by common appliances to function (Kalogirou, 2013). In most cases, it has been observed that these devices are cost-effective and provide modest power for fans, lighting, communications, and water pumping (Foster et al., 2010).

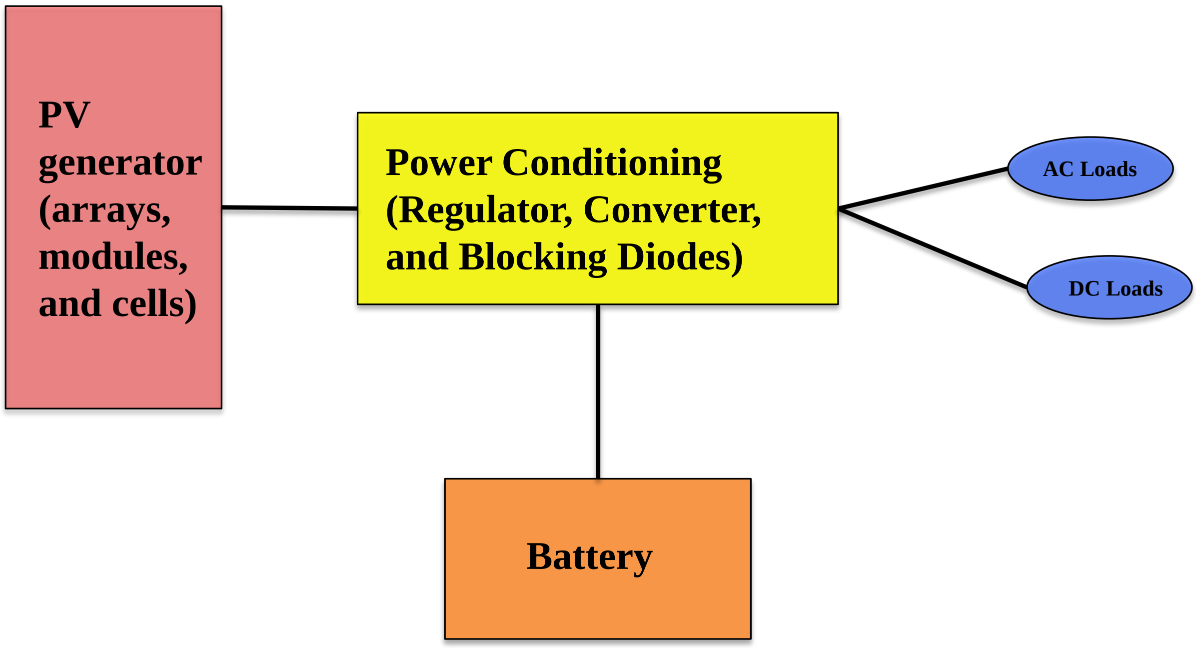

Figure 5-2: Schematic Diagram of the Application of a Stand-alone PV system

Source: Reproduced from (Hansen et al., 2001)

Figure 5-2 shows the schematic diagram of the application of a stand-alone PV systems. In grid-connected systems (or grid-tied systems), decentralised applications are supported. The inverter converts DC electricity generated by the system into AC power that can be distributed during the daytime (Foster et al., 2010). Depending on the situation, the electricity may be used right away, or it can be transmitted and resold to an energy company. In scenarios where solar power cannot be generated in the evening, the network can provide electricity (Foster et al., 2010). Due to the grid's capacity to store energy, no battery storage system is necessary (Kalogirou, 2013).

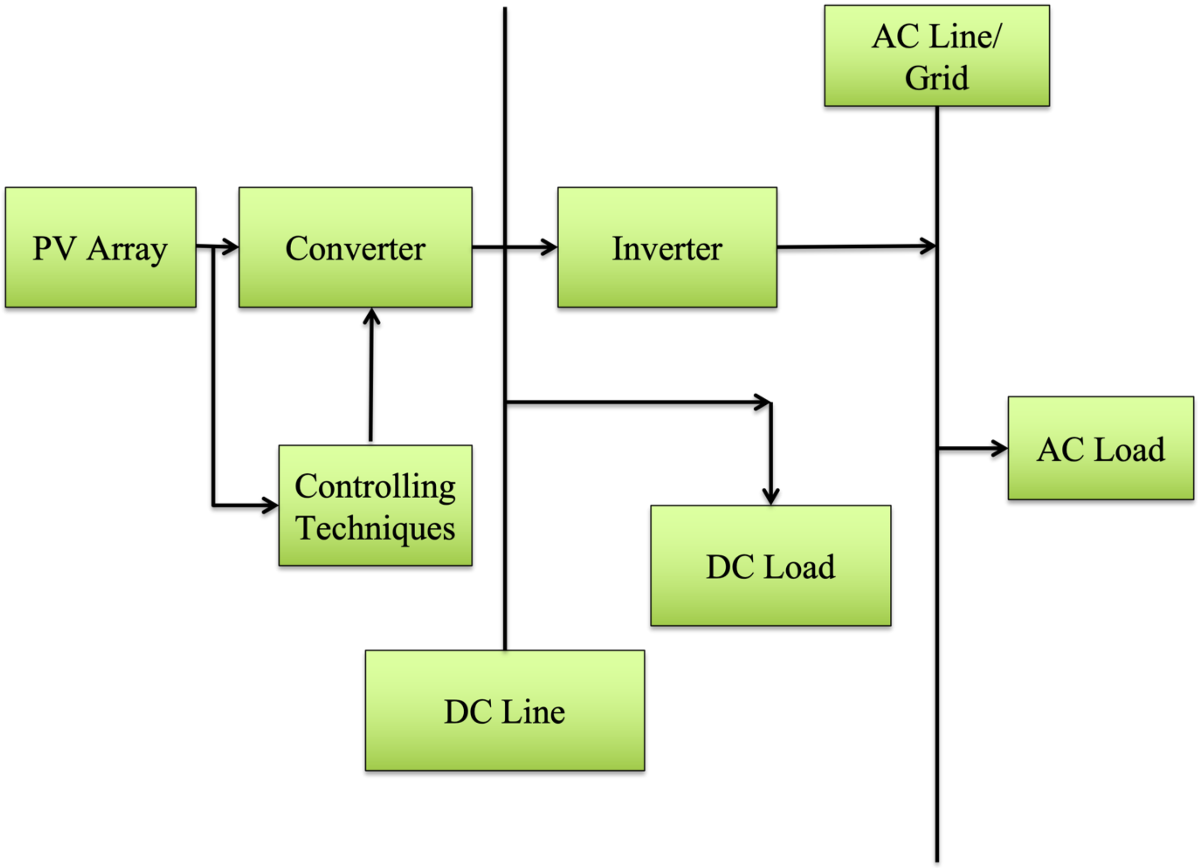

Figure 5-3: Schematic Diagram of the Application of a Grid Connected PV System

Source: Reproduced from (Kumar and Sharma, 2014)

5.2 Solar PV Systems

Several photovoltaic technologies have been developed, but few have been commercialised, and others remain in the research phase. In the solar PV market, the frequently used technology is crystalline silicon (c-Si) which has two types. The first type is monocrystalline, formed by slicing single crystal boules into wafers. Polycrystalline has a different process altogether. Polycrystalline silicon is carved out of a cast block of silicon by sawing into bars and wafers (World Energy Council, 2016). Polycrystalline technology has become the dominant trend in manufacturing crystalline silicon cells (Bruton, 2002). Monocrystalline solar panels are currently less expensive than polycrystalline panels, but this is expected to change in the near future, as their price might become comparable to polycrystalline panels. The commercial availability of other PV cell technologies, such as amorphous silicon (a-Si), thin-film, and organic, goes beyond crystalline silicon (World Energy Council, 2016). A thin-film module is constructed by depositing layers of photosensitive materials on low-cost backings like glass, stainless steel, or plastic. However, manufacturing thin-film products are less expensive than manufacturing crystalline products, which consumes more materials. Despite their price advantage, thin-film modules such as copper-indium/gallium-diselenide/disulphide (CIS/CIGS) and cadmium telluride (CdTe) have reached a certain level of commercial viability. However, their active materials usually determine their conversion efficiency (World Energy Council, 2016).

5.3 Solar Thermal Systems

Solar thermal technology extracts heat from the sun by using solar radiation. In addition to providing heat and cooling, it can also be used to power a heat engine that drives a generator and produces electricity (World Energy Council, 2016). Thermodynamic solar collectors transfer heat using working fluids such as oil, water, salts, air, and carbon dioxide (Abdullatif, Okonkwo and Al-Ansari, 2021). A concentrated solar collector concentrates the sun's energy on a tube containing fluid using mirrors (Munz and Hays, 2009). Sunlight heats the fluid through the mirrors, producing extremely high temperatures (World Energy Council, 2016). The refrigeration process is driven by solar-heated fluid in absorption chillers. Absorption chillers reduce greenhouse gas emissions generated on-site and greenhouse gas emissions generated by burning fossil fuels to generate electricity. It is also worth noting that unless a battery system is integrated with solar PV systems, solar PV systems can only work in daylight unless the solar energy is directly converted into electrical energy (World Energy Council, 2016). Compared to solar PV technologies, solar thermal technologies can provide energy throughout the day, making them attractive for large-scale energy production. Subsequently, a large amount of heat can be stored during the day and converted into electricity when needed when it is needed (World Energy Council, 2016). There are two types of thermal systems. They include:

- **Low-Temperature Solar Thermal Systems:** These include flat plate collectors and evacuated tube collectors. 'Greenhouse effect' is essential to the operation of the system. The transparent or translucent surface of the solar collector lets incident solar radiation (high energy, short wavelength) pass through. By using glazed panels, less heat is lost by convection from the hot absorbent surface. In these applications, the heat loss will not be as significant as panels that operate at higher temperatures, such as TVP solar, water and space heating, and swimming pools (World Energy Council, 2016).

- **High-Temperature Solar Thermal Systems:** In high-temperature solar thermal systems, two different methods of collection are utilised. This involves utilising a line focus collection method and a point focus collection method to collect solar thermal energy (World Energy Council, 2016). Sunlight is focused on a line receiver by a line focus collector that tracks the sun on one axis. The concentration factor for line focus collectors is 60-80, producing heat at high temperatures (100-550°C) (World Energy Council, 2016). Furthermore, their operation is technically easier and comparatively more economical. In point focus techniques, sunlight is tracked along two axes and concentrated at a single point, enabling temperatures of up to 800°C (World Energy Council, 2016). Industrial purposes or electricity generation can be achieved with the high-temperature heat from these systems (i.e., concentrating solar power). The concentration of solar radiation is done by using mirrors in concentrated solar thermal power generators. Heat can be transferred directly to a turbine or a working fluid to generate electricity. The four types of high-temperature thermal systems include parabolic trough collector (PTC), linear fresnel reflector, central receiver, and parabolic dish (World Energy Council, 2016).

5.4 Solar Farms

Governments are promoting renewable energy technologies (RETs) globally to lower greenhouse gas emissions. As a result, solar farms and other forms of renewable energy are being developed. In solar farms, photovoltaic (PV) panels are used in large numbers to produce clean, green electricity at scale, usually for feeding into the grid. According to van den Berg and Tempels (2022), in 2018, more solar farms were built in the Netherlands, increasing from 22 in 2017 to more than 80. Solar farms are increasing not just in number but also in size. According to statistics, solar farms in 2019 typically covered an area of around 20 hectares, compared to less than two hectares for the first solar farms (van den Berg and Tempels, 2022). Subsequently, renewable energy is generally supported by a large number of people. In many countries, solar energy has the most positive image, leading to greater deployment of solar energy (Nuortimo et al., 2018). In some areas, energy projects are often accepted with little resistance (Anderson et al., 2012), whereas in others, they are often strongly opposed (Sütterlin and Siegrist, 2017). Residents more critically view renewable energy technologies because of their aesthetic, environmental, and economic impacts on their direct environment. In this situation, they are often less supportive of RETs, and even opposition can develop (Zoellner et al., 2008). The result is a delay or cancellation of projects (Anderson et al., 2012). According to Sütterlin and Siegrist (2017), there is a difference in the level of public acceptance of renewable energy technologies on different scales. This is also regarded as the "national-local gap".

Furthermore, solar farms are emerging as a major source of renewable energy. However, little research has been into this area (Roddis et al., 2018). Solar farms typically generate about five megawatts at peak (MWp), which is enough to power 1,200 homes while reducing carbon dioxide emissions by 500 grams per kilowatt hour (g/kWh) (Jones, Hiller and Comfort, 2014). To build such a farm, 15 hectares of land would be required, with up to 20,000 solar panels covering 30% of the surface area (Jones, Hiller and Comfort, 2014). For maximum light absorption, toughened glass with an anti-reflective coating is used on the upward-facing surfaces of the panels. To maintain space for habitats and plants, solar panels are arranged in arrays on aluminium and steel frames (Jones, Hiller and Comfort, 2014). They are inclined 25 per cent between 1.0 and 2.65 metres above the ground. To facilitate access and minimise shading, they are usually arranged in rows and interspaced between rows to ensure easy access (Jones, Hiller and Comfort, 2014). There is usually a perimeter fence around solar farms, and many of them are built behind existing or newly planted hedges that screen them from view (Jones, Hiller and Comfort, 2014). Maintenance procedures typically include performance monitoring, fault analysis, diagnosis, and replacement of parts, maintaining landscapes, performing annual inspections, and securing equipment (Jones, Hiller and Comfort, 2014). In a survey published by Solar Voltaic Energy (2013), 91 major "solar energy schemes" had been completed by April 2013, with another 56 being approved or under construction, as well as 32 proposals or in the planning stages. The global irradiation and solar energy potential throughout the UK range from 980-kilowatt hours per square metre in the far north of Scotland to 1,240 kilowatt hours per square metre in southwest England.

Several solar farm projects have been built in the southwest and southeast of England, indicating high development pressure in these areas. In Rushcliffe Borough, Renewable Connections has applied for a solar energy farm of 49.9 MW at Church Farm (Renewable

Connections, 2022). Upon completion, the project would provide power to 14,000 homes in Rushcliffe Borough, making an important contribution to climate change mitigation. Located at Church Farm, Gotham Road, Kingston on Soar, Church Farm Solar Farm is proposed to be built on 70 hectares of agricultural land (Renewable Connections, 2022). Even though the immediate area predominantly consists of agricultural land, the nearby Ratcliffe on Soar coal power station and Segro East Midlands Gateway Logistics Park fall within an industrialised zone (Renewable Connections, 2022).

Additionally, East Midlands Parkway train station is 1.4km away. If installed, a solar farm of this type could generate 49.9 MW and operate for up to 40 years (Renewable Connections, 2022). The installation will be removed after a designated period, restoring the land to its natural state, and improving its soil health and biodiversity. An existing substation will connect to existing powerlines running through the site boundary to export the power generated to the grid. Furthermore, the connection will not require the construction of new pylons. Depicted in Figure 5-4 is a proposal from renewable connections.

Figure 5-4: Proposal for Solar Farm in Rushcliffe Borough

Source: (Renewable Connections, 2022)

5.5 Use of Battery Energy Storage System (BESS)

Solar and storage investments are driven primarily by emotions and economics (SolarPower Europe, 2020). Homeowners have been able to consume their green power products since the move away from full feed-in tariffs. Battery technology allows this to be achieved to a greater extent, thus allowing for greater power independence (SolarPower Europe, 2020). Solar rooftop systems have been much cheaper than retail electricity in most European countries for several years. However, battery storage's rapid cost improvements are making solar and storage a much more competitive proposition in more and more European countries (SolarPower Europe, 2020). The addition of batteries to solar systems has been made possible through different incentive programs. Homeowners can now consume their green energy products themselves, with batteries helping to make it possible to do so to a greater extent and at a time of their choosing (SolarPower Europe, 2020). However, solar PV output and battery charging profiles should be controlled to prevent the battery from being fully charged in the morning (IRENA, 2015). This could result in the maximum solar power production being exported to the grid at the time of its maximum output. The reason is that solar radiation reaches its peak during or just before noon. There is a possibility that this export does not coincide with grid peak demand periods (IRENA, 2015). Consequently, renewable energy supplies exceed demand, especially in distribution networks, resulting in voltages that exceed tolerable limits and curtailing renewable energy resources.

Renewable energy deployment may also be limited when many distributed solar PV systems are installed in the same area (IRENA, 2015). In addition to providing a certain degree of power independence, solar and storage will still allow prosumers to take advantage of the benefits and safety of public/investor-owned distribution systems. Through subsidy programs, solar systems and, more recently, battery energy storage systems have rapidly and continuously decreased in cost and price, making them increasingly attractive to homeowners (SolarPower Europe, 2020). Over 2015-2019, prices for small solar systems have fallen by around 18% in Germany, the world's largest solar & storage market (SolarPower Europe, 2020). BESS was later deployed in Italy and UK, two other leading solar markets with notable installed residential solar system capacities at later times. German, Italian, and British markets accounted for 90% of overall installations up until 2017. Approximately 2% of all residential solar PV systems across Europe had a battery at that time, and the total residential storage capacity in Europe was 350 MWh. In the years that followed, home battery storage systems were also deployed in Austria, France, and Switzerland. It is estimated that 65,500 residential BESS systems were installed in Europe in 2018, generating 505 MWh of energy. Residential storage installations doubled in 2019 due to the demand for solar systems (SolarPower Europe, 2020). As of 2019, there were 63,000 residential BESS currently in operation with a combined capacity of around 496 MWh. As a result, residential storage capacity increased by 75% in 2018 compared to the previous year.

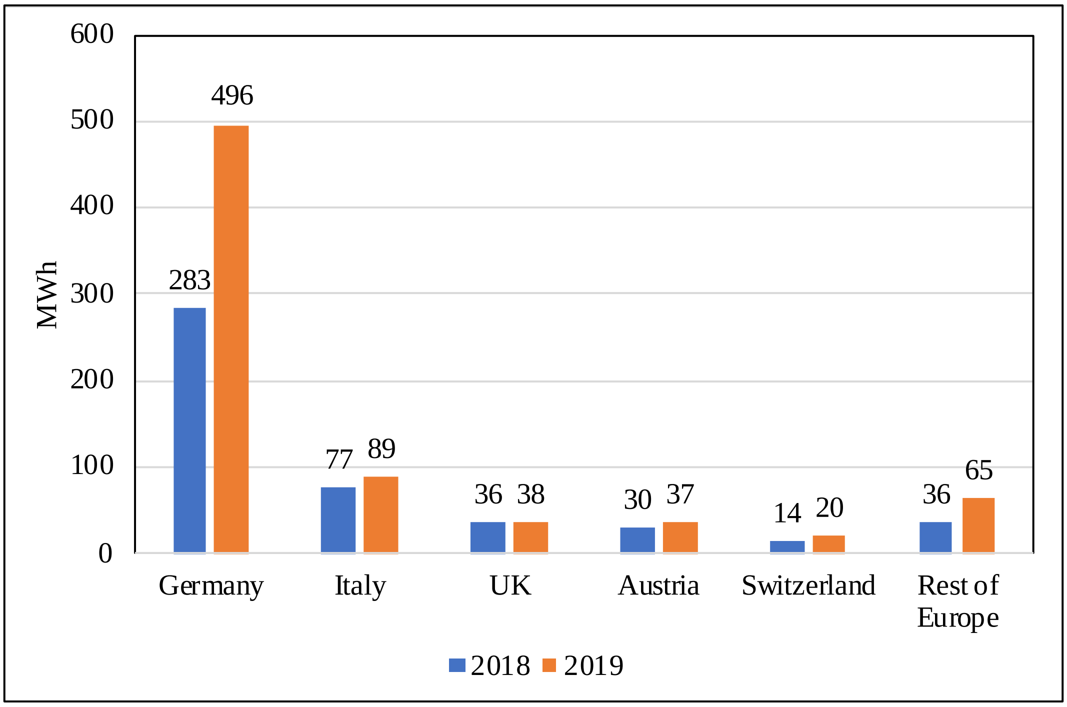

Figure 5-5: Top 5 BESS Residential Markets in Europe from 2018-2019

Source: Reproduced from (SolarPower Europe, 2020)

Figure 5-5 demonstrates that the BESS is gradually becoming a viable option in the storage of energy, and with evidence of its performance, this growth phenomenon is certain to continue. Furthermore, it can alleviate capacity constraints on the local grid. Since the FIT scheme's end and the SEG regulation's beginning, UK home solar and storage markets have transitioned from subsidy-driven to non-subsidy-driven (SolarPower Europe, 2020). PV installations among residential customers decreased after the end of the FIT scheme, which affected residential BESS installation rates as well. This contradicts the findings from the Department for Business, Energy and Industrial Strategy (2021), which showed an increase in solar panel installation after the closure of the FiT scheme. Furthermore, SolarPower Europe (2020) suggests that in subsequent years, no large uptake should be expected due to the lack of a specific support scheme and the likely transition period needed for new SEG offers to mature. In the absence of an ongoing assessment of support schemes for residential storage and the prevalent political uncertainty in the UK, the growth of battery systems will continuously be observed (SolarPower Europe, 2020).

5.6 Breakdown of Cost Components of a Solar PV

Due to the dynamic nature of the solar PV sector, the costs of the generation today are likely to become the future benchmark. In the last decade, prices for solar PV electricity have dropped dramatically; as economic financing and policy / fiscal incentives become more available, they are expected to drop further (World Energy Council, 2016). Equipment costs do not differ much across countries in current scenarios; however, their prices are determined by financial engineering. Due to differing financing terms and solar resources, solar PV project yield and returns vary widely between countries (Dobrotkova, Surana and Audinet, 2018).

Therefore, this section explores PV equipment costs. Various elements make up a complete solar PV system. Various players from different sectors contribute to integrating these elements through substantial efforts across a large supply chain. Supply chain components include solar modules, inverters, electrical infrastructure, mounting structures, and energy storage components from the balance of system (BoS) (World Energy Council, 2016). PV module costs and BOS costs together make up the capital cost of a PV system. Since raw materials determine the array of PV cells within a PV module, the cost of the BoS includes structural and electrical costs as well as soft costs associated with system development, such as customer acquisition, permits, installation labour. In the case of off-grid applications, the battery or other storage system cost must also be added. The table below shows the breakdown of the component costs associated with solar PV.

Table 5-2: Component Costs Associated with Solar PV

Component	Cost
Semiconductor	Capital & equipment cost + raw materials (e.g., silicon, saw slurry, saw wire) + utilities + maintenance & labour + manufacturer margin
Cells	Capital & equipment + raw materials (metallization, dopants) + utilities + maintenance & labour + manufacturer margin
Modules	Capital & equipment + raw materials (glass, ethylene vinyl acetate (EVA), metal frame, junction box) + utilities + maintenance & labour + margin + shipping + retailer margin
Inverter	Capital & equipment + raw materials (magnetics, board, enclosures) + power electronics + utilities + maintenance & labour + manufacturer margin
Balance of system / Installation	Mounting + hardware + wiring + design + installation

Source: Reproduced from (World Energy Council, 2016)

5.7 Levelized Cost of Electricity (LCOE)

Researchers, investors, project managers, and policymakers widely use LCOE to measure project cost efficiency (Reichelstein and Sahoo, 2015; Regulator, 2020). Project managers or investors, for example, can compare a technology's LCOE to the wholesale price of electricity to assess its competitiveness. As a result, the LCOE helps to determine the price point at which a renewable energy project can be justified as a suitable investment, which will determine which green energy projects to invest in (Reichelstein and Sahoo, 2015; Regulator, 2020). In addition, LCOE values could be used to assist policymakers in setting renewable energy policies. To set future incentive policies, policymakers can consider existing policies influencing LCOE calculation (Zhao, Chen and Thomson, 2017). Although the LCOE calculation of variable renewable energy (VRE) is more challenging than traditional LCOE methods, the results can be used for these applications (Shen et al., 2020).

A few factors influence the LCOE of renewable energy projects, including location and the nature of renewable energy sources. However, there may be interdependencies among the input variables for the VRE LCOE (Shen et al., 2020). As the intermittency of VRE can increase grid-related costs, LCOE calculations at the plant level are insufficient to determine the cost (Shen et al., 2020). Thus, the intermittency of VRE makes its LCOE more uncertain and riskier to estimate. LCOE for renewable energy is sensitive to policies affecting renewable energy and harmonisation issues (Shen et al., 2020).

Table 5-3: Residential and Commercial Sector Solar PV LCOE by country or state, from 2010-2019

Sector	Market	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
		2020 USD/kWh										
Residential	Australia	0.332	0.260	0.189	0.165	0.155	0.107	0.099	0.089	0.082	0.072	0.069
	Brazil				0.263	0.246	0.235	0.188	0.157	0.126	0.108	0.089
	China			0.164	0.145	0.140	0.108	0.104	0.097	0.079	0.068	0.063
	France		0.720	0.522	0.440	0.333	0.203	0.190	0.176	0.172	0.168	0.165
	Germany	0.304	0.264	0.206	0.187	0.175	0.145	0.142	0.139	0.145	0.135	0.135
	India				0.133	0.129	0.094	0.086	0.075	0.067	0.064	0.055
	Italy	0.409	0.363	0.250	0.230	0.163	0.139	0.129	0.122	0.114	0.110	0.104
	Japan	0.460	0.455	0.397	0.301	0.253	0.226	0.204	0.189	0.171	0.164	0.159
	Malaysia				0.187	0.186	0.163	0.152	0.128	0.110	0.095	0.089
	Republic of Korea				0.226	0.227	0.171	0.166	0.143	0.131	0.126	0.110
	South Africa				0.202	0.182	0.157	0.149	0.136	0.120	0.103	0.091
	Spain				0.183	0.160	0.123	0.117	0.110	0.107	0.105	0.103
	Switzerland				0.307	0.277	0.262	0.258	0.252	0.230	0.216	0.21
	Thailand				0.252	0.203	0.185	0.181	0.161	0.138	0.112	0.104
	United Kingdom				0.330	0.345	0.305	0.276	0.278	0.270	0.256	0.236
	California (US)	0.309	0.293	0.256	0.224	0.212	0.215	0.209	0.189	0.180	0.174	0.176
	Other US states	0.307	0.283	0.233	0.204	0.205	0.204	0.180	0.164	0.158	0.156	0.150
Commercial	Australia					0.133	0.108	0.098	0.087	0.083	0.075	0.071
	Brazil							0.157	0.124	0.104	0.093	0.075
	China		0.182	0.148	0.130	0.108	0.095	0.089	0.087	0.072	0.064	0.060
	France	0.632	0.327	0.240	0.243	0.239	0.196	0.168	0.187	0.178	0.155	0.131
	Germany		0.255	0.177	0.156	0.142	0.115	0.120	0.116	0.114	0.105	0.106
	India								0.071	0.066	0.063	0.055
	Italy	0.325	0.282	0.172	0.142	0.140	0.116	0.109	0.102	0.095	0.093	0.088
	Japan			0.339	0.279	0.215	0.174	0.170	0.165	0.154	0.148	0.132
	Malaysia					0.175	0.133	0.130	0.100	0.088	0.081	0.078
	Republic of Korea								0.139	0.126	0.116	0.101
	Spain		0.259	0.230	0.217	0.199	0.106	0.105	0.096	0.091	0.087	0.075
	United Kingdom							0.209	0.196	0.190	0.181	0.179
	Arizona (US)	0.282	0.252	0.224	0.182	0.154	0.163	0.149	0.136	0.121	0.123	0.116
	California (US)	0.262	0.254	0.206	0.193	0.157	0.153	0.158	0.151	0.140	0.136	0.130
	Massachusetts (US)	0.438	0.402	0.323	0.280	0.267	0.249	0.244	0.212	0.208	0.210	0.190
	New York (US)	0.444	0.401	0.340	0.271	0.245	0.229	0.215	0.191	0.183	0.181	0.188

Source: Reproduced from (IRENA, 2020)

As residential PV systems became more common, the lifecycle cost of the systems declined steeply over time. Table 5-3 describes the LCOE of residential PV systems in these markets at 5% weighted average cost of capital (WACC). The LCOE decreased from 0.304/kWh to

0.460/kWh in 2010 to between 0.055/kW to 0.236/kWh in 2020, a drop of 49% to 82%. Despite its relatively modest solar resources, Germany has been one of the strongest markets for residential solar PV over the past ten years. German residential systems' LCOE fell by more than half between 2010 and 2020, while Japanese residential systems' LCOE declined by 65% during the same period. Italy and Australia, known as historically better-resourced markets, saw sharper reductions during that decade. In Italy, the LCOE of residential systems declined by threequarters between 2010 and 2020. A 79% reduction was observed in Australia, which was the highest of the markets listed in Table 3.3. India, China, Australia, Spain, and Malaysia, where irradiation conditions are ideal, and installation costs are rapidly declining, have achieved very low LCOEs since 2013. Over the period 2013 to 2020, within these low-cost markets, the LCOE range decreased from USD 0.133/kWh to USD 0.187/kWh and USD 0.055/kWh to USD 0.103/kWh, a reduction of 45% to 59%. LCOE for residential PV systems has also fallen below USD 0.97/kWh in India, China, and Australia since 2017. India's LCOE of USD 0.055/kWh in 2020 proved to be the most competitive, while China's was 14% higher. Compared to India, Australia had a quarter higher LCOE for residential systems. Brazil and Malaysia saw a reduction of 17% and 7% in residential energy systems between 2013 and 2020, respectively, reaching USD 0.089/kWh. In Italy, France, and the US markets, the LCOE for commercial PV up to 500 kW declined by 50% and 79% between 2010 and 2020. Based on 2020 estimates, LCOE varied from USD 0.137/kWh in France to USD 0.190/kWh in New York. For commercial PV up to 500 kW, India and China had the lowest average LCOE in 2020, at USD 0.055/kWh and USD 0.060/kWh, respectively. After undercutting Australia, the reference LCOE benchmark for commercial systems, until 2017, India and China have become more competitive regarding LCOE of commercial systems. There was a 23% drop in India and a 30% drop in China's LCOEs between 2017 and 2020, respectively. As of 2020, the LCOE value of commercial systems in Australia was 30% higher than in India, despite a decline of 18% during that period. Additionally, Malaysia, Spain, and Brazil had the lowest LCOEs of commercial PV in 2020. Compared to the LCOE of Australian commercial systems, they were within 5% and 10% of USD 0.075/kWh to USD 0.079/kWh. In 2020, the highest LCOEs were observed in New York and Massachusetts at USD 0.18/kWh and USD 0.190/kWh. In 2010, the average LCOE for commercial PV fell from USD 0.262/kWh and USD 0.632/kWh to USD 0.063/kWh and USD 0.190/kWh in 2020, a reduction of 70% to 79%. Subsequently, a decline of 10% to 13% is expected between 2019 and 2020 (IRENA, 2020).

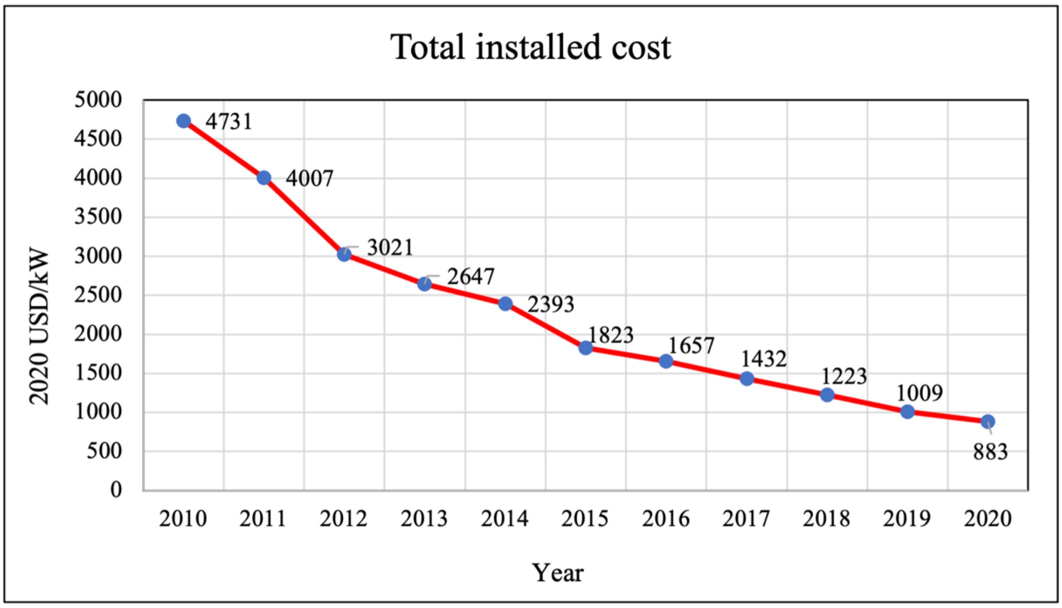

Figure 5-6: Global Weighted- Average Total Installed Cost for PV from 2010-2019

Source: Reproduced from (IRENA, 2020)

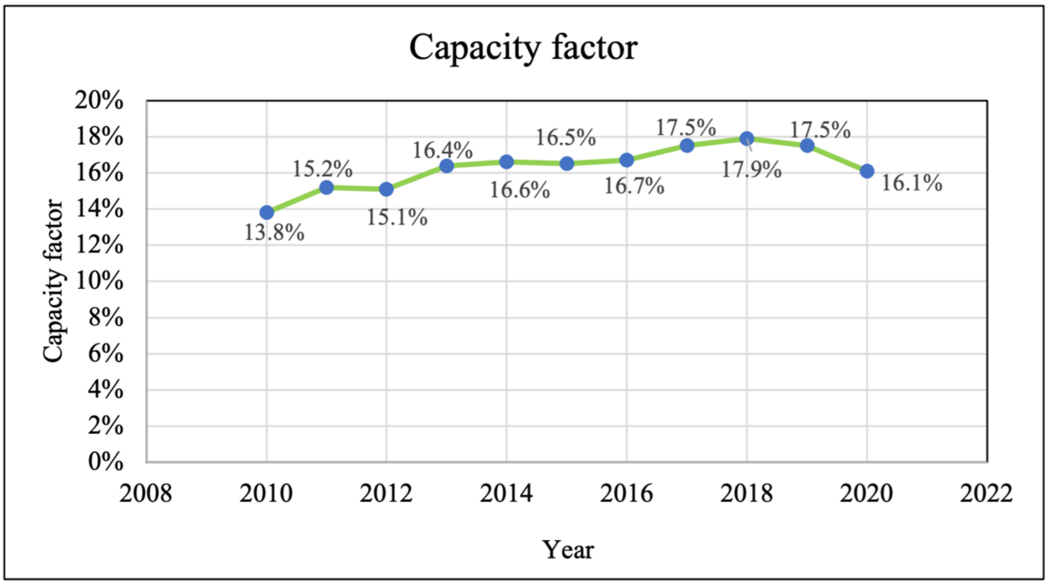

Figure 5-7: Global Weighted- Average Capacity Factor for PV from 2010-2019

Source: Reproduced from (IRENA, 2020)

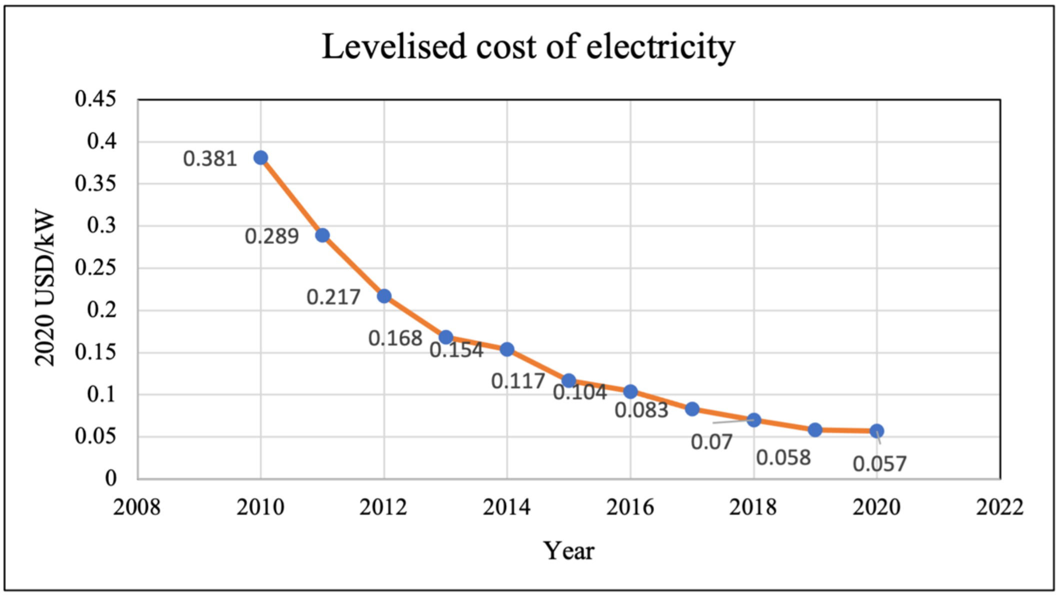

Figure 5-8: Global Weighted- Average Levelized cost of Electricity for PV from 2010-2019

Source: Reproduced from (IRENA, 2020)

Figures 5-6, 5-7, and 5-8 are the global weighted average total installed cost, the capacity factors, and LCOE for solar PV from 2010 to 2020. Between 2010 and 2020, utility-scale photovoltaic plants' global weighted-average levelized cost of electricity (LCOE) declined by 85%, from USD 0.381/kilowatt hour to USD 0.057/kWh. In 2020, the global capacity-weighted-average total installed cost of projects commissioned worldwide was USD 883/kilowatt (kW), an 81% reduction from 2010 and a 13% reduction from 2019. Between 2010 and 2020, total installed systems costs in commercial rooftop markets decreased by 69% to 88%. In 2010, the global weighted-average capacity factor for new, utility-scale solar PV was 13.8%; in 2020, it will be 16.1%. This change is due partly to changing inverter load ratios, partly to a shift in market irradiance, and partly to the increased use of trackers, largely due to bifacial technology adoption (IRENA, 2020).

5.8 Factors to Consider for Solar PV Roof Mounting

The use of solar panels, particularly on rooftops, is becoming more common in urban environments. Although they may reduce heating and cooling energy demand for buildings and the surrounding urban environment, their installation on rooftops might impact the energy consumption of buildings (Brown et al., 2020). Some factors should be considered when deciding to implement solar energy. They include:

- **Available roof area and Orientation**: Residential areas account for a large portion of energy consumption, and these consumption rates increase considerably in the evenings (Anderson et al., 2017; Validzic, 2017). Several obstacles hinder energy production in residential areas. A house roof's direction, slope, strength, and shadow exposure are the most common obstacles to PV solar energy (Kouhestani et al., 2019). PV panels can also create anxiety in people due to electric phobias when there is not enough space in gardens for them to be used or when shadows cast on them cause distortions in the aesthetic appeal of the gardens (Jurasz et al., 2020). However, even if all the problems mentioned above are resolved, the cumulative amount of energy produced by roof-mounted solar PV cannot meet the energy demands of all city residences. An example is shown in Figure 5-9.

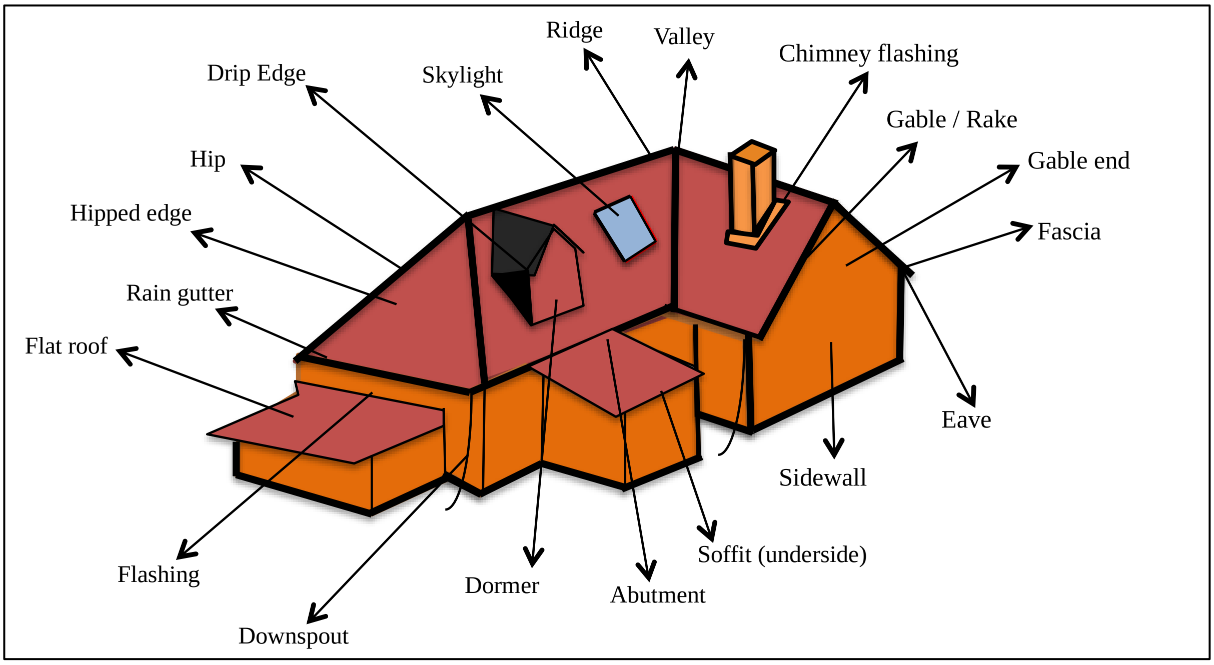

Figure 5-9: Geometry of a Roof

Source: Reproduced from (Brava, 2022)

- **Impact of shadow:** Photovoltaic systems are subject to shadowing effects when obstacles prevent them from receiving the same amount of incident radiation. As a result, cells that receive lower irradiance levels can absorb rather than produce power (Veerapen and Wen, 2016). This, therefore, implies that shading from nearby buildings, trees, etc., could reduce the performance of solar energy generation.

- **Structural capability of the roof:** Failure of structural elements or structures occurs when they cannot support loads or lose their strength (Richards et al., 2011). Failures commonly occur due to excessive deflection in a structural beam or a sagging roof, insufficient connection strength, splitting of the top chord of a wood beam, or roof penetrations that can cause roof leaks that can ultimately cause structural degradation (Richards et al., 2011). Therefore, before installing a rooftop solar energy system, it is necessary to assess the roof structure. The amount of solar array required for a building depends on how much electricity individuals consume each month (Mittal et al., 2019). However, some structural designs hinder the implementation of solar panels, which involves the complexity of the design of given structures (Mittal et al., 2019). In the event that the existing structure must be modified for solar installation, the assessment should address whether there is sufficient capacity to accommodate additional loads.

5.9 Summary

This chapter provided insight into the requirements for solar energy implementation. It identified the different type of solar systems applications, a breakdown of cost of components, the levelized cost of electricity (LCOE) of solar energy globally during a 10-year span, and the factors to consider for solar PV mounting.

Chapter 6: Preliminary Theoretical Framework

6.1 Introduction

This chapter introduces the preliminary theoretical framework used in this study. According to Kerlinger (1979), theoretical constructs are a bundle of interrelated definitions and propositions that make up a systematic illustration of phenomena by specifying relationships among variables with the intention of explaining and predicting them. Therefore, the theoretical framework utilised in this study is the combination of behavioural reasoning theory and diffusion of innovation theory.

