The environmental impact of renewable energy

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Keywords
Renewable energy, sustainable environment, Hydropower, Solar energy, Geothermal energy, Ocean energy, Bio energy

Abstract

Purpose: *The purpose of this study is to ascertain the environmental impact of renewable energy sources.*

Methodology: *The research combines a pragmatist epistemology and an exploratory, inductive technique. Using the United Kingdom as a case study, the study collects primary data on participants' perspectives, perceptions, and attitudes regarding the connection between renewable energy sources and the environment through a self-administered survey (with 400 subjects) and in-depth interviews (sample size 25).*

Findings: *Participants expressed worry about climate change and a keen understanding of the favourable effects of renewable energy sources on the environment, particularly in terms of pollution reduction, global warming reduction, and climate change mitigation.*

Practical Implications *- The primary rationale for increased calls for the transition away from non-renewable energy sources is the desire to mitigate their negative environmental implications. Renewable energy sources must be expanded to meet this goal. Additional study is needed to identify viable policy pathways for accelerating the transition to renewable energy.*

Originality: *To the best of the researcher's knowledge, this is the first study combining self-administered survey with 400 subjects and in-depth interviews with 25 subjects in the United Kingdom on the public's perspective of renewable energy, its status of development, hurdles, and role in mitigating global warming and climate change.*

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Introduction

Renewable energy resources, commonly referred to as clean energy sources, are derived from naturally replenishing sources. These are self-sustaining energy sources that exist naturally and can be harnessed indefinitely. Using fossil fuels has had disastrous consequences for the environment, the most egregious of which are global warming, climate change, and pollution that contributes to poor health outcomes (Perera 2018; Lelieveld et al. 2019). Each country must decide its energy portfolio in accordance with its energy resources endowment and accessible technologies that are socially equitable, commercially viable, and have the least negative environmental impact.

According to research, the current rate of usage of non-renewable energy would result in depletion. Global crude oil production has peaked and will begin to drop — indicating that crude oil stocks are

depleting (Bardi 2019). However, the primary source of concern has not been diminishing supply, but rather that demand will soon exceed the maximum quantity that can be extracted safely. This watershed event is most likely to occur at the global peak, when depleting reserves force cumulative production to peak and then drop; this is projected to occur soon. Although abundant oil supply is the bedrock of contemporary industrial economies, the ability to sustain and expand supply is increasingly an urgent challenge.

Renewable energy sources benefit society, businesses, and governments by reducing emissions, lowering energy prices, and promoting environmental sustainability. As a result, the beneficial effect of these sources on the ecosystem cannot be ignored. While significant progress has been achieved in bringing some renewable energy sources to reality, such as geothermal, solar, and wind energy, additional effort is required to maximise these sources' potential to generate sustainable energy on a worldwide scale. Renewable energy is critical for a variety of reasons. To begin, the future of the world population's health is contingent upon our capacity to phase out fossil fuels in favour of more environmentally friendly energy sources (Stagner & Ting 2021). Future generations turn to current generations to address the issue in order to ensure the long-term viability of a healthy and clean atmosphere and diverse ecosystems.

While extra study is required for some renewable energy sources (such as tidal energy), more mature renewable energy projects utilising wind, geothermal, hydroelectric, and solar energy can still be developed. By increasing the share of renewable energy projects, society as a whole, including individuals, corporations, and government agencies, will embrace clean energy. Renewable energy sources and technologies are commonly recognised as environmentally friendly; their optimal use minimises negative environmental impacts and generates little secondary waste. Additionally, they are sustainable in the context of current and future social and economic demands and needs. Renewable energy sources, in general, offer an excellent potential to counteract global warming and climate change by lowering greenhouse gas (GHG) emissions.

Research Rationale

The widespread and sustained use of non-renewable energy resources has grave consequences for human health and well-being; they are inextricably linked to the environmental repercussions of non-renewable energy resources, which are worth investigating. As a result, it's unsurprising that ongoing exploitation of these resources imposes a major health burden due to the environmental damage caused by the extraction, processing, and disposal of by-products, such as nuclear energy. The environmental impact of non-renewable energy supplies varies significantly depending on their source, such as nuclear energy, coal, natural gas, or oil. Climate change and global warming are two of today's most important issues. It has a variety of negative consequences for the environment and human health and well-being, including extreme weather events such as heatwaves, flooding, storms, hurricanes, and droughts, which frequently wreak havoc and inflict enormous misery and even death.

The overall balance has a detrimental effect on health. The 2003 European heatwave demonstrated that high-income, industrialised nations are not immune to climate change. Climate change, as exemplified by the greenhouse effect and global warming, is the most serious environmental problem related with energy production and consumption. Energy production, mostly through the combustion of fossil fuels, is critical to resolving the issue.

GHG emissions, particularly methane and carbon dioxide, are undoubtedly the most well-known and significant consequence of the current over-reliance on non-renewable energy supplies, prompting considerable worry about their role in fueling climate change. For example, carbon dioxide emissions from energy use contribute considerably to global warming in Europe, accounting for around 75% of

man-made GHG emissions in the EU, mostly from coal burning (Eurostat 2021). While natural gas emits substantially less carbon dioxide than coal, this does not mean that it is an effective means of mitigating climate change, as drilling and extraction frequently result in methane leaks. Methane is five times more effective as a GHG than carbon dioxide at trapping heat. Climate change has an impact on energy demand and supply in terms of resource availability, exploitation, and transportation. In other words, climate change has an impact on energy policy across all industries. Unsurprisingly, governments are turning to renewable energy sources to mitigate climate change by reducing GHG emissions, so avoiding the health and environmental consequences associated with non-renewable energy sources such as fossil fuel combustion and nuclear energy.

Research Aims and Objectives

The purpose of this study is to ascertain the environmental impact of renewable energy sources. The study is primarily concerned with the following specific objectives about the effects of renewable energy sources, particularly on environmental sustainability.

- Identify the key renewable energy sources that can be used to mitigate global warming's effects and advance environmental sustainability.
- The effect of renewable energy on the long-term viability of the environment
- Identify the impediments to the implementation of renewable energy projects aimed at enhancing the global environmental sustainability framework while reducing greenhouse gas emissions that contribute to global warming.

Literature review

The Nexus between the Energy Sector and the Environment

Numerous studies have been conducted on climate change and global warming, and some have found that humans and human activities are primarily responsible for undesirable changes. Fossil fuel burning ranks among the top contributors to increased GHGs emissions (Perera 2018; Lelieveld et al. 2019; Welsby, Price, Pye, & Ekins 2021). This constitutes a reasonable basis for questioning the argument that global warming and climate change result principally from natural processes. Volcanic activities, for example, emit a paltry 300 million tons of carbon dioxide annually, accounting for only 1 per cent of the net carbon dioxide emission in a year (Prothero 2017; Prothero, Shermer, & Linse 2017). Prothero (2017) further argues that technological changes will not suffice to forestall the temperature increase limit by 1.5 °C. Attaining this objective is contingent on changes in human behaviour, including lifestyle changes intended to reduce energy consumption from vehicular traffic that relies on fossil fuel obtained by refining crude oil. This suggests that global warming, climate change, and the fate of humanity rests on its capacity to achieve energy efficiency in the near future.

