RENEWABLE ENERGY MANAGEMENT - CHALLENGES IN THE INDIAN INDUSTRIAL SECTOR

by

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ABSTRACT

RENEWABLE ENERGY MANAGEMENT – CHALLENGES IN THE INDIAN INDUSTRIAL SECTOR

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This study examined the viability, challenges encountered, and sustainability of renewable energy in the industrial sector. The goal of the study was to give recommendations for industrial organizations that want to change towards the use of sustainable energy with reasonable costs. The main research questions focus on problems of implementation of RE (Renewable Energy) in industrial facilities, the regional differences of sources of RE including wind, solar, hydro sources in different regions of India and developing an overall strategic plan to integrate RE in industries. The research method used in the study is descriptive research with a quantitative strategy the research instruments used were a structured questionnaire survey of 300 respondents in 300 industrial enterprises across five regions of India. These regions were chosen concerning their specific climatic environment and energy mix such as hot and dry, hot and humid, coastal areas and hilly regions. The data was analysed with the help of IBM SPSS software where the emphasis was made on the ordinal regression to determine the effects of challenges and barriers for RE adoption. According to the analysis done with the help of such data, one can conclude that there is enough evidence to reject the null hypothesis and to state that there are very serious obstacles that prevent the integration of renewable energy in industrial contexts. The study

gives specific suggestions to the industrial organizations on how to eliminate these barriers and use energy efficiently according to the climate change objectives. Thus, this research enhances the understanding of RE management in the industrial sectors, as well as provides direction towards economic and environmental sustainability.

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Abbreviations	Full Form
RE	Renewable Energy
CE	Consumer Engagement
GE	Geothermal Energy
HPP	Hydropower Plant
GW^{th}	Gigawatts Thermal
MBOE/d	Million Barrels of Oil Equivalent Per Day
Mtoe	Million Tonnes of Oil Equivalent
PV	Photovoltaic
CSP	Concentrated Solar Power
W·m−3	Watts Per Cubic Meter
4GDH	4^{th} Generation District Heating
3GDH	3^{rd} Generation District Heating

CHAPTER I:

INTRODUCTION

1.1 Background

The global community is undergoing fast transformation, characterized by the emergence of a closely interconnected network of nations. This phenomenon is driven by the increasing energy requirements essential for fostering social and economic progress, as well as promoting well-being and healthcare. As the global population continues to increase rapidly, there is a corresponding increase in the need for energy services to meet essential human needs such as transportation, communication, lighting, and cooking. Nevertheless, the escalation in energy usage is not without its associated costs. A fundamental worry that has emerged is the urgent need to secure a sustainable and lasting energy source, while also mitigating the detrimental impacts of energy production on climate change.

The process of energy transition entails the substitution of fossil fuel-dependent economies with economies that are reliant on renewable energy (RE) sources (Afonso, Marques and Fuinhas, 2021). Scholars contend that the process of transition encompasses more than mere technological advancements, as it necessitates a confluence of economic, political, institutional and social transformations (Gaziulusoy and Brezet, 2015; Koch-ØRvad and Thuesen, 2016).

According to Coenen *et al.* (2021), the complexity of the transition landscape is heightened. Transitions in energy systems exhibit variations across different countries and these variations can even be observed within the same country. These differences can be attributed to specific obstacles provided by topographical factors, previous development of national energy markets and cultural influences (Lowitzsch, 2019). The methodologies employed for the production and utilization of specific types of sustainable energy exhibit a range of variations (Maradin, 2021). The International Renewable Energy Agency (IRENA) analyses the global development of six fundamental forms of RE.

Coal's greater energy density compared to fuels derived from biomass propelled it to prominence as the primary energy source during the Industrial Revolution. It is undeniable, however, that the landscape has changed dramatically over time. Coal, oil and natural gas have all been major contributors to the world's energy needs since the 1970s. At the same time, the world's population has exploded, expanding at an exponential rate with no signs of slowing down. This concurrent increase in energy consumption and CO2 emissions can be directly attributed to the occurrence of these two occurrences. The already severe issue of climate change has been exacerbated by this, making it one of the twenty-first century's most important concerns.

In this context, our research into RE management in the industrial sector takes on further significance. The goal is to not only address the growing energy needs of manufacturing facilities but also to think about how adding RE sources into their operations can affect those facilities It’s critical to mitigate the environmental impacts of energy production while also ensuring a steady supply of energy.

The role of scientists and researchers in advancing global sustainability has been given more prominence in the United Nations' SDG. 169 different goals make up the SDGs. Climate change, poverty and inequality are just a few of the pressing issues that these objectives and targets aim to address. Within this framework, RE sources play a key role. Energy sustainability may be attained by the utilization of RE sources, which also have the potential to significantly reduce greenhouse gas emissions from fossil fuel-based power plants.

The goal of this study is to investigate the potential and patterns of sustainable development via the use of RE sources, with a simultaneous focus on mitigation of climate change. Also find out the contribution of RE sources towards the aforementioned endeavour, while also examining the obstacles that may arise within the industrial sector. Utilizing meticulous examination and assessment of concepts, approaches, and scholarly articles, the research endeavours to provide significant perspectives for the attainment of a sustainable future.