6.2 Theories Adopted for Renewable Energy Consumer Adoption

The behavioural aspects of management disciplines have recently attracted the attention of scholars and practitioners alike. This phenomenon has led to the development of sub-disciplines such as behavioural finance, behavioural marketing, and behavioural operations management. According to Greve, (2001), social sciences generally accept and apply behavioural theories. It has been shown that the theory of reasoned action (TRA) explains different determinants of human behaviour, as does the theory of planned behaviour (TPB) and the theory of explanation-based decision making (TEDM) (Pennington and Hastie, 1993; Fishbein & Ajzen, 1975; Ajzen, 1991). As an advancement of seminal technology acceptance theories such as TPB, behaviour reasoning theory is a new theory in the field of marketing (Westaby, 2005). By analysing BRT, researchers are able to determine the relationship between beliefs or values, motivations (both for and against), attitudes, subjective norms, and perceptions of behavioural control, intentions, as well as user behaviour metrics.

Several studies suggest that BRT has several advantages or merits over other behavioural theories (Ryan and Casidy, 2018; Westaby, 2005). A key feature of BRT is that it includes both reasons for and reasons against, which provide a better understanding of human decision-making (Sahu, Padhy and Dhir, 2020). These two perspectives affect user intentions and actual behaviour in different ways. They are not just opposites but critical, yet different and equally important. In addition, both reasons for and against are context-specific; hence, they provide a wealth of information about the context (Sahu, Padhy and Dhir, 2020). To understand human behaviour and decision-making processes, BRT adds alternative cognitive routes by exploring reasons. In addition, BRT has shown that values and beliefs significantly influence user behaviour and reasons (Sahu, Padhy and Dhir, 2020). Further evidence of these advantages can be found in analyses of previous BRT studies, which indicate that BRT-based models explain the variance of the dependent variable more effectively than other behavioural theories (Claudy et al., 2015).

Furthermore, several variables have been previously adopted to examine relationships between BRT constructs. These include values and beliefs (Briggs et al., 2010), financial and economic benefits (Claudy et al., 2013, 2015), budgetary constraints (Diddi et al., 2019), awareness of environmental impacts (Park et al., 2017), benefits for the environment (Claudy et al., 2013, 2015), the importance of openness to change (Pillai and Sivathanu, 2018), and a change in lifestyle (Diddi et al., 2019).

Incentives and policies drive the diffusion of renewable energy technologies (RETs) because they are technically challenging, have high upfront costs, and lack a level playing field, but they have distinct advantages in terms of energy security, environmental impact, and social welfare. Growth rates and underlying diffusion factors are analysed and studied in diffusion modelling. According to Rogers' theory of diffusion of Innovations, the diffusion process can lead to inequality when an innovation has financial benefits for its adopter. This is because 'individuals or units in a system who are most in need of a new idea are the last to adopt it'. A number of diffusion models have been developed for RETs based on barriers to adoption, as well as approaches based on techno-economic factors, learning curves, and experience curves. In the case of commercial products, these diffusion models do not consider the crucial factor of policy influences, which is essential for the diffusion of RETs. Because policies are a driving force behind RET diffusion, RET diffusion models should allow for explicit links between diffusion parameters and policies. Several authors have reviewed diffusion modelling approaches (Meade, 1984; Mahajan, Muller and Bass, 1990, 1993; Baptista, 2000; Meade and Islam, 2001, 2006). It shows how new products, services, and technologies are diffused and how research is increasing in both theoretical and empirical areas. In their analysis of optimal price policies associated with the diffusion of new products, Robinson and Lakhani (1975), introduced marketing variables in the parameterisation. A set of policies, incentives, and regulations are being used by the government to create the demand for RETs. For varying periods ranging from 5 to 15 years or more, RET applications have received government subsidies and continue to attract several incentives (Orr, 2003). As RETs face a number of constraints, research has focused primarily on the challenges and barriers that prevent their diffusion. It is necessary to examine the diffusion of RET using diffusion theory and models.

There have been a number of economic studies that have utilised learning curve approaches; however, time series data should also be considered in relation to policy changes as well as social and technological factors that influence diffusion (Orr, 2003). Over time, innovation diffuses through channels of communication used by social system members. The decision-making process is not authoritative or collective, and each member of the social system is responsible for making his or her own innovation decisions. Subsequently, it involves five steps (Orr, 2003). Firstly, it consists of knowing and becoming aware of how innovation works. Secondly, based on the persuasion person's attitudes toward the innovation, they determine whether it is favourable or unfavourable. Thirdly, an innovation is either adopted or rejected by a decision person based on their activities. Fourthly, an innovation is implemented by a person who puts it into practice. Lastly, it is the role of the confirmation person to evaluate the outcomes of an earlier innovation decision. Persuading opinion leaders most easily foster positive attitudes toward innovation (Orr, 2003). According to Rogers, Sighal and Quinlan (2014), change agents should target a certain type of opinion leader based on the nature of the social system. A social system can be classified as either heterophilous or homophilous. The heterophilous social system has the advantage of accommodating changes in norms. They attract a more significant number of people from different backgrounds, suggesting they are more interested in learning new things. Opinion leadership within these systems is more innovative since they are desirous of innovation (Orr, 2003). Behavioural reasoning theory and diffusion theory could be used to also impact urban development. A behavioural approach to public administration increasingly uses the theory to explain policy processes, but it has limitations (Hassan and Wright, 2020).

6.3 Preliminary Theoretical Framework

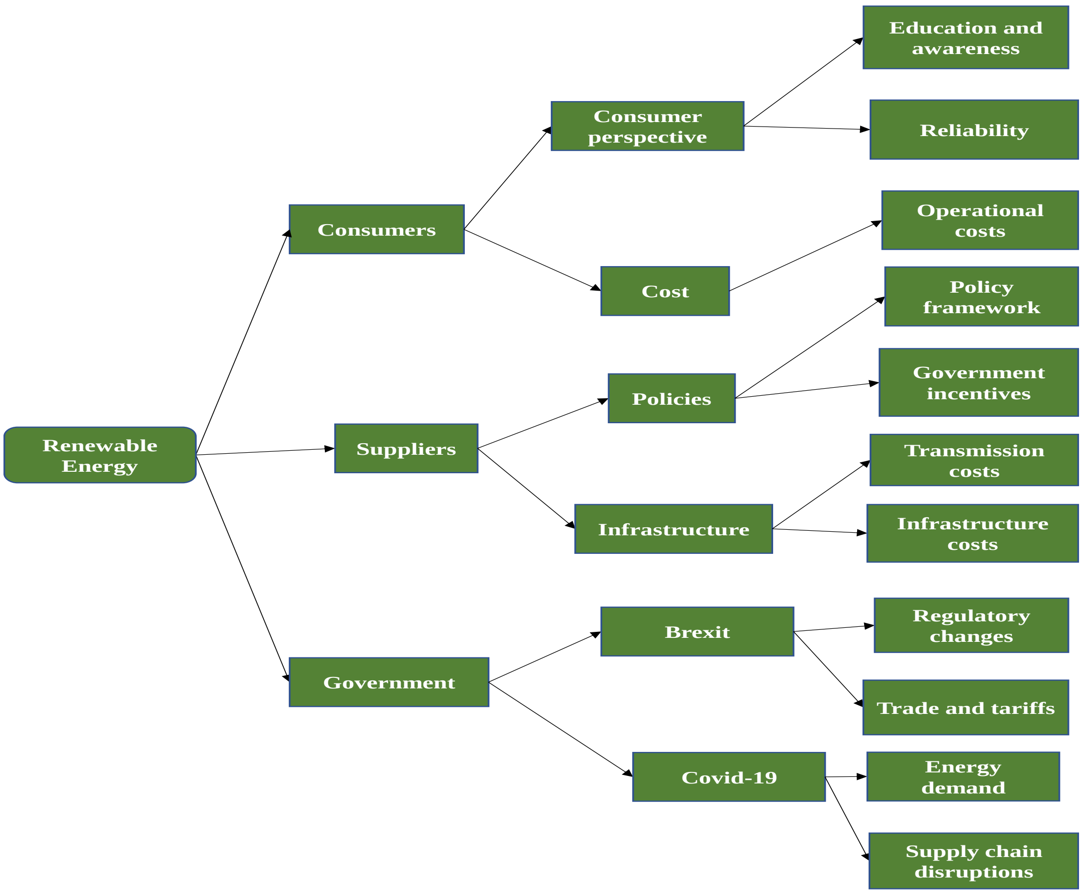

Figure 6-1: Preliminary framework

Source: Author's Own

Depicted in Figure 6-1, is the schematic diagram of preliminary theoretical framework which provides a basis for the research methodologies implemented in this study. The establishment of RE projects in the urban environment requires an understanding of the factors that affect the stakeholders involved. Prior research conducted in the literature review of this study outlined the issues faced by the energy suppliers, the government, and the consumers of energy. It has also identified the corresponding impact of the issues the stakeholders encounter in implementing renewable energy sources. Analysis of the consumer sector showed that to improve consumer perspective education and awareness need to be prioritised to address their concerns regarding the reliability of RE systems (Fields et al., 2016). Similarly, the cost of renewables is an issue as this is affected by factors such as consumers' perception of the operational costs required for the lifecycle of renewable energy systems (Aydin, 2009). Analysis of the suppliers' perspectives showed that the most important factors include the uncertainty of policies and the lack of requisite infrastructure. This inherently is affected by policy frameworks and government initiatives. Additionally, emphasis needs to be placed on the development of the required infrastructure as this could enable suppliers to improve reliability and increase the efficiency of the deployment of renewable energy sources (Painuly, 2001). However, the associated costs for infrastructural improvement need to be considered. Subsequently, governmental bodies are crucial in the implementation of renewable energy. Ultimately, the impact of Brexit and Covid have been evident in the UK's renewable energy agenda, and this has had several consequences. These include the fluctuation in the demand for energy, energy prices, and supply chain disruptions (Department for Business, Energy and Industrial Strategy, 2021).

6.4 Summary

A theoretical framework for renewable energy consumer adoption has been established. Additionally, this is critical because it provides the structure for supporting the research problem that aims to enable the UK to reach its goal of producing 100% renewable energy by 2025. Furthermore, it also connects existing knowledge with the literature review and provides a structure for the design of the questionnaires, interviews, and the factors analysed during the roof survey analysis. The next chapter will identify the methodology utilised in this study.

Chapter 7: Methodology

7.1 Introduction

In general, the importance of research cannot be overstated because it provides the researcher with the ability to pursue and have some control over and a deeper understanding of a chosen course of study. Furthermore, since a PhD degree is a research-based study, it involves a rigorous and systematic process of contributing knowledge and investigating problems ethically. The process of designing a research study is an empirically supported decision-making process (Hakim, 1987). Furthermore, it requires a thorough understanding of all the different dynamics and controls involved in the research for it to be successfully conducted (Blaikie and Priest, 2019). EasterbySmith et al. (2012) state that there are several approaches to determining the answer to a research problem. This can be achieved through the review of literature, which provides a sufficient basis for conducting a literature review. The significance of gaps in the research field and how to outline the direction in which researchers should be conducting research to fill the gaps in the research field must be of paramount importance academically.

Several authors have also highlighted that researchers have a responsibility to choose an appropriate research gap after identifying it, as well as explain how they might use the various methods and vital elements available for accomplishing the research objectives (Creswell, 2007, Hatch and Farhady, 1982, Groenewald, 2004). Mathews and Ross (2010) claim that novice researchers focus more on developing methods rather than focusing on conducting research. However, to conduct a successful research project, a researcher needs to focus on the research problem and tailor the methods to address it, structuring a plan to address the research objectives and the research question. According to Cooper, Schindler, and Sun (2006), research questions play an important role in determining the success of any project. An important consideration when choosing a research method is to ask the right questions. The right question will inevitably attract the right answers, which will lead to reliable research results for the study. Therefore, it is imperative that a research design be implemented to achieve the research goals. Consequently, the purpose of this chapter is to reinforce the importance of research methodology to address this necessity.

7.2 Methodological Approach Adopted

Over the past decade, there has been a conflict between qualitative and quantitative research in behavioural and social sciences (Tashakkori & Teddlie, 2003; Teddlie & Tashakkori, 2003). There has been a recent development in mixed methods approaches that promise to bridge the gap between these two traditions (Haverkamp, Morrow, & Ponterotto, 2005). Alternatively, qualitative approaches focus on the "whole person" holistically within the context of the individual's natural environment (Gelo, Braakman, Gerhard, & Benetka, 2008). In addition to the following, the qualitative approach has some strengths. They provide detailed and in-depth accounts of human experiences (beliefs, emotions, and behaviours), complemented by narrative accounts that are analysed within the context of their observations (Guba & Lincoln, 1994).

Furthermore, qualitative approaches allow an in-depth analysis of complex human, family, and cultural experiences on a scale beyond the capability of measuring scales and multivariate models (Plano Clark, Huddleston-Casas, Churchill, Green, & Garrett, 2008). In addition to difficulties in integrating observations or cases, the qualitative approach has limitations when assessing links and associations between observations, cases, or constructs (Kirk & Miller, 1986). Moreover, qualitative research methods lack well-defined, prescriptive procedures (Morse, 1994), which makes it difficult to draw definitive conclusions and confirmatory findings, which are crucial to scientific research. There are two types of sequential mixed methods designs. They include sequential and concurrent (Creswell, Plano Clark, Gutmann, and Hanson, 2003). Sequential designs collect quantitative or qualitative data at first, followed by the collection of the other type of data at a later stage. Comparatively, concurrent models collect both types of data simultaneously.

According to Creswell et al. (2003), each of these two categories can have three specific designs depending on the degree to which qualitative and quantitative data are prioritised. It also depends on how the data is analysed and integrated, and whether or not the theoretical basis underpinning the study methodology is to bring about social change. According to Creswell et al. (2003), three concurrent mixed methods designs exist. They include concurrent triangulation, concurrent nested, and concurrent transformative. Although qualitative and quantitative data are collected during the same stage of these designs, one form of data may be given priority over the other. Combining qualitative and quantitative data in a concurrent triangulation design can better interpret relationships among variables of interest. During a concurrent nested design, qualitative and quantitative data are collected simultaneously, although qualitative data is given higher priority (Creswell et al., 2003). A concurrent transformative design shares some similarities with sequential nested designs in that it is theoretically driven to initiate social change or advocacy and may be used to support a wide range of viewpoints. There remains a need, within the context of these design approaches, for a methodology that integrates qualitative data with quantitative numerical data (Schwandt, 1994). Considering that qualitative and quantitative approaches have their strengths and weaknesses, an integrative methodology will be helpful for concurrently combining both techniques in a way that offers the descriptive richness of text narratives as well as the precision of quantitative methods in measuring and testing hypotheses (Carey, 1993; Hanson et al., 2005). Therefore, a concurrent triangulation mixed methodology approach was used in this study, which combined qualitative interviews with a quantitative survey. It is primarily aimed at corroboration or cross-validation using qualitative and quantitative studies. Initially, data is collected and analysed separately, then combined.

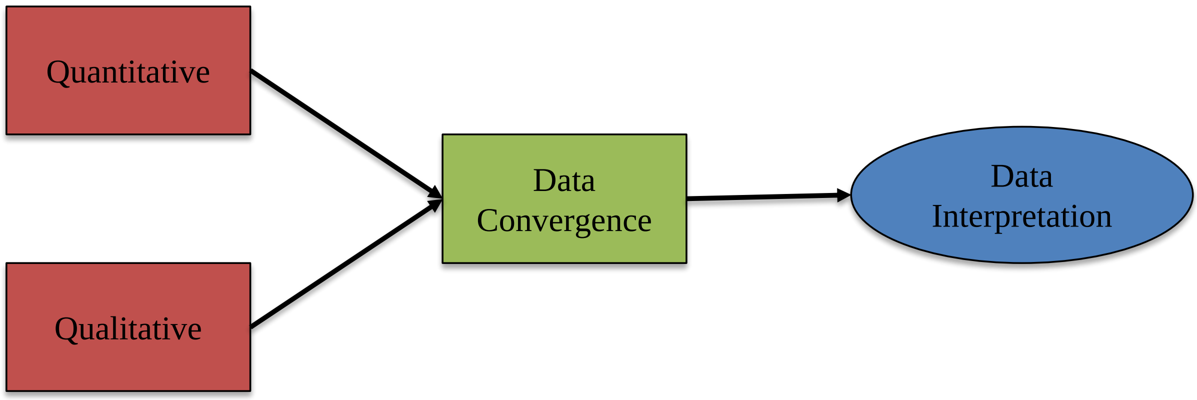

Figure 7-1: Schematic Diagram of a Concurrent Triangulation Design

Source: Reproduced from (Warfa, 2016)

As defined by Creswell (2007), qualitative methods are 'constructivist' models that analyse and explore words from individuals or groups to understand social problems, while quantitative methods analyse and measure variables using numbered data. There are advantages and limitations to both qualitative and quantitative approaches. According to Silverman (2013), qualitative research is useful in understanding the perspectives and experiences of individual people in a relatively limited number of cases in a thorough manner. In quantitative surveys, correlation and regression analysis are used to test hypotheses and theories constructed (Silverman, 2013). A combined qualitative and quantitative approach was chosen in this study to benefit from both qualitative and quantitative approaches. Each method is an arguably better way to answer different types of research questions relating to renewable energy's social dimensions. For the researcher to achieve the objectives of this thesis, a concurrent triangulation mixed methodology approach is required to gather data that is both extensive and deep. Furthermore, multiple methods can be utilised to allow for interesting lines of inquiry to be explored further by utilising another method after being exposed to one method.

According to Silverman (2001), aggregating data sources does not yield a complete picture or a 'true' picture of the social world. Reliability and validity are the most important factors to consider when using qualitative or quantitative methods in research. The reasons for choosing either a qualitative or quantitative method for this study were determined by examining the reliability and validity of the research methods. According to Golafshani (2003), reliability refers to both the 'reliability' and the 'repeatability' of results. Nevertheless, Hammersley (2018) provides a widely used definition of reliability which states that reliability refers to the consistency with which instances are assigned to the same category by different observers or the same observer on different occasions. In qualitative research, cases that are often 'quite personal' are usually explored, reducing the methodology's reliability (Silverman, 2013; Silverman, 2014; Bryman, 2016; Babbie, 2014). According to Silverman (2014), the reliability of qualitative research can be enhanced by comparing research by several researchers and by using standard methods and formats for data collection. According to Maxwell (1992), validity is another quantitative term that refers to determining whether an instrument measures what it alleges to measure. There are, however, several limitations to quantitative research.

In many cases, respondents cannot provide the most relevant or appropriate answers to the research questions because of the structure of the questions (Babbie, 2014). Additionally, quantitative research has an inflexible study design that is unchanged throughout the entire study, which means several important variables are often omitted (Babbie, 2014). Lastly, when respondents do not respond to a survey question in quantitative research, data errors can result since the survey questions may draw respondents who share similar views on the topic. In contrast, the rest of the target group may respond (Dillman, 2002). Therefore, combining quantitative and qualitative approaches can help reduce their limitations in terms of reliability and validity. In this study, methods were selected based on the research questions. Subsequently, 1838 houses in Nottingham will be surveyed based on their roof complexity, location, and house orientation to provide further insight on the adoption of renewable energy sources such as solar energy. This would provide a better understanding of the issues impacting the growth of solar energy whilst the data derived would then be used to analyse the findings from the interviews and the questionnaire to understand if it agrees with previous literature.

7.3 Research data collection

Data collection is essential to research, and inaccurately collected data will affect the credibility of the findings and outcomes (Stack, 1995). Initially, a quantitative survey was administered; subsequently, semi-structured and structured qualitative interviews were conducted, which included additional questions based on the questionnaire responses. This additional set of questions, akin to those in other published literature, is intended to enhance understanding of the issues under study and provide interviewees with a chance to elaborate on any strong opinions or details they may have.

7.4 Primary data collection

A theoretical framework can be better understood by utilising data collected in research (Etikan, Musa and Alkassim, 2016). In order to ensure the accuracy of the data collected, the method and source of data collection must be carefully chosen. This is especially important since improperly collected data cannot be corrected solely through analysis. This study uses two methods of primary data collection. They include convenience sampling and purposive sampling. Convenience sampling method is utilised for the data collected for the public questionnaire, while purposive sampling is used for the interview data collection. The whole population would be ideal for every type of research, but most of the time, the population is almost finite, and it is impossible to include every subject. In this sense, convenience sampling is used by most researchers (Phakiti and Paltridge, 2015). This type of nonprobability, non-random sampling (also referred to as Accidental Sampling or Haphazard Sampling) includes members of the target population who are accessible, geographically close, available during a certain time, and those who are willing to participate (Given, 2008). In addition, researchers may choose subjects that are readily accessible to them (Bernard, 2017). In some instances, convenience samples may be viewed as 'accidental samples' simply because they are located near where the researcher is conducting his or her research, whether geographically or administratively. However, using purposive sampling, also known as judgment sampling, participants are chosen specifically because of their qualities.

An underlying theory or set number of participants is not necessary for this technique. Essentially, the researcher determines what information is needed and seeks out people who can provide that information due to their knowledge or experience (Etikan, Musa and Alkassim, 2016). This process is utilised in qualitative research to identify and select cases with high informational content to maximise resource use. Selecting and identifying knowledgeable and proficient individuals in a particular phenomenon is an important step in the research process. The importance of being available and willing to participate, as well as being able to express and articulate your thoughts and experiences, is also stressed (Etikan, Musa and Alkassim, 2016; Spradley, 2016). There are also several types of purposive sampling. They include maximum variation sampling, homogeneous sampling, typical case sampling, extreme/deviant case sampling, critical case sampling, total population sampling and expert sampling (Etikan, Musa and Alkassim, 2016).

However, this study will be utilising homogenous sampling as it seeks to focus on the residents with their experiences with solar energy, the residents without solar energy, and the councils' available methods to promote the use of renewables. This study also aimed to determine the importance of renewables to energy companies. This includes current investments in the renewable energy sector, their customer base, and the barriers they face while trying to implement renewable energy, if any. However, the researcher was faced with resistance from the selected companies as they believed the researcher was requesting privileged information. This could be because of the perceived threat of their competitors utilising the findings to add value to their organisations (Bengtsson and Kock, 2000). The model used to establish the selection of individuals for the purposive sampling utilised in this research is shown below.

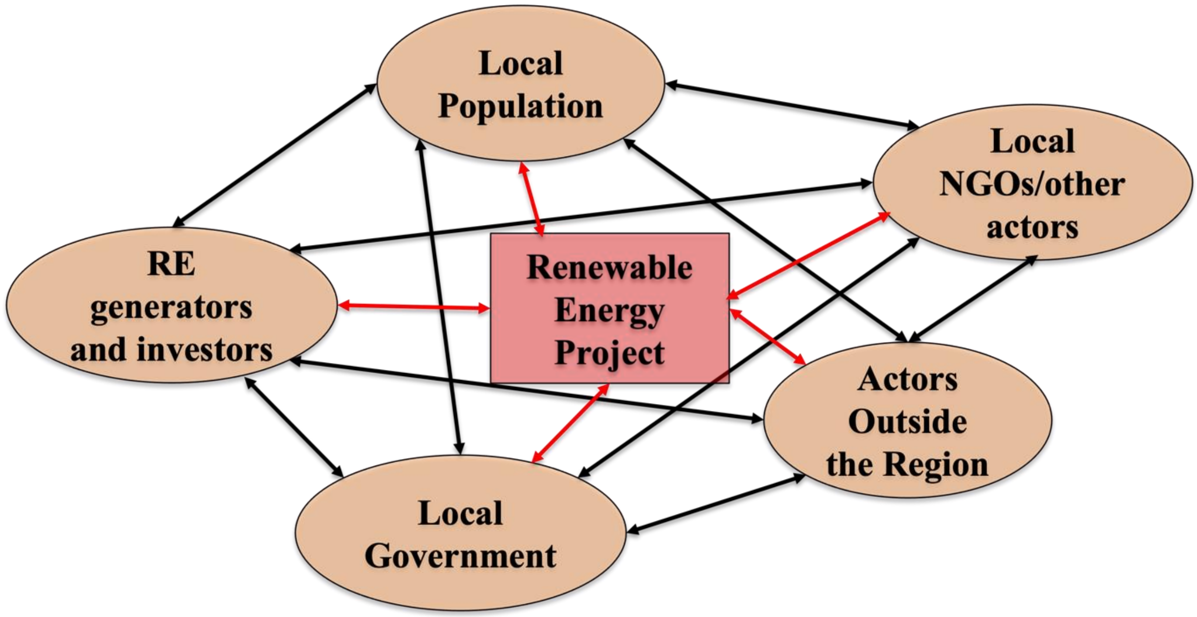

Figure 7-2: Relevant Stakeholders Involved in Renewable Energy Projects

Source: Reproduced from (Del Rio and Burguillo, 2008)

Figure 7-2 outlines the relevant stakeholders involved in renewable energy projects. They include the investors of RE, the local government, the actors outside the region, local NGOs and the local population. To further clarify the impact the stakeholders have, it is imperative to identify the characteristics and contributions to RE adoption. Firstly, local governments are responsible for the provision of the necessary infrastructure to incentivise an area for the development of renewable energy (Del Rio and Burguillo, 2008). This includes providing and maintaining the infrastructure along with providing other facilities to encourage the growth of RE in the local governments (Del Rio and Burguillo, 2008). Additionally, the local governments are responsible for increasing the local benefits that result from renewable energy projects such as requesting compensation which evidently can improve communities through either hiring people from the local community or offering a reduced price for electricity (Del Rio and Burguillo, 2008). The local population's perception and acceptance of renewable energy is crucial to RE implementation due to the issues associated with renewable energy sources such as noise, aesthetics, and the impact on land. Therefore, they have the right to reject any projects as they believe that they are the stakeholders most likely to be affected either negatively or positively (Del Rio and Burguillo, 2008). Subsequently, local NGOs have a crucial role in renewable energy development. They retain the right to reject a project if it is deemed to have significant environmental impacts such as impacting the local ecosystem, potential noise pollution, and visual intrusions (Del Rio and Burguillo, 2008). This is paramount because although the implementation of renewable energy sources has environmental benefits such as reducing carbon emissions, they could inadvertently produce negative externalities (Kagel, Bates and Gawell, 2005; Paulillo et al., 2020; Boyle, 2012; Charlier, 2009; Maxwell et al. 2022). Renewable energy investors are also equally important as they provide capital investment into renewable energy projects however, they may encounter investment risks (Del Rio and Burguillo, 2008). Additionally, these investors could benefit by obtaining facilities from the local government. However, they are required to convince the local government that the projects they are proposing to implement contribute to a certain extent to local sustainability (Del Rio and Burguillo, 2008). Consequently, actors outside the region might be affected either negatively or positively. Regardless, they are unlikely to make any disputes as they are not significantly impacted by the development and implementation of renewable energy sources (Del Rio and Burguillo, 2008).

Furthermore, a study of research methods suggests that questionnaires, literature, and interviews are complementary and differ from each other in several ways. According to Oppenheim (2000), the large sample sizes of questionnaires make them an objective research tool that produces generalisable results. However, many factors may threaten results, including poor questionnaire design, sampling and non-response errors, biased questionnaire wording, unreliability among respondents, ignorance, misunderstanding, reluctance, or bias, errors in coding, processing, and statistical analysis, and a faulty interpretation of results. Furthermore, using questionnaires may be seen as overly dependent on instruments, rendering measurement procedures inaccurate (Bryman, 2008). Although structured interviews are more reliable than unstructured interviews, interviewers lack the ability to ask 'uptake' questions to probe participants' responses (Antaki & Rapley, 1996). Through structured interviews and questionnaires, it is unlikely that one will be able to gain innumerable 'different' kinds of data, which could render the entire interview exercise redundant. According to Segal & Coolidge (2003), structured interviews decrease the amount of variance in the information provided in interviews. However, structured interviews may be the most beneficial in terms of reliability. The structure of structured interviews improves reliability in several ways by standardising and systematising the questions interviewers ask and how they are presented. There are two methods utilised to derive the primary research for this study. They include the use of a public survey and a case study. The survey was distributed on online platforms to collect valuable information from the public in the UK while the interviews and roof survey was conducted with the residents in Nottingham. The data reduction methods are shown below:

- **Interviews:** Conducting interviews via MS Teams, by phone, or online platform.
- **Questionnaires:** Distributing designed questionnaires digitally via social media platforms and online databases.
- **Roof survey:** Using Google Earth to capture 1838 houses based on their roof orientation, complexity, and location.

7.5 Survey Questionnaires

Ideally, a research question should begin broad and be narrowed with knowledge of the literature after gaining a solid understanding of the problem. Information is gathered through a questionnaire and interviews with the council, homeowners, and customers. Closed-ended questions were asked on the questionnaire utilised in this study. Also, questionnaires were given to both current and potential renewable energy users to find out their knowledge of renewables and satisfaction with their renewable energy appliances or sources, if applicable.

7.5.1 Sample Size

Studies show that quantitative research findings can be generalised to represent the entire population of a particular region with a sufficiently large sample size (Silverman, 2013; George & Bennett, 2005). To establish The sample size was derived considering the population size of the UK (66,796,807) as of 2019 (Office for National Statistics, 2021). Using the formula shown below, the calculated sample size for the Public Questionnaire was 385 respondents. However, the number of responses returned was a total of 620. This also showed a response rate of the questionnaire was 89% as 700 questionnaires were distributed, and 620 responses were returned.

Sample size = $z^2 \times p\,(1-p) / e^2 / 1+(z^2 \times p\,(1-p) / e^2 N)$

Where:

z = Z value

p = percentage expressed in decimal form

N = population size

e = margin of error

To balance the accuracy and practicality of findings (SurveyMonkey, 2022), the following assumptions were made:

z = 95% confidence level

e = 5%

7.5.2 Pilot Study

Pilot studies are necessary to ensure that respondents can comprehend the data collection tools and provide comprehensive responses (Hakim, 1987). During this step, the data collection instruments are tested among a smaller number of participants with the objective of assessing the wording and clarity of the questions, as well as their ability to generate robust data that can effectively address the research objectives. Additionally, respondents were required to provide feedback on the tools' usability, compliance with the standard design, and overall effectiveness (Matthews and Ross, 2010). In response to the highlighted process above, the pilot study participants provided some helpful feedback.

- Four respondents observed some errors with the structuring of some questions, which could impact the understanding of the questions. They also outlined that there was some use of complicated wording in some parts, which made the process cumbersome.

- Furthermore, two respondents identified spelling errors, which in some cases could have changed the entire understanding of the outcomes for various questions. Thus, the questions were further simplified to ensure the wording in the questionnaire was consistent and provided clarity for respondents.

The use of the pilot study proved to be a good resource whilst reinforcing that clarity and conciseness are essential in survey questions. As a result, the researcher was able to conclude that the comments that were received were helpful in improving the main questionnaire in general.

7.5.3 Mean and Standard Deviation

During the analysis of the collected data, mean and standard deviation (SD) were calculated to ensure the data collected corresponded with what was expected. In Wohland, Rigler and Vogel's (2001) study, it was suggested that SD of a very large spread denotes that there are lots of errors in the data, whereas SD of a low spread may denote a lack of variance, which is no better than SD of a small spread. Moreover, statistical calculations with zero variance may not be possible, depending on the data scale (Jamieson, 2004). A more complex inferential statistical analysis can only be conducted after determining the normality of the data distribution.

7.5.4 Questionnaire Question Themes:

Each section of the questionnaire was designed to understand the following themes:

- Background information of respondents
- The relationship between educational background, price, age, and gender with the importance of switching to more environmentally friendly energy sources.
- The reasons for overreliance on natural gas and oil.
- Their application of renewable energy sources
- The most important factors hindering their implementation

7.5.5 Questionnaire Data Analysis

There are three commonly used measures for analysing the relationship between two variables, the Pearson correlation coefficient, Spearman's rank correlation coefficient (Spearman's rho), and Kendall's rank correlation coefficient (Kendall's tau). De Vaus (2002) recommends the latter two methods for data that are not normally distributed. Different data sets require different correlation coefficients. Pearson's correlation coefficient is used when evaluating linear relationships between continuous or interval data. When the order of the data is meaningful to the analysis, Spearman's rho and Kendall's tau can be applied to ordinal data.

Additionally, Kendall's tau has less sensitivity to data outliers and smaller data samples (Bonett & Wright, 2000; Long & Cliff, 1997). The survey data were analysed in three stages to identify relationships between variables. To check the normal distribution of the data, a preliminary test was performed. This study used the Shapiro-Wilk test to determine the normality of the entire distribution. A scatter plot was used to investigate the relationship between qualification and household income. This was used to observe for a linear relationship. Subsequently, after analysing the variables to check if they are related monotonically, spearman rank correlation was used to calculate the strength and corresponding direction of the relationship between the variables (Pallant, 2020). Statistical Package for Social Sciences (SPSS) 27 was used to analyse all data. A significance value of $p<0.05$ was assigned to all variables, whereas a significance value of $p<0.01$ was assigned to all high significance values.

7.6 Interview Design

The council and homeowners were asked open-ended questions during the interviews. The open-ended questions ensured a brief and confidential interview. The method adopted during this process involved using semi-structured interview questions for the homeowners and residents utilising solar energy whilst using a structured interview for the homeowners and residents that do not utilise solar energy. The latter method was adopted because the researcher had gained clarification of the research topic, and this provided a baseline for implementing the use of structured questions. The selection criteria used for this study involved the researcher researching areas in Nottingham city based on their affluence and poor nature and delivering letters to homes with visible solar panels and also homes without solar panels. Regarding homeowners utilising solar energy, this will provide insight on some of the key reasons for solar energy implementation. It also aims to capture their experience with solar, why people install solar panels in their homes and explore the benefits that they have been experiencing and challenges they might have faced.

7.6.1 Interview Protocol

The interviews involved 92 individuals from homes in Nottingham, UK, other parts of the UK, and the Nottingham council. The researcher aimed to also interview solar energy providers but was faced with resistance as they deemed the information requested as privileged information.

7.6.2 Interview Question Themes

The interview questions designed for the council placed emphasis on certain areas. The interview consisted of 8 open-ended questions to ensure that further questions were asked based on the response of the interviewee from the council. They include:

- The council's observation of the current intake of renewable energy in residential and commercial buildings.
- The lack of solar panels on roofs in Nottingham, despite the increase in the number of new developments in the area.
- What the council is implementing to increase the utilisation of renewable energy.
- To understand the current barriers to providing cost-effective renewable sources.
- To identify what the UK should do to enhance the utilisation of renewable energy in homes.
- To identify the initiatives the government or local councils are providing to encourage more people to install renewable energy, such as solar energy.

The interview questions for the home residents using solar panels consisted of the following areas:

- The length of time they have had their panels installed.
- The reason for the installation of the panels.
- The financial benefits from their installation.
- Energy bill savings from the solar panels.
- If there were any issues encountered with areas such as mortgage and insurance.
- If there have been any infrastructural damages such as water leaks due to the solar panels' installation.
- The proposed method of payment for the panels.

The interview questions for the home residents that did not utilise solar panels consisted of the following areas:

- The financial burden of bills on their household.
- The level of insulation in their residence.
- Their willingness to implement solar energy.
- The reasons hindering them from implementing solar energy.
- The payback period they would prefer if they decided to invest in renewable energy.
- Their awareness of the cost savings of solar energy.

7.7 Coding the Interview

According to Saunders et al., (2015), coding interview data is a prelude to data analysis, aiming to transform the data into meaningful information. Developing codes from unstructured data allows the data to be coherent by identifying relationships and representing them as themes that can be compared to form theoretical arguments. Codes are also used as a means of organising and interpreting interview data within a research context, including the problem statement, the research goals, and the research question facilitates the organisation and interpretation of the findings (Saunders et al., 2015).

In this study, datasets derived from this work are analysed after the appropriate number of responses have been collected, and themes and patterns will be identified. The coding process utilised in this study is thematic analysis. The researcher examined the data to identify common topics, patterns, themes and ideas that repeatedly occurred during analysis. This enabled the researcher to understand respondents' knowledge, perceptions, views and experiences regarding renewable energy adoption. Braun and Clarke (2006) stated that thematic analysis has several benefits such as summarising key features identified in large data sets enabling researchers to provide a clear and organised report through a well-structured approach. Subsequently, the themes can either be developed inductively or deductively. An inductive approach is characterized by a researcher having the themes utilised in research to be determined by prior data. However, a deductive approach involves developing themes based on theory or existing knowledge (Braun and Clarke, 2006). Therefore, this study utilises a deductive approach to analyse findings from the interviews collected. Furthermore, coding was done using NVivo 12 qualitative data analysis (QDA) software through the following steps:

- Initial codes will be generated from the transcribed data, and qualitative data types and patterns will be identified using the deduced themes.
- After the data has been conceptualised, critical themes will be aligned with the qualitative data.
- The categories will then be connected to segment the data. A spreadsheet can then be used to compile the data for the researcher.
- Following this, the important variables for the data analysis will be arranged in columns using codes.
- Following that, the hierarchy will be determined between the categories that have been segmented. Using this method, the researcher can determine which category is more important to the study and visualise the results accordingly.
- Using the data, the findings from the interviews will be compared to previous literature and questionnaire results to see if they are consistent.
- Further analysis of the findings will be conducted to further understand and analyse the conceptual framework, and alterations may be made if necessary.

7.8 Ethics in Research

To adhere to established morality and ethical standards, researchers must consider the ethical guidelines established (Saunders, Lewis, and Thornhill, 2015). Research participants' dignity, welfare, and rights are protected by these principles. They also govern the conduct of research projects. According to Creswell (2013), research procedures involving human participants are of greatest significance regarding ethical concerns. Flick (2015) suggests that ethical principles are essential to a study because they help the researcher comply with legal requirements. In addition to building trust among subjects, they facilitate higher-quality research because personal data is involved. Furthermore, by adhering to research ethics, the researcher can avoid pitfalls that can limit the accessibility of the research findings of other researchers and the usefulness of the findings to the researcher.

- **Use of informed consent**

Informed consent involves providing participants with enough information so they can make an informed decision about participating in a study (Saunders, Lewis and Thornhill, 2015). To ensure participants understand that participation in the study is entirely voluntary, they should be clearly informed that they could withdraw at any time. When a participant withdraws from the study, the researcher never uses the data provided to that point by the participant. Furthermore, individuals who have reached majority age or are legally able to consent are usually able to give informed consent. In conducting this study, online interaction will be used to collect data. As participants may not be sure about participating, they may worry about invasion of privacy. The researcher using "informed consent" will prevent this. Participants will be informed of how their data will be used. In addition, participants will remain anonymous throughout the study and will only be used for purposes related to this study. Lastly, participants would be informed of their right to withdraw from the research at any time if they see fit.

- **Use of privacy**

Creswell (2013) defines privacy as the measures taken by researchers to protect respondents' identities. Research participants are entitled to confidentiality to mitigate the risk of harm to them due to their participation in any proposed study. For compliance with ethical standards, the participants' identities were protected, and their participation was used only for research purposes. In this study, no raw data are included, except for summaries and excerpts, as the researcher did not collect personal information. Furthermore, excerpts are used carefully to preserve anonymity.

- **Confidentiality**

Saunders, Lewis and Thornhill (2015) argue that it is the researcher's responsibility to make sure that access to the raw data between the researcher and the respondent is restricted. There is a possibility that the data could contain sensitive information about the entities referenced. Additionally, the data collected for this study conforms to the requirements of the General Data Protection Regulation (GDPR). Accordingly, the data will be retained for up to ten years after the research is completed.

As it pertains to how to obtain ethical approval for the research to be conducted, to collect the data and for the research to be analysed, Nottingham Trent University (NTU) Research Ethics Committee approved the researcher's research with a risk assessment. Research approval was contingent on demonstrating compliance with NTU's Research Ethics Policy and considering the issues mentioned above. Participant informed consent was mandatory, all data collected during the study was kept confidential and could only be used for research. Furthermore, all data held by the researcher must be retained until the study is completed, and then destroyed within a specified timeframe. According to ethical considerations and legal requirements, it is imperative that every piece of information acquired from research regarding individuals is kept strictly confidential and stored securely. Datasets derived from this work will be deposited in Nottingham Trent University's institutional data repository and will be made public at the time of publication. Data will also be stored on external devices such as flash memory devices and stored in a secured file cabinet on the university premises. During the entirety of this project, only the researcher will have access to these storage devices.

7.9 Summary

There are several advantages and limitations to qualitative and quantitative analysis and this chapter explains their respective merits and pitfalls, as well as the rationale behind the choice of these methods for this research. It has highlighted the importance of utilising the right methods for efficient and effective research. It details the philosophy underpinned in this research and the reasons for the selected research design and methodology. In addition, it has been described how the sample sizes were calculated, and the research population and target groups for the data collection have been identified. The instrument used to collect quantitative and qualitative data analysis is described in detail. Furthermore, there has been a discussion of the study's reliability and ethical issues considered. A discussion of the "Public Questionnaire" follows in the next chapter.

Chapter 8: Statistical analysis of the 'Public Questionnaire'

8.1 Introduction

This chapter provides the analytical statistics of the data collected through the online questionnaire for the purpose of evaluating the: a) the awareness of participants on environmental preservation; b) the energy efficiency of their homes and resulting impacts on energy consumption; c) their understanding of the benefits and challenges of the implementation of renewable energy; d) if their energy providers promote energy efficiency and renewable energy utilisation. The results are shown below:

8.2 Demographics of the Respondents

8.2.1 Country of Residence

Table 8-1: Respondents' Distribution According to Their Residential Status

Rank value	Option	Count
1	Permanent resident in the UK	603
2	Living temporarily in the UK	12

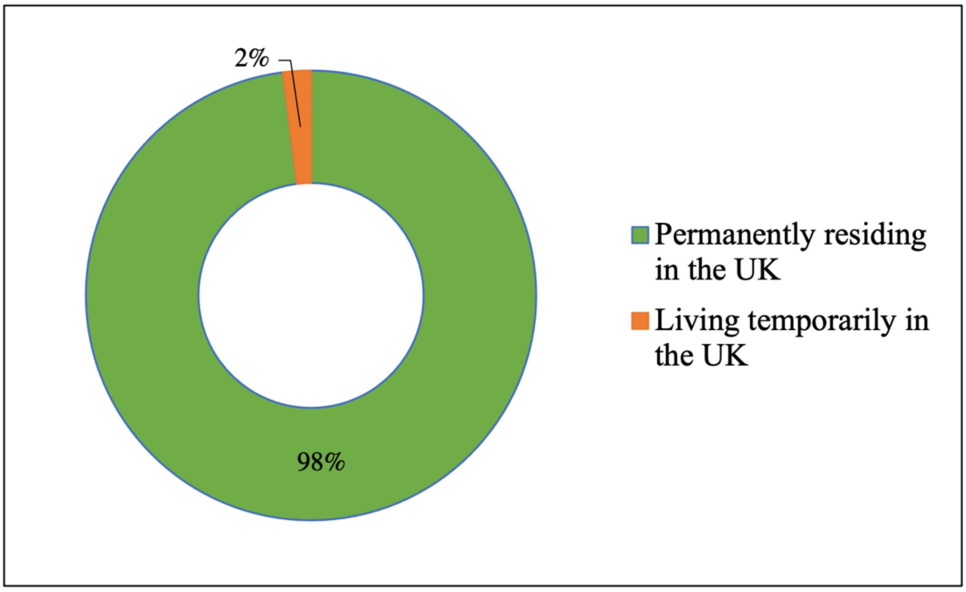

Figure 8-1: Distribution of the Respondents According to the nature of their Residence

The respondents all reside in the UK either permanently or temporarily with 98% and 2% respectively.