Over the last decade, changes in climatic conditions have caused global temperatures to increase. Dai et al. (2022) conducted an exhaustive study of the role of the energy mix in climate change vulnerability. They found that sudden climate change increased the average global temperatures over the last few decades and resulted in the melting of polar glaciers and ice sheets and the cryosphere shrinking. There is a consensus in the literature that climate change constitutes the greatest threat to ecosystems' stability. Fossil fuels are a leading reason for the rapid global temperature increase. Burning fuels such as natural gas, oil, and coal to produce electricity to power factories and homes releases vast amounts of carbon dioxide, which traps surface radiation from the sun, resulting in the greenhouse effect that causes global warming. According to Dai et al. (2022), as a notable part of the energy sector, electricity generation is responsible for 25 per cent of GHGs emissions, illustrating its steep impact on global warming and climate

change. Its effect on climate has other spillover impacts on other vulnerabilities, including food security and health.

Although power generation constitutes the primary channel through which the energy sector affects the environment, it is possible to reduce venerability and its negative impacts through increased reliance on renewable energy resources. Barnes & Samad (2018) remark that industrialised and developing countries are not different concerning their reliance on traditional electricity production methods. Dai et al. (2022) share the same view, noting that the EU used 40 per cent of its primary energy supply to produce electricity in 2005 and that 55 per cent of the electricity generated in the region was from burning fossil fuels. Energy is an essential factor in long-term economic and social development. However, contentious energy sources, particularly non-renewable energy resources, have significantly burdened the environment through their climate change impact.

The undesirable impacts of the heavy reliance on non-renewable energy sources are widely acknowledged in the literature. Shah (2017) and Vengosh and Weinthal (2022) note the close link between water utilisation and energy production by emphasising energy production's heavy dependence on limited water resources. The multidimensional dynamic between energy production and water consumption is a cause for concern due to the limited availability of water resources. Nearly all energy production methods rely on water; these processes consume a vast amount of this precious yet limited resource. Most non-renewable energy sources must burn fossil fuels such as coal or natural gas to produce energy. The vast amounts of heat produced during this process boils the water required to produce the steam used to spin the turbines, generating electricity. The processes involved in refining fuels used in transportation, coal mining, and even growing crops used in biofuel production all require water (Arshad & Abbas 2018; Carmona-Moreno 2021). Humanity's failure to drastically change the current energy production methods will inevitably result in undesirable environmental ramifications.

The link between the energy sector and the environment is evident in water pollution, a consequence of unsustainable energy production methods. According to Mohamed (2020), the intimate connection between energy production and water consumption means that issues inevitably lead to problems for the other, resulting in dangerous implications for water pollution and aquatic plants and animals. The veracity of this argument is not difficult to see. The water used for energy production, such as in coal-fired plants, is often pumped back to the source, usually rivers, lakes, streams, and similar water bodies. According to Righter (2014), a study by the Union of Concerned Scientists revealed that comparing wind and coal power revealed that coal generation causes soot, smog, and acid rain and generates heat (which causes global warming) toxic chemicals.

Righter (2014) further notes that mining, transporting, and storing coal consumes enormous amounts of energy even as it pollutes water and land while disposing of the sludge and ash resulting from the process creates additional environmental problems. Most importantly, coal-fired power plants use unsustainably high amounts of water (estimated at 2.2 million gallons annually for a 500 megawatts coal plant). The water returned to the source is between 20°C and 25°C warmer, resulting in thermal pollution that reduces the fertility of aquatic animals and increases their heart rate (Righter 2014). Moreover, the water that returns to the source is usually dangerously toxic for the environment and humans. The heavy reliance on water to produce non-renewable energy is hurting the environment by choking aquatic life and threatening marine ecosystems. While non-renewable energy sources provide short-term benefits, the high cost they impose in terms of chronic disease, water and air pollution, and noise pose a danger to the environment and human and aquatic life. Dai et al. (2022) emphasise that emissions from burning fossil fuels include carbon dioxide and other toxic air pollutants; these affect the environment negatively and pose a considerable threat to children's cognitive and behavioural development.

Water and food scarcity is among the foremost challenges associated with climate change. Dai et al. (2022) observe that the brisk population growth rate will push water demand to 12,400 cubic kilometres by 2050 from the current 6,800 cubic kilometres. The authors also note that a deficit of 3,300 cubic kilometres will persist even after improving irrigated agriculture's efficiency and management. The energy sector can contribute to the transition to more sustainable energy sources through investments in renewable energy sources and green, renewable energy. In this regard, the literature widely acknowledges that hydroelectric, solar, and wind power are mostly free of the significant environmental impacts that typify non-renewable energy sources (Spellman 2014; Breeze 2019). Unlike power plants that rely on fossil fuels, renewable energy sources do not produce toxic contaminants such as nitrogen and sulphur oxides and methane and carbon dioxide that damage the environment through acid rain and global warming.

Kominkova (2009) notes that hydropower projects often cause temporary emissions from equipment and dust pollution and that flooding and vegetation decomposition during the reservoir creation process often release GHGs such as carbon dioxide and methane. However, not only is the magnitude of these effects contingent on the project's location, magnitude, age and the amount of flooded soil carbon and vegetation, but their impact also pales compared to the ongoing emissions from fossil fuel-powered plants. Through renewable energy sources, the energy sector can contribute to climate change mitigation by reducing GHGs and air pollutants compared to using biofuels or fossil fuels. The significance of such an intervention is evidenced in the consensus in the literature that climate change adaptation and mitigation rank among the notable challenges of the twenty-first century (Brooks et al. 2019). The high dependency on fossil fuels and the increasingly global energy consumption is at the core of the said challenges. Therefore, success in mitigating climate change and global warming from the energy sector will require the sector to embrace clean, renewable energy. The EU and similar bodies have a crucial policy role to play in making this energy transition a reality.

The Available Renewable Energy Mix

Policymakers globally are prioritising efforts to reduce GHG emissions to contain climate change and global warming; this is the case for the EU and other regions. Although no transnational agreements exist within the renewable energy mix context, politicians have been promoting programs that ramp up carbon dioxide reduction and promote economic decarbonisation through promoting renewable energy resources (Wozniak, Badora, Kud, & Wozniak 2022). Renewable energy derives from natural and eternal energy flow in the environment and includes direct solar energy, hydropower, bioenergy, ocean (tidal) energy, wind, and geothermal energy. Indeed, Europe, and most parts of the world, are endowed with most or all of these resources.