8.2.2 Gender

Table 8-2: Respondents Distribution According to the Gender

Rank value	Option	Count
1	Male	161
2	Female	455

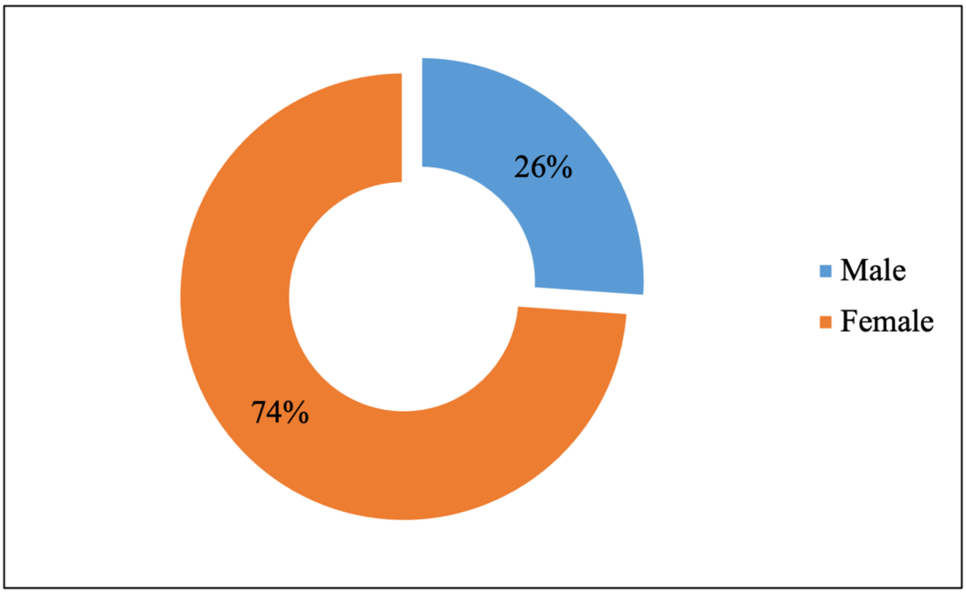

Figure 8-2: Distribution of the Respondents According to the Gender

To ensure this study is free of bias, a 50/50 male to female ratio is ideal. However, this study has a majority of female respondents, with 74% and 26% male.

8.2.3 Age

Table 8-3: Respondents' Distribution According to their Age Group

Rank value	Option	Count
1	18-24	61
2	25-35	203
3	35-44	155
4	45-54	105
5	55-64	75
6	65 or over	20

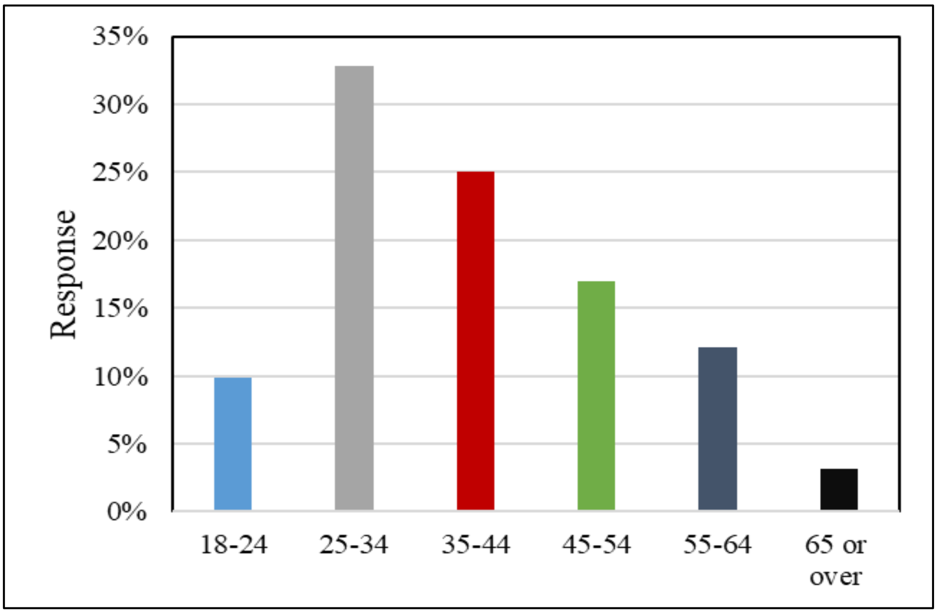

Figure 8-3: Distribution of the Respondents According to the Age

The respondents aged 18-24 represented 10% of the returns, 25-34 represented 33% of the returns, 35-44 represented 25% of the returns, 45-54 represented 17% of the returns, 55-64 represented 12% if the returns, and age 65 or over, represented 3% of the returns.

8.2.4 Level of Education

Table 8-4: Respondents Distribution According to their Level of Education

Rank value	Option	Count
1	PhD	15
2	MA/MSc	101
3	BA/BSc	257
4	Diploma	97
5	Secondary school	140
6	Primary school	3
7	Other	7

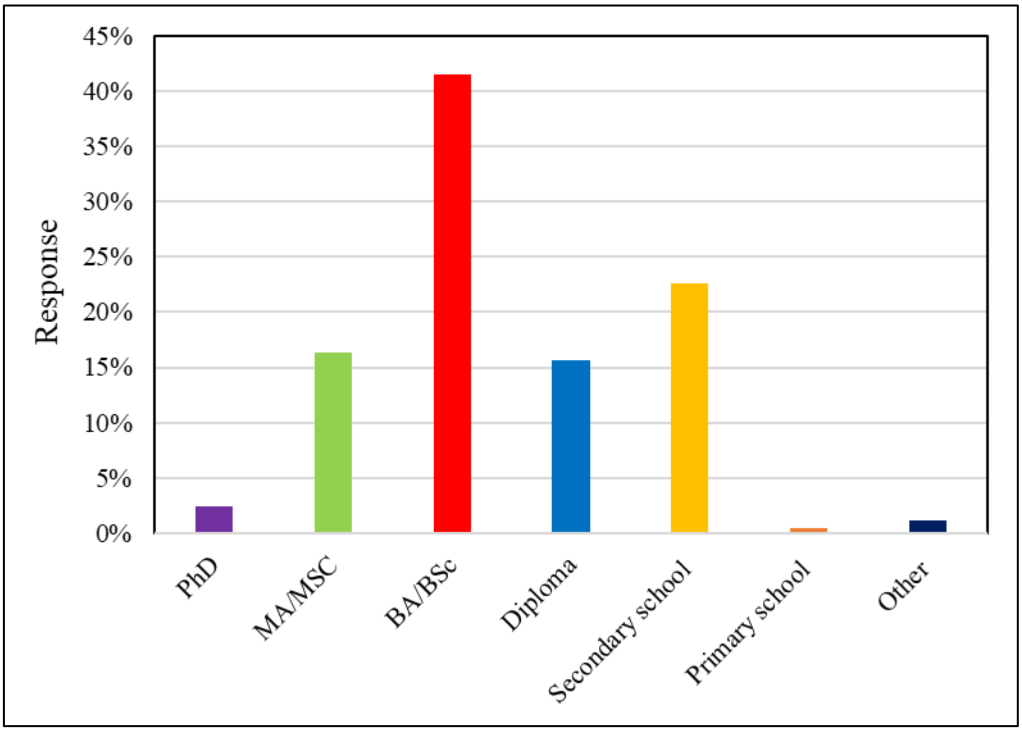

Figure 8-4: Distribution of the Respondents According to Qualification

This demographic is useful to understand the relationship between the use and awareness of renewable energy and level of education. Regarding the qualification of respondents, 18% of the respondents have achieved a postgraduate qualification with 2% for doctorate and 16% for masters respectively. Respondents who achieved a bachelor's degree represented the largest proportion of the respondents with 42%, while 23% achieved a secondary school certificate, diploma 16%, 1% achieved a primary school qualification, and respondents who specified other accounted for 1% of the returns.

8.2.5 Occupation

Table 8-5: Respondents Distribution According to their Occupation

Rank value	Option	Count
1	Student	41
2	Civil servant	47
3	Teacher/University lecturer	33
4	Self employed	61
5	Retired	31
6	Free lancer	16
7	Private sector employee/ Director	219
8	Unemployed	71
9	Other	101

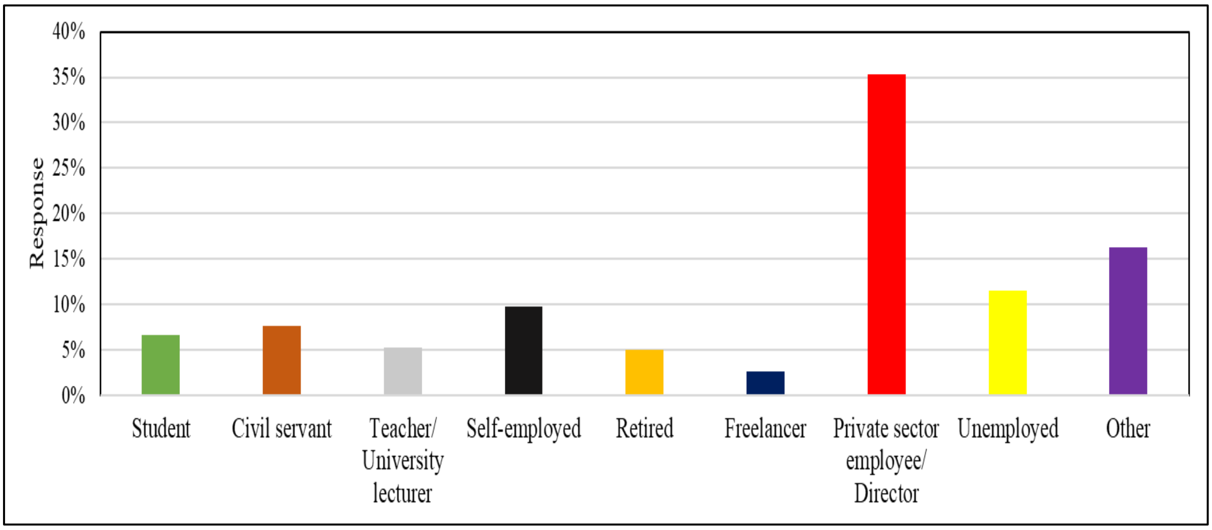

Figure 8-5: Distribution of the Respondents According to Occupation

The occupation of the respondents shows that 7% of the respondents are students, 8% are civil servants, 5% are teachers/lecturers, 10% are self-employed, 5% are retired, 3% are freelancers, 35% are private sector employees/directors, 12% are unemployed, and 16% of respondents account for other such as mental health worker, public sector manager, police officer, local government employee, IT technician, teaching assistant, and NHS physiotherapist.

8.2.6 Accommodation type

Table 8-6: Respondents Distribution According to their Type of Accommodation

Rank value	Option	Count
1	Own house	346
2	Rented house	131
3	Own flat	32
4	Rented flat	86
5	Caravan/traveller	0
6	Other	20

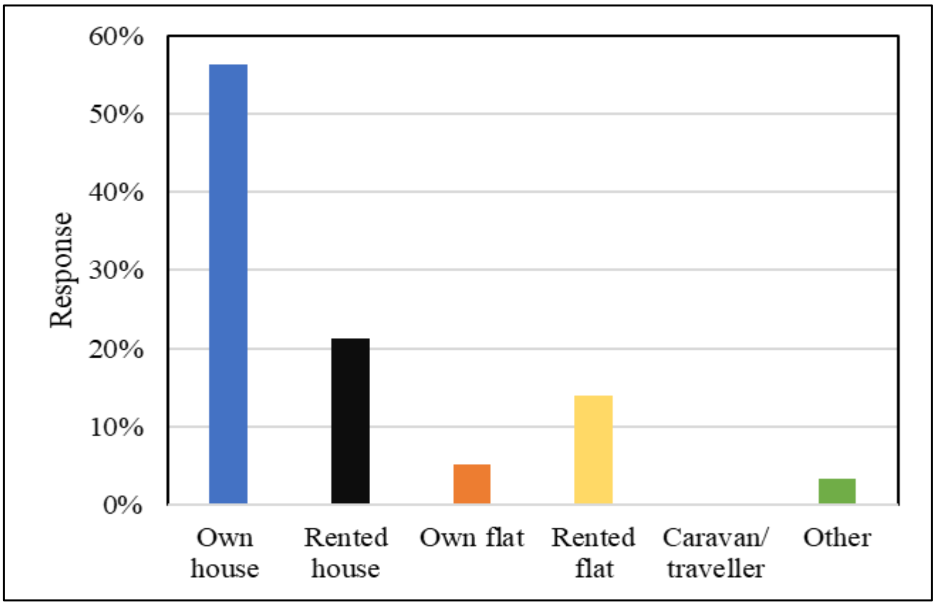

Figure 8-6: Distribution of the Respondents According to Accommodation Type

Depicted in Figure 8-6 is the type of accommodation, which the respondents reside in. It shows that 56% of respondents own their home, 21% of the respondents reside in a rented house, 5% own flats, 14% reside in a rented flat, while 3% specified other.

8.2.7 Income of Respondents

Table 8-7: Respondents Distribution According to their Income Monthly

Rank value	Option	Count
1	Less than £1500	87
2	£1500-£2499	156
3	£2500-£3499	145
4	£3500-£4499	113
5	£4500 or above	77
6	Prefer not to say	40

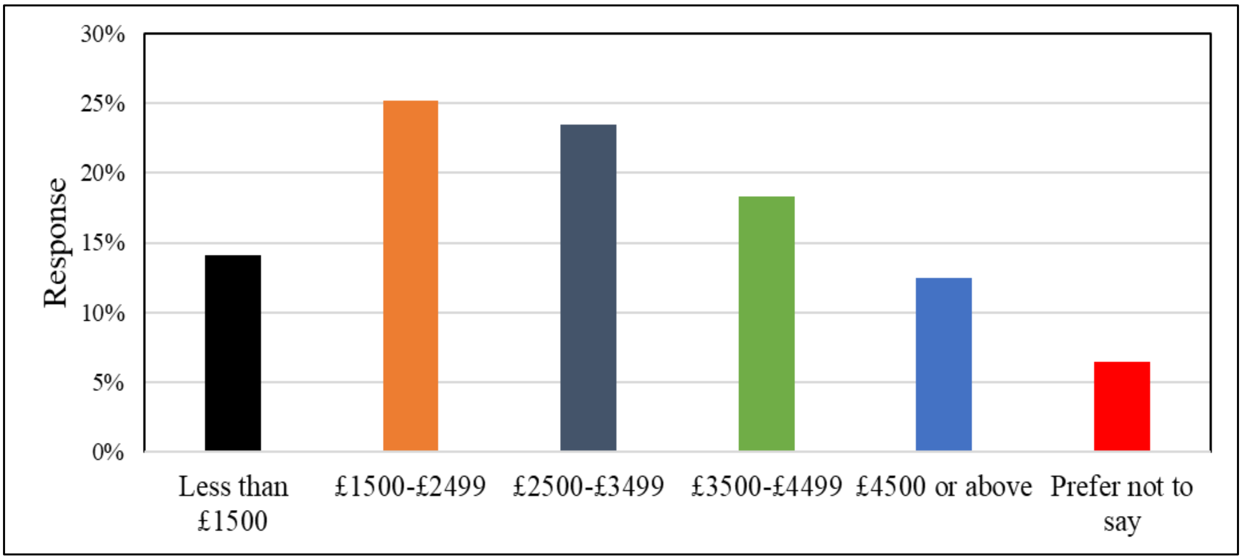

Figure 8-7: Distribution of the Respondents According to Household Monthly Income

Depicted in Figure 8-7 is the distribution of the annual income of the respondents recruited for this study. It shows that 14% of the respondents earn less than £1500. Subsequently, 25% that accounted for the highest percentage earned £1500 to £2499, and this was closely followed by the respondents who earned £2500 to £3499 with 24%. Respondents that earned £3500 to £4499 constitute 18% of the respondents while 13% earned £4500 or above and 7% preferred not to specify their actual earnings.

8.2.8 Level of insulation

Table 8-8: Respondents Distribution According to their Home Insulation

Rank value	Option	Count
1	High level of insulation	100
2	Medium level of insulation	332
3	Poor level of insulation	142
4	Don't know	42

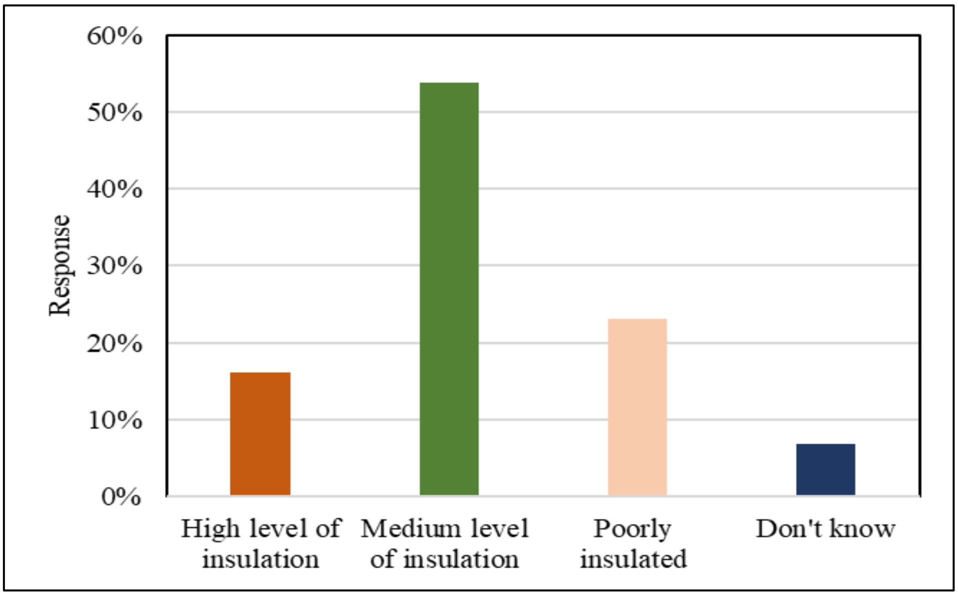

Figure 8-8: Distribution of the Respondents According to Level of Insulation

Depicted in Figure 8-8 is the type of insulation in individuals' homes and residences. It showed that 16% of respondents utilised high level of insulation in their homes. Subsequently, majority of the respondents utilised medium level of insulation with 54%. The respondents that stated that their residence was poorly insulated accounted for 23% while 3% of respondents didn't know the exact type of insulation utilised in their residence. Descriptive statistics reveal an overall mean of 2.87 (SD= 0.79).

8.2.9 Use of Renewable Energy for environmental protection

Table 8-9: Respondents Distribution According to Perception of the Use of Sustainable Energy to Save the Environment

Rank value	Option	Count
1	Strongly agree	244
2	Agree	285
3	Neutral	71
4	Disagree	13
5	Strongly disagree	3

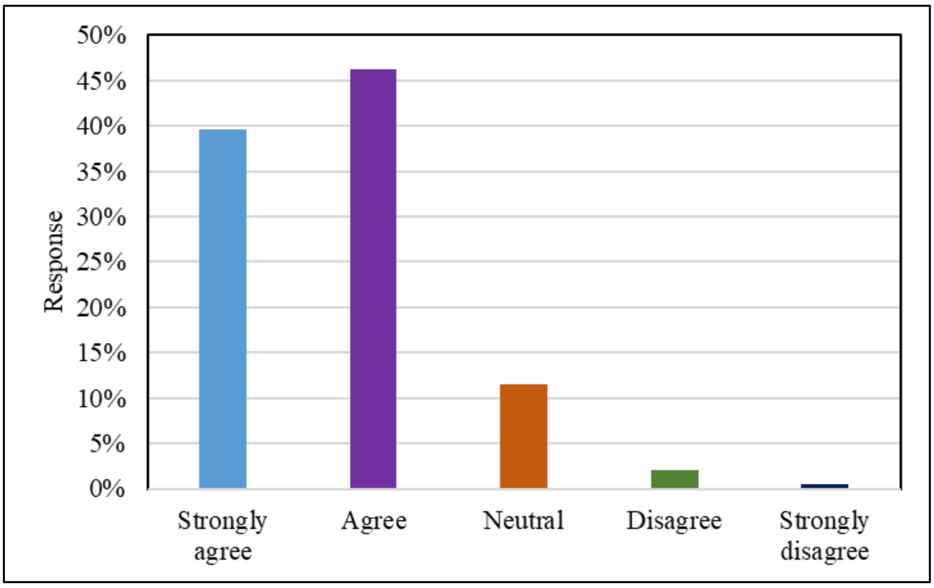

Figure 8-9: Distribution of the Respondents According to the Use of Renewable Energy for Environmental Protection

Depicted in Figure 8-9 is the response from respondents regarding the use of renewable energy to save the environment. Respondents firmly agree on the issue of preserving the environment with 40% stating they strongly agree, 46% stating they agree, and the respondents that stated they are neutral, or disagree, or strongly disagree have 12%, 2%, and 1% respectively. This also agrees with literature with respondents stating that they are aware of the adverse effects of fossil fuels on the environment (Moghavvemi, Jaafar, Sulaiman and Parveen Tajudeen, 2020).

8.2.10 The Role of Human activities on Global Warming

Table 8-10: Respondents Distribution According to their Perception of the role of Humans to Global Warming

Rank value	Option	Count
1	Strongly agree	293
2	Agree	230
3	Neutral	73
4	Disagree	13
5	Strongly disagree	6

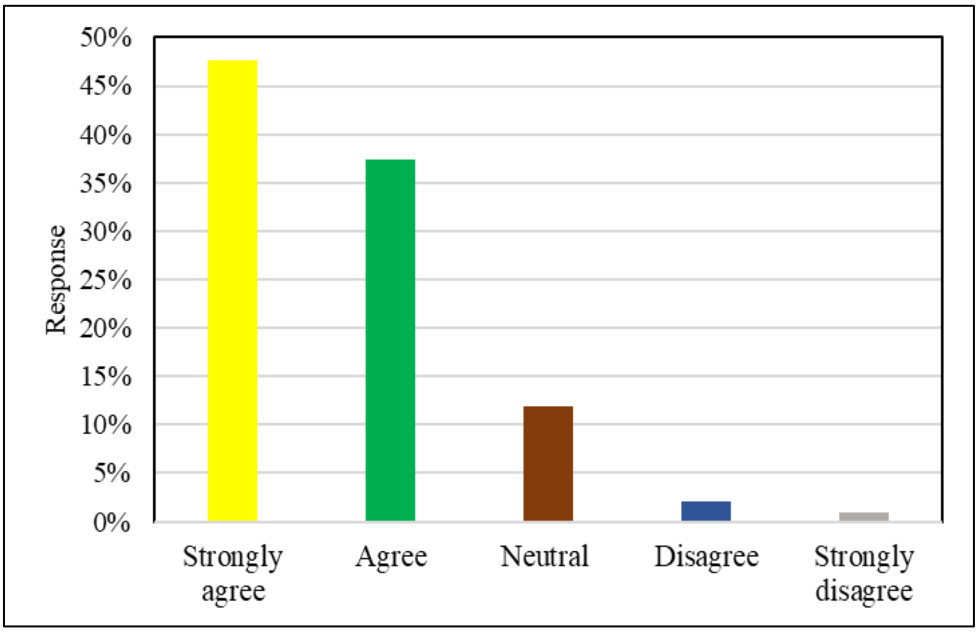

Figure 8-10: Distribution of the Respondents According to Awareness Human Activities on Global Warming

Depicted in Figure 8-10 is the perception of the respondents on the impact of human activities to the rise in greenhouse gas emissions. Majority of respondents stated that they strongly agree with 48%, and 37% stating that they agree. However, the number of respondents that are neutral, disagree, or strongly disagree was 12%, 2%, and 1% respectively. This contradicts the literature, which identifies the lack of awareness and understanding of global warming as one of the reasons impeding the adoption of renewables from consumers (Leiserowitz, 2007).

8.2.11 Financial Burden of Bills

Table 8-11: Respondents Distribution According to the Financial Burden of Bills

Rank value	Option	Count
1	Always	129
2	Often	176
3	Sometimes	209
4	Rarely	79
5	Never	24

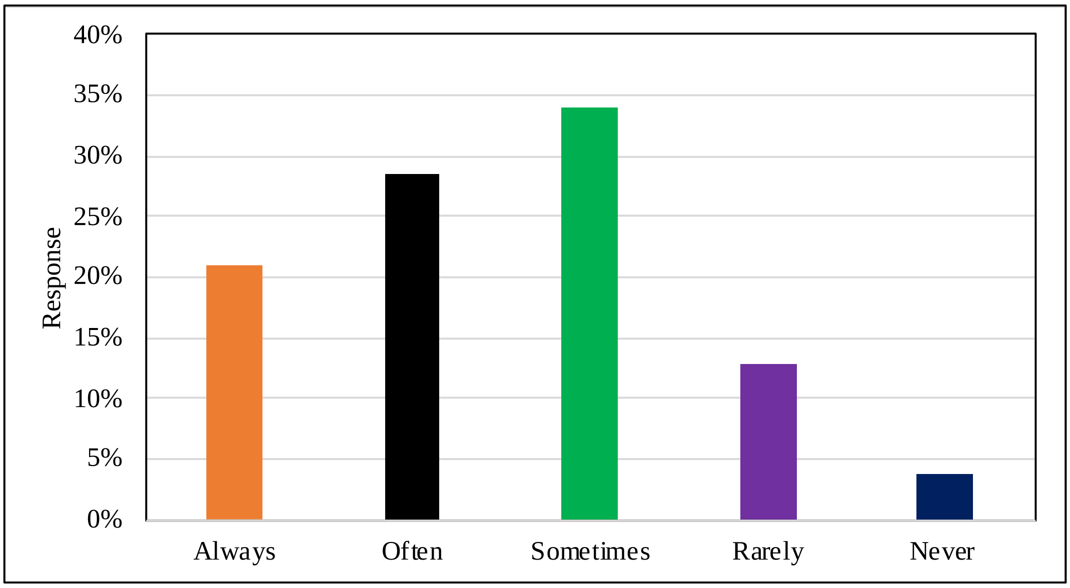

Figure 8-11: Distribution of the Respondents According to Financial Burden of Bills

Figure 8-11 shows that majority of the respondents stated that they are currently experiencing a financial burden regarding bill payments with 21% and 29% identifying that they either always or often have difficulties with paying bills. However, 34% stated that they sometimes experience difficulties with payment of bills. Other respondents stated that they either rarely experienced financial difficulty accounted for 13% and 4% respectively. Subsequently, the questionnaire was distributed in January 2022 until August 2022. In that specified time, the energy price cap in the UK had increased from 4.1p/kWh (pence per kilowatt hour) of gas to 8p/kWh and 20.8p/kWh of electricity to 29p/kWh (ICAEW, 2022). This shows that the financial impact of the rise of energy bills in the UK is evident. Furthermore, this is expected to increase further following the recent increase in energy prices.

8.2.12 Reasons Hindering Renewable Energy Implementation

Table 8-12: Respondents Distribution According to the Reasons Hindering their Adoption of Renewable Energy

Rank value	Option	Count
1	Financial reasons	282
2	No adequate space	115
3	Health and safety issues	7
4	Legal issues	20
5	Lack of information about the technology	227
6	Reduce my house value	4
7	Mortgage issues	3
8	Need for life expectancy and maintenance	56
9	Other	91

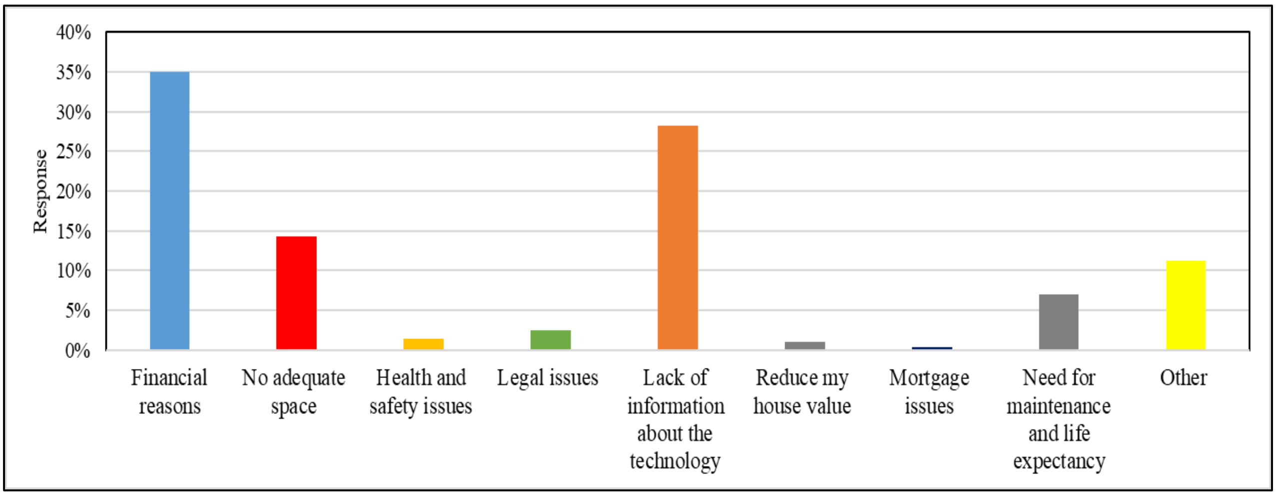

Figure 8-12: Distribution of the Respondents According to The Reasons Hindering Renewable Energy Implementation

Figure 8-12 shows that the reasons that hindering respondents from implementing renewables in their homes. Majority of the respondents stated that financial reasons were hindering them from adopting renewables with 35%. This was closely followed by the lack of information about the technology with 28% of respondents. Another notable response was the selection of no adequate space with 14%. These highlighted reasons shows that the findings agree with literature which state that financial constraint and lack of information are key factors in the implementation of RE (Rawea and Urooj, 2018; Cedrick and Long, 2017; Owusu and Asumadu-Sarkodie, 2016). Respondents that stated that health and safety, legal issues, reduction of house value, mortgage issues, need for maintenance and other accounted for 1%, 3%, 1%, 1%, 0.4%, 7%, and 11% respectively. Descriptive statistics reveal an overall mean of 3.8 (SD= 2.82). Further granular analysis identified that the respondents that stated 'other', specified the exact reasons, which can be used to further provide clarity on the issues they face. Some of the key comments of participants include:

- There was a growing theme of participants who specified that it was the role of the landlord to make modifications to the homes not them. According to a participant, there is no authority to make modifications to their current residence stating, *"I am staying in a rented house and need permission from landlord to install renewable energy technologies"*.
- Another stated that they *"Lack of control over energy sources as I am in a rented flat"*. This indicates that due to not owning their home, they are unable to implement renewable sources.
- Another participant indicated that it is the responsibility of the landlord stating, *"Energy provision is determined by the landlord"*.
- Another stated that they are *"Limited in what I can implement as I don't own the property"*.
- Another stated that the *"Landlord gets to decide things like type of boiler, gas cooker etc."*
- Another participant stated, *"I am in a council shared house, and they deal with the bills, so I don't actually know which energy company it's with"*.
- Another participant stated that it is a *"Rented accommodation so not my choice"*.
- Another participant stated that *"It is a rented house and I have no option to use renewable sources"*.
- Another stated that *"It is in a shared property so I don't believe we could get them unless the property manager allowed it"*.

- Another stated, *"I don't own the property, so I am unable to install and use renewable energy systems"*.
- Another participant stated that *"It's a housing association flat so restricted"*.
- Another participant indicated that they reside in a *"Council owned sheltered house"*.
- Another stated that *"As rental tenants we can't make modifications to the house"*.
- However, another participant also highlighted that not only do they not have the authority to make modifications, but the building is also registered as a listed building stating, *"It is privately rented and a listed building"*.
- Another participant stated that they had attempted to embark on implementing sustainability sources but get refused by the council to make any alterations stating, *"Council refused planning permission for turbine and panels"*.
- Like the previous participant, another participant showed concern about implementing renewable such as solar as it is it would be impeded by *"Planning issues as live-in a conservation area"*.
- Another participant showed concern stating that the *"Cost of initial set up"* required for renewable energy sources is a crucial factor.
- Another participant was quite concerned about the level of insulation in the residence whilst also stating that the end of the FiT scheme has also hindered any potential interest considering the financial requirement stating, that they are *"Unable to benefit from feed in tariffs because room cavity walls don't have external insulation - too expensive without government help"*.
- Another participant indicated that it might be too early to consider making any alterations to the home stating, *"I only bought the house three months ago"*.
- Another participant showed concern about the potential production power from the solar panels being limited due to shading stating that their *"Roof not suitable for solar panels due to shade from neighbour's large tree"*.
- Another participant stated that the buildings age should be considered and that could be one of the key factors stopping the landlord from considering it as a viable option stating that the *"Landlord won't, and age of building"*.
- Another participant was adamant that solar panels wouldn't be applicable on the roof of their residence stating, *"My roof doesn't work with solar. I do buy renewable energy from my energy company"*.

- Another participant showed concern about the work that would be required to the existing structure to implement renewable sources stating, *"Scale of building work required for modifications to support e.g., ground or air sourced central heating"*.
- Another participant believed that renewable energy sources are *"Less efficient than regular energy"*.
- Another participant stated that they would need the help of the council stating they *"Would require my housing association to sort."*
- Another participant indicated that it had never been considered by stating that they *"Have never thought about it"*.
- Another stated it is *"Not my responsibility"*.
- Another participant stated that they require the council to make renewable sources available stating, *"Council not provided it yet"*.
- Another participant indicated that they utilised renewable energy supplied from a sustainable energy provider but then some issues with the company occurred stating, *"I was with a renewable energy company, but it went bust and I was forced to move to British Gas"*.
- Another participant stated that they utilised both energy from fossil fuels and renewables *"I am using renewable in addition to non-renewable"*.
- Lastly, another participant specified that due to the issue of the location of the house, the utilisation of renewables would be difficult stating, *"Due to our rural location, access to renewables is limited"*.

The findings show that there in rental properties, the owner has very little incentives to invest in sustainable energy sources because heating costs are shared equally, therefore there are fewer reasons to conserve energy (Wuertenberger et al., 2011). However, for the participant that stated that the use of renewables would be difficult, perhaps this could provide a potential for the utilisation of stand-alone solar PV systems.

8.2.13 Responsibility of Homeowners for Global Warming Reduction

Table 8-13: Respondents Distribution According to the Responsibility of Homeowners to the Reduction of Global Warming

Rank value	Option	Count
1	Strongly agree	66
2	Agree	243
3	Neutral	189
4	Disagree	90
5	Strongly disagree	27

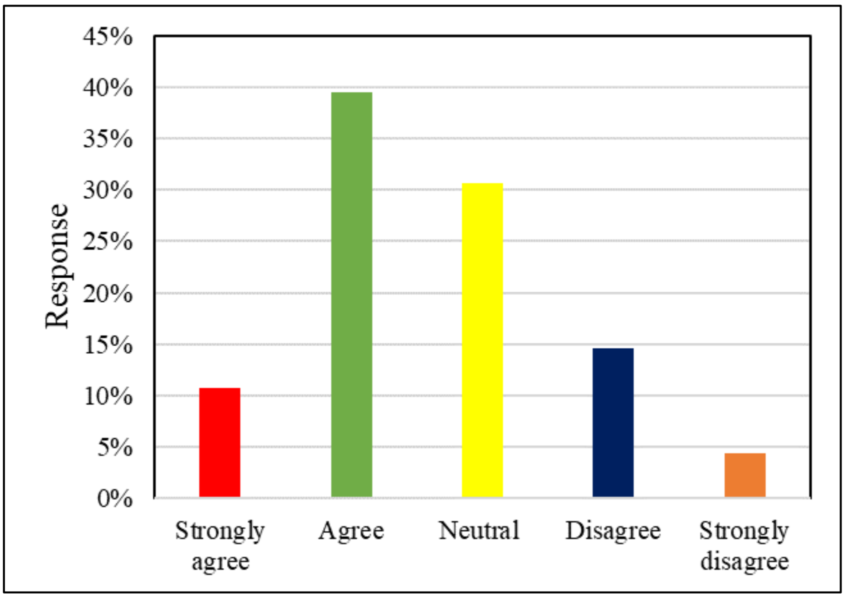

Figure 8-13: Distribution of the Respondents According to The Perception of Responsibility of Homeowners to Reduce Global Warming

Figure 8-13 shows respondents' perception regarding the belief that the responsibility of reducing the effects of global warming. It shows that respondents are not only aware of the deteriorating state of the environment, but they are also aware of the role and impact of homeowners to this phenomenon. As shown, 11% of respondents stated they strongly agree while 40% stated that they agree totally accounting for over 50% of the responses. However, 31% stated that they had a neutral stance. The respondents that stated that they disagree or strongly disagree accounted for 15% and 4% respectively.

8.2.14 Governments and Businesses Responsibility Regarding Global Warming

Table 8-14: Respondents Distribution According to the Responsibility of Governmental Bodies and Businesses to the Reduction of Global Warming

Rank value	Option	Count
1	Strongly agree	272
2	Agree	282
3	Neutral	71
4	Disagree	13
5	Strongly disagree	3

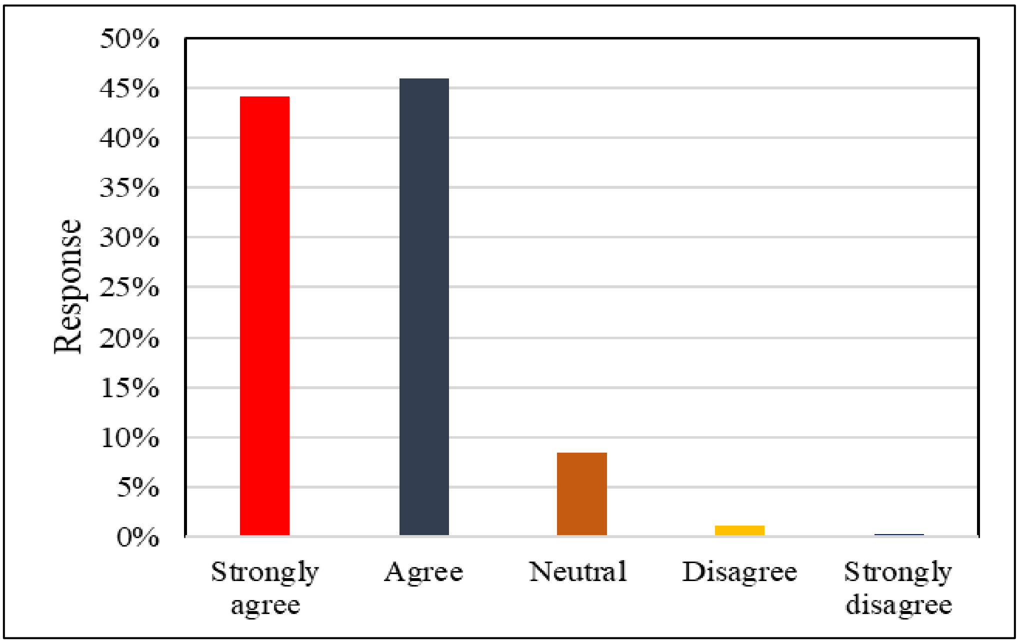

Figure 8-14: Distribution of the Respondents According to The Perception of Global Warming Reduction by the Government and Businesses

Depicted in Figure 8-14, respondents expressed their belief in the role of governmental bodies and business in the reduction of global warming. Overwhelmingly, 90% of respondents stated that it is the responsibility of the government and businesses to reduce the impact of global warming on the environment with 44% and 46% respectively. Other respondents either had a neutral stance or disagreed with 9% and 1% respectively.

8.2.15 Reason for Renewable Energy Adoption

Table 8-15: Respondents Distribution According to their Reasons for Adopting Renewable Energy

Rank value	Option	Count
1	Reduced energy bills	131
2	Increase my house value	15
3	Stable energy prices	48
4	Improved public health	47
5	Other	94

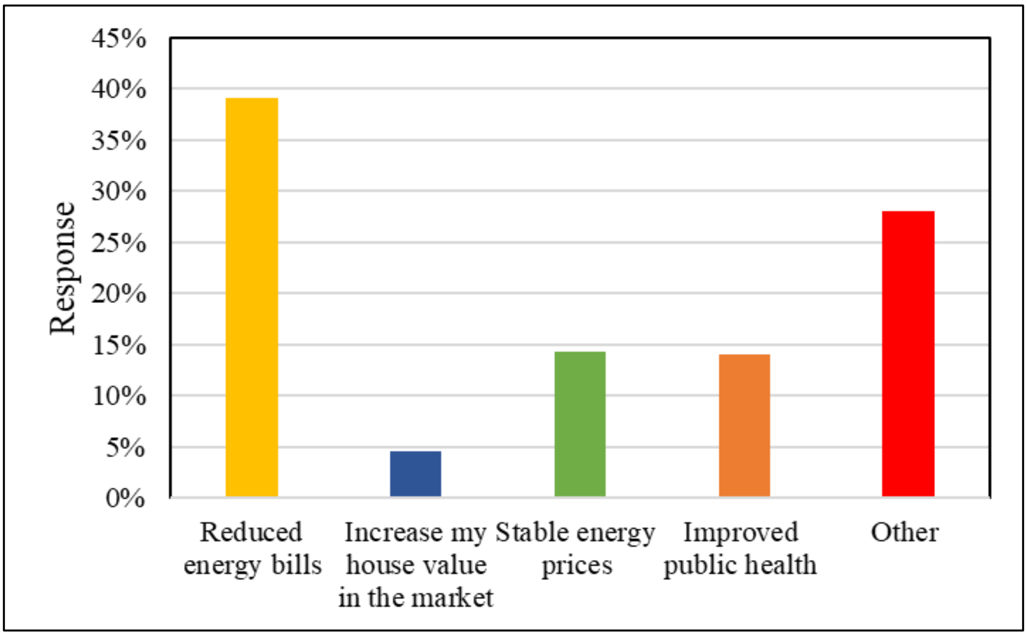

Figure 8-15: Distribution of the Respondents According to The Reasons for Renewable Energy Adoption

Depicted in Figure 8-15 are the respondents identified that to be crucial for adopting renewable energy sources. Reduction of energy bills was stated as the most important factor with 39% affirming this. Respondents that specified the stability of energy prices and improved public health are crucial each accounted for 14% while 5% stating the increase in house value in the market is the most important factor. However, a sizeable number of respondents specified other with 28%. Descriptive statistics reveal an overall mean of 2.87 (SD= 1.69).