1. Hydropower

Hydroelectric power is a crucial part of the global energy mix harnessed from moving water, usually rivers and streams. The water's kinetic energy is used to turn turbines that, in turn, generate electric power. Most hydropower projects often include dams with reservoirs, in-stream projects, and run-of-rive projects and differ significantly in project scale. Hydropower is a mature technology that contributes tremendously to the transition to cleaner energy sources. According to Owusu and Asumadu-Sarkodie (2016), how hydropower reservoirs operate provides additional health and security benefits beyond clean, renewable energy. For example, reservoirs are essential elements in the food security and drought control matrix; they provide water for irrigation, drinking water, and sustainable fishing activities. Most importantly, it provides energy using natural mechanisms that rely on gravity, significantly minimising

any negative impact on the environment. The mass of the water stored in the reservoir determines the potential energy.

According to Owusu and Asumadu-Sarkodie (2016), the primary advantages of hydropower as a renewable energy source is that it releases no particulate pollution, is easily upgradeable, and can store energy for a long time. For example, Li, Lin, and Xu (2021) study examined the air pollution problem in China within the context of hydroelectric generation. Air pollution from haze and smog is pressing public health and environmental problem in China, especially in high polluting areas typified by spatial agglomeration. Li et al. (2021) found that hydropower can inhibit haze while promoting sustainable economic growth; renewable energy sources such as hydropower can ensure energy security while also contributing to the United Nations Sustainable Development Goals. This points to the significant potential role of hydropower in mitigating climate change and ensuring a healthy environment, especially considering that the current installed hydropower capacity is far less than the resource's potential. The underutilisation of hydropower point to the immense potential of renewable energy sources to ensure energy security and their potential role in mitigating the undesirable effects of non-renewable energy sources on the environment.

2 Solar Energy

The term 'solar energy' is often used to define or label several technologies. These include photovoltaic cells that convert direct sunlight into electric energy and solar thermal systems for heating water, and systems that rely on sunshine to heat fluids, directly or indirectly, to produce steam that produces electricity by turning a turbine. It also refers to passive solar systems, which utilise innovative constructions techniques to maximise the benefits of solar irradiance using windows, openings, and building materials. According to Zaręba et al. (2022), there is no dearth of sunlight in most world regions, which presents a considerable potential to provide plentiful, clean energy while reducing humanity's dependence on non-renewable energy sources. "Direct" solar energy technologies rely on the sun's direct solar energy, such as photovoltaic technology. Some technologies – such as ocean thermal and wind energy – rely on solar energy directly after its absorption on the earth and conversion to secondary forms. However, using solar irradiance directly for electricity generation or concentrating it to meet lighting needs and produce thermal energy fall under "direct" solar energy.

Citing the World Energy Council data, Owusu and Asumadu-Sarkodie (2016) contend that the net energy from solar radiation reaching the earth's surface far exceeds 7,500 times the global energy consumption. Solar energy promises to reduce GHG emissions tremendously. Replacing half of the thermal electricity production from fossil fuels with photovoltaics would reduce global carbon dioxide emissions within the next three decades. Several projects have been initiated to assess photovoltaic systems' feasibility (Bush 2020). In this regard, Fouquet (2018) notes that the capital expenses for small photovoltaic projects make them suitable for household investment, decoupling any dependence on industry or government power sources. This makes small-scale photovoltaic projects particularly attractive to remote rural areas not served by national grids or where electricity grids have been slow to expand.

Whether solar energy – including photovoltaic and passive solar technologies – can and will be a crucial part of the renewable energy mix and its role in climate change policy depends on their economic feasibility. However, it is evident from the literature that solar energy systems and other non-carbon emitting energy sources have the potential to reduce future GHG emissions considerably. Regrettably, the present economics are such that solar energy is a tiny part of the energy mix. According to Levenson (2017) and Mohd (2017), in the absence of technological breakthroughs to make photovoltaic systems

cheaper, widely available, and improve power conversion and storage efficiency, widespread adoption will remain a challenge.

3 Geothermal Energy

Geothermal energy is the energy that derives naturally from the heat inside the earth's core; it is associated with the planet's internal structures and the physical processes occurring therein. According to Owusu and Asumadu-Sarkodie (2016), while the heat found in the earth's crust and its deeper sections is tremendous, it is seldom concentrated and occurs at depths too vast for mechanical exploitation. Some areas of the earth's inner parts can be drilled to access geothermal power and the steam extracted from geothermal reservoirs utilising wells. Studies have documented the potential of geothermal energy in mitigating climate change. Bromley et al. (2010) contend that the environmental impact of geographical developments is relatively negligible. Compared to other energy sources, geothermal energy's relatively tiny carbon footprint for surface facilities – such as pipelines and power plants – present a significant environmental advantage. However, they also caution that disposing of the wastewater that often has contaminants (such as arsenic, mercury, and boron) and gases such as carbon dioxide and hydrogen sulphide are significant issues with geothermal energy extraction.

Although geothermal energy is not without its environmentally damaging by-products, various innovative methods have been devised to deal with the problem. Examples of these methods include reinjecting all the gases, water, and condensates back to the ground and mineral extraction and chemical treatment (Soysal & Soysal, 2020). Similarly, Bromley et al. (2010) emphasise that cost of treating geothermal waste is meagre, typically between 1 and 2 per cent of the generation cost. As high-temperature systems, geothermal power plants often produce natural carbon dioxide exhausted from the steam turbines. However, this is usually less than 10 per cent of the net carbon dioxide emission from fossil fuel combustion; carbon dioxide emission from low-temperature geothermal emissions is insignificant (Bromley et al., 2010).

It is evident from the literature that technical potential is not a restricting factor concerning future geothermal energy utilisation. As Marope, Holmes, and Chakroun (2015) remark, the rate of geothermal energy adoption will be contingent on material limitations, demand, economics, and social factors. In this regard, Bromley et al. (2010) note that electricity generation from already identified geothermal resources will potentially grow from the current 10-gigawatt electrical (GWe) to an estimated 140 GWe by 2050. The authors are confident that 70 GWe will be attained using already existing geothermal power generation technologies and that the remaining is attainable only if available technologies mature as anticipated. There is no doubt that offshore geothermal resources and terrestrial resources with no apparent surface manifestation are yet to be discovered; their successful development could add thousands of GWe in the future. The potential of geothermal energy to contribute to GHG emissions reduction, particularly carbon dioxide, is contingent on each region's energy diversification. There will always be more potential to reduce GHG emissions and contribute positively to climate change mitigation in places where fossil fuels constate a significant share of the overall energy mix, such as in Europe and most parts of the world.

4 Ocean Energy

Ocean energy, broadly categorised into tidal and wave energy, has been harvested for a few decades. Nevertheless, the increasing concern on the impact of non-renewable energy sources on the environment in recent years has resulted in the ramping up of research endeavours and the development of new technologies to harness ocean energy's immense potential for electricity generation. Various governments, business organisations, universities, and utility companies have invested tremendous amounts of financial and technical resources toward realising the potential that ocean energy promises, currently accounting

for a negligible proportion of the net energy generation resources (Smil 2016; Moriarty & Honnery 2022). Climate change through GHG emissions reduction is among the fundamental drivers of power generation using ocean energy because it is an entirely renewable, 100 per cent reliable, and predictable energy source. Ocean energy partly relies on another distinct renewable energy source: wind power. Although renewable energy in its own right, wind energy still constitutes part of the ocean energy mix because it is part of wave energy.

Ocean energy – often considered an environmentally friendly and clean renewable energy source – is slowly becoming a prominent part of the renewable energy mix. According to Owusu and Asumadu-Sarkodie (2016), a key benefit of ocean power is its consistency all year round compared to other renewable energy resources – such as solar energy and wind – because of the moon's unvarying orbit around the earth. According to Neill and Hashemi (2018), ocean power generators can be categorised into the oscillating water column (OWC) and tidal turbines. The former utilises ocean waves by compressing air in closed chambers, forcing wind to flow through turbines. Overall, ocean energy is currently the costliest to develop of all renewable energy resources; this gap is likely to increase with the plummeting solar and wind power prices. Nevertheless, Owusu and Asumadu-Sarkodie (2016) observe that the evolution of the technology and the espousal of new policies to facilitate its implementation paves the way for new marine renewable energy sources that will likely attract private sector investment. This ultimately makes ocean energy more competitive and contributes to its capacity to contribute meaningfully toward climate change mitigation.

5 Bioenergy

Bioenergy refers to renewable energy sources derived from biological sources, including biodiesel used for transportation and electricity generation. Electricity generation, for example, attracts various biological sources, including biogas from animal waste and compost material, as well as bioethanol from crops such as sugarcane, soybean, wood chips, wheat straw, and corn. According to Belyakov (2020), a key benefit of energy generation from bioresources is that it is frequently a residue or by-product. It does not result in competition between land resources for fuel and land for food production. Currently, worldwide biofuels production is relatively low, although the repertoire of bioresources for energy production has been increasing. As Owusu and Asumadu-Sarkodie (2016) note, while biodiesel consumption in the US alone stood at 15 billion litres as of 2016, the growth rate stands at between 30 and 50 per cent annually and stood at 30 billion litres as of 2012. Bioenergy potential is vast enough to meet the GHG emissions reduction objective while simultaneously ensuring the future supply of renewable energy.

Methodology

The current study adopted an exploratory, inductive approach. The exploratory approach attempts to answer pressing questions, such as the continued reliance on non-renewable energy sources and the potential for large-scale adoption of renewable energy sources to mitigate the detrimental impact of fossil fuels on the environment. The basis of the exploratory approach is investigating the cause-effect relationship. Similarly, the inductive approach begins with research aims, questions, and objectives that need to be addressed during the research. As Jebb, Parrigon, and Woo (2017) note, given the interdisciplinary nature of academics, scientific progress can be maximised only when inductive and deductive approaches are mingled. Therefore, the researcher felt that employing an exploratory, inductive approach should be encouraged, thereby informing the reliance on exploratory data analysis to identify, explore, and empirically establish the veracity of the phenomenon of interest.

The study is based in the UK. According to UK's Department for Business, Energy & Industrial Strategy (2022), as of 2020, renewable energy sources – particularly biomass, wind, hydropower, and solar

– made up an estimated 43 per cent of the United Kingdom's 312 TWh domestic power production. Electricity production from renewable sources plummeted considerably due to unfavourable weather in 2021. The Department for Business, Energy & Industrial Strategy (2022) further notes that wind dropped 14 per cent, worsened by reductions in solar and hydropower generation. The current study employs a case study strategy to examine the potential for renewable energy sources to mitigate climate change due to their favourable impact on the environment.

This study utilised the survey method using a simple probability sampling where a small group of participants were randomly selected from the target population; a sample size of 400 individuals was determined. The self-administered survey approach proved the most convenient for the researcher.

The survey questions were open-ended and required the respondents to convey their views and opinions concerning renewable energy trends, the role of renewable energy resources in mitigating climate change, and their benefits to the environment. The survey also utilised a 5-point Likert style questionnaire that required participants to indicate whether they were concerned about climate change and global warming; responses ranged from "highly concerned" and "highly unconcerned."

To shed more light on the state of renewable energy resources, this study relied on semi-structured interviews with energy sector stakeholder representatives – including environmental organisations, regulatory bodies, and energy producers and distributors – and households. The sample size 25. According to Pradeep (2021), the sample size must be sufficiently large to adequately describe the phenomenon being studied while simultaneously avoiding repetitive or redundant data. Qualitative research aims to attain saturation or the point where including more participants does not yield additional information or perspectives. This is sometimes known as the point of diminishing returns with a large sample because it yields more data but not necessarily more information or perspectives. Pradeep (2021) further notes that 20 to 30 participants seem a good number based on research on the issue. Some studies with as few as 10 participants have been successful and yielded applicable results. Therefore, this study settled on 25 interview participants as the ideal sample size.

Interview participants were selected using snowball sampling, where the researcher sent an invitation to potential participants who forwarded the invitations to their acquaintances. This way, the respondent population progressively grew larger. The researcher recruited only the first few respondents consistent with the profile of the required participants. The recruited participants then referred others with the same attributes that the researcher sought. The researcher conducted the interviews online because of the ongoing concerns about COVID-19. However, this greatly hindered some finer attributes of semi-structured interviews, particularly information conversation before, during, and after interviews. The researcher first sought participants' informed consent before conducting the interviews.

Findings

Figure 1: An overview of participants' socio-demographic data

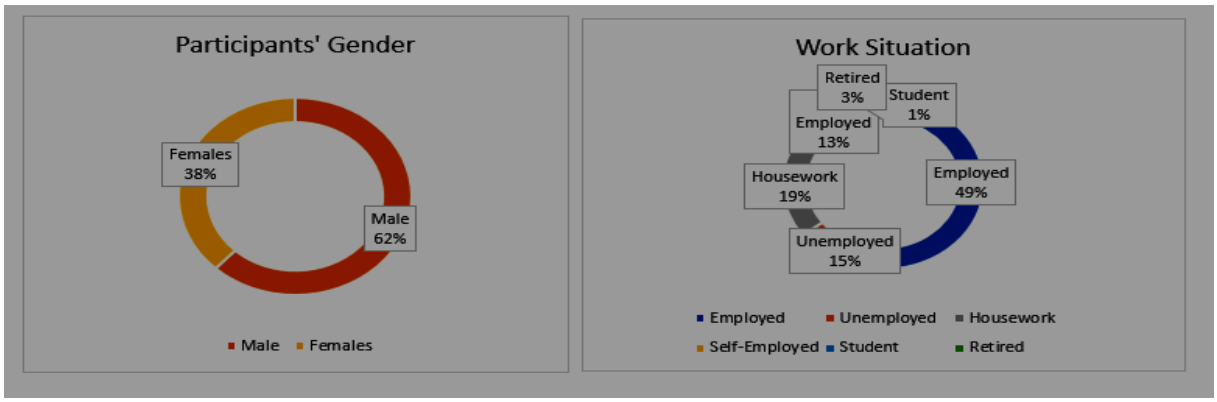


Figure 1 gives an overview of the participants' socio-demographic data. According to the presented values, 38 per cent (152) of the participants (N=400) were females, while 62 per cent (248) were males. Concerning their work situation, 1 per cent (3) were students, 49 per cent (198) were employed, 15 per cent (61) were unemployed, 19 per cent (78) engaged in housework, 13 per cent (50) were unemployed, and 3 per cent (10) were retired.