8.2.16 Use of Renewable Energy In the UK

Table 8-16: Respondents Distribution According to the Renewable Energy Sources Desired to be Used in the UK

Rank value	Option	Count
1	Solar energy	369
2	Wind energy	480
3	Bio-mass energy	144
4	Geothermal energy	141
5	Hydro energy	324
6	Don’t know	95
7	Other	28

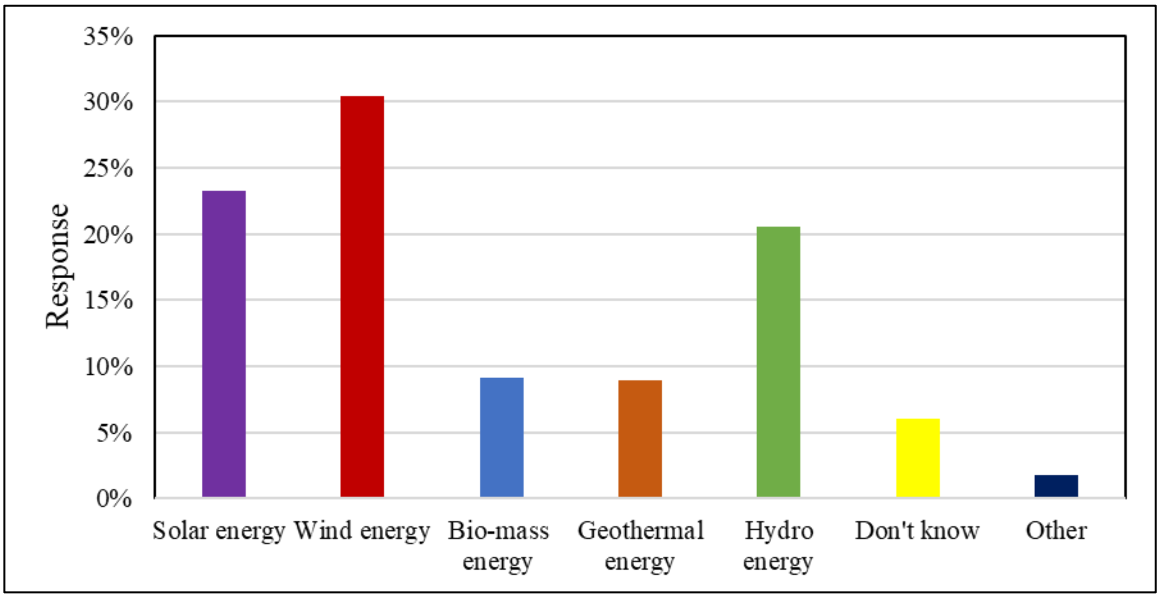

Figure 8-16: Distribution of the Respondents According to Renewable Energy to Be Used in the UK

It is immediately apparent that respondents stated that the renewable sources that should be used in the UK include wind energy with 30% and solar energy with 23% as is shown in Figure 7-16. This therefore suggests that there could be an opportunity to promote BEWT to residents as they are receptive to the idea of wind energy in the UK. Respondents that stated that the UK should use more of hydro energy accounted for 21% of the returns. The use of biomass and geothermal energy was accounted for with 9% each. Lastly, respondents that specified other and don't know accounted for 2% and 6% respectively. However, the respondents that stated 'other' specified that they would prefer the use of nuclear power, district heating, tidal energy, and air or ground source heat pumps. This is evident in Figure 7-17 which shows the lack of awareness of respondents regarding the use of heat pumps as an alternative source of energy.

8.2.17 Awareness of Heat Pump Technology

Table 8-17: Respondents Distribution According to their Awareness of the Use of Heat Pump Technology

Rank value	Option	Count
1	Yes	229
2	No	385

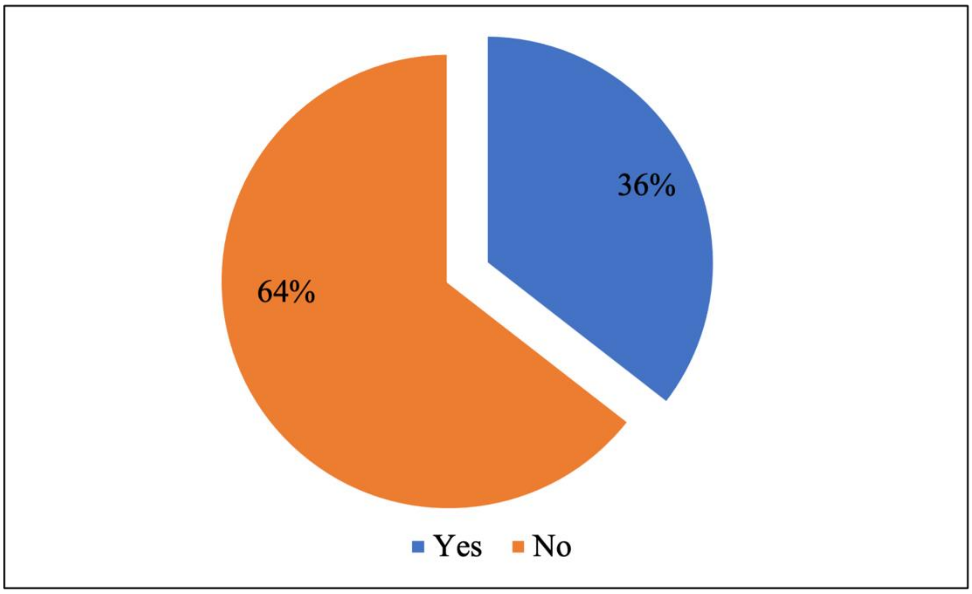

Figure 8-17: Distribution of the Respondents According to Awareness of Heat Pump Technology

8.2.18 Factors to Consider for Renewable Energy Implementation

Table 8-18: Respondents Distribution According to the Factors they Consider When Implementing Renewable Energy (Multiple answers)

Rank value	Option	Count
1	Installation	506
2	Running cost	519
3	Environmentally friendly	304
4	Appearance	125
5	Switching cost between suppliers	212

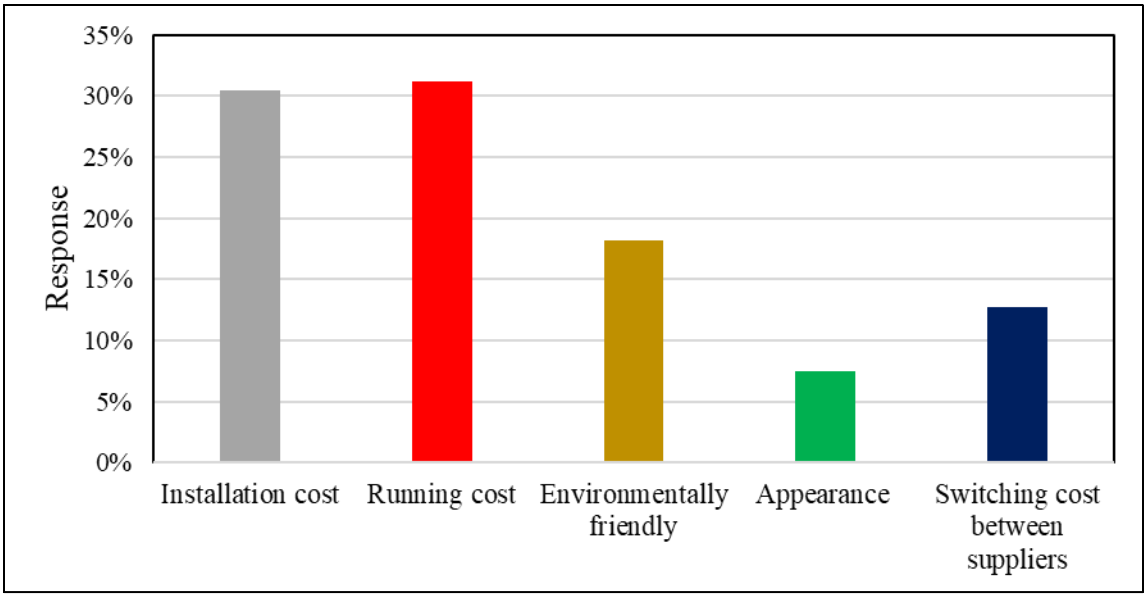

Figure 8-18: Distribution of the Respondents According to Crucial Factors to Consider

In Figure 8-18, the respondents highlight the most important factors they consider when implementing renewable energy. Installation cost and running costs rank highly on the respondents' factors necessary with 30% and 31% respectively. The environmentally friendly nature of the resource accounted for 18%, while the ability to switch cost between suppliers accounted for 13%. Lastly, respondents stated the appearance was the least crucial factor accounted for 8% of the returns. Descriptive statistics reveal an overall mean of 2.41 (SD= 1.33).

8.2.19 Promotion of Renewables by Energy Providers

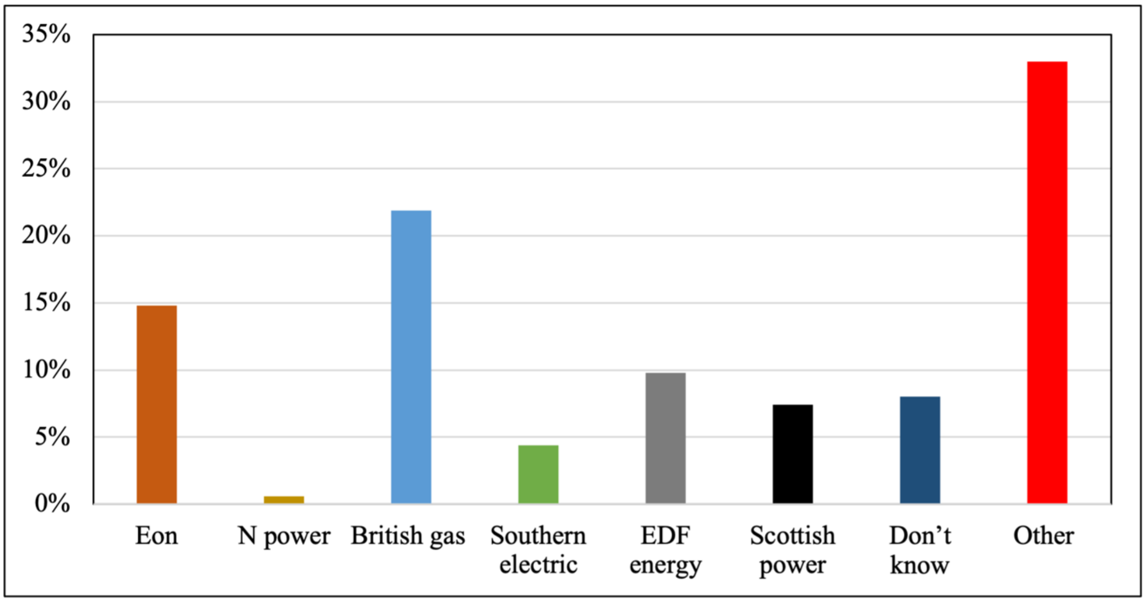

Figure 8-19: Distribution of the Respondents According to Energy Provider

Figure 8-19 showed that Eon supplied energy to 15% of the respondents; N power supplied 1% of the respondents' energy, while British gas supplied 22% of the respondents, Southern electric supplied 4%, EDF energy supplied 10%, Scottish power supplied 7%, while don't know and other accounted for 8% and 33% respectively. To further understand if the energy providers promoted the switch to renewables, the researcher further asked the respondents if they are aware of any methods in which their energy providers promoted renewables to them. The responses showed that 62% of the respondents stated that their energy supplier promoted renewable energy, 30% said that their energy provider didn't and 8% stated that they don't know.

8.2.20 Energy Source of Choice

Table 8-19: Respondents Distribution According to the Renewable Energy Sources Desired to be Used in their Homes in the UK

Rank value	Option	Count
1	Solar energy	399
2	Bio-mass energy	55
3	Geothermal energy	70
4	Hydro energy	107
5	Don't know	189
6	Other	16

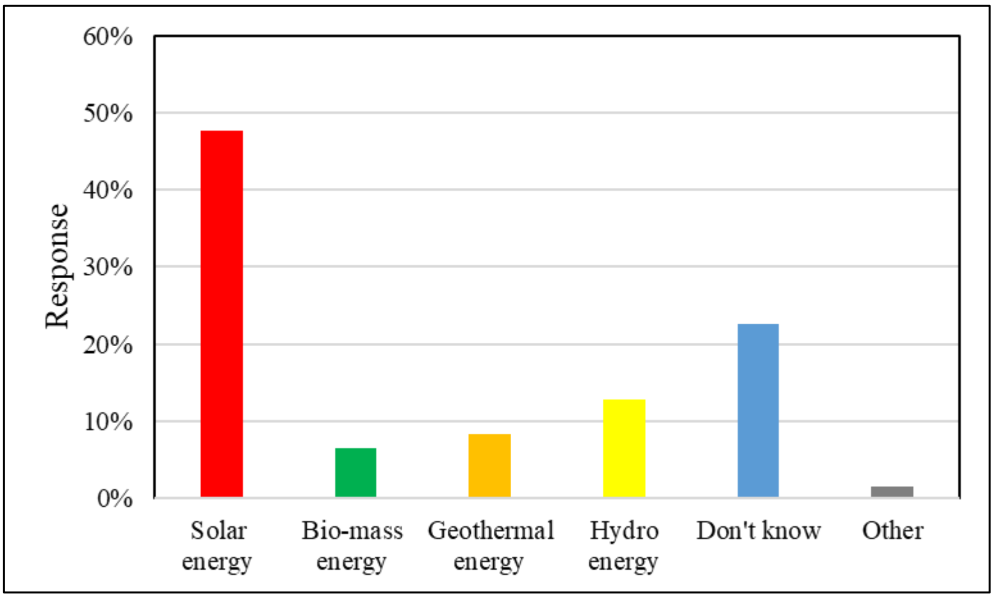

Figure 8-20: Distribution of the Respondents According to Renewable Energy Source of Choice to be Used in their Homes

A staggering 48% of the respondents stated that they would implement the use of solar energy in their homes. Following this, 23% of the respondents stated that they don't know what renewable energy source they would prefer to implement in their homes. The respondents that specified that they would prefer hydro energy accounted for 13% while biomass, geothermal and other accounted for 7%, 8%, and 2% respectively. This shows the willingness of respondents to implement renewable energy most especially solar energy.

8.2.21 Recent Standpoint on Renewable Energy

Table 8-20: Respondents Distribution According to their Recent Standpoint on Renewable Energy Sources

Rank value	Option	Count
1	Strongly agree	68
2	Agree	195
3	Neutral	274
4	Disagree	67
5	Strongly disagree	14

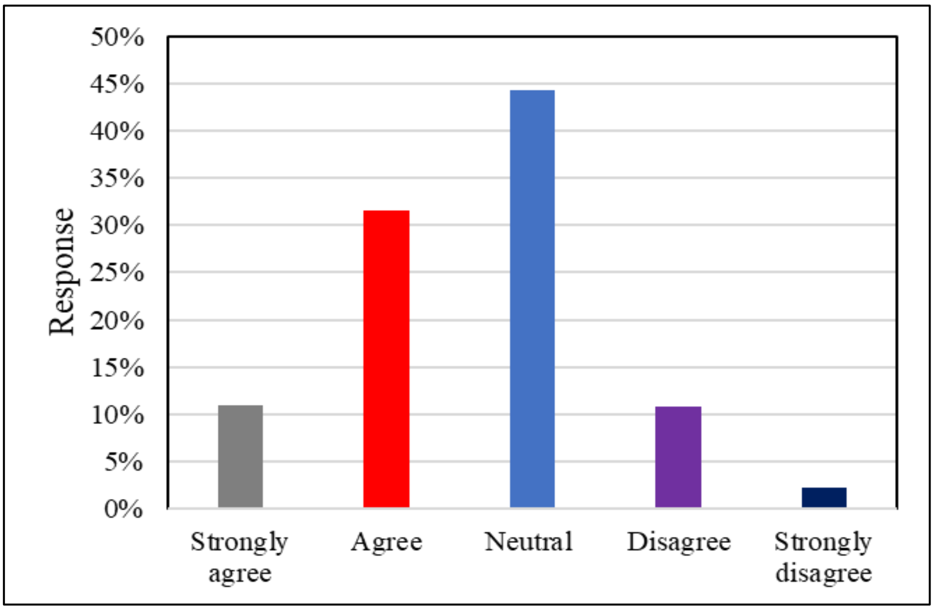

Figure 8-21: Distribution of the Respondents According to Standpoint on Renewable Energy

Following the continuous gradual increase in the price of energy, the researcher was inclined to ask the respondents about their standpoint on renewable energy based on the inconvenience of bills. The findings show that a combined 43% of respondents stated that they strongly agree and agree with 11% and 32% respectively. However, 44% of the respondents stated that they had a neutral standpoint regardless of the financial burden of bills and with the price cap certain to increase. Respondents that stated that they disagree and strongly disagree accounted for 11%

and 2% respectively. This could prove to be a hindrance to the implementation and could be attributed to the installation cost of renewables, running costs, lack of information about the technology, and the issue with respondents renting their homes.

8.2.22 Appliance Use of Renewable Energy

Table 8-21: Respondents Distribution According to their Appliance Use of Renewable Energy Sources

Rank value	Option	Count
1	Yes	27
2	No	586

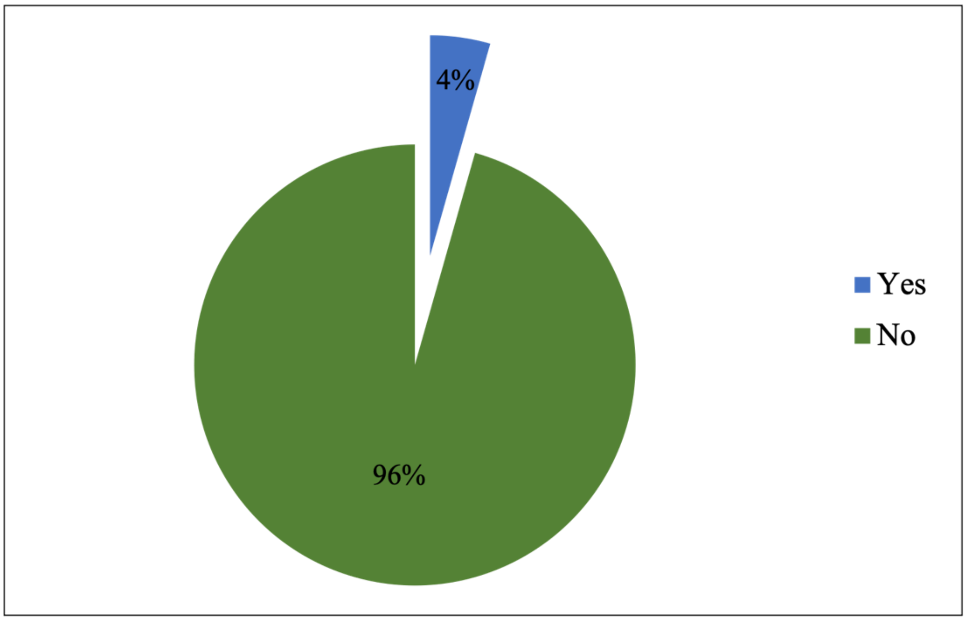

Figure 8-22: Distribution of the Respondents According to Appliance Use of Renewable Energy

Depicted in Figure 8-22, 96% of the respondents stated that they do not use any appliance that utilises renewable energy. However, 4% of the respondents stated that they utilised some sort of renewable energy appliance in their homes. Some of these appliances identified include:

- A participant stated that they utilised *"Electric bike off solar panels"* which is an electric bicycle with an integrated electric motor to assist propulsion.
- Another participant stated that they utilised *"Rechargeable batteries".*
- Another participant stated that they utilised *"Solar panels on the roof".*
- Another indicated that they used renewable energy to provide for some of the heating requirements in the home stating that they use a *"Heater through solar energy".*
- Likewise, the previous participant, another participant utilised solar energy systems to provide hot water for their home stating that they use *"Solar thermal for hot water".*
- Another participant indicated that they utilised only energy supplied from green sources stating, *"Our electricity company is 100% renewable".*
- Another participant likewise the previous participant stated that they utilised only green energy for *"All appliances".*
- Another participant indicated that they are under the assumption that because their energy supplier is identified as a renewable energy supplier, that the company obviously obtained its energy from only renewables. However, they also had other appliances that utilised renewable energy sources stating, *"Our electric suppliers are renewable so they should be using renewables. cooker, TV, washing machine, computers".*
- Another participant also stated that they used *"All electrics".* This implies that they utilise a wide range of renewable sources in their homes which also shows impressive awareness of the benefits of utilising renewable energy sources.
- Another participant was sceptical but assumes that their gas and electric are supposed to come from sustainable sources stating, *"Our gas and electric are supposed to come from renewable sources".*
- Similar to the previous participant, another participant stated that their energy supply was from a renewable energy company but after the company went out of business, they were moved to a supplier that utilised non-renewables *"Our energy supply was a renewable firm, but they were one that went bust (People's Energy) and now we've been moved to a non-renewable".*
- Another participant stated that they utilised renewable energy sources to provide a portion of the heat required in their home using *"Electric storage heaters".*

- Another participant indicated that they utilised a *"Solar powered phone charger"*. This could provide a good foundation to help introduce residents in the UK to the benefits and reliability of renewable sources.
- Another participant stated that *"We have solar panels and appliances that do not use more energy than the panels typically produce".* This indicates that residents in the UK are aware of the benefits that are gained from utilising energy saving equipment's.
- Another participant stated that they utilised lights powered by sustainable sources to illuminate their *"Garden lights".*
- Another participant stated that they utilised *"Solar panels".*
- Another participant stated that utilised renewable energy for *"Electric power points for the cars".*
- Another participant stated that they utilised *"On green tariff".* This indicates that the participant purchases electricity from their supplier which is also purchases their energy from renewable energy to a certain extent. This also indicates that energy providers are promoting the use of sustainable energy to their customer base.
- Another participant stated that they purchased their energy through renewable energy suppliers by stating, *"Wholly green through supplier".* This could also indicate that as awareness of the impact on fossil fuels becomes more widespread, consumers are making decisions to move to green energy suppliers.
- Another participant stated that they utilise *"Electricity (generated by wind)".* This could indicate the use of BEWT's as an alternative to fossil fuels being explored by residents in the UK.
- Lastly another participant stated that sustainable energy provides hot water requirements by stating *"Water heater is solar powered".*

This evidently indicates that renewable energy sources are growing in the UK and also indicates that there is an increasing awareness of the environmental impacts of fossil fuels.

8.2.23 Payback Period for Renewable Energy

Table 8-22: Respondents Distribution According to their Expected Payback Period on the Implementation of Renewable Energy Sources

Rank value	Option	Count
1	1 year	68
2	3 years	195
3	5 years	274
4	10 or more years	67

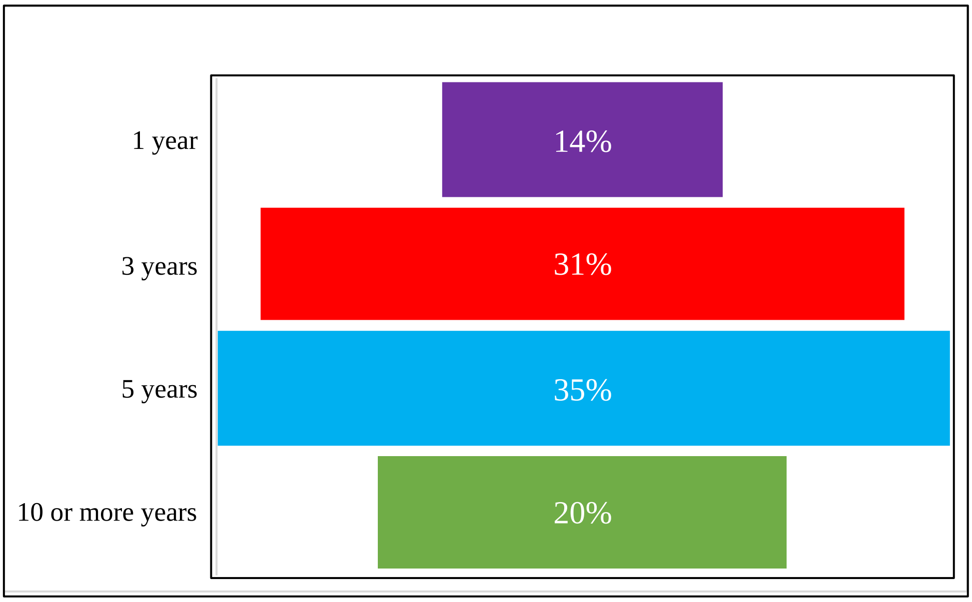

Figure 8-23: Distribution of the Respondents According to Payback Period on Renewable Energy

Depicted in Figure 8-23, 14% stated that they would prefer a payback period of 1 year. Secondly, 31% and 35% of the respondents stated that they would want a payback period of 3 years and 5 years respectively. Lastly 20% of the respondents stated that they would want a payback of 10 years or more.

8.3 Normality Test of the Data Obtained in the Qualification and Household Monthly Income

Table 8-23: Test of Normality of the Data

Kolmogorov-Smirnov				Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Qualification	0.256	618	0.000	0.896	618	0.000
How much is your monthly income in total?	0.169	618	0.000	0.924	618	0.000

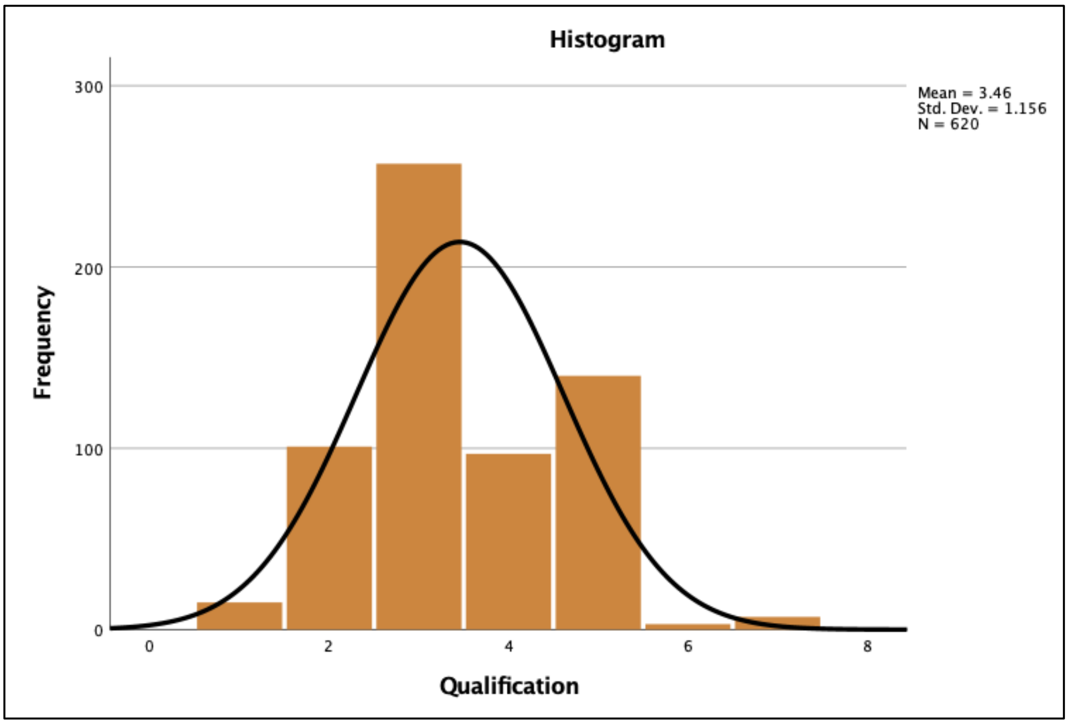

Figure 8-24: Test of Normality of Distribution in Qualification

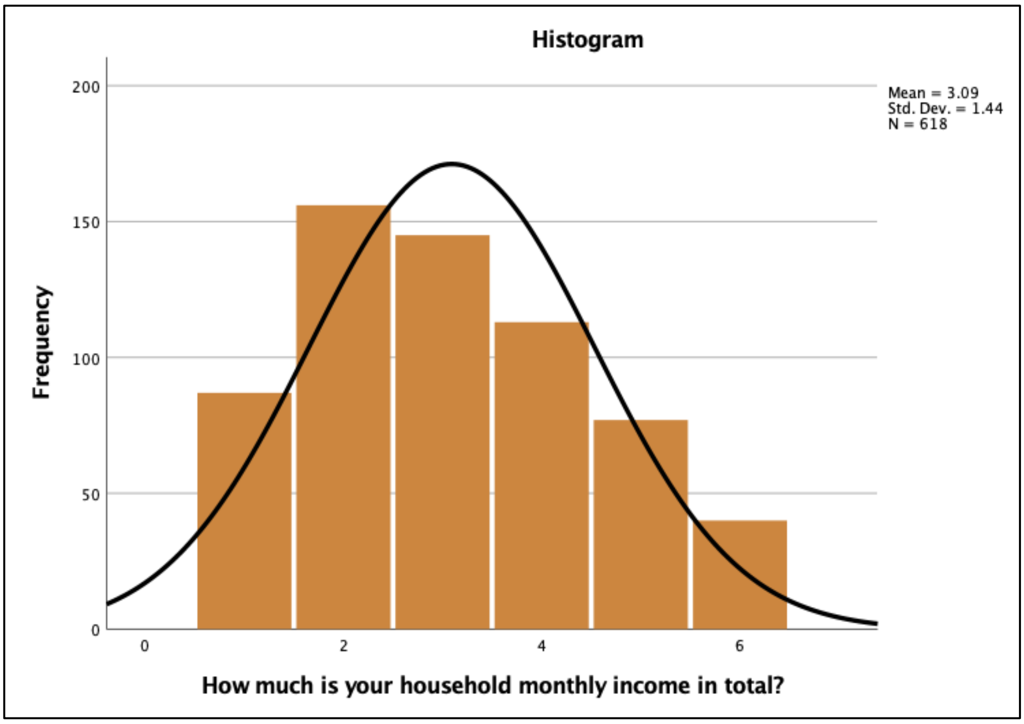

Figure 8-25: Test of Normality of Distribution in Household Monthly Income

Depicted in Table 8-24, Figure 8-24, and Figure 8-25 shows that the data is normally distributed. The test of normality used for this research is the Shapiro-Wilk.

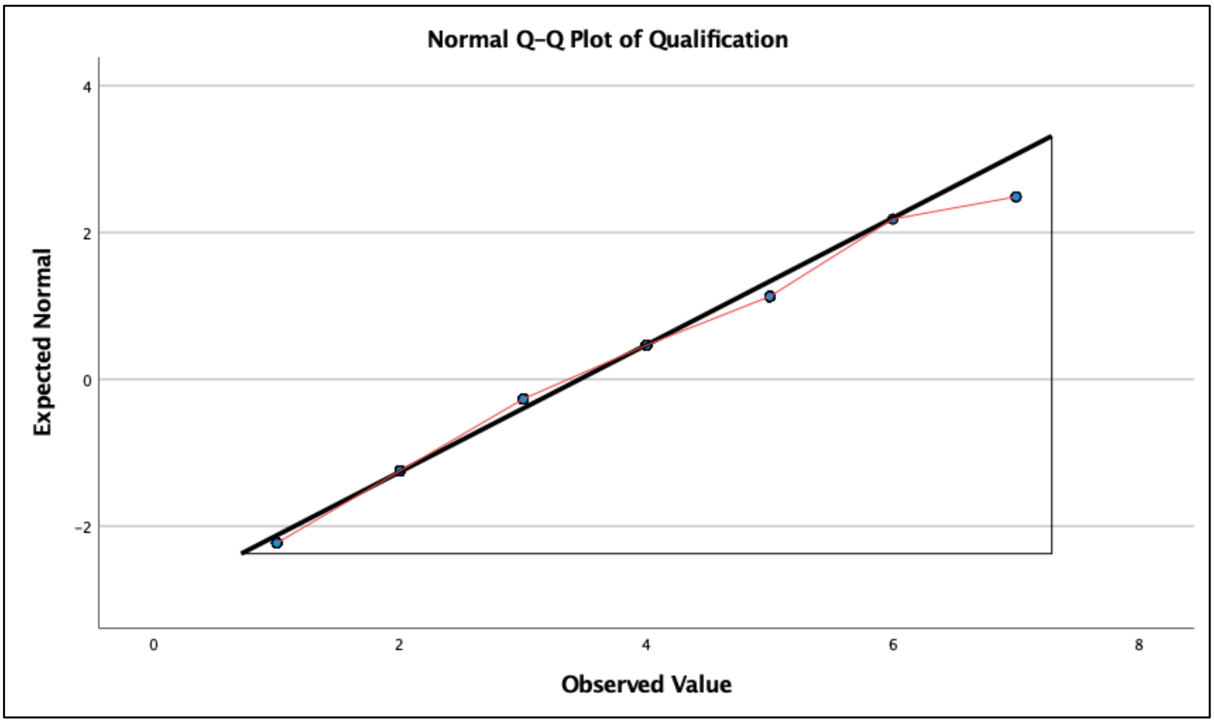

Figure 8-26: Normal QQ Plot of Qualification

However, Figure 8-27 depicts that the normal and detrended Q-Q plot

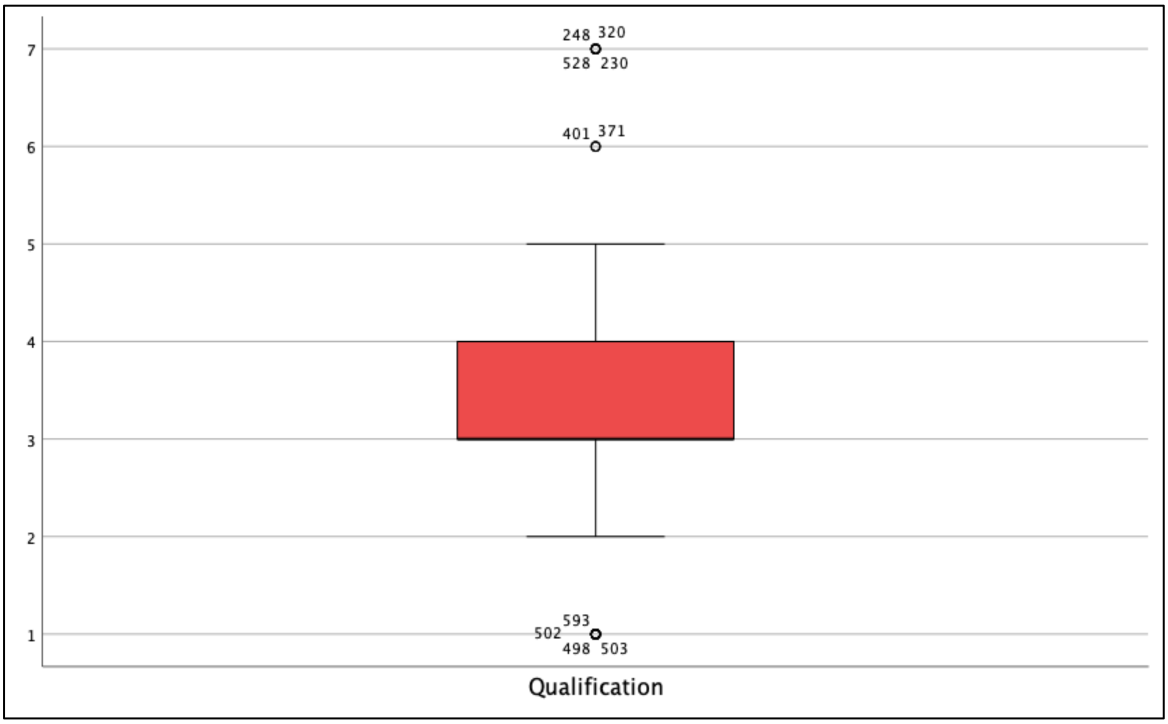

Figure 8-27: Box plot of Distribution in Qualification

Depicted in Figure 8-27 shows that there are outliers in the box plot. This therefore violates the assumptions for Pearson correlation and requires the use of Spearman rank order correlation for this analysis.

8.3.1 The Impact of Qualification on Renewable Energy Awareness

Table 8-24: Correlation Between Qualification and Awareness of Heat Pump Technology

			Qualification	Are you aware of the heat pump technology and its use in heating?
Spearman's rho	Qualification	Correlation Coefficient	1.000	0.100*
		Sig. (2-tailed)		.013
		N	620	614

Table 8-24 shows that with the increase in level of qualification, there was an increase in the awareness about the use of heat pump technology (Spearman's rho= 0.100 and p<0.05). This could be because the pursuit of a higher qualification gives individuals exposure to acquire the knowledge about the use of renewable energy sources.

Table 8-25: Correlation Between Qualification and Awareness of Global Warming Caused by Human Activities

			Qualification	What do you think about the following statement: Global warming is caused by human activities?
Spearman's rho	Qualification	Correlation Coefficient	1.000	0.217**
		Sig. (2-tailed)		.000
		N	620	615

Depicted in Table 8-25 is the statistical relationship between the qualification of respondents and the awareness of the impacts of humans to the ever-growing climate crisis (Spearman's rho= 0.217 and p<0.01). It indicates that as the qualification of respondents increased it also increased their awareness of their role in the climate crisis. This could also demonstrate the growth of curriculums of educational institutions incorporating knowledge of the climate crisis (Neal-Boylan, Breakey and Nicholas, 2019; Kniveton, el al., 2015; Perking et al., 2018).

Table 8-26: Correlation Between Qualification and Awareness the Awareness of the Government Impact on the Control the Carbon Footprint in the UK

			Qualification	What do you think about the following statement: It is the responsibility of the governmental organisations and businesses to reduce the UK's carbon footprint?
Spearman's rho	Qualification	Correlation Coefficient	1.000	0.121**
		Sig. (2-tailed)		.003
		N	620	615

Table 8-26 shows that as respondents achieved a higher qualification, they believe that the government has a crucial role to exhibit to eventually reduce the carbons footprint (Spearman's rho= 0.121 and $p<0.01$). To achieve this, policies need to be implemented such as tax reductions and installation discounts for renewables, as well as markets to manage renewable energy certificates and portfolios (Bowden and Payne, 2009). Additionally, due to the relatively high upfront costs associated with solar and other renewable energy sources, governments remain responsible for monitoring and guiding solar energy applications around the world through the use of a variety of policy tools (Lo, 2014; Solangi et al., 2011). Policy frameworks need to be well designed in order to minimise capital costs for developers and regulatory risk for investors (De Jager et al., 2008).

8.3.2 The impact of Age on Renewable Energy Adoption

Table 8-27: Correlation Between Age and the Issue of Maintenance and Life Expectancy of Renewable Energy Systems

			Age range	If you don't use renewable energy at home, please state why? (Need for maintenance and life expectancy)
Spearman's rho	Age range	Correlation Coefficient	1.000	0.126**
		Sig. (2-tailed)		.002
		N	619	620

Table 8-27 indicates that as the age of the respondents increases, the need and understanding of the maintenance required and life expectancy of renewable systems becomes more prevalent (Spearman's rho= 0.126 and $p<0.01$). This could be because of as individuals age; their financial responsibilities could hinder them from implementing RE sources. Furthermore, considering the high upfront cost for sustainable systems such as solar, this could imply substantial costs for maintenance and repairs. However, this could be improved by educational awareness of the maintenance required for RE systems and the benefits.

Table 8-28: Correlation Between Age and the Standpoint on Renewable Energy Systems

			Age range	Have the recent changes in gas prices affected your standpoint on renewable energy?
Spearman's rho	Age range	Correlation Coefficient	1.000	0.107**
		Sig. (2-tailed)		.008
		N	619	617

Table 8-28 shows the corelation between age range and standpoint on renewable energy systems also considering the recent increase in price of electricity (Spearman's rho= 0.107 and p<0.01). This shows that as respondent aged, the viewpoint their adoption of renewables is a lot stronger, and this has also been helped by the continuous increase in the price of electricity.

Table 8-29: Correlation Between Age and the Lack of Adoption of Renewable Energy Sources Due to Lack of Adequate Space

			Age range	If you don't use renewable energy at home, please state why? (No adequate space)
Spearman's rho	Age range	Correlation Coefficient	1.000	-0.116**
		Sig. (2-tailed)		.004
		N	619	619

Table 8-29 suggests that as the respondents age lowers, the more worried they are about the lack of available space to install renewable energy sources such as solar energy (Spearman's rho= -0.116 and p<0.01). This could be because individuals younger preferably rent homes, so they do not have the authority to make alterations to the homes they reside in and are more likely to move homes in short periods so implementing renewable sources seems like an unnecessary commitment to make (Wuertenberger et al., 2011).

Table 8-30: Correlation Between Age and the Payback Period for Renewable Energy

			Age range	What payback period would you expect if you invest in renewable energy?
Spearman's rho	Age range	Correlation Coefficient	1.000	0.192**
		Sig. (2-tailed)		.000
		N	619	617

Depicted in Table 8-30 indicates that as individuals got older, they preferred a longer payback for renewable energy sources (Spearman's rho= 0.192 and p<0.01). This could therefore suggest that people older prefer a longer payback period because they are more stable and own their homes and are unlikely to move houses as often as younger people would.

8.3.3 The impact of Income on Renewable Energy Adoption

Table 8-31: Correlation Between Monthly income and the Thermal Insulation in Homes

			How much is your monthly income in total?	How do you describe the house you live in in relation to thermal insulation?
Spearman's rho	How much is your monthly income in total?	Correlation Coefficient	1.000	-0.173**
		Sig. (2-tailed)		.008
		N	615	616

Table 8-31 indicates that as the income of households increased the less inclined, they were to implement thermal insulation measures in their homes (Spearman's rho= -0.173 and $p<0.01$). This also suggests that the residents that earned less income implemented more energy efficiency measures to ensure they do not have to pay excess amounts of money to heat their homes also considering the continuous increase in the price of energy bills.

Table 8-32: Correlation Between Monthly income and the Financial Burden of Bills

			How much is your monthly income in total?	Are electricity bills becoming a financial burden to your household?
Spearman's rho	How much is your monthly income in total?	Correlation Coefficient	1.000	0.202**
		Sig. (2-tailed)		.000
		N	618	616

Table 8-32 indicates that regardless of the earning of the respondents, the financial burden of bills remains an issue (Spearman's rho= 0.202 and $p<0.01$). This can be seen as an issue as the price cap for energy is also estimated to rise further in the latter parts of the year (ICAEW, 2022). Therefore, consumers' affordability will continue to be an issue that needs to be addressed considering the impact of the rise in energy bills.

8.3.4 Benefits of Using Renewable Energy Sources

Table 8-33: Correlation Between Use of Renewable Sources for Reduction of Energy Bills and Stable Energy Prices

			If you are using renewable energy at home, please state why? (Reduced energy bills)	If you are using renewable energy at home, please state why? (Stable energy prices)
Spearman's rho	If you are using renewable energy at home, please state why? (Reduced energy bills)	Correlation Coefficient	1.000	0.338**
		Sig. (2-tailed)		.000
		N	620	620

As shown in table 8-33, statistical analysis showed that the respondents that utilised renewable energy sources were those inclined with the purpose of attaining stable energy prices (Spearman's rho= 0.338 and $p<0.01$). This indicates that there are several ways which renewable sources such as solar energy can be used to save money. As a result, the energy bill of residents is lower because they purchase less energy from the grid. In addition, they may be able to earn money back from the SEG through payments (Ofgem, 2019).