Concern about Climate Change

The survey item to gauge participants' concern about climate change utilised a 5-point Likert style questionnaire that required them to indicate whether they were concerned about climate change and global warming; responses ranged from "highly concerned" and "highly unconcerned." Part of the goals of this study was to conduct a trends analysis to ascertain changes in trends concerning renewable energy use; concerns about climate change were thought to predict changes in trends towards renewable energy adoption. The results are displayed in Figure 2 below:

Figure 2: Participants' concerns about climate change

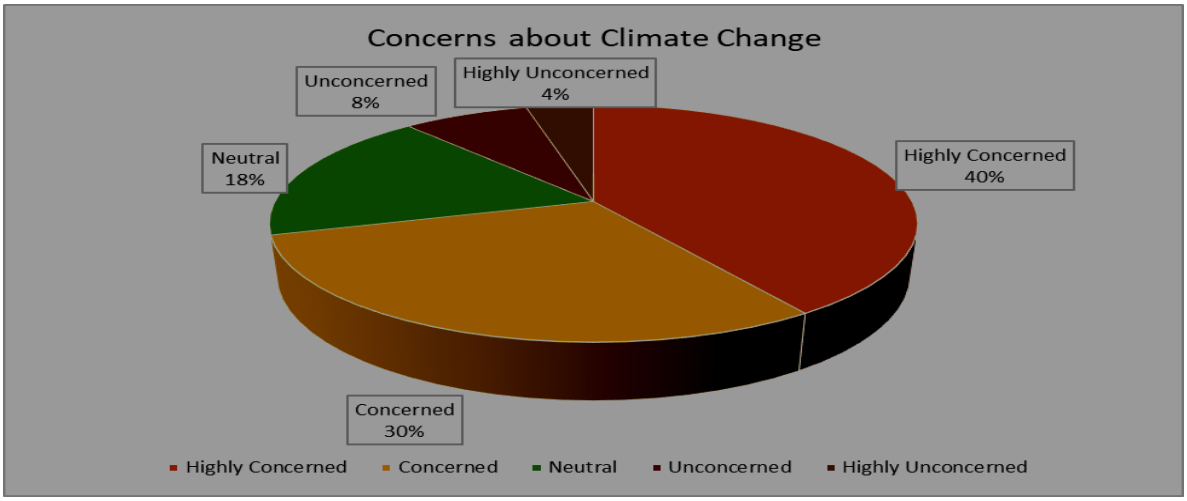
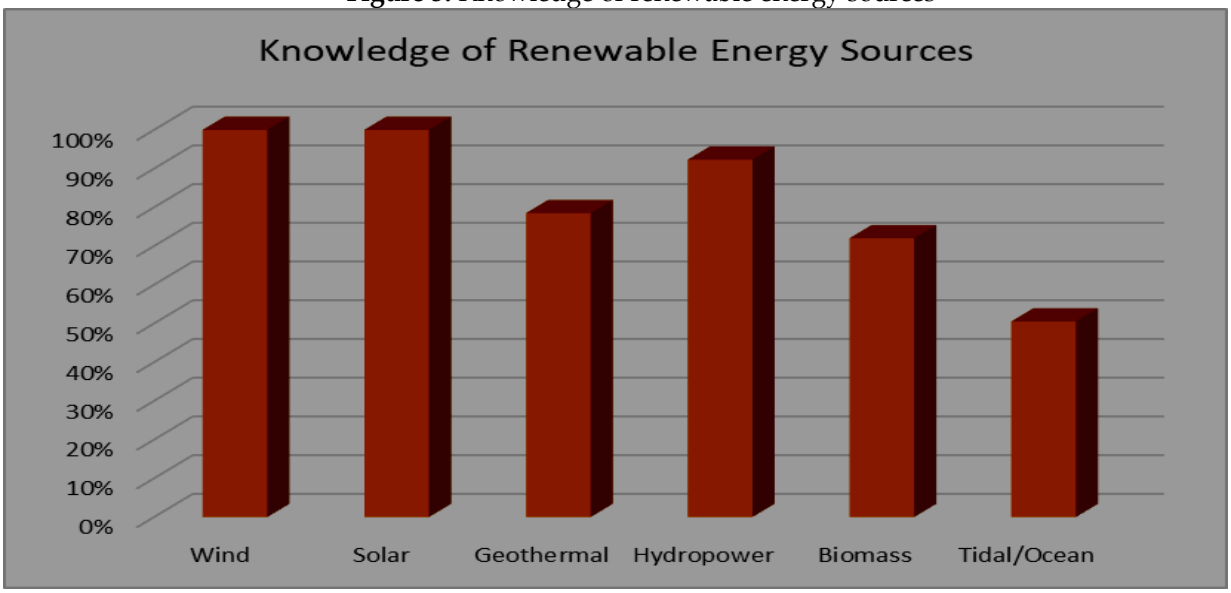


Figure 2 above summarises participants' concerns about climate change. 40 per cent indicated that they were "highly concerned" about climate change, 30 per cent were "concerned," 18 per cent were "neutral" (neither concerned nor unconcerned), 8 per cent were "unconcerned," and 4 per cent were "highly unconcerned.

The Knowledge of Renewable Energy Sources

An assessment of public knowledge, awareness, and attitudes towards renewable energy resources is essential for establishing acceptance. Public knowledge and perception of various energy sources are also crucial for the future planning of energy portfolios. The survey assessed the respondents' state of knowledge of the various renewable energy resources. Like the "concerns about climate change" construct, the knowledge of renewable energy sources and the knowledge of environmental problems associated with non-renewable energy was thought to predict changes in trends toward renewable energy adoption. Figure 3 below summarises the knowledge of these resources among the surveyed participants.

Figure 3: Knowledge of renewable energy sources

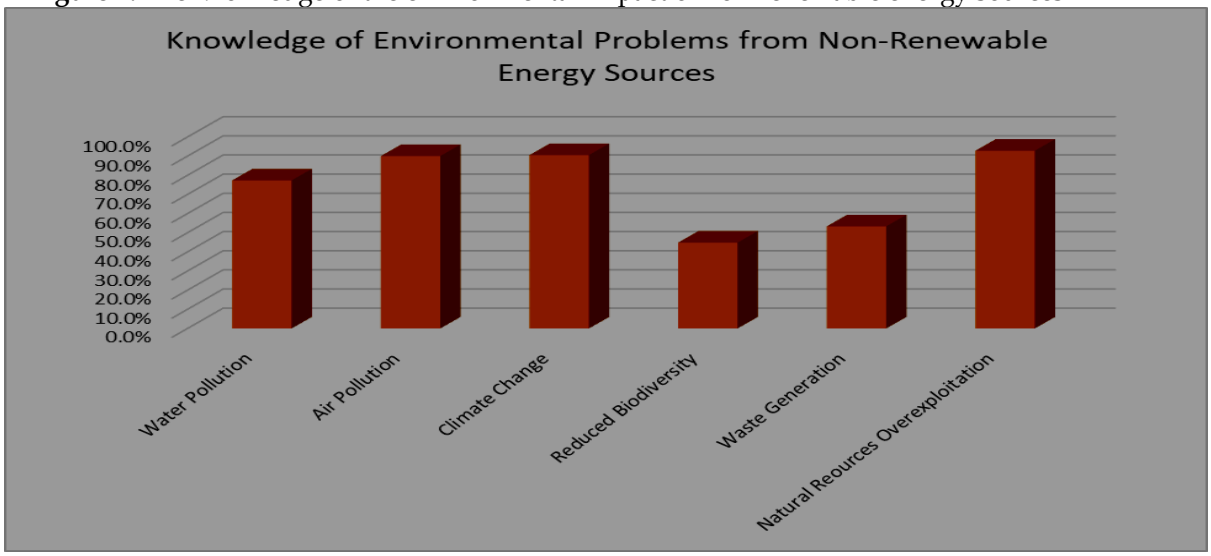


All the participants indicated knowing wind and solar energy as renewable energy sources. The knowledge of hydropower as a renewable energy source was also high (92.3 per cent). However, participants seemed to be relatively less knowledgeable on renewable energy sources such as geothermal (78.5 per cent) and biomass (72 per cent). The knowledge of tidal (ocean) energy as a renewable energy source was the lowest at 50.5 per cent.

Knowledge of Environmental Problems from Non-Renewable Energy Sources

Fossil fuels, including natural gas, oil, and coal, cause more substantial harm to the environment than renewable energy resources across various measures, including water and air pollution, wildlife and natural habitat loss, GHG emissions, and water use. With this knowledge, the survey set out to gauge participants' knowledge of the environmental problems resulting from the heavy reliance on non-renewable energy sources. The findings are summarised in Figure 4 below:

Figure 4: The knowledge of the environmental impact of non-renewable energy sources

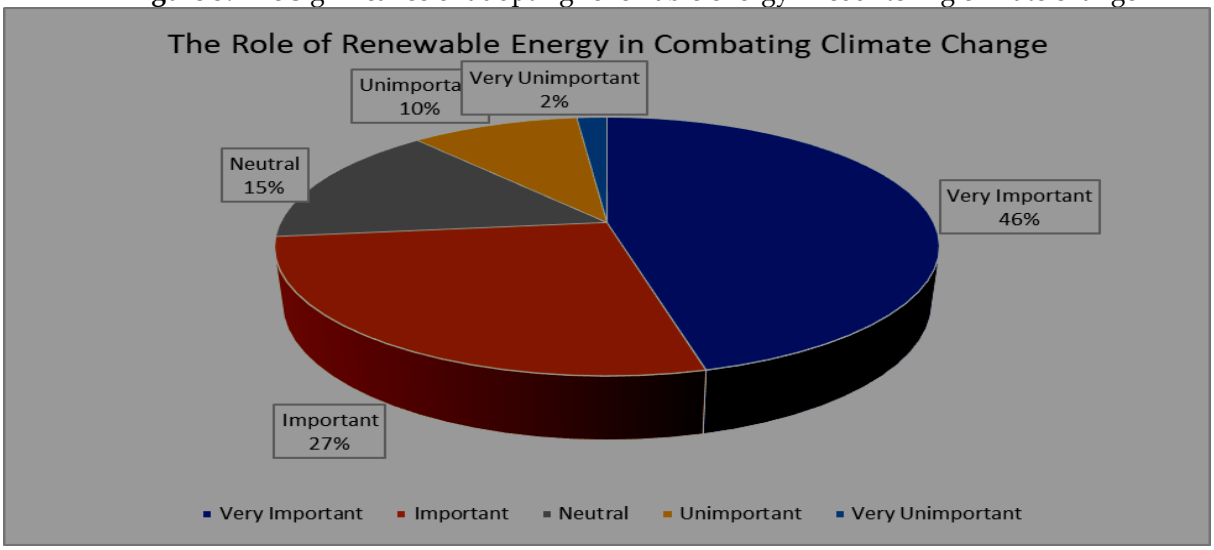


Participants' knowledge seemed highest on environmental problems such as natural resource overexploitation (92.8 per cent), climate change (90.5 per cent), air pollution (90 per cent) and water pollution (77.3 per cent). The state of knowledge on non-renewable energy sources' impact on the environment was lowest for waste generation (53.3 per cent) and reduced biodiversity (44.8 per cent).

Views on the Role of Renewable Energy in Combating Climate Change

On average, the knowledge level on the role of renewable energy in combating climate change was high. This knowledge was also thought to predict the trends toward renewable energy adoption in the UK. Figure 5 below summarises participants' perceptions regarding the significance of using renewable energy as a climate change action.

Figure 5: The significance of adopting renewable energy in countering climate change