Table 8-34: Correlation Between Use of Renewable Sources for Reduction of Energy Bills and Improved Public Health

			If you are using renewable energy at home, please state why? (Renewable energy bills)	If you are using renewable energy at home, please state why? (Improved environmental health)
Spearman's rho	If you are using renewable energy at home, please state why? (Renewable energy bills)	Correlation Coefficient	1.000	0.285**
		Sig. (2-tailed)		.000
		N	620	620

Table 8-34 depicts that as residents wanted reduced energy bills, they simultaneously wanted an improved environmental health (Spearman's rho= 0.285 and $p<0.01$). This shows that intentionally or unintentionally, as people install renewable energy sources such as solar energy, they reduce their bills and help reduce the production of greenhouse gases from the burning of fossil fuels to fulfil the ever-growing energy demand.

Table 8-35: Correlation Between Use of Renewable Sources for Reduction of Energy Bills and Use of Solar Energy

			If you are using renewable energy at home, please state why? (Reduced energy bills)	Are you using one of the following renewable energy sources? (Solar energy)
Spearman's rho	If you are using renewable energy at home, please state why? (Reduced energy bills)	Correlation Coefficient	1.000	0.359**
		Sig. (2-tailed)		.000
		N	620	620

Table 8-35 indicates that one of the main factors that motivated the respondents to implement solar energy in their homes was to reduce the prices of their energy (Spearman's rho= 0.359 and $p<0.01$). This indicates that residents are aware of the benefits of solar energy such as reduction of energy bills, low maintenance costs, and its diverse applications for solar PV to generate electricity or solar thermal to heat the home.

8.3.5 Hypothesis Testing

The use of correlation coefficient does not provide any information about the cause and effect. Furthermore, the use of correlation coefficients does not specify the influence a variable has over another as it is a measure of relationship between two variables (IBM, 2021). However, regression technique is used to estimate the strength of a relationship between dependent and independent variables. In this technique, one or more independent variables are used to predict the value of a dependent variable. Using regression analysis, it is possible to calculate how much variance a set of independent variables accounts for in a dependent variable (IBM, 2021). The hypothesis testing method used for this study is linear regression. Linear regressions are used to determine the direct relationship between a continuous dependent variable and a nominal, ordinal, interval, or ratio independent variable (IBM, 2021). By examining the predictors included in statistical models, the linear regression test examines how the independent variable affects the dependent variable's mean.

1. **Hypothesis 1:** There is a significant impact of Age on Awareness

The hypothesis tests if Age has a significant impact on Awareness. The dependent variable Age range was regressed on predicting variable Awareness to test H1. The R value depicts a simple correlation of 0.283, which indicates a low degree of correlation. The R^2 value indicates the total variation in the dependent variable. Therefore, this suggests that 8% can be explained, which is quite low. The results predicted that Age $F(4, 612) = 13.348$ can play a role in affecting Awe (0.129, 0.569, -0.401, 0.258), $p<0.001$. The results are depicted in table 8-36.

Table 8-36: Hypothesis Testing for the Impact of Age on Awareness

Hypothesis	Regression Weights	Beta Coefficient	R	R^2	F	t-value	p-value	Hypotheses Supported
H1	Age → Awr	0.129	0.283	0.08	13.348	2.323	0.000	Yes
		0.569				3.260		
		-0.401				-3.119		
		0.258				4.496		

2. **Hypothesis 2:** There is a significant impact of Income on Renewable Energy Adoption

Hypothesis 2 tests if Income has significant impact on renewable energy adoption. The dependent variable Income was regressed on predicting variable Renewable energy adoption to test H2. The R-value depicts a simple correlation of 0.253, which also indicates a low degree of correlation. The R^2 value indicates that 8% of renewable energy adoption is accounted for in income. The results also predicted that Income F (2, 610) = 20.785 can play a role in affecting Adoption (-0.265, 0.270), $p<0.001$. The results are depicted in table 8-37.

Table 8-37: Hypothesis Testing for the Impact of Income on Renewable Energy Adoption

Hypothesis	Regression Weights	Beta Coefficient	R	R^2	F	t-value	p-value	Hypotheses Supported
H2	Inc→ Adp	-0.265	0.253	0.064	20.785	-3.688	0.000	Yes
		0.270				5.133		

3. **Hypothesis 3:** There is a significant impact of Reduction of Energy Bills on Use of Renewable Energy Sources

Hypothesis 3 tests if the perception of Energy bill reduction has significant impact on the use of Renewable Energy. The R value depicts a correlation of 0.501, which also indicates a high degree of correlation. The R^2 value indicates that 25% of the use of renewable energy sources is accounted for in the reduction of energy bills. The results also predicted that Energy Bill Reduction F (3, 616) = 68.841 can play a role in affecting Adoption (0.278, 0.486, 0.391), $p<0.001$. The results are depicted in table 8-38.

Table 8-38: Hypothesis testing for the impact of Reduction of Energy Bills on Use of Renewable Energy Sources

Hypothesis	Regression Weights	Beta Coefficient	R	R^2	F	t-value	p-value	Hypotheses Supported
H3	Bill→ Adp	0.278	0.501	0.251	68.841	4.948	0.000	Yes
		0.486				8.975		
		0.391				7.018		

8.4 Summary

This chapter has provided statistical analysis of the data collected from the public in the UK regarding their awareness and use of renewable energy sources. It has identified the attitude and use of renewable energy of the participants and the reasons hindering the adoption of renewables from a consumer's perspective. Observations have shown that some of the key factors that hinder the implementation of renewables such as solar to be financial reasons, lack of available space, payback period, and insufficient knowledge about renewable energy sources. The next chapter goes on to provide an analysis of the roof survey of 1838 houses in Nottingham, UK.

Chapter 9: Analysis of Roof Survey in Nottingham

9.1. Introduction

This methodology aims to analyse the growth of renewables such as solar energy in Nottingham, UK. It utilises analysis of roofs of residential homes based on their orientation, complexity of their roof design, and affluence and impoverished nature of the selected area. The sample size of this analysis is 1838 houses, and placemarks have been used to identify critical findings on some of the houses using google earth. Subsequently, a photovoltaic geographical information system (PVGIS) is utilised after the researcher has identified the appropriate sample size. By utilising this tool, it is possible to estimate the energy production of a PV system connected directly to the electricity grid without using any batteries on an average monthly and yearly basis. As part of the calculation, solar radiation, temperature, wind speed, and type of PV module are considered. Modules can be mounted in various ways, such as in a free-standing rack mounting or incorporated into a building surface according to the user's preference (PVGIS, 2022). Using PVGIS, the researcher can determine which slope and orientation are most likely to maximise the energy received each year. In addition to solar irradiance and temperature, PV modules' performance is also affected by the spectrum of sunlight. However, the exact parameters vary between different types. The following types of modules can currently be estimated as having losses due to temperature and irradiance effects:

- Crystalline silicon cells
- Thin film modules made from cis or cigs
- Thin film modules made from cadmium telluride (CdTe)

In addition, this correction will not be calculated for other technologies, particularly amorphous technologies. Performance calculations will consider the temperature dependence of the chosen technology if one of the three options above is selected. Using the other option or unknown, the analysis assumes a loss of 8% of power due to temperature effects. This figure has been found realistic in temperate climates (PVGIS, 2022). CdTe and crystalline silicon are currently the only materials that can be calculated to determine the effect of spectral variations. In PV modules, azimuth is defined as the angle between the modules and the direction due south.

Therefore, -90° is East, 0° is south, and 90° is West (PVGIS, 2022). Figure 8-1 shows the schematic diagram to further explain the importance of the azimuth angle.

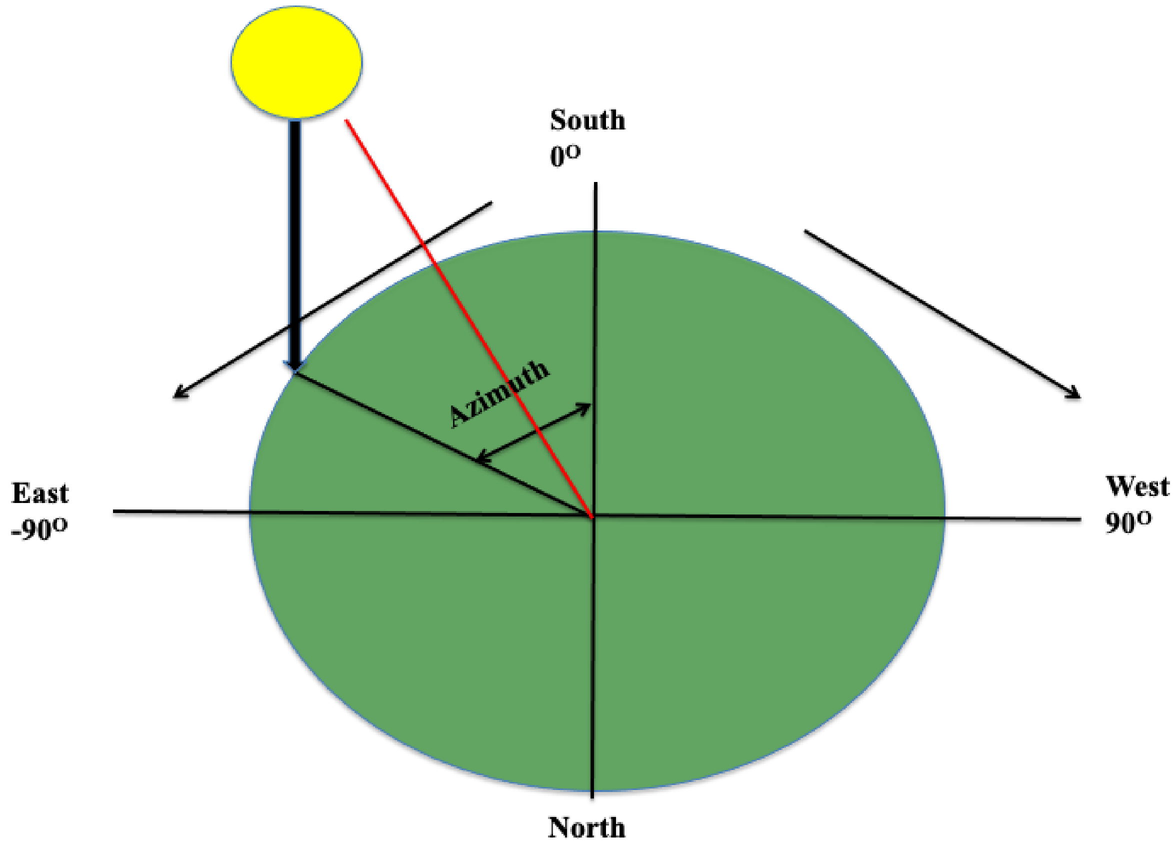

Figure 9-1: Schematic Diagram of Azimuth Angle

Source: Reproduced from (Ben Othman, Belkilani and Besbes, 2022)

When PV modules are installed on an existing roof, slope and azimuth angles are already known. The application can, however, calculate the optimal inclination and orientation values for you if an inclination and the orientation are chosen considering fixed angles throughout the year. The findings are shown below:

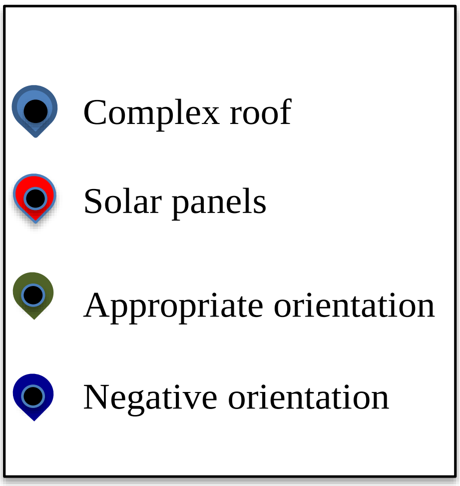

Figure 9-2: Description of Placemarks Utilised

Figure 9-3: Roof Survey 1

Source: (Google Earth, 2022)

Figure 9-4: Roof Survey 2

Source: (Google Earth, 2022)

Figure 9-5: Roof Survey 3

Source: (Google Earth, 2022)

Figure 9-6: Roof Survey 4

Source: (Google Earth, 2022)

The various roof surveys above identified some houses with solar panels and several without solar panels. Some key findings showed that most houses selected for the roof survey analysis situated in the affluent area of Nottingham had no solar panels despite having the appropriate orientation. Additionally, most houses in the impoverished area of Nottingham also had no solar panels despite having the appropriate orientation. However, it was identified that a house with a negative orientation had implemented solar panels on its roof among the houses in the impoverished area. Other key findings showed that some houses were orientated at angles which could impact the production of solar panels if installed on the roof of specific homes. Generally, the findings showed a lack of adoption of solar energy in Nottingham. However, to further analyse the impacts of orientation and the results from PVGIS are shown below:

1. Assumption 1 for a south-facing roof:

- Uses crystalline silicon PV technology
- Slope of 40^{o}

- Roof / Building-integrated
- Azimuth 0^o
- PV installed (kWp): 2kWp

Changes in output due to:

- Angle of incidence %: -3.12
- Spectral effects %: 1.94
- Temperature and low irradiance %: -6.85

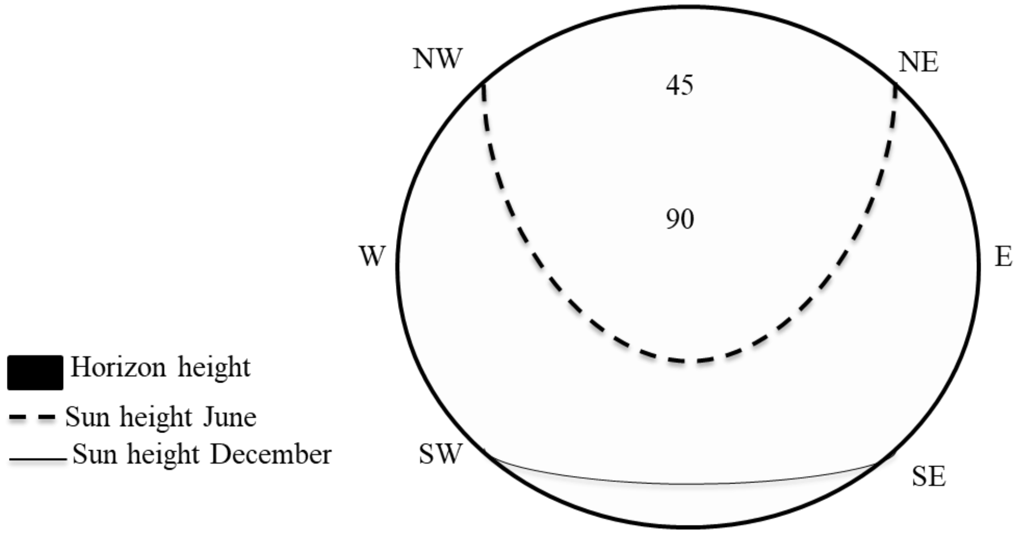

Figure 9-7: Outline of Horizon Due South (PVGIS, 2022)

Source: Reproduced from (PVGIS, 2022)

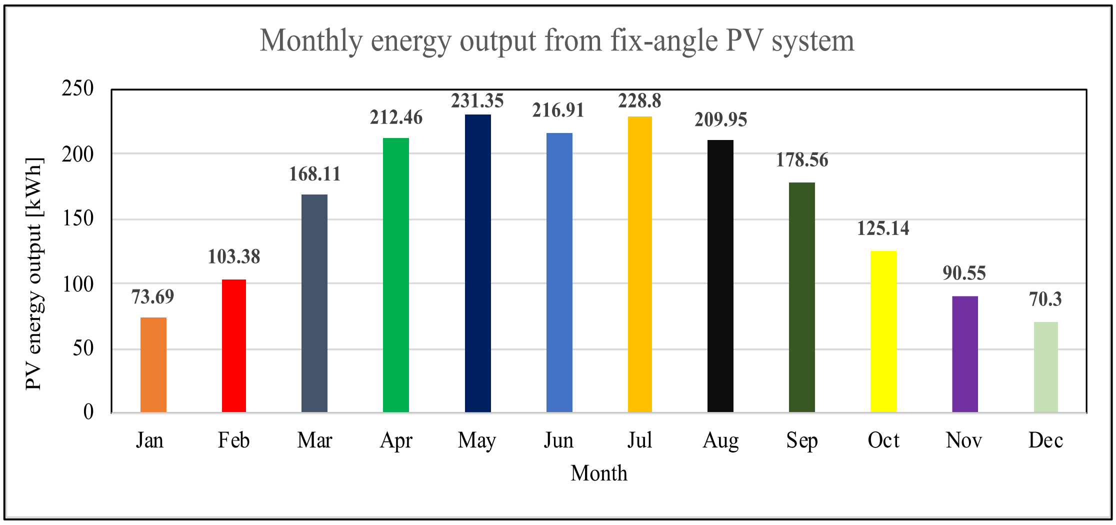

Figure 9-8: Monthly Energy Output Production Due South

Source: Reproduced from (PVGIS, 2022)

Simulation outputs:

- Yearly PV energy production [kWh]: 1909.2
- Yearly in-plane irradiation [kWh/m2]: 1206.61
- Year-to-year variability [kWh]: 60.65
- Total loss %: -20.89

The assumptions used were derived from estimating the solar energy production of a 2kW solar system for houses in roof survey 1, is depicted in Figure 8-3. Using an optimum slope of 40^{o} PVGIS (2022), the derived production showed that systems in the due south orientation would produce a yearly PV energy production of 1909.2kWh. It also showed a year-to-year variability of 60.65kWh which refers to the changes in solar activity. This includes the solar cycle, solar variation, and the relative change in the amount of radiation transmitted by the sun. It also showed yearly in-plane irradiation of 1206.61kWh/m2 and a total loss of -20.89%. Further analysis showed that an average UK household uses 242kWh of electricity per month (ICAEW, 2022). Therefore, the calculation of the potential energy saving is calculated below.

Using the formula: $(V_2 - V_1) / |V_1| \times 100$ (CalculatorSoup, 2022)

Where:

- V_1 = Start value
- V_2 = End value

Therefore, the use of solar PV could provide approximately 29%, 30%, and 43% of the electricity needs in the winter months, which include from December to January. In the spring, the panels could provide approximately 69%, 88%, and 95% of homes' energy needs in March, April, and May. In the summer months, the panels could provide 89%, 95%, and 87% of the electricity needs in June, July, and August, respectively. In autumn, solar panels could supply 74%, 52%, and 37% of electricity needs.

2. Assumption 2 for 45 degrees northwest facing roof is depicted in Figure 8-6.

- Uses crystalline silicon PV technology
- Slope of 40^{o}
- Roof / Building-integrated
- Azimuth 135^{o}
- PV installed (kWp): 2kWp

Changes in output due to:

- Angle of incidence %: -5.22
- Spectral effects %: 1.64
- Temperature and low irradiance %: -8.44

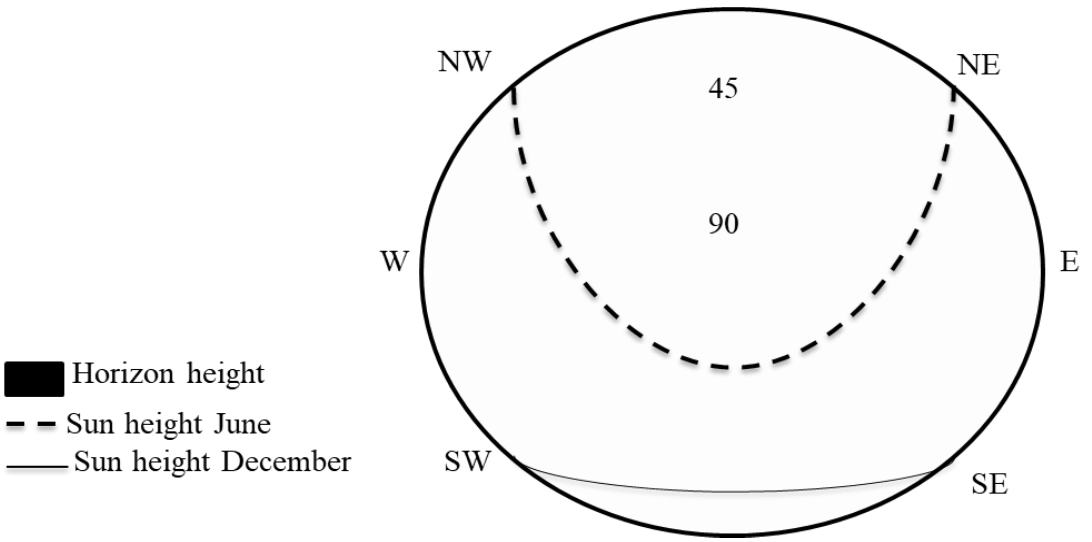

Figure 9-9: Outline of Horizon West (PVGIS, 2022)

Source: Reproduced from (PVGIS, 2022)

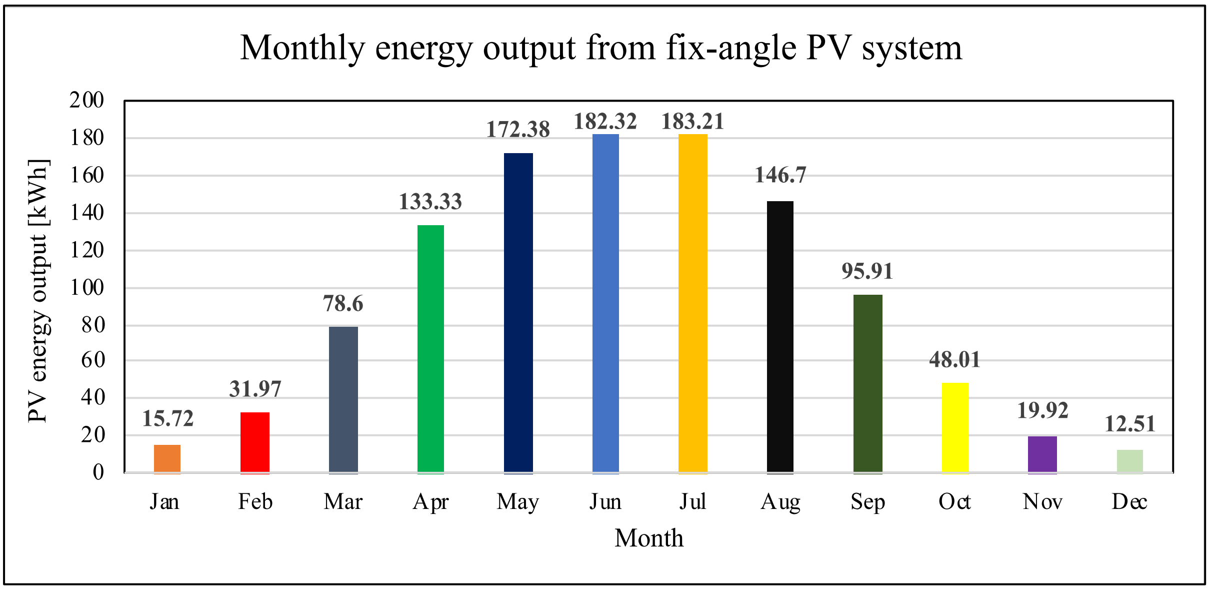

Figure 9-10: Monthly Energy Output Production West

Source: Reproduced from (PVGIS, 2022)

Simulation outputs:

- Yearly PV energy production [kWh]: 1120.57

- Yearly in-plane irradiation [kWh/m2]: 738.66
- Year-to-year variability [kWh]: 27.69
- Total loss %: -24.15

The derived production showed that systems in the northwest orientation would produce a yearly PV energy production of 1120.57kWh. It also showed a year-to-year variability of 27.69kWh which refers to the changes in solar activity. It also showed yearly in-plane irradiation of 738.66kWh/m2 and a total loss of -24.15%. Therefore, the use of solar PV could provide approximately 5%, 6%, and 13% of the electricity needs in the winter months, which include from December to February. In the spring, the panels could provide approximately 32%, 55%, and 71% of homes' energy needs in March, April, and May. In the summer months, the panels could provide 75%, 76%, and 61% of the electricity needs in June, July, and August, respectively. In autumn, solar panels could supply 40%, 20%, and 8% of electricity needs.

3. Assumption 3 for -90 degrees for an east-facing roof.

- Uses crystalline silicon PV technology
- Slope of 40^{o}
- Roof / Building-integrated
- Azimuth -90^{o}

Changes in output due to:

- Angle of incidence %: -3.83
- Spectral effects %: 1.75
- Temperature and low irradiance %: -7.21

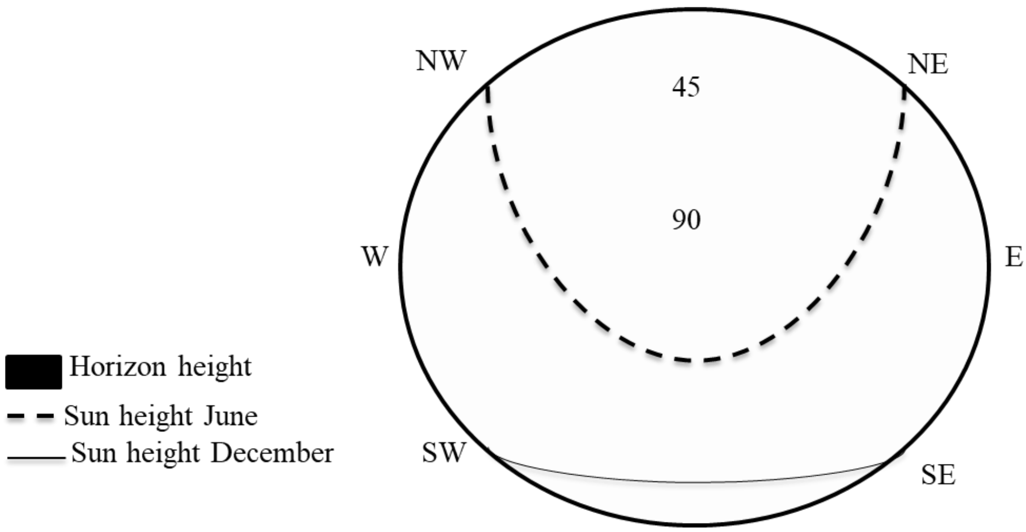

Figure 9-11: Outline of Horizon East (PVGIS, 2022)

Source: Reproduced from (PVGIS, 2022)

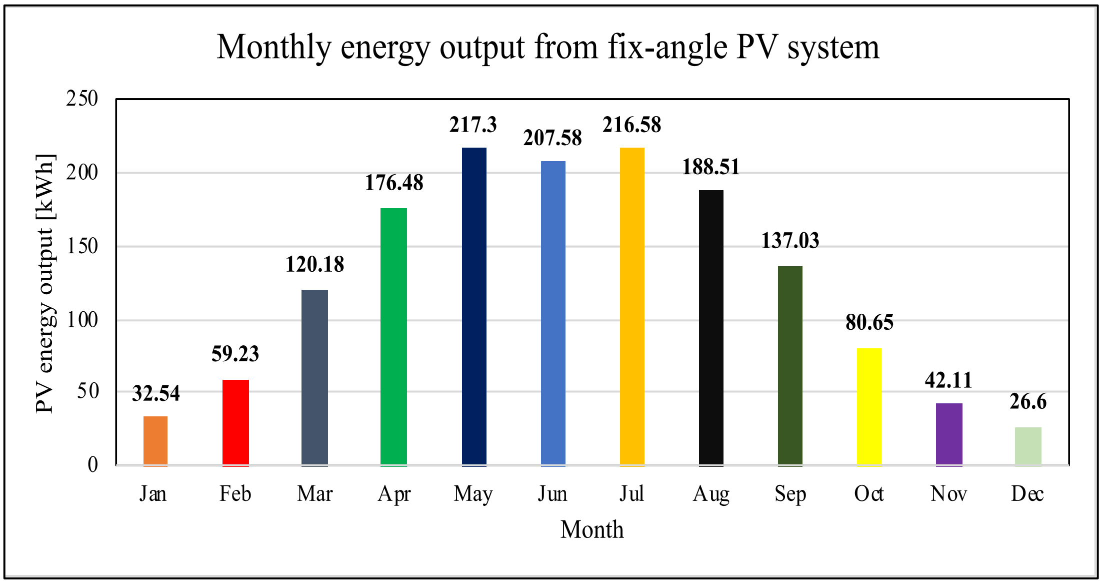

Figure 9-12: Monthly Energy Output Production East

Source: Reproduced from (PVGIS, 2022)

Simulation outputs:

- Yearly PV energy production [kWh]: 1504.78

- Yearly in-plane irradiation [kWh/m2]: 963.49
- Year-to-year variability [kWh]: 61.24
- Total loss %: -21.91

The derived production showed that systems in the northwest orientation would produce a yearly PV energy production of 1504.78kWh. It also showed a year-to-year variability of 51.74kWh, which refers to the changes in solar activity. It also showed yearly in-plane irradiation of 963.49kWh/m2 and a total loss of -21.91%. Therefore, the use of solar PV could provide approximately 10%, 13%, and 24% of the electricity needs in the winter months, which include from December to February. In the spring, the panels could provide approximately 50%, 73%, and 90% of homes' energy needs in March, April, and May. In the summer months, the panels could provide 86%, 89%, and 78% of the electricity needs in June, July, and August, respectively. In the autumn months, solar panels could supply 57%, 33%, and 17% of electricity needs.

Upon closer inspection, it becomes clear that the optimum orientation of solar panels in the UK is due south (Hussein, Ahmad and El-Ghetany, 2004), and thus houses with orientation not facing due south are bound to experience loss. However, this analysis does not consider other factors, such as shading. Furthermore, the complexity of the roof design could also prove a hindrance, as shown in Figure 8-3. It shows that even with the appropriate orientation, it would still be quite challenging to implement solar panels as they are not designed to accommodate the shape or positioning of the panels. To further elaborate on the importance of the utilisation of solar energy in the residential area, the tonnes of carbon dioxide equivalent (tCO_2e) for the different orientations are calculated using the formula below:

Emissions = Total energy consumption (electricity) x Emission Factors (electricity) /1000 (HM Government, 2022)

Using 242kWh of electricity consumption per month would result in 2900kWh of electricity per year.

Emissions = 2900 x 0.21233kgCO_2e /1000 = 0.6tCO_2e

Carbon savings after solar energy installation

For due south installation:

= 2900 – 1909.2 = 990kWh

= 991 x 0.21233kgCO_2e /1000 = 0.2tCO_2e

For northwest installation:

= 2900 – 1120.57 = 1779.43kWh

= 1779.43 x 0.21233kgCO_2e /1000 = 0.4tCO_2e

For east installation:

= 2900 – 1504.8 = 1395.2 kWh

= 1395.2 x 0.21233kgCO_2e /1000 = 0.3tCO_2e

This shows that implementing renewable energy, such as solar energy, can considerably reduce the CO_2 emissions generated from the residential sector from either south, east, or west orientations. Nevertheless, it should be noted that the most tCO_2e reduction is achieved from a due south orientation. Based on the current price cap of energy, the price of bills is calculated to provide a clearer picture of the effects of solar energy.

Assumptions include:

- Standing charges for January – March 2022: £186 (ICAEW, 2022).
- Standing charges for April – September 20202: £200 (ICAEW, 2022).
- Standing charges for October – December 2022: £200 (ICAEW, 2022).
- Solar panels orientation due south

Table 9-1: Estimated Price of Monthly Energy Bills 2022

Month	Energy price cap for electricity	Electricity cost without solar energy per year	Electricity cost with solar energy orientation due south
January	0.28p/kWh	£83	£19
February	0.28p/kWh	£83	£19
March	0.28p/kWh	£83	£17
April	0.29p/kWh	£87	£17
May	0.29p/kWh	£87	£16
June	0.29p/kWh	£87	£17
July	0.29p/kWh	£87	£17
August	0.29p/kWh	£87	£17
September	0.29p/kWh	£87	£18
October	0.33p/kWh	£96	£20
November	0.33p/kWh	£96	£21
December	0.33p/kWh	£96	£21

Source: Author's Own

The results shown in Table 9-1 and Figure 9-13 clearly show a reduction in the price of bills when calculated using solar energy. Furthermore, the payment from the SEG scheme was not considered in this analysis as the payment could also have additional financial benefits depending on the generation of energy from panels being sold to the grid. This further indicates that utilising solar energy would help reduce CO2 emissions and help consumers achieve considerable savings on energy bills.

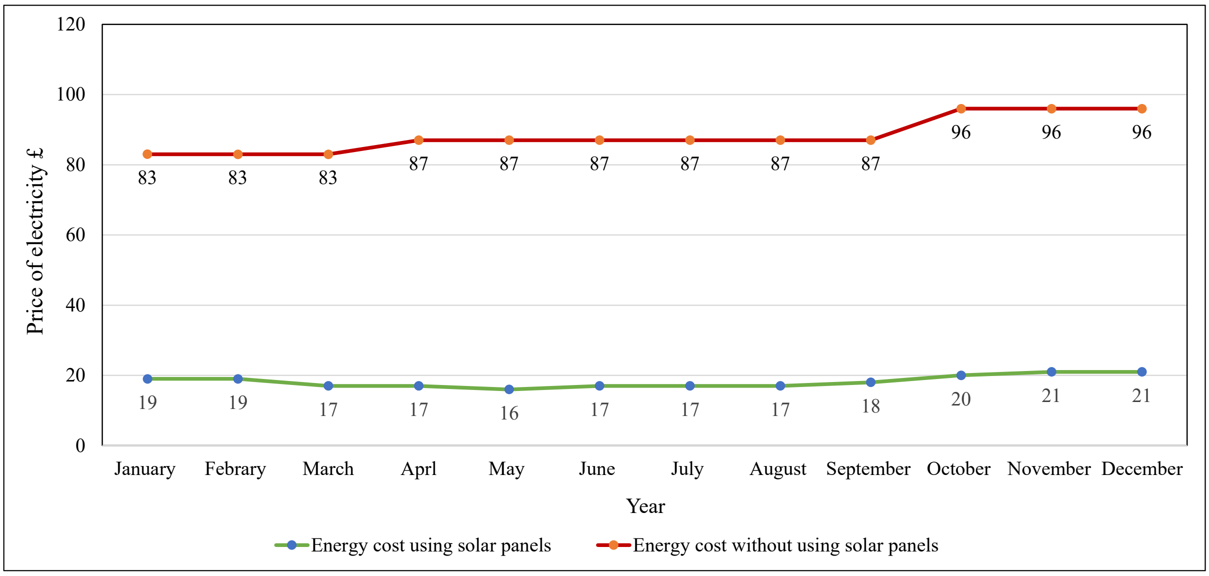

Figure 9-13: Estimated Price of Monthly Energy Bills 2022

Source: Author's Own

Table 9-2: Diversity between Affluent and Poor Areas in Nottingham

	Negative orientation	Complex roof	Solar panels	Apprpriate orientation
Affluent areas	287	140	28	229
Poor areas	490	14	184	466

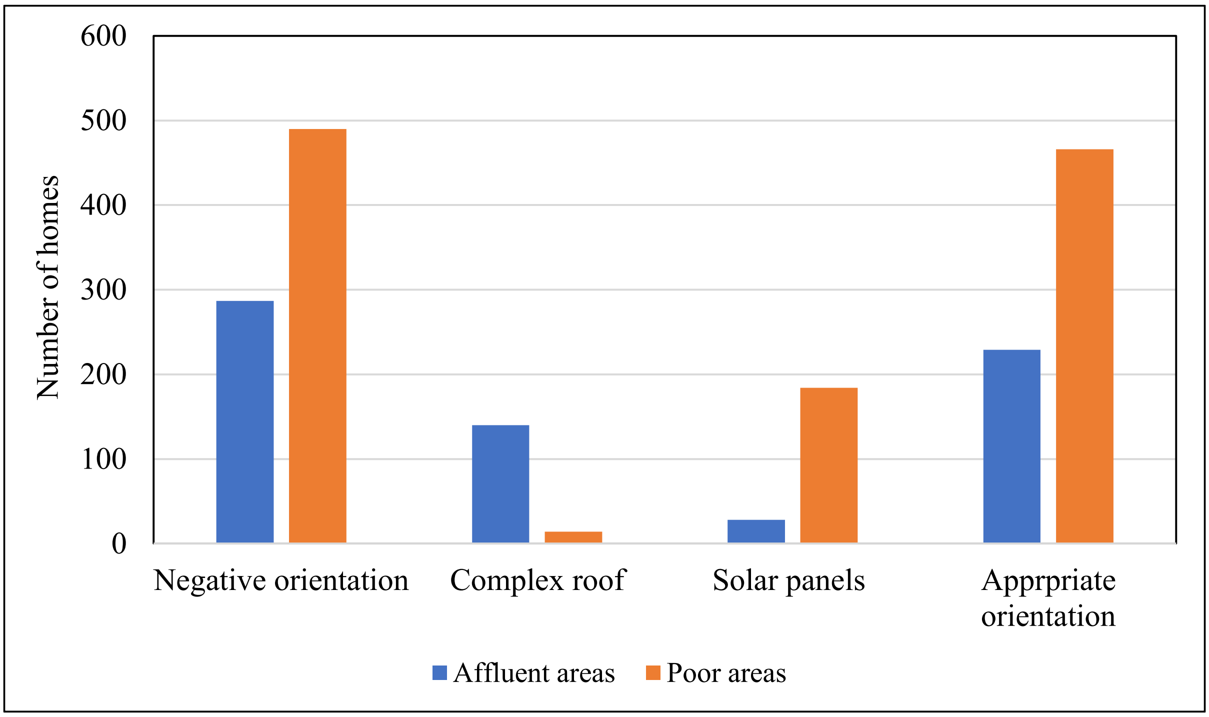

Figure 9-14: Diversity between Affluent and Poor Areas in Nottingham

Source: Author's Own

Figure 9-14 shows the diversity in structural design and adoption of renewable sources between affluent areas and poor areas. In the rich areas, 41% of the houses surveyed had negative orientation, 20% had complex roof designs, 4% had implemented solar panels, and 33% had the appropriate orientation to benefit from the implementation of solar panels. In the poor areas, 42% had a negative orientation, 1% had a complex roof design, 16% had implemented solar panels, and 40% had the appropriate orientation that could benefit from the implementation of solar energy. These statistics show that the adoption of solar energy is not growing at the expected rate despite the sustainable energy strategy established by Nottingham city council. Moreover, several elements highlight the trends in the variables between the use of solar energy to reduce carbon emissions and steps to encourage energy independence. These involve the cost of the installation of renewable energy systems which could also be impacted by the Covid-19 pandemic, location and climate which could impact the efficiency of solar panels (Sarver et al., 2013). This could be a contributory factor in the negative perception of the use of renewable sources like solar energy in the UK. Additionally, other factors such as the lack of knowledge of the benefits of renewable energy sources, access to sufficient financing schemes, and insufficient grid infrastructure which could limit the ability of homeowners to generate and sell the excess energy generated are essential (Hakimi and Moghaddas-Tafreshi, 2014). Furthermore, analysis of the diversity between the affluent and poor areas shows that the poor areas utilised more renewable energy sources such as solar energy. It also showed that a considerable number of homes with negative orientation and the homes with appropriate orientation are not utilising solar panels. This raises a concern about unequal access to affordable warmth and capital deprivation. The main factors associated with the aforementioned issues include inadequate housing (Krieger and Higgins, 2002), economic inequality (Bartiaux et al., 2019), fuel poverty (Gillard et al., 2017), infrastructural limitations and energy infrastructure (Bartiaux et al., 2019). Therefore, it is paramount for the Nottingham Council to tackle the identified issues facing deprived areas through investment in energy efficiency methods, providing financial support, and developing initiatives to encourage renewable energy adoption.

Consequently, it is imperative to understand the importance of energy justice in the Nottingham city maps district. This involves an understanding of the key principles of energy justice in Nottingham City and the identification of possible opportunities to promote energy justice. In 2006, Nottingham City was the most energy self-sufficient in the UK generating 3% of its heat and power from the use of renewables (Nottingham City Council, 2010). The city's local authority is also having a positive impact on its citizens in its reaction to the rising cost of energy prices (Nottingham City Council, 2010). The council is offering every household energy-saving measures most especially in its buildings to help reduce carbon emissions and improve the sustainable operation of its buildings. Subsequently, the UK Climate Impacts Change Programme (UKCIP) stated that the weather in the East Midlands will considerably decline with wetter, windier and warmer seasons. This could have adverse impacts on the city of Nottingham with increased temperatures and less water available for the reservoir system in River Trent and Derwent. Nottingham city council have also set out steps to reduce energy use in public sector infrastructure (Nottingham City Council, 2010). This includes reducing the use of electricity and gas in Nottingham city council estates, in domestic properties, in industrial and commercial properties and tackling fuel poverty. This highlights that the renewable energy agenda is firmly supported by the Nottingham City Council however more investment is required to achieve more sustainability targets.

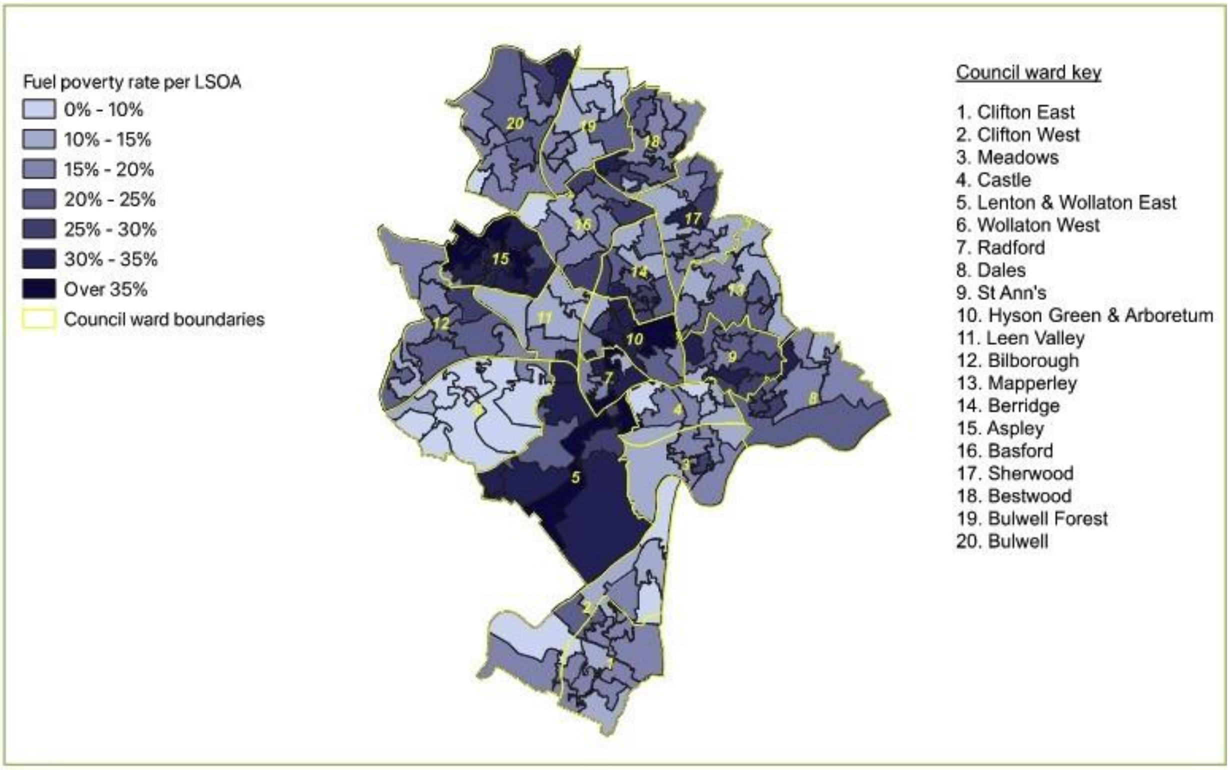

Figure 9-15: Fuel Poverty Map of Nottingham

Source: (Nottingham City Council, 2022)

Depicted in Figure 9-15 is the fuel poverty rate per lower super output area (LSOA) in Nottingham, UK. In September 2018, Nottingham City Council made strides into ensuring that it reduces the rate of fuel poverty by launching a Fuel Poverty Strategy. This was established through the Domestic Energy Efficiency Fuel Poverty subgroup (DEEFP). This was considered a crucial action to embark on as statistics showed that 20.6% of houses situated in Nottingham have been identified to be fuel poor (Nottingham City Council, 2022). Additionally, due to the national lockdown issued to curb the widespread of the Covid-19 pandemic, the energy consumption in homes across England increased by 3.4% in gas usage and 5.3% in electricity consumption in 2020 (Nottingham City Council, 2022). To further emphasise the impact of the lack of affordable warmth and energy efficient homes, it has been identified that living in cold homes could have detrimental impacts. This includes the increased risk of health deterioration and excess winter deaths (EWDs) (Nottingham City Council, 2022). This could also increase the pressure on public services such as the NHS. Subsequently, other impacts to children exposed to these living conditions include respiratory issues, poor emotional wellbeing, and the inability to attain adequate education (Nottingham City Council, 2022). Therefore, it is imperative to provide adequate subsides and grants to ensure that home energy efficiency is prioritised and the health and wellbeing of the citizens of Nottingham is safeguarded.