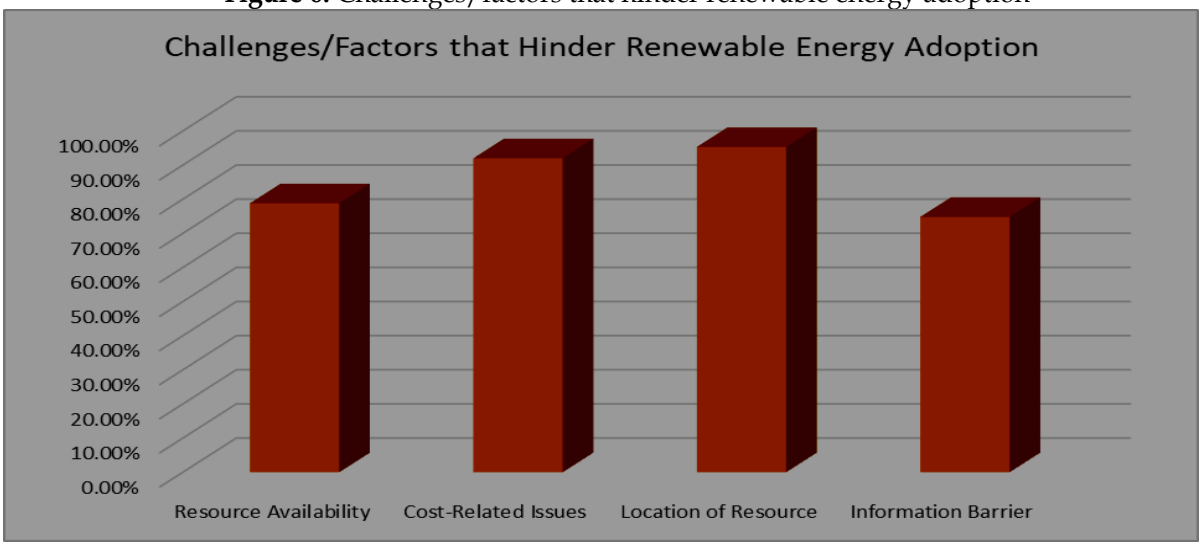


A significant majority of the survey participants thought that renewable energy resources were "very important" (46 per cent) or "important" (27 per cent) in combating climate change. Cumulatively, this constituted 73 per cent of the participants. 15 per cent were neutral on the matter, and only 12 per cent thought that renewable energy sources were "unimportant" or "very unimportant" in countering climate change.

Challenges/Factors Hindering Renewable Energy Adoption

Most renewable energy resources depend on natural sources such as tides, the sun, and wind. The availability of these resources depends on the specific location in which they are harnessed and the time of the year due to seasonal changes (such as winter conditions). The cost of producing energy from these resources also varies compared to non-renewable sources and even among the renewable energy sources. This survey item sought to determine participants' perceptions concerning the factors that hinder the widespread adoption of renewable energy sources.

Figure 6: Challenges/factors that hinder renewable energy adoption



Most participants thought that resource location (95.3 per cent) and cost-related issues (92 per cent) were the foremost hindrances to adoption. Still, a significant percentage also thought that resources availability (78.8 per cent) due to seasonal variations and information barriers (74.8 per cent) were also to blame.

Interview Results

An analysis of the interviews resulted in four distinct themes concerning the impact of renewable energy on the environment. The analysis was accomplished using qualitative comparative analysis (QCA), an approach to qualitative data analysis that uses the Boolean values of 0 and 1 to denote the absence or presence of identified themes. Table 1 below is a truth table with the identified themes from the respondents' answers. These themes were essential because they were salient in interviewees' responses and were essential in identifying prevailing attitudes towards renewable energy sources and their role in the future mitigation of climate change and other environmental problems from non-renewable energy resources.

Table 1: Truth table showing the identified themes; 1 denotes the theme's presence in the respondent's answers while 0 denotes its absence.

Respondent	Themes			
	Reduced Pollution	**Improved Public Health**	**Inexhaustible Energy that Promotes Reliability and Resilience**	**Reduced Global Warming and Climate Change Mitigation**
Jane	1	0	1	1
Morris	1	1	1	1
Smith	1	1	1	0
Innocent	1	0	1	0
Mary	1	1	1	1
Merge	1	1	1	1
Tom	1	1	1	1
Heather	1	0	0	0
Bob	1	1	1	1
Harry	1	1	0	1
Richard	1	1	1	0
Caleb	1	0	1	1
Judith	1	1	0	0
Sally	0	1	1	1
Douglas	1	1	1	1
Kennedy	1	1	1	1
Michael	1	0	1	1
Liz	1	1	0	1
Susan	1	1	1	1
James	0	0	1	0
Wilson	1	1	1	1
Lucas	1	0	0	1
Ava	1	1	1	1
Emma	1	1	1	1
Oliver	1	1	0	1

Theme 1: Reduced Pollution

Renewable energy sources such as hydropower, solar, and wind produce no emissions and, therefore, cause no pollution. Biomass and geothermal produce some air pollutants, but these are usually much less than non-renewable energy sources such as gas- and coal-fired power plants. This knowledge was evident in the responses (23 of the 25 interviewees believed that adopting renewable energy sources inevitably results in reduced pollution). For example, Jane noted:

Solar panels and wind turbines have become increasingly common in the UK, and the reason for this is apparent. One of the benefits of such a system is that no combustion is involved, meaning that no harmful gases and similar substances are discharged into the atmosphere.

Other respondents also noted the significance of renewable energy resources in improving air quality by reducing fine particulate matter, ozone production and reducing the frequency of smog and acid rain. For example, Richard noted:

Significant impacts of non-renewable energy on air quality are particularly notable in communities close to power plants that rely on fossil fuels. Communities near renewable energy sources, such as solar farms, do not need

to worry about the particulate matter from fossil fuel combustion or even nitrogen oxides, the primary chemical precursor to ozone.

Theme 2: Improved Public Health

Environmental health plays an essential part of any public health system. Therefore, any discussion of the environmental impact of renewable energy sources is incomplete without a discourse on the public health benefits because the two are intertwined. Renewable energy sources reduce chemical and similar environmental exposure in soil, food, water, and air by providing communities with cleaner and healthier environments. For example, Sally observed:

Climate change is real and affects nearly every aspect of human health in many ways. Non-renewable energy sources are a significant contributor to poor health by threatening safe drinking water and clean air; they will likely undermine the progress to ensure improved global health.

Similarly, Wilson noted, "the interaction between the environment and human health is known to many and has been the subject of extensive research. Environmental risks affect human health directly through exposure to poisonous agents or indirectly by damaging life-sustaining ecosystems." 18 of the 25 respondents acknowledged that renewable energy resources benefit public health.

Theme 3: Inexhaustible Energy that Promotes Reliability and Resilience

Renewable energy sources are inexhaustible; they are only affected by regional variations in weather conditions that can make biomass, solar, hydropower, and wind energy unavailable or less available depending on the season. However, other renewable energy sources such as geothermal can be exploited ad infinitum. In this regard, Emma noted:

Abundant biomass from plant matter, sunny skies, strong tidal energy, abundant wind, fast-moving water from rivers and streams, and heat from deep within the earth provide a wide variety of energy sources whose supply is constantly replenished. In fact, with proper government facilitation and education, even rural areas can benefit from the micro-hydro potential of small streams.

It is also known that renewable energy sources such as solar and wind are less susceptible to large-scale failure due to their modular nature and distribution. Kennedy noted, "Distributed systems are naturally resistant to severe weather events because they are spread out over massive geographical areas.

Naturally, a severe weather event in one site is not likely to lead to power outages in the whole region." Some respondents also thought that renewable energy resources fostered resilience and promoted reliability. For example, Bob argued:

Non-renewable power plants are known to rely heavily on water for cooling. Because of this, water scarcity can harm power generation. Moreover, the water used for cooling is often contaminated when it is eventually released to the source, creating negative additional environmental and public health issues. Most renewable energy sources require no water to generate electricity, making them reliable in conditions that could result in the shutting down of fossil-fuel-powered plants.

Douglas also expressed similar sentiments, noting, "the climate change and global warming consequences of our increased reliance on fossil fuels means that the risk of disruptive weather events has increased, increasing the need for cleaner, more resilient energy solutions." Most participants (19 of the 25 respondents) agreed that renewable energy sources are essential in providing inexhaustible energy that promotes reliability and resilience.

Theme 4: Reduced Global Warming and Climate Change Mitigation

Human activities are significant contributors to the increase in atmospheric carbon dioxide levels and other GHGs that have resulted in global warming and climate change. Some participants argued that the

role of renewable energy sources in reducing global warming and mitigating climate change is indispensable. For example, Michael noted:

In the United Kingdom, a significant percentage of greenhouse gasses derive from our energy sector, especially transportation and electricity. Generating electricity using renewable sources such as solar, wind, and geothermal to power electric cars can significantly reduce greenhouse gas emissions, reducing global warming and climate change.

Carbon dioxide is the most well-known GHG, although others such as methane are also responsible for global warming.

Most emissions derive from the combustion of fossil fuels, primarily natural gas and coal. In this regard, Caleb remarked, "Unlike non-renewable sources, renewable energy resources have a relatively smaller greenhouse gas footprint that makes them ideal for reversing climate change." Even after accounting for "life cycle" emissions associated with renewable energy sources – such as emissions from the entire stage of renewable energy technology life from manufacturing to commissioning, operation, and decommissioning – emissions from renewable sources are still minimal.

Discussion

The results indicated that most respondents were concerned about climate change. Therefore, it was unsurprising that most agreed that renewable energy sources were essential in combating climate change. Indeed, consistent with the findings of this study, most people in the UK are well knowledgeable about the various renewable energy sources such as biomass, hydropower, solar, wind, geothermal, and tidal (ocean) energy. This answers the research question, "What is an example of renewable sources of energy?" The increasing switch from non-renewable energy to renewable sources has primarily been driven by the former's detrimental impact on the environment; the knowledge of the risks of non-renewable energy was evident in participants' answers. Most participants identified pollution, climate change, and global warming as the significant risks burning fossil fuels poses to the environment. Fossil fuels – particularly natural gas and oil – produce significant quantities of particulate matter and carbon dioxide when burnt, leading to global warming and climate change.

Water and air pollution from burning natural gas, oil, and coal is associated with negative public health outcomes, including cancer, neurological damage, heart disease, and other severe health problems. These affect everyone and can lead to adverse developmental outcomes for children. Most of the water and air pollution that results in negative health impacts can be avoided using clean energy technologies such as hydropower, solar, and wind that do not produce these emissions. In the United Kingdom, fossil fuel combustion for energy production accounts for a significant fraction of carbon emissions. This is also true for the most Western world, including Europe and the United States. Unlike non-renewable energy, renewable energy sources help reduce GHGs emissions and the effects of climate change because they have a small GHG footprint. Even after accounting for emissions throughout the life cycle of renewable energy technologies, including emissions during manufacturing, project commissioning, operation, and decommissioning, it is still evident that these energy sources produce significantly fewer emissions.

Producing energy by burning fossil fuels is also water-intensive, creating competition for water resources with other sectors such as agriculture and reducing the available water for other human use. However, although renewable energy sources produce clean energy, others present similar problems associated with non-renewable sources. For example, biomass plants might require water for cooling, although water used in such cases is usually safe for injection back to the source. It is worth emphasising that biomass electricity generation can exert undesirable global warming and climate change impacts depending on whether it is sustainably sourced. Increasing the proportion of renewable energy sources in the UK's energy portfolio and other countries' energy sources will make it possible to replace carbon-intensive non-renewable energy sources, reducing the UK and the world's GHG emissions.

The study also identified several barriers to renewable energy sources. Most of these sources are location specific. For example, for optimum performance, wind turbines should be erected in locations with frequent, sustained winds, often at higher elevations above the earth's surface, in coastal areas, and gaps between mountains. Operating wind power plants is not a straightforward undertaking achieved simply by erecting a wind turbine. Careful planning must be done that considers turbine positioning and how fast and frequently wind blows at the site. Cost is another factor; most renewable energy sources are costly to establish on a large scale. For example, the cost of drilling a geothermal well is estimated at 40 per cent of the net investment cost for a high-temperature power plant, often running into millions of dollars that must be spent before the power plant can start making money (Dickmann 2017). One might assume that geothermal would be a leading energy source with all its advantages. However, it constitutes less than 1 per cent of the energy used globally. Like solar and wind, a barrier to its adoption is location. Geothermal reservoirs are often too complex and costly to reach in most places. Only a few countries – including the Philippines, Iceland, and Kenya – produce significant electricity from this resource.

Awareness was also identified as a barrier to renewable energy adoption. Raising awareness about the availability of renewable energy sources by providing individuals and governments with advice and information would help lessen the impact of this barrier. This would involve increasing awareness about feasible technology, finance, and policy options and collaborating with the financial sector to encourage investment in renewable energy sources by reducing the risks involved in undertaking such projects.

Conclusion

The current rate of non-renewable energy consumption will result in depletion. This watershed will likely happen at the global peak when diminishing reserves cause the cumulative production to reach its peak and decline afterwards. Renewable energy sources provide advantages for society, businesses, and governments, including emission reduction, reduced energy costs, and environmental sustainability. Therefore, the positive impact of these sources on the environment cannot be overlooked. The renewable energy issue is an important one for various reasons. First, the future of the global population's health rests on the ability to phase out fossil fuels in favour of cleaner energy sources. Future generations look up to the current ones to act on the problem to guarantee the longevity of a healthy and clean atmosphere and various ecosystems. Increasing the proportion of renewable energy projects will increase the uptake of clean energy by society, including individuals, businesses, and government agencies. Renewable energy sources and technologies are widely accepted as clean energy sources; their optimal use reduces undesirable environmental impacts and produces little secondary waste.

Recommendations

Countering global warming and climate change is the responsibility of all nations. This study revealed overwhelming support for adopting renewable energy sources in the UK due to its benefit to the environment and its potential to combat climate change. Some socio-demographic segments indicated a neutral position, while a small number exhibited a negative attitude towards renewable energy sources. As a result, the UK, and indeed all European countries and nations elsewhere in the world, should develop policy initiatives to integrate private partnerships and public participation to ensure innovative renewables technologies (mini-grid and off-grid systems) to improve access to renewable energy sources. The popularity and acceptance of clean energy sources will only increase. Therefore, it is essential to engage the public to increase their input in evaluating the advantages and relative costs of various renewable energy sources and technologies within their impact on the environment. More awareness and education will result in favourable policies that will spur widespread adoption.

Implications for Future Research

The overarching reason for increasing calls for the shift from non-renewable energy resources is the need to reduce their negative environmental impacts. Currently, the rate of renewable energy deployment seems on track, although the growth rate must increase if these resources are to play a meaningful role in mitigating climate change. In this regard, future research will need to be conducted on the most effective policy pathways to accelerate the transition to renewable sources in ways that align with the facilitating infrastructure.

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