9.2 Summary

This chapter analysed the different types of orientation of solar panels in Nottingham, UK, based on their roof complexity, orientation, and location using google earth and PVGIS. It then proceeded to calculate the tCO_2e of an average household in the UK and compared it with the tCO_2e if solar energy is implemented regardless of the orientation. It was discovered that the orientation for solar panels to achieve optimum output is due south; however, east, and west-orientated roofs could also provide decent output for homes in the different seasons of the year. Using a south orientation, the electricity bills for households could be reduced drastically and help alleviate the financial burden of energy bills on families. The next chapter will provide an in-depth analysis of the interviews with homeowners about solar energy usage and its lack of adoption.

Chapter 10: Analysis of the Interviews with Residents Regarding Solar Energy

10.1 Introduction

This chapter discusses the data derived from semi-structured interviews and structured interviews with both users and non-users of solar energy in Nottingham, UK. It begins by identifying the factors that are responsible for the implementation of solar energy by consumers and then goes on to understand the performance and benefits they have experienced from using them. For non-users, it identifies the factors hindering their implementation of renewables such as solar. 92 interviews were conducted of which 12 were with solar panels users, and 80 for individuals without. Pseudonyms such as principal investigator (PI) for the researcher and interviewee 1 are also used to ensure the anonymity of interviewees, adhering to the ethical standards required for online research (Gerrard, 2020).

10.2 Utilisation of solar energy

10.2.1 Reasons for Implementing Solar Panels

In the researchers' quest to understand the reasons why residents have implemented solar panels in their homes, interviewees were asked to specify their reasons. This provided an opportunity for a range of views to be detected. The sections below represent some of the key findings from the interviews.

- A majority of the interviewees indicated the cost benefits as the crucial factor in encouraging them to implement solar energy. They stated that:
- *"It was a lot cheaper".*
- *"Money savings on electricity".*
- *"Cost effective".*
- *"To reduce electricity costs".*
- *"To save money".*
- *"Cheaper energy".*

- In addition to the cost benefits, another interviewee indicated that the crucial factor in their implementation of solar energy was because of the *"Income from energy generated"*.
- Another interviewee indicated that they utilised the government scheme to implement solar energy stating that *"They were offered as part of the Green Grant"*.
- Another participant indicated that the crucial factor was *"To reduce carbon footprint"* which shows their awareness of the impact of fossil fuels.
- Lastly, another interviewee indicated that it was already part of the fabric of the house stating, *"It was preinstalled"*.

The responses in a clear and concise manner show that residents are aware of the financial benefits of implementing a sustainable source of energy like solar energy and hence they decided to install them. It was also observed that a resident utilised the government scheme using the green grant. Another notable observation was a resident who stated that the solar panels were preinstalled in the home.

10.2.2 Financial Benefits of Solar Panels

The researcher was also inclined to discover if the residents that implemented solar energy have experienced any financial benefits from them. The following is a list of their responses:

- Several interviewees indicated that the reduction of their energy bill is evident after implementing solar energy. They stated:
- *"Lower bills"*.
- *"Reduced cost"*.
- *"It has saved me a lot of money"*.
- *"Cut the cost of my bills"*.
- *"Slight decrease in power bill allowing me to afford greener options"*.
- *"My bills are reduced"*.
- *"Financially lesser strain on me"*.
- Another interviewee stated that they are *"Still waiting for the first bill"*.

- Another interviewee stated that *"Selling back to the grid"* is financially beneficial to them.
- Another interviewee indicated that they are *"Still waiting for the first bill"*. This indicates that this interviewee recently implemented solar energy and is hopeful for energy savings.
- Another interviewee stated, *"So far in a short period none. Although, the panels were fitted with no direct cost to me"*. This indicates that this interviewee could have utilised the government scheme hence no additional cost is incurred from the installation of panels.
- Lastly, another interviewee stated, *"I have benefitted from the feed in tariff by getting paid for the energy I export to the grid"*. This further emphasises the success of the FiT scheme in the UK.

The responses show respondents have experienced less financial strain on them after implementation of solar energy. Furthermore, some of the interviewees stated that they have not yet experienced any financial benefits as they are waiting for their bill. To show relationship between the themes mentioned previously, a comparison diagram is shown below.

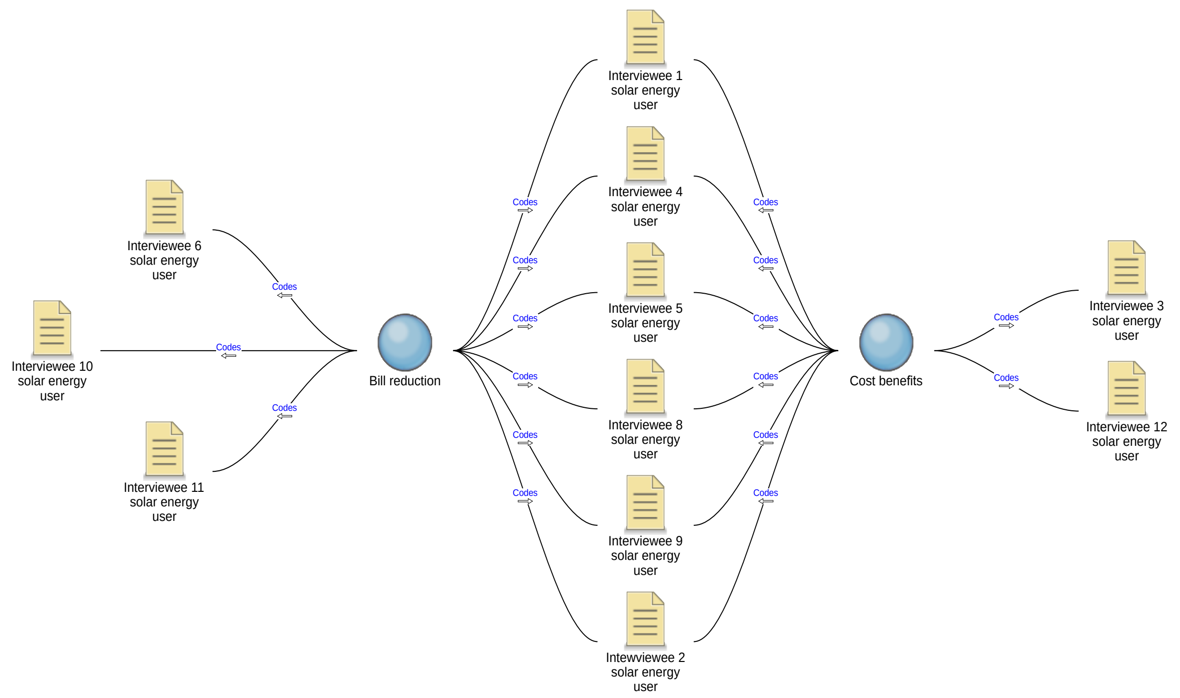

Figure 10-1: Comparison Diagram of Bill Reduction and Cost Benefits (NVivo QDA output)

Figure 10-1 depicts the comparison between themes of bill reduction and cost benefits. Interviewee 6, 10 and 11 uniquely stated that the reduction of bills is the key factor behind their adoption of solar energy. Interviewee 3 and 12 stated that the cost benefit associated with solar energy was the key factor in their implementation of solar energy. However, the interviewees that stated that these two factors were key are depicted in the middle row stating a combination of these two factors impacted in their desire to implement solar energy. The interviewees were also asked if they had experienced any infrastructural damage due to the installation of the panels and they all stated that they had not experienced any. The researcher also decided to further clarify on the maintenance of the panels and all the interviewees also stated that that they only carried out maintenance once every year or not at the moment. However, the interviewee which stated that the panels were preinstalled stated that the panels are rentals. Interviewees also stated the form of payment during purchase as either full payment or monthly payment. However, more interviewees stated to have paid fully for their system rather than use the option of making monthly payments. To further show the responses from the interviewees, a hierarchy chart is shown in Figure 10-2.

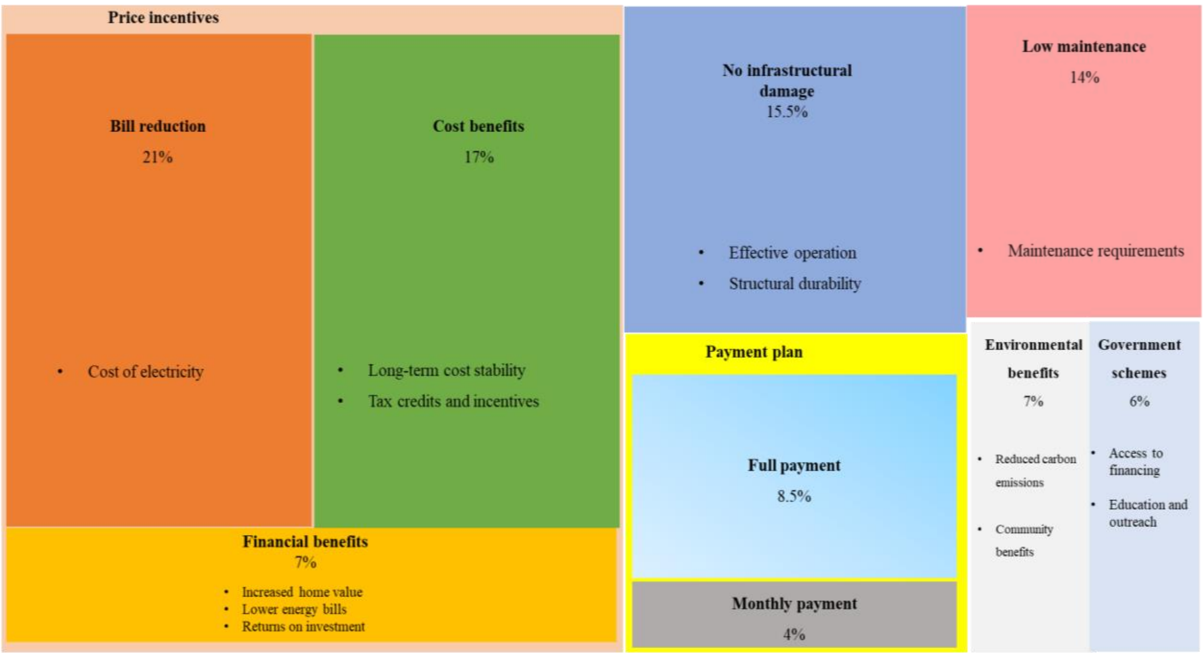

Figure 10-2: Hierarchy Chart of Solar Energy Use

Source: Reproduced from (NVivo QDA output)

The findings show several factors responsible for the adoption of solar energy in homes in Nottingham, UK. The findings shown in the hierarchy chart also highlights the response metrics to further provide more insight to the themes of the interview responses. These are centred around the reduction of bills, the cost benefits associated with the adoption of solar panels, the financial benefits such as payment from feed-in-tariffs, and the environmental benefits. Firstly, the variables considered to be crucial in the respondents' reasons for implementing sustainable energy sources for the reduction of bills involve the rising costs of electricity (21%). Secondly, the variables considered to be crucial in the respondents' reasons for cost benefits for implementing sustainable energy sources involve the long-term cost stability of energy, the tax credit and incentives (17%). Additionally, the variables considered to be crucial in interviewees implementing sustainable energy sources involve the effective operation of the solar energy system hence there are no recorded infrastructural damages (15.5%). Subsequently, the variables considered to be crucial in the respondents' reasons for the financial benefits of implementing sustainable energy sources involve returns on investment and an increase in the value of their homes (7%). Likewise, the variables considered to be crucial in the respondents' reasons for the environmental benefits of implementing sustainable energy sources involve the reduced carbon emissions and community benefits such as supporting local clean energy initiatives established by the council (7%). The variables considered to be crucial in the respondents' reasons for implementing sustainable energy sources with the help of governmental schemes involve their access to financing which provides them with options that enable the cost of any installed renewable energy equipment to be spread over time. The interviewees also identified an awareness of the government schemes available which resulted in them make informed decisions (6%). Furthermore, government schemes have been utilised as residents explore the methods available to them while other residents use a payment plan of either monthly payments or full payments.

10.3 Lack of Use of Solar Energy

This section explores the reasons hindering the growth of solar energy in the UK in residential areas. This involved the collection of factors from 80 interviewees who reside in Nottingham, UK. The findings are shown below:

10.3.1 Financial Burden of Bills

The researcher sought to find out if the interviewees that had not implemented solar energy had experienced or are currently experiencing any financial hardship with the payment of bills. This would prove to be a basis as the researcher explores factors that could positively or negatively impact the adoption of solar energy. The findings are shown below:

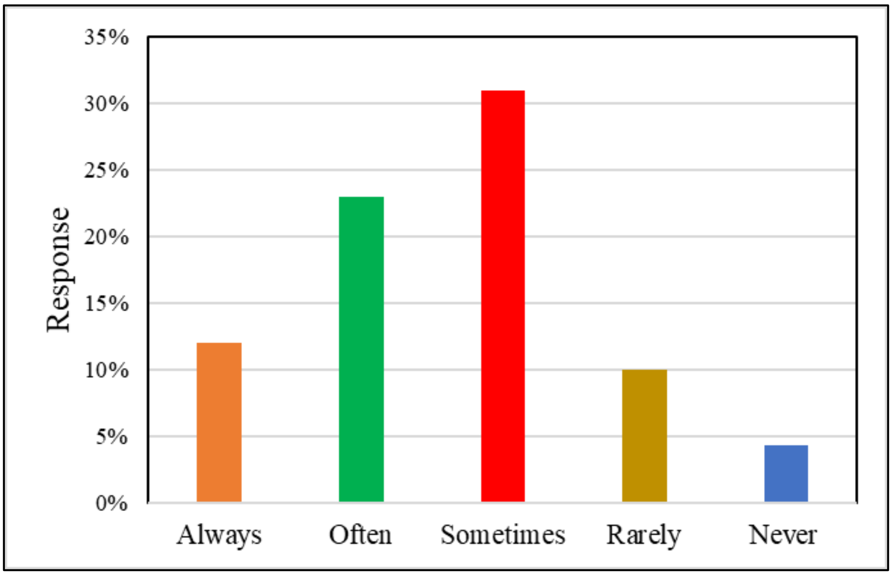

Figure 10-3: Interviewees Response Regarding the Financial Burden of Bills

Figure 10-3 depicts that the interviewees are currently facing the burden of bills with 12% stating always and 23% stating often. The highest proportion of the interviewees stated that they sometimes have financial issues with the payment of bills with 31%, while rarely and never accounted for 10% and 4% respectively.

10.3.2 Level of Insulation

To understand the thermal efficiency in homes, the researcher inquired about the type of insulation which the interviewees had in their homes. Their responses are shown below:

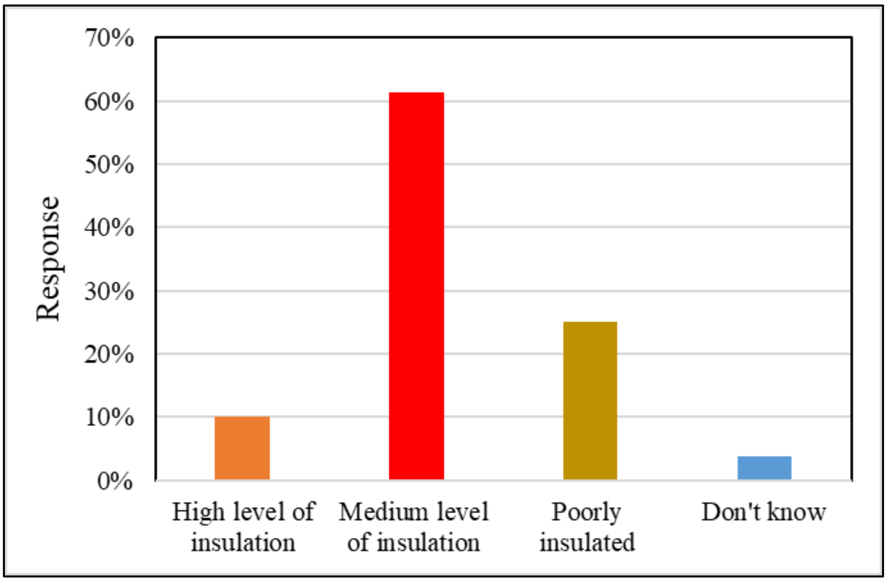

Figure 10-4: Interviewees Response Regarding the Level of Insulation

Figure 10-4 depicts that 10% of the interviewees have high level of insulation in their homes, 62% have medium level of insulation, 25% have poorly insulated residences, while 3% don't know what type of insulation which their residence utilises. . To further understand if the type of insulation utilised in the residences of the interviewees impacts the energy consumption, comparison diagrams are used in Figure 10-5, 10-6, and 10-7. This is crucial because a home with poor insulation would impact on energy use thereby increasing the energy consumption. This would then result in an increase in the price for heating homes and require more energy supply from the grid generated. However, this emphasises the need to implement more low cost energy sources and further develop renewable energy development. The analysis showed that regardless of the type of insulation the interviewees had in their homes, they still struggled with the payment of bills. This shows that the use of energy efficiency measures does not guarantee less use of energy in homes (Visscher et al, 2016; Bertoldi, Rezessy and Oikonomou, 2013). However, it should be accompanied by discipline in the behavioural pattern of energy usage (Visscher et al, 2016), as well as insulating other equipment's such as using thermal jackets for boilers and insulating pipes (Tojiboyev, 2021), replacing faulty electrical equipment with energy saving equipment (Bond, 2011), and adopting the implementation of smart meters (Zhou, Xu and Ma, 2010).

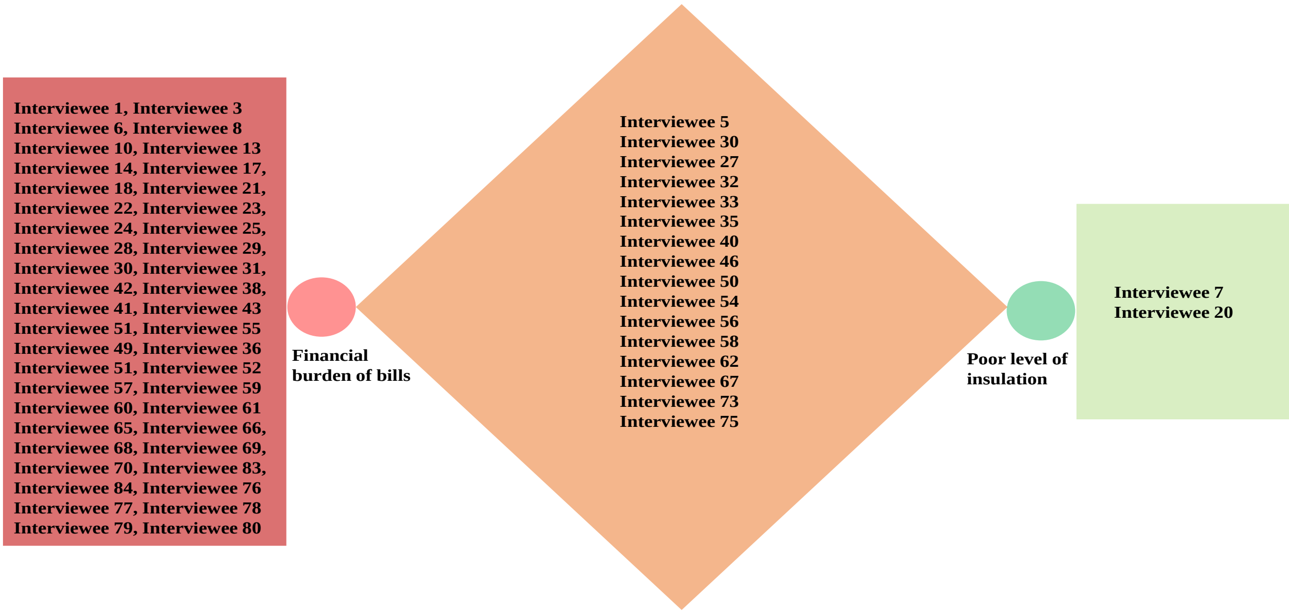

Figure 10-5: Comparison Diagram of the Relationship between Poor Level of Insulation and Financial Burden of Bills

Source: Reproduced from (NVivo QDA output)

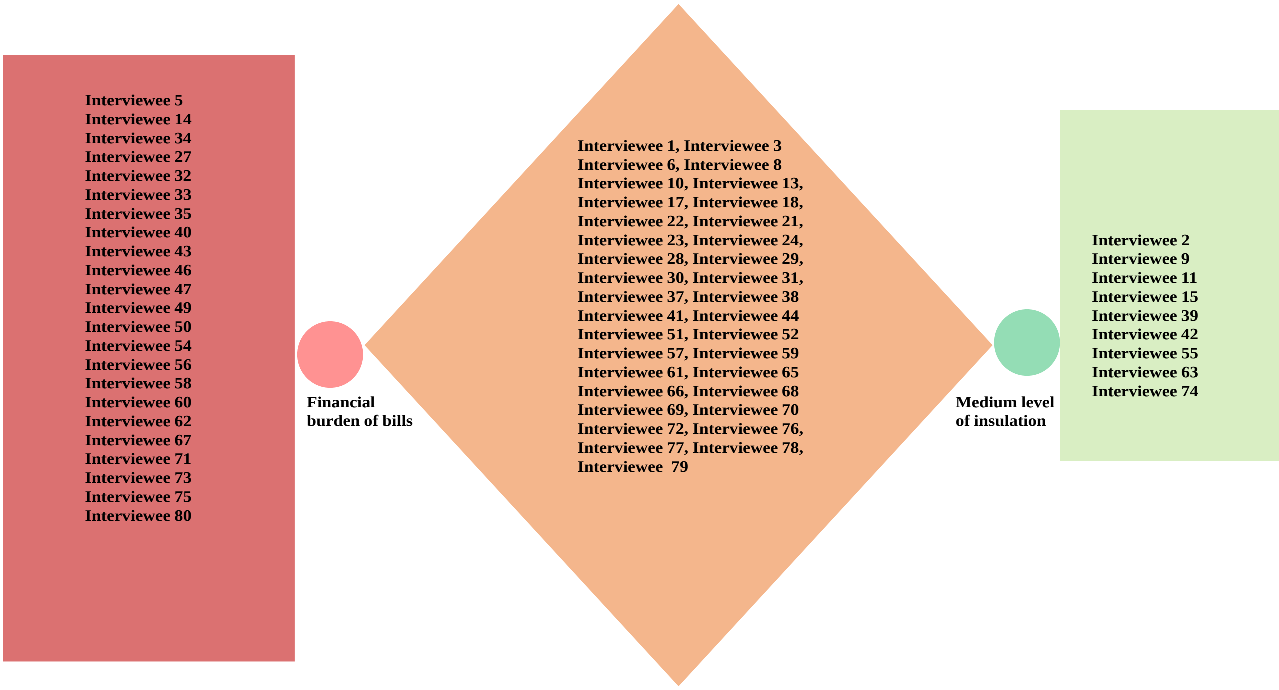

Figure 10-6: Comparison Diagram of the Relationship between Medium Level of Insulation and Financial Burden of Bills

Source: Reproduced from (NVivo QDA output)

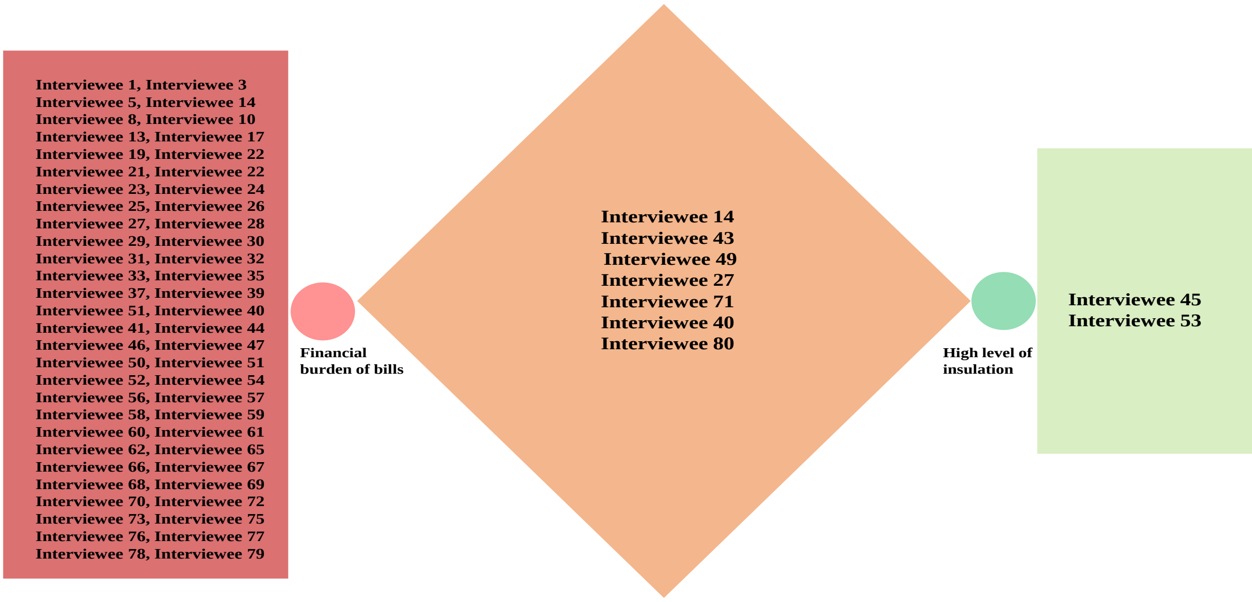

Figure 10-7: Comparison Diagram of the Relationship between High Level of Insulation and Financial Burden of Bills

Source: Reproduced from (NVivo QDA output)

10.3.3 Awareness of Renewable Energy

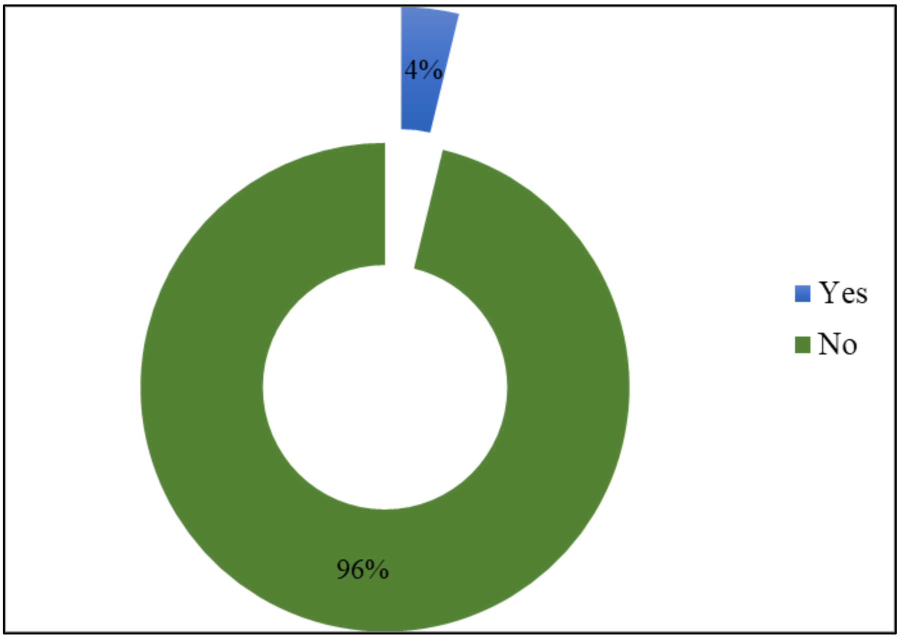

Figure 10-8: Interviewees Use of Renewable Sources on their Appliances

The interviewees were asked if any of their appliances uses renewable sources and astonishingly 97% of people don't have any appliances that utilise any form of renewable sources. This can be a prove to be a hindrance because utilisation of RE could be improved if residents utilised more renewables in other aspects of their homes. As a building block of a smart grid, the smart home is one of the most basic components (Elma et al., 2013). Smart grid infrastructure coupled with smart homes will, in addition to monitoring electrical demand, can optimise existing grid resources by utilizing streaming demand data. Further, renewable energy sources can be integrated into existing grids more easily (Elma et al., 2013).

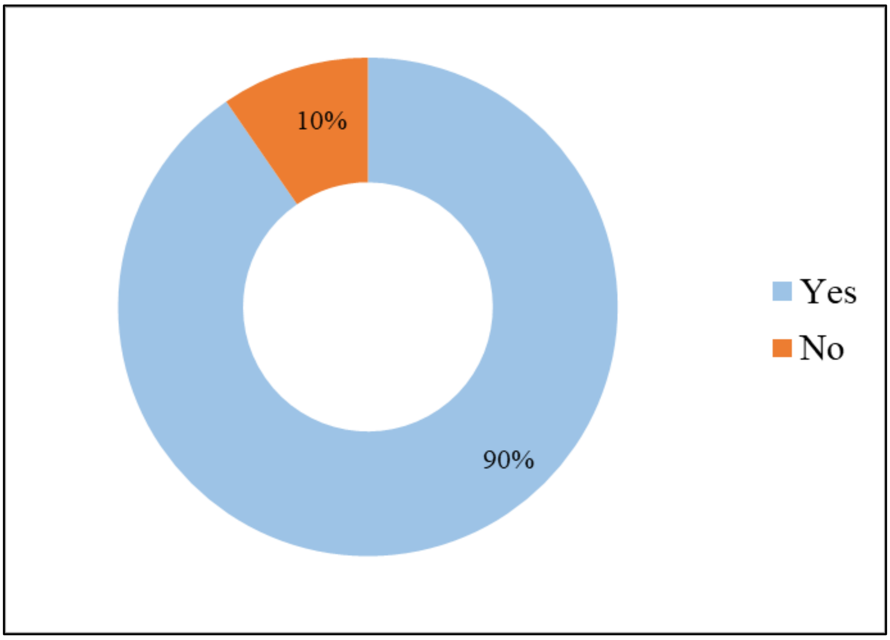

Figure 10-9: Interviewees Response about the Likelihood of Implementing Solar Energy

Depicted in Figure 10-9, majority of the interviewees stated that they would like to implement solar energy with 90% stating yes and 10% stating no. This shows that they are quite open to the idea of implementing solar energy in their homes.

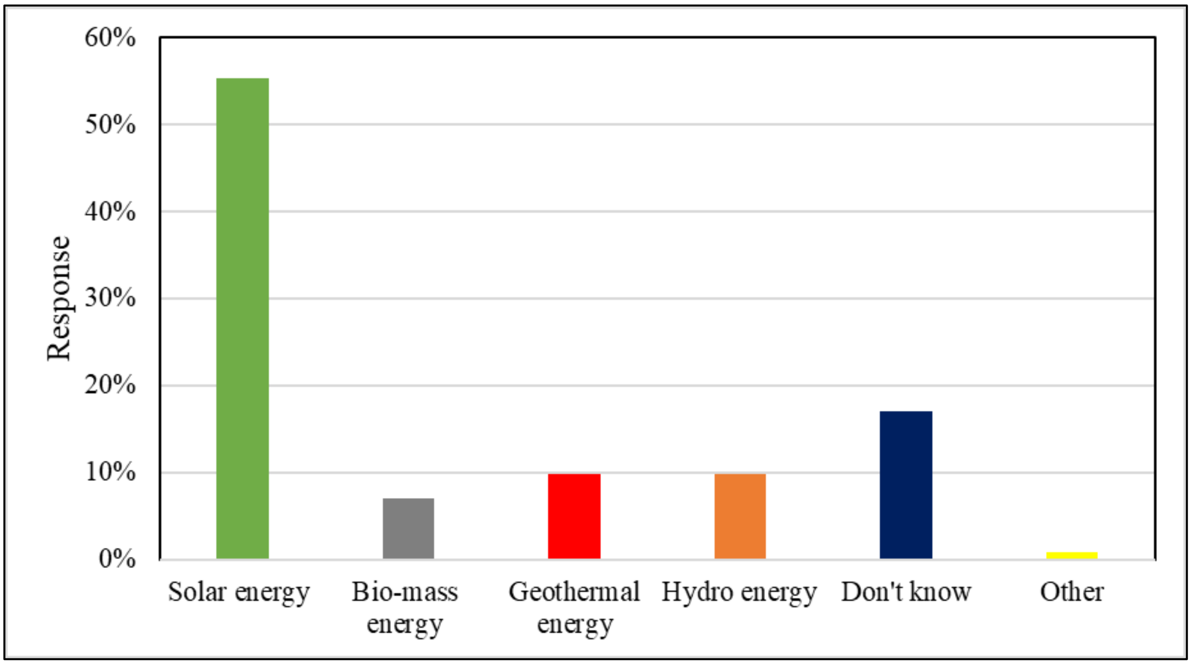

Figure 10-10: Interviewees Preferred Renewable Sources for Home Use

The interviewees were asked if they would like to implement RE sources in their homes. The results were very encouraging as residents opted to use solar energy in their homes. The largest proportion of the returns was solar energy with 54.2%, biomass with 6.1%, geothermal with 10%, hydro energy with 10%, and the interviewees that stated that they don't know or stated other accounted for 19% and 1%. Interviewees were also asked if they knew that solar energy could save them money and 88% specified yes, 43% stated no, and 8% said that they don't know. This proves that the awareness of the benefits of solar energy isn't as widespread as it is supposed to and this need to be addressed by governmental bodies and energy providers.

10.3.4 Issues Hindering the Implementation of Renewable Energy

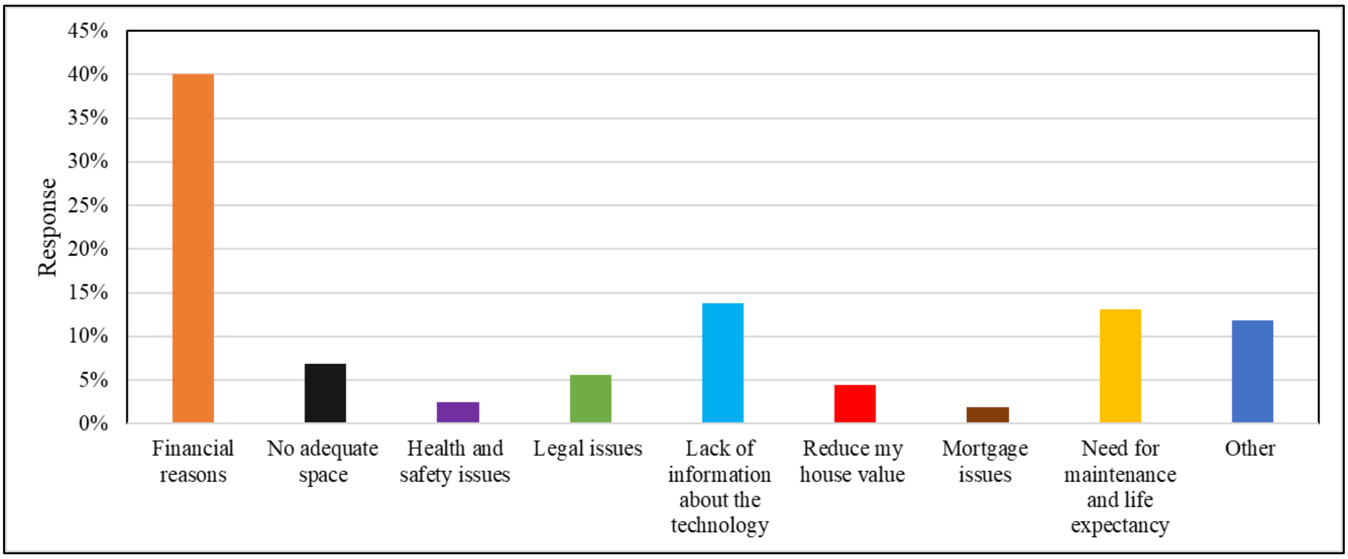

Figure 10-11: Issues Hindering Interviewees from Implementing Renewable Energy

Depicted in Figure 10-11, interviewees stated that the issue of financial difficulties is the most prevalent in implementing sustainable energy in their homes with 39%. Lack of information, need for maintenance and life expectancy, and lack of adequate space accounted for 14%, 13%, and 8%, respectively. The interviewees that stated that the most important factors include health and safety, mortgage issues, and the reduction of the house value accounted for 2%, 2%, and 5%, respectively. Subsequently, the interviewees that stated other accounted for 12% of the returns. The findings identified from the responses of 'other' are shown below:

An interviewee stated, *"Hopefully planning a loft conversion, so I need to finalise those plans before I know what I can do with the roof."* This indicates that, logically, residents should adopt home efficiency measures before implementing sustainable energy sources like solar energy.
Another interviewee stated, *"I'm in a rented house, and the landlord wouldn't accept it as she would be worried it would be costly"*. This also agrees with findings from the public questionnaire, which identify the lack of interest in implementing sustainable energy sources in residences as they do not own the homes.
Another interviewee showed concern about the *"Likelihood of selling in the future - potentially 5 years away"*. This is also highlighted in the public questionnaire and the interview with participants stating that most participants said they would prefer a quick payback on any investment made in renewable energy technologies.
Another interviewee also shared the same views as the previous interviewee stating that they are *"Likely to move houses within payback period"*.
Another interviewee commented, *"Concerned about the effect of panels on the roof"*. This implies that the resulting impact on the structural capability of the roof and the corresponding impact of legal issues and insurance is crucial in the interviewee's thought process.
Another interviewee stated, *"We live in a bungalow and haven't been offered by our housing association"*. This also highlights the importance of government grants to help promote the implementation of renewable energy in the UK.
Another interviewee stated, *"My type of roof is not compatible with the installation of solar panels"*. This could indicate crucial factors such as the complexity of the roof design, as this automatically discourages the implementation of solar energy in the UK.
Lastly, another interviewee stated that the *"Lack of time to organise"* hinders the idea of exploring sustainable energy methods. This could imply that residents see the implementation of solar energy as an effort-intensive process as it involves considerable planning hence the assumption that sufficient time is required.

10.3.5 Returns on Investment

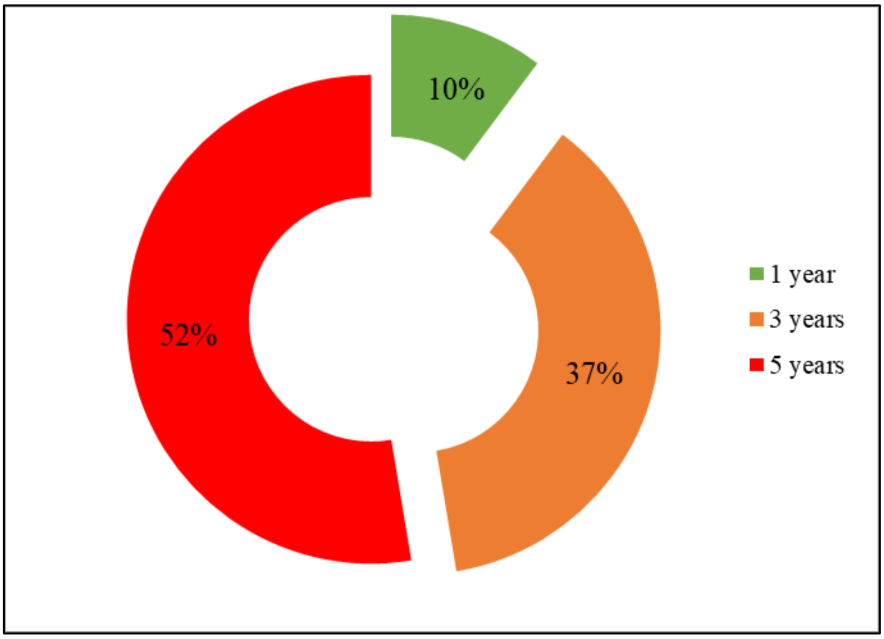

Figure 10-12: Returns on Investment for Interviewees from Implementing Renewable Energy

The researcher decided to investigate the proposed payback for renewable energy investments. Their responses showed that residents prefer a payback period of 5 years, with 52% of the returns. Subsequently, 37% of the interviewees stated that they would prefer 3 years payback period. Lastly, the interviewees that said they would prefer a 1year return on investment accounted for 10% of the interviewees. A hierarchy chart is utilised in Figure 10-13 to depict the themes identified from respondents' responses.

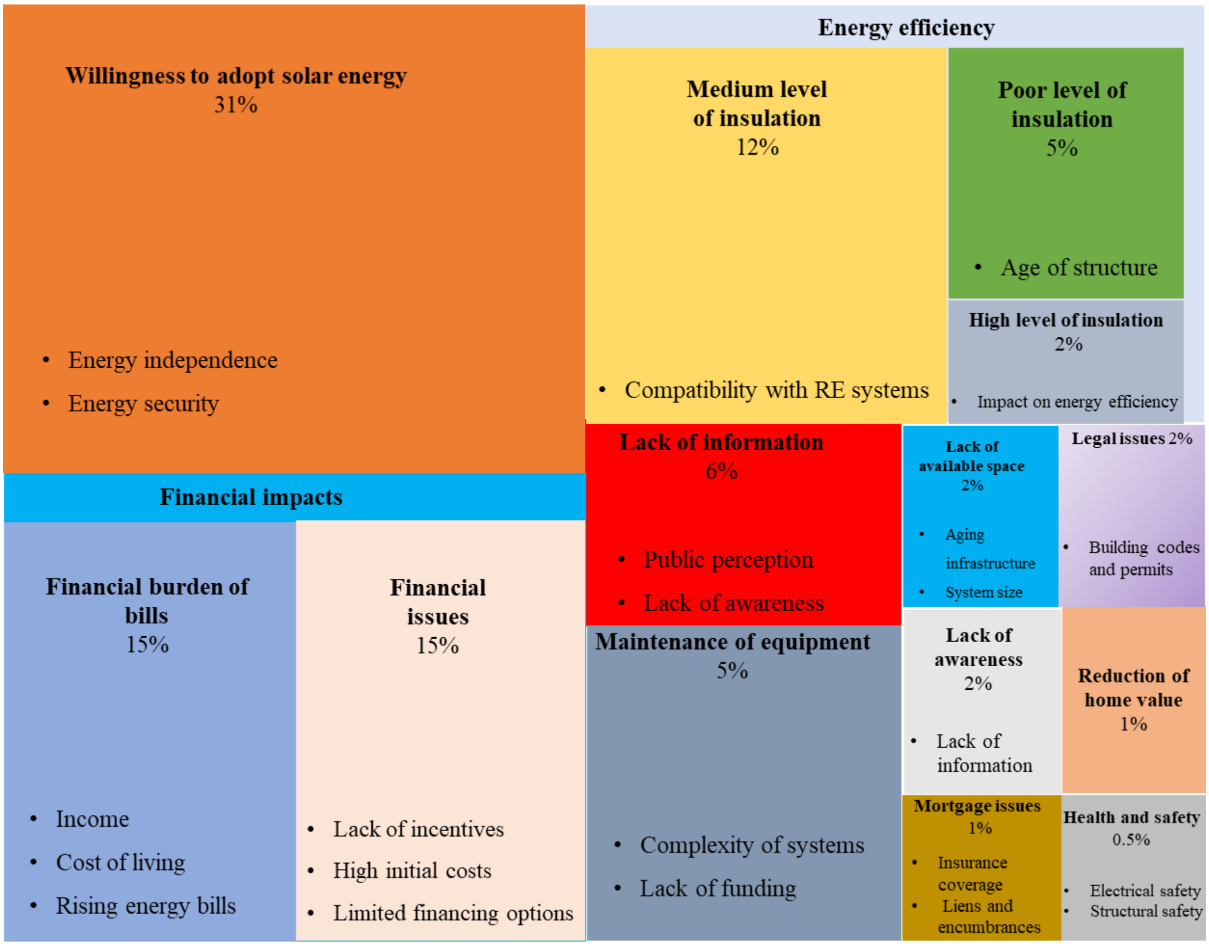

Figure 10-13: Hierarchy Chart of Lack of Solar Energy Use

Source: Reproduced from (NVivo QDA output)

The variables considered to be crucial in encouraging interviewees thereby increasing their willingness to implement sustainable energy sources involve energy independence and energy security (31%). This would result in reducing the reliance on the energy supplied by energy companies and the vulnerability to energy price fluctuations. Additionally, the variables considered to be crucial in hindering interviewees thereby impacting their decision to implement sustainable energy sources are identified. This involves the financial burden of bills which could be attributed to the income of interviewees and the rising cost of energy bills (15%), financial issues which could be attributed to the high initial cost associated with renewable energy sources, lack of incentives, and limited financing options (15%). Other reasons include the potential cost that could be incurred during the maintenance of these sources such as solar energy which could be attributed to the complexity of renewable energy systems and lack of funding during the life cycle renewable energy sources (5%). Subsequently, the lack of information could be attributed to public perception, the complexity of renewable energy sources such as solar energy and lack of awareness (6%). Other variables include the lack of available space which could be attributed to an ageing infrastructure and system size of renewable energy sources like solar energy (2%), reduction of their home value which could be attributed to the reliability of renewable energy sources and their aesthetics (1%), mortgage issues which could be attributed to insurance coverage and liens and encumbrances which may hinder an interviewees ability resell or refinance a property in the future, and home appraisals (1%). This is crucial because appraisers may not be aware of the impact and benefits of the renewable energy source and as such may not appropriately value it. Legal issues are also regarded as crucial in the adoption of renewable energy by interviewees, and this could be attributed to building codes and permits (2%). The issues with health and safety could be attributed to electrical safety and structural safety (0.5%). This is crucial because improper installation could result in electrical hazards such as electrocution and systems installed poorly could cause structural issues hence, they should only be installed by qualified personnel. Subsequently, the lack of awareness of the cost benefits of renewable energy sources could be attributed to the lack of information due to the lack of awareness campaigns to equip individuals with the appropriate knowledge on how to adopt renewable energy (2%). Lastly, the type of insulation in homes is also crucial when adopting renewable energy sources as it has an impact on energy efficiency with medium level of insulation with 12%, poor level of insulation with 5% which highlights the age of structures, and high level of insulation with 2%. This is of paramount importance because of buildings compatibility with renewable energy systems such as the use of spray foam insulation to increase the performance of heat pumps as it prevents air leaks (Rad, Fung and Leong, 2013).

10.4 Summary

This chapter discusses the responses to the interviews conducted with residents in Nottingham and other parts of the UK. Several relationships were also identified between the themes identified during the coding of the interviews. Furthermore, the study examined the barriers deterring participants from utilising solar energy and how likely residents are to do so. In the next chapter, the researcher will analyse the interview conducted with a high-ranking council employee.

Chapter 11: Analysis of the Interview with Nottingham Council

11.1 Introduction

This chapter discusses the data derived from semi-structured interviews with a high-ranking staff member at the council in Nottingham, UK. The interviewee is in a senior position responsible for forming the strategies for adopting renewable energy in the city towards net zero. This therefore provided valuable insight into the development of renewable energy in Nottingham. It begins by identifying the factors responsible for the implementation of solar energy by consumers and then goes on to understand the issues that impact the council's ability to improve the adoption of solar energy in the area. The findings are shown below:

11.1.1 The Growth of Solar Energy in Nottingham, UK

The researcher sought to understand the importance of sustainability to the Nottingham council as well as the growth of solar energy in the area.

- *"I guess in subject to the buildings; we are quite lucky within the city because our portfolio holders like the councillors are very much behind a sustainable Nottingham. They are very much behind the solar PV technology because it is very tried and tested. After all, solar panels have been around since the '70s, probably earlier than that. So, it is a proven technology that works. We are also quite fortunate that we took advantage of the feed-in tariff when it was around, so most of our sites have got associated feed-in tariffs as well. Now when we are looking to deploy solar on a building because we don't have to get the technology signed off because it's already tried, tested, and proven. So, when I identify a building that would be suitable for solar PV or any other form of renewable energy, the sign-off procedure is relatively simple".*

This indicates that solar energy is becoming a widely recognised technology, enabling its implementation to become relatively simple (Mekhilef et al., 2012). The researcher also aimed to know the growth level of solar energy in the area as this would further clarify the councils' energy agenda.

- *"Also, regarding the citizens of Nottingham across our council homes, we have got around 20000 to 25000 domestic social homes that are owned and operated under Nottingham city homes at the moment, and out of those, there are about $3^{1}/_{2}$ thousand domestic properties that have got solar PV on. When the Feed-In-Tariff was there, it was paying for the system. However, what would be good would be to see how we can continue to roll out solar PV domestically in a way that would be beneficial for the tenant, even more so now with the rise in energy prices. Even across our sites, we are paying about 35-36 per unit kilowatt-hour, which is a lot of money. However, this does have a benefit. This provides an opportunity because when you are paying so much money for electricity, it does make solar energy more viable. The bit that is unknown is what the market will look like in one to two years. We don't have the expertise or market intelligence to understand what is driving the price of electricity to rise apart from the obvious impact of the conflict between Russia and Ukraine".*

The interviewee also provided further insight into other sustainable measures being implemented in Nottingham.

- *"There is a strong risk that we are assuming that the energy prices could keep rising for 15 to 20 years, but in all honesty, we don't know. In other projects we are doing across our East Croft depot, we are involved in a ground-breaking project which is partially European funded and partially funded by the authority. It is under the branding of clean mobile energy, and it is a vehicle to grid project. What this project entails is that we have received funding, and we are in the process, and a lot of them have been replaced already, but we are in the process of replacing all our refuse collection lorries with electric ones, so they have batteries and motors in them. Also, around 35 smaller vans will be swapped over for electric vans. On the same site across the same depot, we have about 3 buildings with solar PV in them with about 150 kilowatts of solar generating capacity on the site. We are looking at having a half a megawatt battery installed, and hopefully, all these will give revenues from grid services. So, we know that our refuse lorries generally start coming back into the depot around 1 pm, and the latest one gets in at around 2.30 pm. The vans also come in and out, depending on when they are being used. Prior to this project, they were 12 to 13 different supplies coming into the depot, but we have removed all of that, and we have* *gone on to one main high voltage with one supply coming into the depot. So previously, with the 3 solar PV systems that I have mentioned, if the energy wasn't being used in that building, then it will just get exported to the grid".*

- *"As of now, we are on one main circuit, and if it's not needed in that building, then it will go into our network to be used somewhere it is needed. If for any reason solar energy is being generated, and it's not being used, it will be stored in a half-megawatt battery which we will have installed very soon. The refuse trucks would either be charged up from the solar PV, and we are also looking to have 100kilowatt of solar PV canopies on the depot along the domestic car park. Also, because the energy stored is vehicle to grid, you can use energy from the grid to charge the batteries, and you could also use energy from the refuse trucks and send that to the grid. However, the grid has a problem with balancing from a frequency and voltage perspective, but we can help them out. This is done on computers and not over a phone call because it must be done in microseconds so one option could be that there is too much energy in the grid, and they need to remove quite a lot of energy. This could then mean the energy could be put in our batteries, and we will get paid for taking that energy from them and we can use that to power our depot trucks. Another angle to that is when there is not enough energy in the network, and they need energy put into it. This means our refuse trucks and the batteries we are having installed are very capable of putting energy back into the grid very quickly, and we get paid well for it. A computer software package controls everything because we need to make sure that by 5 am to 6 am when the lorries need to go out that there's enough energy in them to conduct their business as usual".*

This shows the considerable growth of sustainability measures in Nottingham and the benefits of using Feed-in-Tariff for solar energy implementation. However, it is paramount to understand the methods used in its implementation in the area.

11.1.2 Benefits of Government Schemes

To understand the benefits the government schemes have provided, the researcher sought to determine their impact on the area.

- *"If we sort of go back before the Feed-in-Tariff, the Feed-in-Tariff ended in 2019 or maybe March 2018. However, when the Feed-in-Tariff had run out, the model for assessing solar PV on a building would just be how many solar panels can you get on a roof, and it doesn't matter what happens to the energy whether it is used on-site or gets exported back to the grid. The majority of the revenue came from the Feed-in-Tariff. We do have to make financial returns within the authority because we have to borrow the money as a capital investment, and we do need to provide returns. However, the returns we have to provide back are very low. Then after examining how many panels can be put on the roof and what the Feed-in-Tariff looks like, we put a business model together after assessing the orientation of the building, and the picture of the building, then we can have a very good understanding of the systems potential output after taking into considerations any local shading or horizon shading on the array".*

This illustrates that the introduction of the Feed-in-Tariff was quite beneficial to the council in various ways, such as providing a financial return and a better understanding of their business model. However, there is one vital point to note: the council is also feeling the impacts of halting the Feed-in-Tariff scheme and introducing the smart export guarantee (SEG) scheme as they have to restructure their business model.

11.1.3 Estimation of Site Production

The use of methods to estimate solar power generation enables a better understanding of the potential of solar energy. The council provided insight into the strategies adopted to understand the estimated solar production of any selected site.

- "*We also have professional software, so we use PVSYST and PVSOL as well to model these buildings. So, when the Feed-in-Tariff went the model got a little bit more involved, so what we do now is we look at the building, we look at the roof, we ascertain how much energy or generated capacity we can get on the roof but then we start analysing half-hourly data and import data for that site. So, we want to know when they are using that energy and how much energy they are using. So, we have defined a good tool especially when you are looking at half-hourly data and half-hourly settlement and it can get quite complicated to look and see what is going to happen with this energy.*

Firstly, we start with a whole year's worth of hourly import data for the site. We would then model the PV system, such as PVSOL, and then put the model into the system and do all the design work there".

- "*Basically, that will generate a report and it will break down hourly generation data across 365 days, so we are basically overlayed the generation data unto the import data and then look to see what is going to happen to the energy generated, and then on the system, we find a way to maximise the generation while minimising the export that is going out to the grid because that will then maximise the financial savings that we see. This is because what we want to do is save as much money as we can possible so that would be the process that we would go through to ascertain firstly whether it is suitable for solar PV, then we have to look at the financial viability of it. Then we get a system designed, then we cost that system up, and we have the skills and expertise within the authority to price the jobs. Now we get to the financial business case, and if the expected returns are achieved, I can get the project signed off. So, it's a good position we are in because our directors and heads of service are 100 percent behind it especially when we are talking about our aspirations to become carbon neutral by 2028, which is a very challenging target".*

This shows that industry-standard software is used to provide an in-depth understanding of factors that could be beneficial or detrimental to the success of a solar project. This also demonstrates that researcher was justified by utilising PVGIS to estimate the solar power generation from panels having different orientations. However, the council utilises a much more complex system to ensure a well-informed decision is reached. It also shows that the hierarchy in Nottingham have embraced the concept of sustainability as they are taking the necessary steps to become carbon neutral by 2028.

11.1.4 Challenges in the Implementation of Solar Energy in Nottingham

There are several issues that could implement the growth and development of sustainable practices in an area. The council highlights some of these issues.

- *“Regarding things that stop us from doing it, that is going to come down to the hard-to-treat building. These include buildings that you have to do planning applications and it gets really complicated and generally expensive. Another issue is within the authority we don’t have lots of surplus cash so what then happens is when our buildings need to be maintained, they are only maintained when it is an emergency. For example, there is a building that is south facing, with no shading and a perfect pitch which would be perfect for solar panels but unfortunately, there is quite a lot of asbestos in that building. This then requires one of two actions. We can either have the asbestos removed, which is quite expensive, or we can get professionals to do the roofing works so we can lay our panels on top. However, the problem with that is the ongoing maintenance of that system because there is asbestos in the roof, and we would try our best to avoid it. Also, we are not only looking at solar PV, but we are also exploring urban wind. There have been quite a few advancements in the technology surrounding urban wind generation. We are trying to understand what sort of buildings they would be suitable for and do we have any of those kinds of buildings. Also, what is the cost of these devices, what is the financial benefit, and how much energy do they generate and then translate them into carbon savings and other forms of benefit. We have also got a few companies that have supposedly got the right form of technology however, we would need funding to try out these technologies. If they are successful, then that is good. We can roll it out, and if they are not, then I would say the trial has been successful because they have given us insight as to the technologies that would not work. Then we would be looking at the government to provide us with some funding to have these trial experiments”.*

- *“What would be interesting to know is why are people not doing it? What concerns do they have and what reservations do they have? Once we can start to understand that, then we can tailor the events around that so we can address the concerns that they have and talk to them about them. We could then also get some case studies and get some people involved that already have solar PV installed so they can talk to other potential customers about the benefits of it. Some people would be motivated by the environment and would want to do it. Others could be motivated by the financial savings associated which would have a higher proportion of people focused on the savings involved. Then you would have people do it because their neighbour has done it and they want to be* *as good as their next-door neighbour. I think the key to this is understanding the barriers and the challenges involved in implementing the use of solar energy in Nottingham. Personally, I am a believer in solar PV, but the only thing stopping me from achieving it is funds. I know it makes financial sense and I know it makes environmental sense, but I just can't afford to do it because my money is needed in other places".*

This identifies that financial issues also affecting the council with the lack of funding to carry out regular maintenance. This could also lead to issues considering the scenario of the presence of asbestos in the roof of a building. Subsequently, inappropriate handling of asbestos could lead to hazardous health impacts for all parties involved (Sonak, Sonak and Giriyan, 2008; Luus, 2007). It also identifies the use of urban wind as an option for energy generation from the residential sector however much research is needed before it is regarded as a viable alternative source of energy for the residential sector (Fields, Oteri, Preus and Baring-Gould, 2016). The reasons hindering individuals from implementing renewable energy is also quite important to the council, as they are unsure how to adapt promotion and informative measures to help tackle the issues. Furthermore, understanding the impacts of Covid could provide much valuable insight.

11.1.5 The Impact of Covid on the Growth of Solar Energy in Nottingham

The impact of Covid-19 pandemic was felt globally, however its impact on renewable energy practices could provide an understanding of the issues faced by the energy sector and entities responsible energy provision.

- *"What clouds this is Covid. However, I can tell you from a solar PV perspective the sector is booming, and I think that has been influenced by the cost of energy. However, it started picking up around November 2021. Nottingham is rolling out solar PV, and it has been for quite a while; and I think the implementation of the Feed-In-Tariff provided a huge part in influencing the uptake of solar PV. However, I believe it has not slowed down, but Covid has clouded things because a lot of non-urgent activity stopped for 18 months. Our services continued and we would carry out maintenance in an emergency but other than that we paused on a lot of work which included feasibility* *studies as well. There are also a lot of commercial buildings that are going to want to take advantage in terms of the savings involved".*

- *"Regarding implementing solar energy from a domestic viewpoint, there are cost savings as well as higher installation costs post-Covid. For example, 9 months ago you could get a 4-kilowatt domestic system installed for £4000 now the price is £6000. Also, the labour costs are going up, the material costs are going up, and everything, in general, is going up. We have also changed the way we are working with contractors. In the past, we would get a cost from them to do an installation and the risks they would take on board themselves. Prices would then be held for 30 to 60 days. Nowadays, contractors would hold their price for 5 days and they don't give off fixed prices. This means the contractors share an open book policy where they share all their costs with us, and they put their margin on top at the end of the job. I am currently writing up tender specifications for renewable energy technologies, specifically solar PV, and I am trying to think of creative ways to get more people to look at it and think it is interesting and quite lucrative which would provide them with funds".*

- *"I do however think there has been a steady incline and considering I have been at the council for 5 years and unfortunately, 2 of those years were us going through the Covid pandemic thereby meaning that things have naturally slowed down. Regardless, since I have been at the council, we have installed an immense number of solar panels in Nottingham. Just because we have lost the Feed-In-Tariff hasn't impacted on the development of solar panels from a commercial perspective. However, the latter is the case in the domestic area. This is because the energy generated is free for the tenants to use how they see fit, and without the Feed-In-Tariff now, there isn't a mechanism for the city to get a payback for that system are the maintenance of these systems. For domestic systems, we haven't installed a retrospective domestic system for quite a few years, but we are still installing it on domestic properties, but that is on new build properties. These are properties where we have received funding from the government known as the social housing decarbonisation fund".*

This illustrates that regardless of the Covid pandemic, the solar PV industry continues to grow at an unprecedented rate (Department for Business, Energy and Industrial Strategy, 2021). However, there are impacts to key components in the deployment of this renewable energy source. These include the rise in cost of installation, labour, and materials. There is also an increase in the rate of installations in new build domestic properties rather than older structures. This could be beneficial as residents in the area could either receive the solar systems prior to the purchase through a mortgage as part of the structure of the home; however, it could face some backlash as some residents might not appreciate being given solar panels without their consent.

11.1.6 The Implementation of Energy Efficiency Measures in Homes

The use of efficiency measures is regarded to be important to ensure the reduction of heat loss and misuse of energy. Therefore, understanding the councils' approach to this would be beneficial as it could ensure that energy is utilised efficiently in homes.

- *"We are utilising those and they are being done across a lot of measures. This involves having a fabric-first approach regardless of whether the building is a commercial building or a domestic building. This approach involves making sure the building is energy efficient. This involves assessing the type of insulation in the building, and the type of light bulbs that are used in the building such as low-energy light bulbs, loft insulation, and cavity wall insulation. This is however impacted by the cost of implementing them. A year ago, solid wall insulation would cost about £12000 but nowadays it is between £15000 to £18000. Regardless, embarking on a fabric-first approach is the right thing to do. This ensures it costs less to heat the property, so the residents are warmer. This is probably my biggest challenge in rolling out solar PV on social housing, thinking about how I get it to pay for itself. We could explore the option of a domestic power purchase agreement which means the residents would purchase the energy that is generated from their roof at a lot cheaper than they would purchase from the grid. However, this could lead to a lot of complaints from disgruntled tenants because there could be a scenario where their next-door neighbour is getting the energy for free using the Feed-In-Tariff, so why do they have to pay for it. This is a bit of a challenge because fuel poverty is increasing, and we really want to help the tenants,* *but we don't have the cash for that. I can't speak for the private properties, but they are all busy, which technically means the domestic private properties are having their systems installed, but I can't validate that with any statistics".*

This indicates that the council is also considering the benefits of insulation in homes. However, with the rising costs in the UK, the cost of insulating a home is substantially a lot more than heating the home which could prove to be counterproductive when convincing homeowners to implement energy efficiency measures. The use of power purchase agreements (PPA) could be beneficial to utilising energy efficiency procedures. Still, it is worth exploring the negatives of PPA such as the gradual increment in the price otherwise known as the escalation rate residents would pay for the electricity their system produces during the specified period of their lease (Taghizadeh-Hesary et al., 2021).

11.1.7 Promotion of Renewable Energy

The use of measures to promote the adoption of renewable energy can develop awareness and increase engagement within residents (Lucas et al., 2021). Therefore, the researcher sought to identify the methods being utilised by the Nottingham council to encourage the adoption of solar energy.

- *"The government must bear some of the responsibility as well in terms of influence. Nottingham city can support to ensure that the citizens of Nottingham are approaching the right contractors. This means we take part in the trusted trader and make sure we keep that up to date and encourage people to leave feedback on there. Also, we could educate people by having local events in local areas where we could talk to people about carbon emissions. We could also link this with our objectives and aspirations such as being carbon neutral by 2028 and what this means for the citizens of Nottingham. Then we could talk to them about the solar installations we have done. We can start by giving confidence to people in the technology, and then we can talk about how homeowners can go about modelling this. We would provide information about the MCS requirement. We could signpost important information and point them in the right direction to get competent people out there to give them quotes for them. We could go with case studies as well".*

- *"Therefore, Nottingham city should be providing these sorts of events or functions in community centres so we can talk about what the council is doing and how the council can support private residents to do something similar. It would be nice to say it would be great to provide some funding as well but unfortunately, the council does not have any money rather the government could do that. However, considering that the current uptake of solar is quite high at the minute, there is no reason for a financial incentive to be implemented. Also, 6 months ago if I was told to put a battery in there to be self-sufficient then my advice would be not to but with the current prices of electricity, I would recommend getting a battery installed, but everything needs to be sized accordingly. It has to be a sensible proposition for the home or the business. My only barrier would be the funds to install a solar PV because factoring in the panels and the battery would range from £6000 to £10000 to do that. Also, the payback time for that is quite long being around 6 years. It is about identifying the barriers and how can we do something about that is the council in a position to do something about that".*

This indicates that the council has developed proposed measures to effectively promote solar energy. The proposed methods highlighted by the council could create a better understanding of the benefits of solar energy. Furthermore, residents need to be aware of licensed contractors to avoid the possibilities of approaching unlicensed contractors to install their solar system. This is important because using an unlicensed contractor could have impacts such as faulty wiring (Ancuta and Cepisca, 2011), delamination and internal corrosion (Omran et al., 2020), roof issues (Urmee el al., 2018), microgeneration certification scheme (MCS) (Hanna, Leach and Torriti, 2018), and micro-cracks (Bond-Hutkin, 2017).

11.1.8 Government Schemes Available

Since the Feed-In-Tariff scheme has been concluded, the researcher sought to identify if there are still financial incentives or schemes that the government or the council utilise to encourage people to install solar panels.

- *"There is financial help available called green homes grant. The green homes grant started in March 2021, and this was known as a voucher scheme where private properties can apply for a grant from the government to make their property more energy efficient. However, a criteria needed to be met. It started by looking at privately owned and privately rented buildings that are not energy efficient. This means you can receive the funding if your property has an EPC grade D or worse and have a household income of less than £30000 a year gross across the whole family income. This is quite important because 2 working adults both doing 40 hours a week earning minimum wage will exceed that amount. However, we then have another approach we can do called LA Flex. If there are multiple children in this property it could then mean more funding, up to £40000 depending on the number of children, they have. That scheme wasn't particularly successful, which then rolled on to phase 1B and phase 2 called LAD (Local Authority Delivery)".*

- *" We are now managing the scheme within Nottingham city where people can apply for funding, and they would receive up to an average of £10000 per property, and they can receive measures for loft insulation, cavity wall insulations, double glazed windows, and solar PV. There is also funding available for 60 homes in Nottingham done on a first come first serve basis. This is known as a whole house retrofit. This means within the whole house retrofit, there's a budget of up to £48000 for private properties only where they will have re-roof if it is needed, they would have double glazed windows if they are needed to be replaced or if they don't have any in, they would have solid wall insulations and then solar PV. We would also look within the property to make sure they have 100 percent led lighting throughout, and make sure hot water tanks have got the insulation. This was all done under phase 1B, and phase 2, and I can say they are working on something called sustainable warmth competition where Nottingham city council has been awarded 5 to 6 million pounds to continue this rollout for next year where funds are available for the same measures. There is quite a bit of work being done in the Nottingham city geographical area for privately owned properties and then a small proportion of privately rented properties can receive this funding too. This is a grant that is not asked to be given back. However, if a property is identified to be in an area of high deprivation and very likely to be in a property affected by fuel poverty then their household income is irrelevant. The important thing is that the property needs to* *be identified by our database. This means they will be eligible to have these changes made regardless of their income provided their property is a grade D or worse".*

This shows that the government is successfully implementing the prime ministers ten-point plan regarding sustainability in the residential sector. However, the measures available need to be communicated to residents to create awareness of the schemes available to them. This could be done through events or functions in the community centre in Nottingham.

11.1.9 Legal and Insurance Impacts of Solar Energy

The implementation of solar energy has been shown to be a viable process to help reduce costs of energy bills. However, the researcher was curious about the legal implications or insurance concerns with having solar panels mounted on resident's roofs.

- *"I can tell you that there's only one type of solar PV, and this can be owned by different people. Previously, when the Feed-In-Tariff was there, there were some schemes called rent-a-roof schemes where an individual could get a call to have a solar PV system fitted on their house and the individual can use the energy generated from the panels free of charge; however, the company that installed it will get their money back from the Feed-In-Tariff. The problem with these is that certain mortgage providers like Santander do not like them and would not offer mortgages with the rent-a-roof installed. If you own them yourself, then I have not heard of any issues where it is difficult to get a mortgage on there. In terms of your insurance going up, I can't see it going up if you have the right accreditations such as MCS certificates and building control have been notified, and you have got your safety certificates because these mean your system has been installed properly by the professionals, but I can't answer categorically whether it would make a difference or not. Personally, I think it would increase the value of the property. Now people are worried about how they are going to keep paying their energy bills. Now it is not too bad, but when we get into winter, and the boilers get used, also factoring people working from home. In all honesty, I am sure it would because all companies wherever they can legitimately increase your price, then there's an opportunity for them".*

This indicated that implementing solar energy does not have any legal or insurance implications on the residents. This also highlights the importance of residents using the right installer for their solar panels to avoid any legal or insurance issues from faulty installed equipment. The variables considered to be crucial in the implementation of renewable energy in the UK from Nottingham city council is shown below in Figure 11-1.

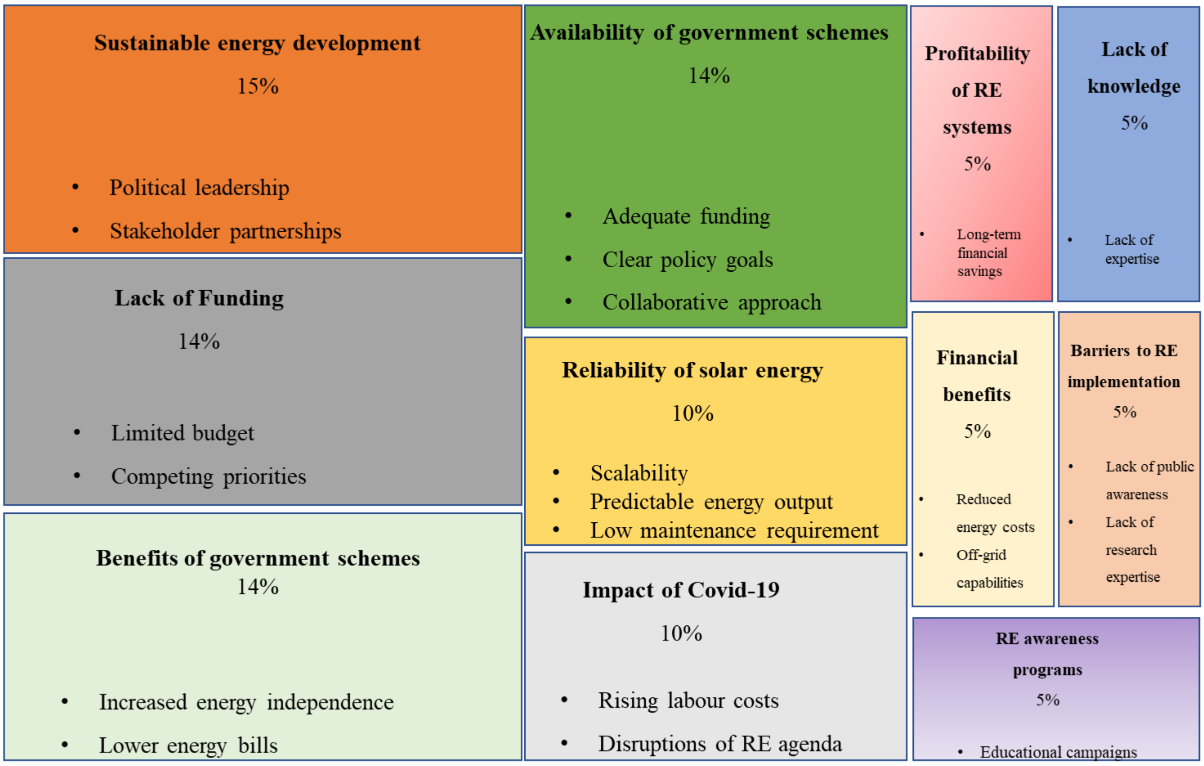

Figure 11-1: Hierarchy Chart of Nottingham City Councils' Perspective on Sustainable Energy Development in Nottingham, UK

Source: Reproduced from (NVivo QDA output)

In the development of sustainable energy, the sub-variables involve political leadership and stakeholder partnerships (15%). This is evident in the council setting targets, allocating resources, and developing sustainable initiatives. Additionally, the government schemes introduced have been quite beneficial to the council (14%). The sub-variables include increased energy independence and the corresponding reduction in energy bills. The availability of government schemes has enabled the council to have funds to implement a fabric-first approach to energy improvements and to address the challenges of houses identified to be enduring fuel poverty (14%). However, the council is faced with other financial issues. Regarding the lack of funding the sub-variables include the councils' access to limited resources and its competing priorities (14%). This is crucial because the lack of funding can result in gaps that impact renewable energy through a limited understanding of the deep-rooted issues in consumer adoption and the inability to effectively manage buildings. This is evident in the councils' inability to effectively handle asbestos in buildings with appropriate orientation to implement renewable sources such as solar energy. The reliability of solar energy has been pivotal to the councils' standpoint on implementing it (10%). The sub-variables include its scalability, predictable energy output and low maintenance requirement. It is also worth noting that its scalability to the energy needs of residents is impacted by the availability of roof space. Furthermore, the profitability of renewable energy systems has been evident in the Nottingham area (5%). The sub-variable responsible for its profitability is identified as the long-term savings gained from its implementation due to its long-life span. The financial benefits of renewable energy implementation include reduced energy costs and off-grid capabilities (5%). This is crucial as it could provide financial benefits to remote areas with unreliable grid connections. The impact of Covid-19 is also evident in the councils' implementation of renewable energy systems (10%). This is evident in the rising cost of labour and renewable energy equipment thereby disrupting the councils' renewable energy agenda. The barriers to renewable energy implementation include the lack of public awareness and the lack of research expertise in identifying the concern with consumers' concerns when considering the use of renewable energy sources. However, the council is prepared to introduce awareness campaigns to help raise awareness of the Nottingham Council initiatives.

11.2 Summary

This chapter analyses the growth of solar energy in Nottingham, the benefits of government schemes used to encourage the uptake of solar energy, the estimation of the production of a site chosen for solar energy, the challenges in the implementation of solar energy, the impact of Covid-19 on the growth of solar energy in Nottingham, the implementation of energy efficiency measures, promotion of renewable energy in the region, government schemes available, and legal and insurance impacts of implementing solar energy from the Nottingham councils' perspective. It shows that regardless of the pandemic, solar energy continues to grow in household implementation; however, with the rising cost of materials, labour, and solar systems in general, more residents would find it difficult to implement sustainable strategies. The next chapter provides the discussion of the findings and the conceptual framework.

Chapter 12: Discussion and Strategy for Renewable Energy Implementation in the UK

12.1 Introduction

In Chapter 6, a theoretical framework for renewable energy consumer adoption has been established. This provides the structure for supporting the research problem that aims to enable the UK to reach its goal of producing 100% renewable energy by 2025.

In Chapter 7, Spearman rank correlation coefficient is used to measure the degree of association between variables used in the public questionnaire. Using this method, problems involving linear associations can be solved. Using a scale of +1 through -1, the correlation coefficient is calculated. In a positive correlation, both variables must increase to achieve a positive result. In a negative correlation, one variable must increase, and the other must decrease to achieve a negative result. It is possible to identify the nature of future trends and predict their implications according to the best requirements when the variables have a positive or negative effect. Furthermore, variables define an event's nature, so the hypotheses established for this study are based on the nature of variables.

In Chapter 8, statistical analysis is provided regarding personal awareness and use of renewable energy sources in the UK, based on data collected from the public through a questionnaire. It has identified the attitude and use of renewable energy of the participants and the reasons hindering the adoption of renewables from a consumer's perspective.

Chapter 9 examines the results of the roof survey of 1838 houses and their use of solar energy or the lack thereof. It identifies houses in Nottingham based on their roof complexity, orientation, affluence, and impoverished nature. Furthermore, to understand the impact of the orientation of the houses in the selected area, a photovoltaic geographical information system is utilised (PVGIS). This enables the researcher to understand the difference in solar panel productions facing different orientations and seasons. It also estimates the energy bill savings and the CO_2 reduction from houses if solar panels are implemented.

Chapter 10 provided the analysis of 92 interviews with residents in the UK, of which 80 reside in Nottingham and 12 in other parts of the UK. The findings analysed various segments of the residents who implemented solar energy in their homes. They include the reasons for implementing solar panels, the financial benefits they have received so far, any issues they might have faced regarding maintenance, structural damages that might have occurred, and any legal implications of installing the panels. For the residents that have not implemented solar energy, the findings analysed the financial burden of bills on their households, the level of insulation in their homes, their awareness of renewable energy sources, and the issues hindering them from implementing renewable sources like solar energy.

In Chapter 11, an interview with a high-ranking member of the council was conducted regarding the growth of solar energy in Nottingham. It also investigated the benefits of the schemes deployed by the government, the challenges faced in the implementation of solar energy, the councils' perspective on the impact of Covid-19 on the growth of solar energy, the implementation of energy efficiency in homes, the promotion of renewable energy in Nottingham, the legal and insurance impacts of implementing solar energy, and the government schemes available for residents in Nottingham.

As this study aims to analyse the different stakeholder perspectives towards the implementation of renewable energy in the UK, the following research questions were formulated:

1. What underlying issues restrict the effective implementation of solar energy in the domestic urban environment in the UK?
2. What are the impacts of Covid-19 on renewable energy developments in the UK?
3. What are the essential factors in utilising renewable energy in the UK?

These questions were addressed by establishing the following objectives:

1. To investigate the challenges and opportunities in implementing renewable energy in an urban environment in the UK, using Nottingham as the case study.
2. To understand which renewables are primarily utilised in the residential sector and why?

3. To analyse the different stakeholder perspectives towards implementing renewables in the United Kingdom.
4. To establish the underlying issues that restrict the effective implementation of renewables in the UK.
5. To compare the United Kingdom's acceptance of renewables with a few developed and developing countries to understand the key factors that enable and restrict its effective implementation.
6. To establish ways of improving the issues involved with the stakeholder in the energy sector to provide recommendations to aid the implementation of renewables in the UK.
7. To develop a theoretical and conceptual framework for RE implementation.

Specifically, the discussion section focuses on the primary data collected through questionnaires, roof survey analysis, and interviews during this research in order to answer the established research questions.

12.2 Summary of the Findings from the Public Questionnaire

The questionnaire sought to understand participants' awareness of environmental preservation, the energy efficiency in their homes and the resulting impacts on their energy consumption. It also sought to analyse their understanding of the benefits and challenges of implementing renewable energy and if their energy providers promote energy efficiency and renewable energy utilisation. The results showed that most respondents have adequate insulation methods in their homes, with a high level of insulation (16%) and a medium level of insulation (54%). The participants also believe that renewable energy should be used to save the environment, with some stating that they strongly agree (40%) and some stating that they agree (46%). Participants are also aware of their role in the deteriorating rate of the environment resulting in global warming, with the vast majority stating that they strongly agree (48%) and some stating that they agree (37%). Participants also believe it is the joint responsibility of the government, businesses, and homeowners to tackle the climate crisis.

Furthermore, following the recent rise in prices of electricity, participants are struggling to pay their bills, with the vast majority stating they either always (21%), often (29%), or sometimes (39%) face financial difficulties in paying for their bills. Subsequently, some participants adopted the use of sustainable energy in their homes. When quizzed about the reasons that motivated them, they stated that the reasons involved the benefits of reduced energy bills (39%), improving the health of the public (14%), the stability of energy prices (14%), and to increase the value of their house in the market (5%). Following this, the researcher embarked on understanding the reasons hindering the participants from using renewable energy sources. Most notably, participants stated that they were concerned about the financial requirement (35%), the issue of no adequate space (14%) to implement the renewable energy source, and the lack of information (28%) to help their decision. Furthermore, they were concerned about the issues that may arise from the need for maintenance (7%), the legal issues they may face (3%), and the health and safety issues that may occur from implementing these sustainable measures (1%). Some participants also specified that because they are renting the house, it is the job of the landlords as they do not have the approval to make necessary modifications. Another participant stated that the age of the building is a concerning factor in making any modifications. Furthermore, another participant stated that they are unable to benefit from the Feed-in-Tariff; hence the sustainability measures would be difficult without the government's help. Some participants then specified that of all the renewables available, they would prefer solar energy (48%), while others stated they would prefer geothermal heat pumps (7%). However, participants also stated that the most crucial factors they would consider involve installation cost (30%), running cost (31%), the environmentally friendly nature of the energy source (18%), the switching cost between suppliers (13%), and the appearance (8%). Lastly, participants stated that they would prefer either 5 years payback period (35%), 3 years payback period (31%), 10 years or more (20%) or 1 year (14%).

12.3 Summary of the Findings from the Roof Survey

The roof survey sought to understand and analyse the growth of renewables such as solar energy in Nottingham. It utilised the analysis of roofs of residential homes based on their orientation, complexity of their roof design, and affluence and impoverished nature of the selected area. The sample size used in this analysis was 1838 houses. Subsequently, a photovoltaic geographical information system (PVGIS) is utilised after the researcher has identified the appropriate sample size. Using this tool, the researcher estimated the energy production of a PV system connected directly to the electricity grid without using any batteries on an average monthly and yearly basis. Findings showed that most houses selected for the roof survey analysis situated in the affluent area of Nottingham had no solar panels despite having the appropriate orientation.

Additionally, most houses in the impoverished area of Nottingham also had no solar panels despite having the appropriate orientation. However, it was identified that a house with a negative orientation had implemented solar panels on its roof among the houses in the impoverished region. The use of PVGIS also showed some key findings. The houses with their roof orientation facing due south experienced the highest production estimation for an average household in the UK using a 2kWp system. Furthermore, it was identified that from the month of May up until August, a south roof could supply over 80% of the energy demand of an average home in the UK. Subsequently, houses with their roof orientation facing west and east still produced considerable output but not as much as the south-facing roof. The CO_2 emissions were also calculated before and after using solar panels, and the results showed a significant reduction in the emissions. In the long run, this could help reduce carbon emissions drastically from the residential sector. To further emphasise the importance of implementing solar energy, the price cap of electricity is used to calculate the potential cost savings. The calculations showed that residents could save considerable energy bills by implementing renewable energy sources such as solar energy.

12.4.1 Summary of the Findings from the Interview with Residents Using Solar Energy

The interview with homeowners who implemented solar energy identified that financial savings and benefits were some of the critical factors that were crucial for their implementation. It also showed that the participants who implemented solar energy had not generally experienced any structural damage to their roofs or building. Lastly, the method of payment utilised by participants showed either monthly or full payments; however, participants mostly preferred to pay in full.

12.4.2 Summary of the Findings from the Interview with the Residents not Utilising Solar Energy

The interviews with residents who did not utilise solar energy showed that the respondents are also experiencing financial difficulties with paying bills. Another key finding showed that regardless of the homes' insulation level, the participants still experienced issues with paying bills. This indicates that using efficiency measures does not guarantee less energy use in homes. The majority of the participants also stated that they did not utilise any renewable sources in their appliances. This can prove to be a hindrance because RE could be improved if residents utilised more renewables in other aspects of their homes. However, when asked about the likelihood of implementing solar energy, an overwhelming 90% of the participants stated that they would. When quizzed about the issues hindering their implementation of renewable sources such as solar energy, the key findings from participants stated the financial reasons (40%), lack of information (14%), need for maintenance (13%), lack of adequate space (7%) were the most crucial factors. Other key findings showed that participants were unsure about the likelihood of selling the house in the future and its effect on the process. The roof compatibility with the implementation of solar panels and having to carry out energy-saving measures such as loft insulation before deciding on the possibility of solar energy were also key considerations. Lastly, a majority of the participants decided that a 5-year payback period would be best suited for them (52%), while the others decided 3 years (37%) and 1 year (10%) would be suitable for them.

12.5 Summary of the Findings from the Interview with the council

The findings from the interview with the Nottingham council identified some challenges they face in implementing solar energy in the area. Analysis of the interview identified a considerable growth of renewables and the benefits of using Feed-in-Tariff for solar energy implementation. However, the introduction of the Feed-in-Tariff was quite beneficial to the council in various ways, such as providing a financial return and a better understanding of their business model. There is, however, one crucial point to note as the council is also feeling the impacts of halting the Feed-in-Tariff scheme and the introduction of the smart export guarantee (SEG) scheme as they are having to restructure their business model. Subsequently, the council utilising industry-standard software is used to provide an in-depth understanding of factors that could be beneficial or detrimental to the success of a solar project. The interview also identified that there are financial issues also affecting the council with the lack of funding to carry out regular maintenance. This could also lead to issues considering the presence of asbestos in the roof of a building. Subsequently, the resulting impacts of inappropriate handling of asbestos could lead to hazardous health impacts.

Furthermore, the use of urban wind is identified as an option for energy generation from the residential sector; however, much research is needed before it is regarded as a viable alternative energy source for the residential sector. It also identified that regardless of the Covid pandemic, the solar PV industry continues to grow at an unprecedented rate. However, there are impacts on key components in the deployment of this renewable energy source, such as cost of installation, labour, and materials. Furthermore, there is also an increase in the rate of installations in new build domestic properties rather than older structures. Lastly, it identified schemes available to residents in Nottingham, but they would require methods to spread awareness, so residents are aware of the available schemes.

12.6 Research Question 1: What underlying issues restrict the effective implementation of solar energy in the domestic urban environment in the UK?

The purpose of this study was primarily to gain a critical understanding of these technologies and strategies by reviewing a wide range of literature on renewable energy technologies, strategies, and policy options globally and in the United Kingdom (Objective 1, 3, 5 and 7). There is still a problem with the dominance of fossil fuels in the renewable energy sector, but many countries are developing programs to develop renewable energy sources. Several reasons are contributing to the growing use of renewable energy, based on the literature review sources. There is a history of renewable energy and an increasing use of renewable energy today. These include disparities in oil prices also attributed to the emergence of the Covid pandemic and the crisis between Russia and Ukraine, which have caused some countries to experience economic crises. However, the environmental, economic, and social benefits that renewable energy offers continues to grow. The use of incentives such as feed-in-tariff has seen renewable energy sources such as solar grow exponentially globally. However, considering that the UK was among the last countries to implement the use of feed-in-tariff, they closed the program shortly after. This could prove to be a hindrance in the forthcoming years as its implementation helped increase the number of installations in the UK. Furthermore, the introduction of the SEG scheme also provides a viable alternative for residents that want to purchase renewable energy sources however they do not offer the same benefits offered by the use of feed-in-tariff. Analysis from a consumers perspective showed that residents in the UK are quite receptive of the idea of however the issues of regarding the cost of implementing and maintaining these equipment's may prove to be a hindrance. Another factor which is crucial is the lack of available space to install these panels. The UK housing design structure involves houses such as detached, semi-detached, and terraced houses. However, the complexity of the design of the roof can also hinder the implementation of the solar panels as there is not enough space to install the panels with altering the structural design of the house. Furthermore, the orientation of a house also impacts the installation of solar panels as a south facing roof offers maximum production than a west or an east facing roof.

12.7 Research Question 2: What are the impacts of Covid-19 on renewable energy developments in the UK?

To further analyse the growth of renewables globally, it was paramount to investigate the effect of Covid-19 on the energy sector (Objective 6 and 7). Following the declaration of the outbreak, sectors had to shut down as this was an ongoing situation. The resulting impacts showed that Covid-19 has had some impacts on the generation of energy in the UK. The government had to embark on swift efforts to comply with Covid-19 restrictions hit energy demand in 2020 from the economy, work, and leisure. Despite the growth of renewable energy sources such as bioenergy & waste, wind & solar power, nuclear output, fossil fuel output were however reduced due to the pandemic-related delay in maintenance activities at the North Sea. Subsequently, as part of its budget announcement for 2020, the UK government announced its spending plan for the year. In the outlined budget, Covid 19 issues were expected to be accommodated, including security measures and the impact on people and businesses. In this proposal, the government proposed to provide energy saving improvements to homes by providing vouchers worth up to £5000 to hundreds of thousands of homeowners.

Additionally, due to the Covid-19 pandemic lockdowns imposed from 2020 to 2021, UK consumption levels have been greatly affected since March 2020. A reduction in consumption was also caused by warmer temperatures in 2020, with an average reduction of 2.8%. This resulted in a reduction of heating degree-days from 5.4 to 5.1. Transport and air consumption decreased by 18% and 60% during the same period. The UK also experienced declines in various industries. Energy consumption in the service sector decreased by 5.6% during the lockdown as factories, shops, offices, and schools closed. Analysis of the Nottingham councils' perspective also indicated some impacts of Covid-19. It showed that the Covid pandemic slowed down work such as feasibility studies and other non-urgent work. However, the installations of solar systems continue to grow as this could be impacted by the continuous rise in the price of electricity. Furthermore, the cost associated with the implementation of solar energy continues to increase and this also adds to the cost incurred by the consumer which could prove to be a hindrance.

12.8 Research Question 3: What are the essential factors in utilising renewable energy in the UK?

An extensive literature review was conducted to explore the main factors influencing the implementation of renewable energy (Objective 2, 4 and 7). A significant part of this process involved identifying frameworks implemented globally to promote renewable energy, all of which implement effective mechanisms. There are a variety of reasons for this disconnect, including a lack of infrastructure, a lack of collaboration within the organisation, limited access to technology, and an insufficient number of training facilities. Furthermore, the implementation of renewable energy policies is crucial to the development of renewable energy. It is imperative that individuals understand the financial and technical aspects of net-zero emissions energy frameworks due to the growing number of public, sub-national, and organisational targets.

Consequently, there has been an increase in studies that investigate how to achieve these net-zero goals, although they are difficult to clarify due to contradictions across countries, differences in model constructions, and assumptions regarding inputs. Subsequently, energy strategies are primarily influenced by three factors: supply security, natural effects, and prices. Therefore, having a clear and focused energy policy is essential for achieving a national-scale energy transition. In the renewable energy industry, insurance is considered one of the key factors because it provides financial protection against project damage. These damages can occur during transportation, manufacturing, technical difficulties, or unexpected natural events. In any case, the insurer of renewable energy resources must provide adequate and reliable information regarding the severity of losses if any damage occurs. Another critical component of promoting RET deployment is the development of sustainable business models within the built environment. In addition to accessing capital and risk outsourcing, building owners may also be able to finance up-front energy costs by leveraging them. Business models often work best when the government changes legislation, for example, to promote business, to make them more effective. In spite of this, business models alone will not lead to significant increases in RET deployment. Studies stated that although RET and energy efficiency measures have many benefits, they are still largely unadopted in the built environment. Additionally, in order to implement sustainable energy in the built environment, new and innovative business models will be required to overcome one or more of these barriers.

Chapter 13: Developing a Conceptual Framework for Renewable Energy Implementation

13.1 Introduction

The use of conceptual frameworks can be used to assimilate various concepts and develop a deep understanding of the research phenomenon (Imenda, 2014). Therefore, a conceptual framework is a summation of disparate findings comprising the review of literature sources used to understand the research questions established in a study and primary data collected (Shikalepo, 2020). This is achieved by establishing a structure which formulates thoughts that clarify the focus of the research. Furthermore, a conceptual framework can be viewed as an approach scrutinising findings from a research analysis and providing relevance to the value of research. It also enables researchers to establish a process of integrating a methodological ecosystem to refine a study's effectiveness, methodology, and research design (Ravitch and Riggan, 2016).

13.2 Conceptual Framework for Consumer Adoption of Renewable Energy

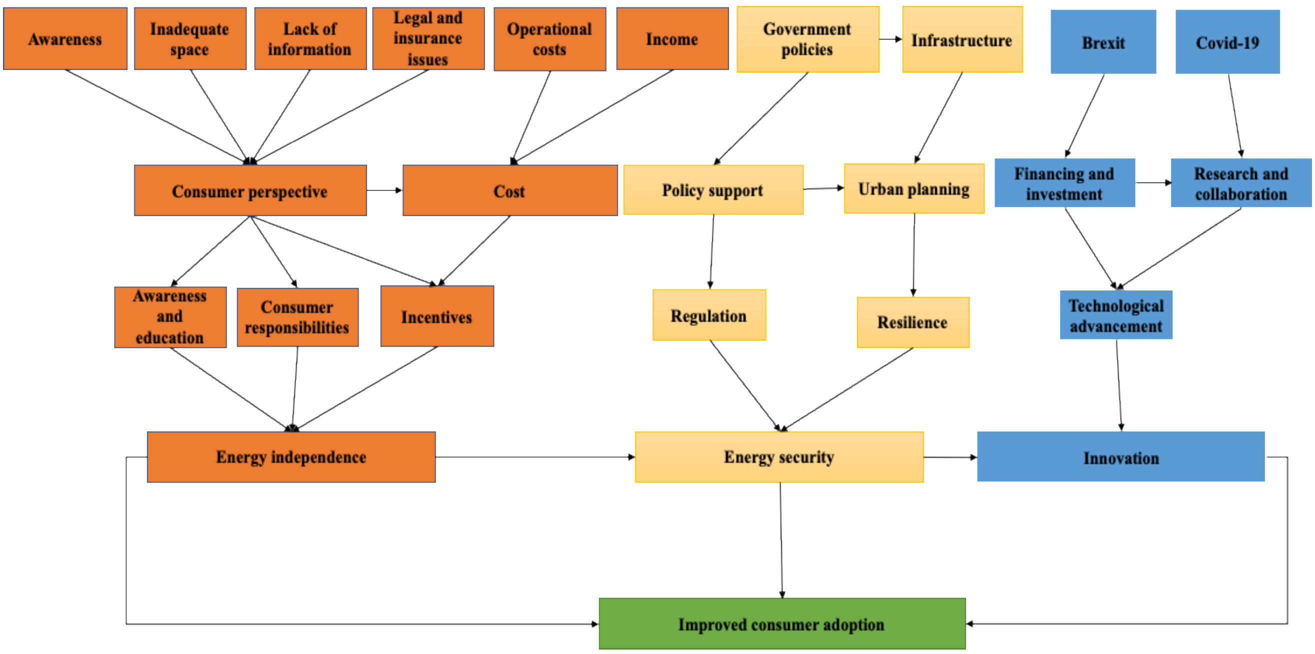

Figure 13-1: Conceptual Framework for Renewable Energy Consumer Adoption

Source: Author's Own

Figure 13-1 illustrates the conceptual framework developed for this study. The conceptual framework for this study is established to provide stakeholders in renewable energy projects with feasible recommendations to effectively increase the growth of sustainability in the urban environment. The proposed framework requires multi-actor partnerships to work collaboratively towards achieving the carbon emissions reduction goals set by the UK government. Regarding the consumers of renewable energy systems, it has been established that the issues prevalent include a lack of awareness of renewable energy sources and schemes to promote them, the lack of adequate space to implement renewable energy systems, the perception of the legal and insurance issues that may arise from renewable energy implementation, the operational costs required the systems, and the income earned from respondents. There was also a correlation between age and renewable energy adoption, qualification and renewable energy awareness, income and renewable energy adoption, and the use of renewable energy for the benefits associated. This includes the improvement of public health, the use of renewable energy for stable energy prices, and the use of solar energy as the preferred choice by respondents. Therefore, addressing the aforementioned issues can improve consumer perspectives and the cost associated with renewable energy systems. There are various ways this could be achieved. This includes education and awareness programs, making renewable energy to be more desirable to the younger demographic. This can be achieved by promoting renewable energy through digital engagement and providing incentives. Likewise, this could impact affordability, reliability, access, and equity.

Additionally, this could improve energy independence for consumers as this reduces the reliance on the supply of energy generated from natural gas and other non-renewable sources of energy. This could also be beneficial in situations where power outages occur (Roslan et al., 2019). Regardless, the use of renewable energy can help develop a stringent system for consumer adoption of renewable energy. Similarly, renewable energy providers are crucial in the development of renewable energy in the urban environment. They are impacted by the issues such as governmental policies and inadequate infrastructure. The use of governmental policies helps subsidise the cost of renewable energy for consumers and suppliers through schemes such as tax credits, feed-in-tariffs, smart export guarantee (SEG) and other financing and investment options. It has also been identified by the Covid-19 pandemic which highlighted the need to decarbonise the use of energy in the residential sector. The infrastructural factor is also crucial to renewable energy adoption as it supports the effective implementation of renewable energy in the UK. This includes investing in upgrading transmission lines, erecting new substations, and addressing the ageing infrastructure of the design of buildings. This could help reduce the maintenance costs associated with buildings and prevent issues such as the limitation of consumers being able to sell energy back to the grid due to the influx of renewable energy sources like solar energy (Dallinger and Wietschel, 2012). The government could address these issues through policy support and implementing urban planning. For instance, policy support would help encourage landlords to implement renewable sources in their rented buildings as they are responsible for the energy efficiency of their buildings as is observed in the responses from the questionnaire. Additionally, the utilisation of government policies for renewable energy could also reduce regulatory barriers and inherently ensure that renewable energy project developers are well equipped with the required expertise to effectively deploy and maintain renewable energy equipment.

Furthermore, urban planning has several benefits such as community engagement, cost savings, energy security, and promotes resilience. It incorporates renewable energy adoption in the design of cities to ensure that communities have unrestricted access to reliable and affordable energy sources. Using the roof survey case study, it can be seen that the majority of the buildings either have a negative orientation or have a complicated roof design. This is crucial because if a customer decides to implement renewable sources like solar energy, they are already at a disadvantage. After all, it won't be considered a viable option after the analysis of solar energy providers. Furthermore, many urban planners work on projects whose timelines extend decades into the future, making their profession ideal for forward thinkers. Therefore, planning efficient and long-lasting cities requires extensive research and development (Naphade, 2011). This is important because designing a city is a complex process involving many factors, and the city's future success depends on ensuring all of these factors are considered (Mycong, Jung and Lee, 2018). Residents' representatives, policymakers, public officials, and private sector producers are the main urban actors involved in urban transformation processes (Stoker and Mossberger, 1994). In terms of function and character, policymakers represent political power. If they reserve decision-making processes for themselves and maintain duplicity, then they can be authoritarian. This is crucial because a regulator coordinates sectors, whereas a manager mediator allocates public resources, works for the community, and acknowledges consensus (Margerum, 2011). Therefore, in this instance, a public official is a manager in an organisation that implements government policies (Lee, Neeley and Stewart, 2021).

Furthermore, private sector developers are characterised by their economic power (Mouton and Shatkin, 2020). However, it might be oriented toward controlling potential self-beneficial processes (Holden, 2015). Subsequently, several diverse groups are represented in the social sector, including the community and residents' representatives. Therefore, communal participation is crucial in urban decision-making (Sanoff, 1999). To support policies and urban planning, regulation from the government is required. This would provide specific guidelines and requirements for housing developers to incorporate sustainability measures into the design of buildings or risk the rejection of proposals to develop projects. This should include ensuring that building codes are met by utilising more sustainable and energy-efficient materials in building construction which could have a positive impact on the health and safety of individuals in the buildings and reduce congestion in cities (Quasim et al., 2021; Ejaz et al., 2019; Liu et al., 2021). Therefore, addressing the issues affecting providers of renewable energy could result in energy security and reduce the dependence on fossil fuels in the urban environment. The impact of the contribution of governmental bodies is at the pinnacle of renewable energy development. The regulatory changes post-Brexit have been beneficial as the UK is tasked with developing its regulations and standards that could improve the development of renewable energy. Subsequently, Covid-19 had an impact on the UK with the energy demand, energy prices, supply chain disruptions and financing and investment. This resulted in the costs of labour and materials for renewable energy systems like solar increasing and further increasing the difficulty for consumer adoption. However, the government have acknowledged the impact of the pandemic by prioritizing its sustainability goals and developing the prime minister's 10-point plan to tackle the issue. This has ensured that sufficient investment has been made to help promote public awareness and subsidise the cost of renewable energy. However, more research and development is required to further improve the UK's net zero emissions target. Furthermore, this study has identified that the use of built environment wind turbines (BEWT) can also help reduce the over-reliance on fossil fuels and could also be beneficial to buildings that are with a negative orientation and have complicated roof designs. This could eventually lead to technological advancement (Owen et al., 2012). However, this involves research and developments into smart grid infrastructure and a identifying more efficient ways of retrofitting the housing stock currently available. Ultimately, the effect of multi-actor partnerships between the consumers, governmental bodies, and energy suppliers would ensure that there is an increase in the support in councils’ and communities can benefit from the deployment of renewable energy.

13.3 Summary

In this chapter, the researcher discussed the conceptual framework for renewable energy consumer adoption. This outlines effective steps with practical scenarios of the impact of the established framework. It therefore suggests that with multi-actor partnerships between the consumers, governmental bodies, and energy suppliers, there could be an increase in the support and growth of renewable energy projects in councils' in the UK and communities can benefit from the deployment of renewable energy. The next chapter offers recommendations for policymakers, outlines the limitations of the study, and outlines potential areas for future research.

Chapter 14: Conclusion, Recommendations and Further Research

14.1 Introduction

This chapter summarises the research aim and objectives and discusses how the previous chapters contributed to achieving them. It then discusses several areas in which this study makes a valuable contribution, along with highlighting a number of caveats that must be considered when interpreting this study. Lastly, the last section of the study discusses potential avenues for further research.

14.2 Thesis Overview

This study aimed to analyse the different stakeholder perspectives toward implementing renewable energy in the UK. Chapter 1 outlined the contents of this thesis and provided demographic and geographical information about the United Kingdom. It also outlined the research problem, the research aim and objectives, and the corresponding research questions. In Chapter 2, during the literature review section, the researcher briefly reviewed the current renewable energy sources, their associated technologies, their characteristics, advantages, and disadvantages. Chapter 3 provided an analysis of the challenges and benefits of renewable energy implementation. This detailed analysis of policies, market drivers of renewable energy, commonly used renewable energy technology in an urban environment, use of feed-in-tariff both globally and in the UK, the introduction of the SEG scheme and its characteristics, impacts of Covid-19 on renewable energy generation, benefits of renewable energy implementation, and models of RE implementation. Chapter 4 identified and analysed the development of renewable energy in the UK. It highlighted the potential use of district heating in the UK to heat homes, the impacts of Covid on energy generation in the UK, the impacts of Brexit on the energy sector, and the impacts of inflation and rising energy prices. It also analysed the issue of fuel poverty, the feasibility of the prime minister's 10-point plan regarding greener buildings, the use of smart meters and its benefits, the impact of energy efficiency in homes, and the use of built environment wind turbines to supplement renewable energy generation in the residential sector. Chapter 5 provided insight into the requirements for solar energy implementation. It identified the different types of solar systems applications, a breakdown of the cost of components, the levelized cost of electricity (LCOE) of solar energy globally during a 10-year span, and the factors to consider for solar PV mounting. Chapter 6 developed a theoretical framework based on an in-depth analysis of literature. Chapter 7 identified the methodology utilised in this study. It explained their respective merits and pitfalls, as well as the rationale behind the choice of these methods for this research. It also highlighted the importance of utilising the right methods for efficient and effective research. Chapter 8 provided a statistical analysis of the data collected from the public in the UK regarding their awareness and use of renewable energy sources. It has identified the participants' attitude and use of renewable energy, and the reasons hindering the adoption of renewables from a consumer's perspective.

Chapter 9 analysed the different types of orientation of solar panels in Nottingham, UK, based on their roof complexity, orientation, and location using google earth and PVGIS. It then calculated the tCO_2e of an average household in the UK and compared it with the tCO_2e if solar energy is implemented regardless of the orientation. Chapter 10 discussed the responses of the interviews conducted from the interviews with residents in Nottingham, UK. It also identified relationships between themes identified during the coding of the interviews. Chapter 11 analysed the growth of solar energy in Nottingham from the Nottingham's councils' perspective via an interview. It also examined the benefits of government schemes used to encourage the uptake of solar energy, the estimation of the production of a site chosen for solar energy, the challenges in the implementation of solar energy, the impact of Covid-19 on the growth of solar energy in Nottingham, the implementation of energy efficiency measures, promotion of renewable energy in the region, government schemes available, and legal and insurance impacts of implementing solar energy. Chapter 12 discussed the data gathered for this study in relation to the research questions and objectives. Thereafter, a conceptual for renewable energy was established in Chapter 13 based on the findings from the literature review, questionnaires, roof survey and interviews in order to help the UK reach its target of providing 100% of its electricity with renewable energy by 2025. Based on empirical research and an analysis of best practices, the final chapter of this research (Chapter 14) provides actionable recommendations for policymakers and legislators in the UK on how to tackle the issue using empirical analysis and expert opinion.

This study has identified that effective multi-actor partnerships are crucial to the implementation of renewable energy in the urban environment in the UK. This study has also outlined the importance of behavioural change and its impact on energy consumption. It specifies that regardless of energy efficiency measures, responsible energy use in buildings should be prioritised. It has also identified the issues affecting the development of renewable energy in Nottingham, UK. The implementation of sustainability in the UK could also help with sustainable development such as the availability of green jobs, economic sustainability, environmental sustainability and social sustainability. This could also help the UK reach its target of providing 100% of its electricity with renewable energy by 2025. The study has also utilised an innovative approach of conducting the roof survey of buildings in Nottingham based on their affluence, poverty, orientation, and complicated roof designs. This survey method has several advantages over data collection methods. The assessment of solar energy potential previously had been performed through satellite images from large-scale studies and aerial photographs (Araya-Muñoz et al., 2014). However, the limitations of the aforementioned approach include the lack of accuracy and detail. The approach utilised in this study provides a more precise analysis to determine the suitability of the building in solar energy implementation. By leveraging this process, the government and councils in the UK can analyse the impact of urban planning in the development of the renewable energy agenda set by the UK. Furthermore, this study has provided findings that can help improve the UK's commitment to its sustainable development goals (SDG). This includes SDG 7 for affordable and clean energy, SDG 9 to develop sustainable and resilient infrastructure and SDG 11 for the development of sustainable cities and societies.

14.3 Recommendations

This study provides recommendations for policymakers in UK to reduce energy demand, promote renewable energy, and enhance sustainability in the residential sector. For sustainability to be achieved on a long-term basis, further government investments in renewable energy must be made. It should be used for the following purposes:

1. Educate all levels of the educational spectrum about renewable energy and increase public campaigning on these topics.

2. Promote awareness of government programs aimed at helping consumers convert to renewable energy sources.

3. In order to reduce energy consumption in residential settings, it is necessary to invest in building insulation and energy-saving technologies.

4. For insulation methods to work effectively, people need to be educated and encouraged to be disciplined in their usage of energy.

5. Develop other renewable energy sources, such as BEWTs, in addition to solar energy, and invest more in their development.

6. To encourage the installation of solar panels, landlords should be offered incentives . Nevertheless, the cost-effectiveness of renewable energy sources is paramount.

7. As an essential component of urban planning, it is imperative to develop policies for implementing sustainability measures. As a result, houses and cities will be designed to accommodate solar panels in the future instead of having complicated roofs and less-than-optimal orientations.

14.4 The Contribution to Knowledge

This study explored the use of renewable energy in the domestic urban environment in the United Kingdom in order to identify the barriers to its utilisation and propose feasible solutions. This study contributed knowledge by identifying the barriers to its growth in the following ways:

1. Critically reviewing literature relevant to global energy demand and renewable energy utilisation strategies, specifically those in the UK.
2. Analysing public opinion from stakeholders in the renewable energy sector in the UK about renewable energy usage and environmental concerns.
3. To equip governmental bodies and renewable energy suppliers in the United Kingdom with knowledge and understanding of the barriers and challenges facing renewable energy consumer adoption in the United Kingdom.
4. Providing unique insight into the domestic renewable energy sector in comparison to other interdependent factors such as social acceptance and lack of knowledge.

5. Contributing to developing effective renewable energy strategies and programmes by establishing an efficient theoretical and conceptual framework for using renewable energy.
6. To create awareness on the impact of urban planning in sustainability implementation when installing solar panels.

14.5 Limitations of the research

Due to the fact that limitations may arise from factors beyond the researcher's control or as a result of geographical and time constraints, it is unrealistic to expect any study to be faultless. In this study, the researcher faced several significant limitations, including:

1. A limitation during the interview stage was that the researcher hoped to collect all the interview data through face-to-face interviews, which would have provided additional information during the conversation. However, the issue of social distancing due to Covid and to ensure the safety of all parties involved, this wasn't suitable. Despite time and geographical constraints, the researcher obtained sufficient data through online interviews to answer the research questions.
2. There was also a limitation of not being able to collect pollution data from official sources or assess the impact of solar energy in the United Kingdom. A discussion about attitudes towards environmental preservation would have gained some additional depth if this had been included.
3. In contrast to face-to-face surveys, online surveys may be more likely to draw a specific group of respondents.

14.6 Further Research

In all projects, there are always going to be several questions that remain unanswered because of time constraints. This section proposes potential directions for further research into domestic renewable energy implementation.

1. Analysis of other stakeholder challenges and opportunities would develop a better insight to further improve the conceptual framework. This involves interviewing manufacturers of solar components, housing developers in the UK, mortgage providers, insurance companies and solar panel providers in the region.
2. Establishing a working relationship with energy providers before attempting to interview them could enable less resistance from companies.
3. Furthermore, an investigation of the future of solar PV could provide substantial evidence to enhance the awareness of the benefits of solar energy. This includes analysis of the use of solar energy beyond fields and rooftops, and the end-of-life management of solar systems through a life cycle analysis.

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Appendices:

Appendix I: Public Questionnaire

Page 2: Questionnaire

2. What country do you live in?

- ○ United Kingdom
- ○ Other

3. Sex

- ○ Male
- ○ Female

4. Residential status if living in the United Kingdom (UK):

- ○ Permanently resident in the UK
- ○ Living temporarily in the UK

5. Qualification

- ○ PhD
- ○ MA/MSc
- ○ BA/BSc
- ○ Diploma
- ○ Secondary school
- ○ Primary school
- ○ Other

6. Age range

- 18-24
- 25-34
- 35-44
- 45-54
- 55-64
- 65 or over

7. Occupation

- Student
- Civil servant
- Teacher/ University lecturer
- Self-employed
- Retired
- Freelancer
- Private sector employee / director
- Unemployed
- Other

8. How much is your household monthly income in total?

- Less than £1500
- £1500 - £2500
- £2500 - £3500
- £3500 - £4500
- £4500 or above
- Prefer not to say

9. What type of house do you live in?

- ○ Own house
- ○ Rented house
- ○ Own flat
- ○ Rented flat
- ○ Caravan/ traveller
- ○ Other

10. How do you describe your house or the flat you live in in relation to thermal insulation?

- ○ High level of insulation
- ○ Medium level of insulation
- ○ Poorly insulated
- ○ Don't know

11. If you are using renewable energy at home, please state why (Tick all that apply)

- ☐ Reduced energy bills
- ☐ Increase my house value in the market
- ☐ Stable energy prices
- ☐ Improved public health
- ☐ Other

12. If you don't use renewable energy at home, please state why (Tick all that apply)

- ☐ Financial reasons
- ☐ No adequate space
- ☐ Health and safety issues
- ☐ Legal issues such as insurance
- ☐ Lack of information about the technology to help my decision
- ☐ Reduce my house value in the market
- ☐ Mortgage issues
- ☐ Need for maintenance and life expectancy
- ☐ Other

13. What do you think about the following statement: It is the responsibility of home owners to reduce the United Kingdom's carbon footprint

- ○ Strongly agree
- ○ Agree
- ○ Neutral
- ○ Disagree
- ○ Strongly disagree

14. What do you think about the following statement: It is the responsibility of the governmental organisations and businesses to reduce the United Kingdom's carbon footprint

- ○ Strongly agree
- ○ Agree
- ○ Neutral
- ○ Disagree
- ○ Strongly disagree

15. What do you think about the following statement: We must use renewable energy to save the environment

- ○ Strongly agree
- ○ Agree
- ○ Neutral
- ○ Disagree
- ○ Strongly disagree

16. What do you think about the following statement: Global warming is caused by human activities

- ○ Strongly agree
- ○ Agree
- ○ Neutral
- ○ Disagree
- ○ Strongly disagree

17. Are electricity bills becoming financially a burden on your household?

- ○ Always
- ○ Often
- ○ Sometimes
- ○ Rarely
- ○ Never

18. Do any of your appliances use renewable sources?

- ○ Yes
- ○ No

a. If you selected yes, please specify

19. Are you using one of the following renewable energy sources (Please tick all that apply)?

- ☐ Solar energy
- ☐ Wind energy
- ☐ Bio-mass energy
- ☐ Geothermal energy
- ☐ Hydro energy
- ☐ Don't know

20. What are the crucial factors you would consider when deciding to switch to alternative sources of energy? (Please tick all that apply)

- ☐ Installation cost
- ☐ Running cost
- ☐ Environmentally friendly
- ☐ Appearance
- ☐ Switching cost between suppliers

21. Are you aware of the heat pump technology and its use in heating?

- ○ Yes
- ○ No

a. If your answer is yes, do you use it in your own home?

22. Which energy company supplies your gas electricity, Tick all that apply?

- ☐ Eon
- ☐ N power
- ☐ British gas
- ☐ Southern electric
- ☐ EDF energy
- ☐ Scottish power
- ☐ Don’t know
- ☐ Other

23. Does your energy supplier promote renewable energy?

- ○ Yes
- ○ No
- ○ Don't know

24. What payback period would you expect if you invest in renewable energy?

- ○ 1 year
- ○ 3 years
- ○ 5 years
- ○ 10 or more years

25. Which of the following would you think the United Kingdom should use more? (Please tick all that apply)

- ☐ Solar energy
- ☐ Wind energy
- ☐ Bio-mass energy
- ☐ Geothermal energy
- ☐ Hydro energy
- ☐ Don't know
- ☐ Other

26. Which of these renewable energy sources would you prefer to use at home?

- ☐ Solar energy
- ☐ Bio-mass energy
- ☐ Geothermal energy
- ☐ Hydro energy
- ☐ Don't know
- ☐ Other

27. Are you aware that electricity generated using renewable energy such as solar panels could save you money?

- ○ Yes
- ○ No
- ○ Don't know

28. Have the recent changes in gas prices affected your standpoint on renewable energy?

- ○ Strongly agree
- ○ Agree
- ○ Neutral
- ○ Disagree
- ○ Strongly disagree

< Previous

Finish ✓

Appendix II: The Interview Letter

Benjamin Nweke
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https://ntusurvey.onlinesurveys.ac.uk/solar-energy-interview

11TH April 2022

<u>Towards a Better Future: The Use of Solar Energy in Nottingham Homes</u>

Dear Sir/Madam,

At Nottingham Trent University, School of Architecture, Design and the Built Environment, we are conducting **anonymous** research to understand the challenges and opportunities in installing solar energy in dwellings to enhance the future of our society.
Our research team has noticed that you have solar panels on the roof of your house and therefore we are very keen to have a phone discussion with you about the reasons and the drives behind this positive approach to sustainability. We are interested to capture your experience with solar and explore why people install solar panels in their homes and the benefits that have been experiencing and challenged they might have faced.

You can answer our questions by scanning the above QR code to visit the website or simply by phone. Any phone discussions or on-line information will be anonymous, and no data will be collected about your address, name or contact details for this study.

My name is Benjamin, and I am a PhD researcher at Nottingham Trent University.
You can call me on 07494821454 or you could scan the QR code to answer the questions on-line.
I look forward to hearing from you soon.

Kind regards,
Benjamin

Appendix III: Solar Energy Usage Interview Questions

Nottingham Trent University

Interview about the impact, use and benefits of Solar Energy - Anonymous.

0% complete

Interview about the impact, use and benefits of Solar Energy - Anonymous. Please provide as much details as possible.

Do you have solar panels in your home?

- ○ Yes
- ○ No

How long you have you had the solar panels installed ?

Why did you install them, what were the main reasons ?

What financial benefits have you gained from them ?

Do you think the solar panels have reduced your monthly energy bill?

Did you face any problems with mortgages, insurance or any other areas?

Was there any water leaks from rain recently or in the past due to the solar panels?

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19TH May 2022

Towards a Better Future: The Lack of Use of Solar Energy in Nottingham Homes

Dear Sir/Madam,

At Nottingham Trent University, School of Architecture, Design and the Built Environment, we are conducting **anonymous** research to understand the challenges in installing solar energy in dwellings to enhance the future of our society.
Our research team has noticed that you do not have solar panels on the roof of your house and therefore we are very keen to have a phone discussion with you about the reasons and the limitations you may be facing. We are interested to explore why people don't install solar panels in their homes considering its benefits.

You can answer our questions by scanning the above QR code to visit the website or simply by phone. Any phone discussions or on-line information will be anonymous, and no data will be collected about your address, name or contact details for this study.

My name is Benjamin, and I am a PhD researcher at Nottingham Trent University.
You can call me on 07494821454 or you could scan the QR code to answer the questions on-line.

I look forward to hearing from you soon.

Kind regards,
Benjamin

Appendix V: Solar Energy Usage Interview Questions

Solar Energy Interview - Reasons for not implementing them

0% complete

This interview is part of an academic study for a PhD in Nottingham Trent University in the UK to understand the reasons why renewable energy sources are not being used in homes. It is an anonymous voluntary interview, and no personal data will be asked. Please do not hesitate to express your opinion based on your experience. This research aims to investigate the lack of renewable energy usage in the UK and globally and public perception towards the technology.

I have read the participation information sheet and I am happy to continue

- ○ Yes

Do you live in Nottingham?

- ○ Yes
- ○ No

Are electricity bills becoming financially a burden on your household?

- ○ Always
- ○ Often
- ○ Sometimes
- ○ Rarely
- ○ Never

How do you describe your house or the flat you live in in relation to thermal insulation?

- ○ High level of insulation
- ○ Medium level of insulation
- ○ Poorly insulated
- ○ Don't know

Would you like to implement renewables in your home?

- ○ Yes
- ○ No

Do any of your appliances use renewable sources?

- ○ Yes
- ○ No

Which of these renewable energy sources would you prefer to use at home?

- ☐ Solar energy
- ☐ Bio-mass energy
- ☐ Geothermal energy
- ☐ Hydro energy
- ☐ Don't know
- ☐ Other

Are you aware of solar energy?

- ○ Yes
- ○ No

Would you like to implement solar energy in your home?

- ○ Yes
- ○ No

What are the reasons hindering you from implementing solar energy in your home? (Please tick all that apply)

- ☐ Financial reasons
- ☐ No adequate space
- ☐ Health and safety issues
- ☐ Legal issues such as insurance
- ☐ Lack of information about the technology to help my decision
- ☐ Reduce my house value in the market
- ☐ Mortgage issues
- ☐ Need for maintenance and life expectancy
- ☐ Other

What payback period would you expect if you invest in renewable energy?

- ○ 1 year
- ○ 3 years
- ○ 5 years

Are you aware that electricity generated using renewable energy such as solar panels could save you money?

- ○ Yes
- ○ No
- ○ Don't know

Appendix VI: Roof Survey

Figure VI 1: Roof Survey 5

Source: (Google Earth, 2022)

Figure VI 2: Roof Survey 6

Source: (Google Earth, 2022)

Figure VI 3: Roof Survey 7

Source: (Google Earth, 2022)

Figure VI 4: Roof Survey 8

Source: (Google Earth, 2022)

Figure VI 5: Roof Survey 9

Source: (Google Earth, 2022)

Figure VI 7: Roof Survey 10

Source: (Google Earth, 2022)

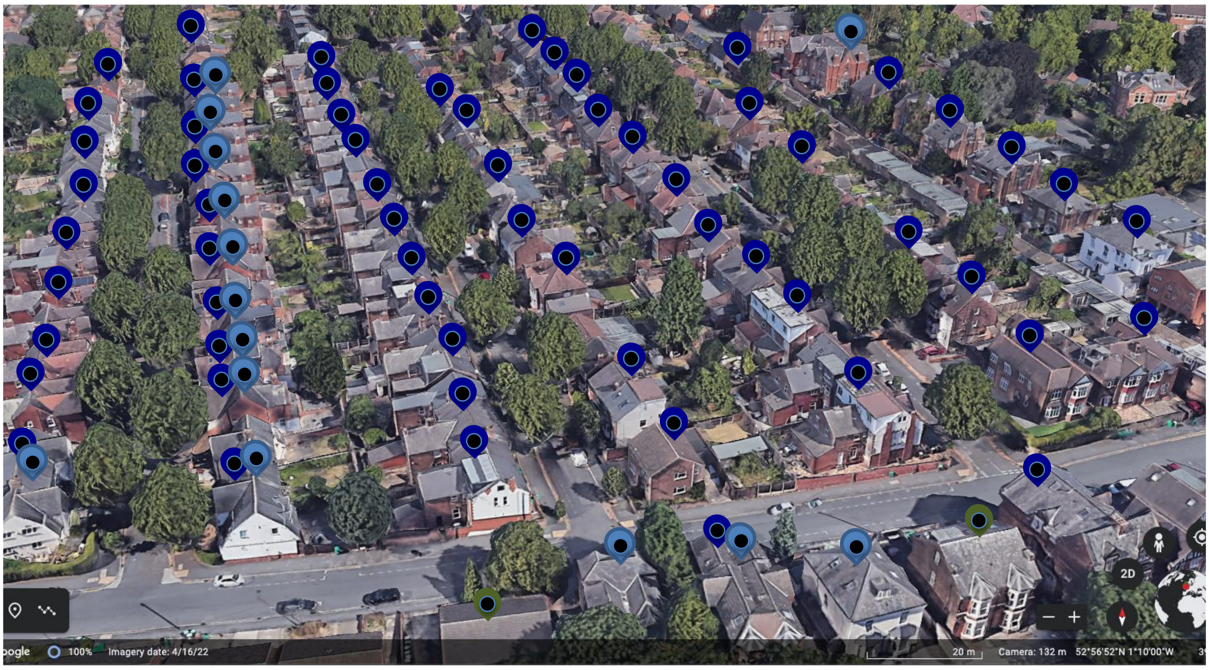

Figure VI 8: Roof Survey 11

Source: (Google Earth, 2022)

Figure VI 9: Roof Survey 12

Source: (Google Earth, 2022)

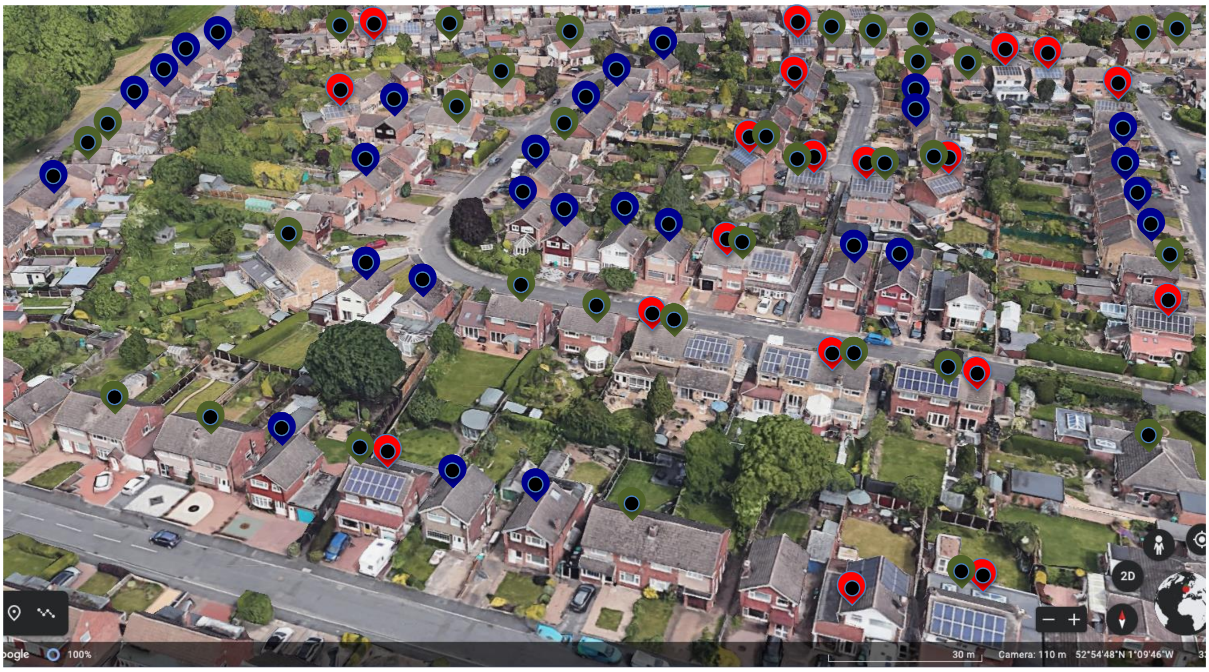

Figure VI 10: Roof Survey 13

Source: (Google Earth, 2022)

Figure VI 11: Roof Survey 14

Source: (Google Earth, 2022)

Figure VI 12: Roof Survey 15

Source: (Google Earth, 2022)

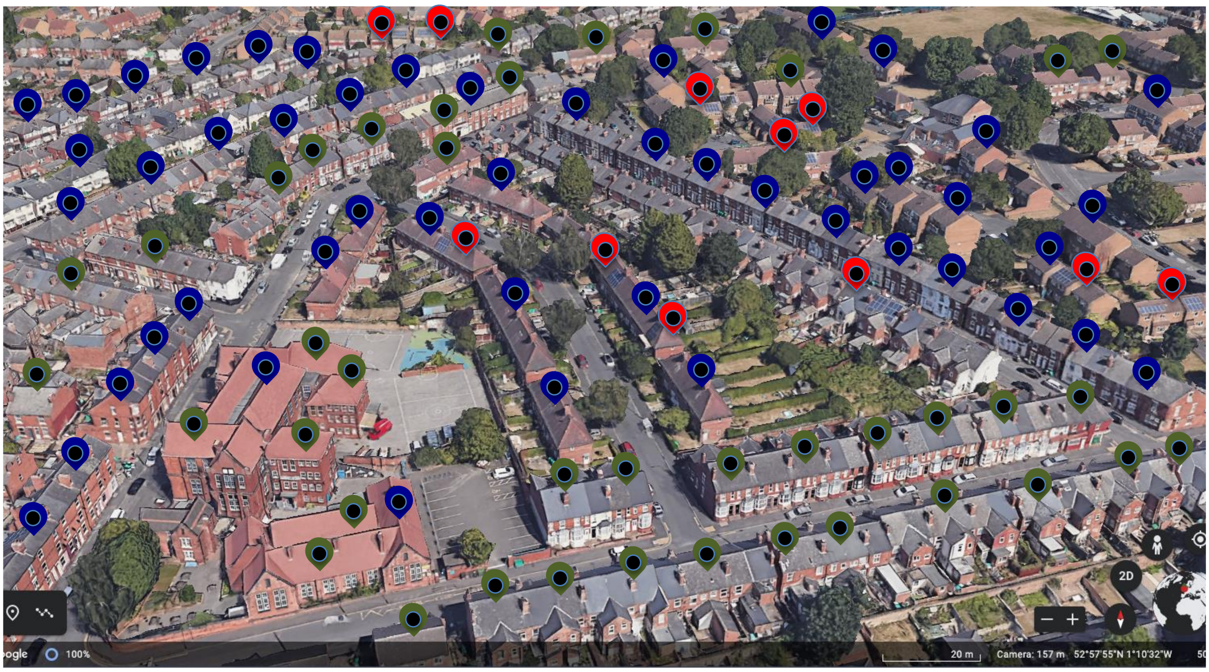

Figure VI 13: Roof Survey 16

Source: (Google Earth, 2022)

Figure VI 14: Roof Survey 17

Source: (Google Earth, 2022)

Figure VI 15: Roof Survey 18

Source: (Google Earth, 2022)

Figure VI 16: Roof Survey 19

Source: (Google Earth, 2022)

Figure VI 17: Roof Survey 20

Source: (Google Earth, 2022)

Figure VI 18: Roof Survey 21

Source: (Google Earth, 2022)