RE sources include a wide variety of abundant naturally occurring resources, such as sunlight, wind, waves, tides, and geothermal heat, etc. The potential of this energy source is considerable, providing a viable and long-lasting energy solution. It is worth mentioning that solar photovoltaic (PV) systems have successfully provided electricity to a significant number of families globally. Additionally, methane digesters have allowed efficient cooking and lighting in more than 44 million households. Furthermore, there have been significant advancements in biomass cook stoves, resulting in positive outcomes for over 166 million homes.

Solar energy is a significant contributor within the realm of RE sources, since it effectively captures and converts the heat emitted by the sun into electrical energy. Solar technologies may be classified into two main categories: passive and active systems. These systems use distinct approaches for collecting, converting and distributing heat.

In light of these developments, shifting from fossil fuels to renewable energy sources is an approach that has great promise for combating climate change, achieving goals outlined in the SDG and guaranteeing a bright future for future generations.

The present study examines the complex aspects of incorporating RE into industrial operations. It aims to identify the obstacles and limitations associated with this integration, evaluate the viability of RE sources in various geographical areas and develop pragmatic suggestions to expedite the shift towards sustainable energy management within the industrial sector. The goal of this academic work is to provide a comprehensive framework for industrial organisations operating in many sectors to enhance their utilisation of RE sources. By doing so, these organisations may effectively maximize the advantages of RE, leading to positive impacts on both economic and ecological aspects.

1.2 Renewable Energy

RE refers to the use of naturally occurring resources, such as wind, biomass, geothermal heat, tides and sunshine, which possess the capacity for regeneration. RE sources, also known as alternative energy sources, have been referred to as such by (Wareham, 1962). The desirability of alternative energy sources has risen due to global energy growth and heightened demand. RE sources have become an essential need for the advancement of civilization. Solar energy, wind power and hydroelectricity are established forms of RE that are advancing steadily. The advancements in these sources will effectively satisfy future energy requirements. The proliferation of new RE sources is seeing significant growth at a quick pace. Although several RE projects are implemented on a global scale, it is important to note that renewable technologies are equally well-suited for deployment in rural and isolated locations. These regions typically face a critical need for energy to support human growth (Taylor, 2010).

The concept of RE sources is fascinating. Energy that is not derived from fossil fuels is considered alternative energy in the perspective of global civilization. Coal, oil and naturally available gases are three most common forms of fossil fuels used to provide energy for a wide variety of human activities, from home heating and electricity production to transportation. However, it should be noted that fossil fuels possess the characteristic of being non-renewable. The resources under consideration are subject to limitations in availability and may eventually become exhausted. Fossil fuels are the result of the transformation of organic matter derived from ancient flora and fauna, which existed several hundred million years ago. Over time, these organic remnants were deeply buried under the Earth's surface, undergoing a collective conversion process that ultimately yielded the combustible substances used as fuel. RE sources jointly provide for around 7% of the total energy requirements. Carbon dioxide, a main greenhouse gas commonly held to be at the root of the global warming phenomena, is released into the ecosystem when fossil fuels are burned. Greenhouse gases are released into the environment by the consumption of these fuels and this is generally accepted as the major cause. The average worldwide temperature was found to have risen by around 1-degree Fahrenheit throughout the course of the 20th century. The environmental consequences of global warming are far-reaching and have wide-ranging effects on several domains. Smog forms as a result of burning fossil fuels, which has hazardous impact on health and the growth of vegetation (Taylor, 2010; Mulvaney, Busby and Bazilian, 2020).

Approximately 16% of the total world energy consumption is derived from renewable sources, whereas conventional biomass accounts for 10% and is mostly used for heating purposes, while hydroelectricity contributes 3.4%. The use of emerging RE sources, including small hydro, modern biomass, solar, wind, geothermal and biofuels, contributed an additional 2.8% to the overall energy mix and is seeing substantial growth. The proportion of RE sources in the production of electricity now stands at around 19%. Within this figure, hydroelectricity accounts for 16% of worldwide electricity output, while other emerging RE technologies contribute 3% (Li *et al.* 2020; Hemeida *et al.* 2022).

Although several RE projects are implemented on a global scale, it is worth noting that renewable technologies are also well-suited for deployment in rural and isolated regions. This is particularly significant since access to energy plays a vital role in fostering human development in such locations. As of the year 2011, a considerable number of families have been supplied with energy via the utilisation of tiny solar photovoltaic (PV) systems. Additionally, a greater number of households have been served by mini-grids that include micro-hydro technology (Wareham, 1962).

Electricity generation, hot water and space heating, transportation fuels and rural energy services for areas without access to the grid—RE may be used in place of traditional fuels. RE sources now account for around 18% of the global power production. Renewable power producers are widely distributed throughout several nations, with wind power alone contributing a substantial portion of energy in certain regions. The percentage of energy generated by wind is particularly high in the states of Iowa (14%), Schleswig-Holstein (40%) and Denmark (20%). Several nations rely heavily on RE sources for their power generation. For instance, Iceland and Paraguay get 100% of their electricity from renewables. Norway follows closely with 98% of its power coming from renewable sources. Brazil obtains 86% of its power from renewables, while Austria relies on renewables for 62% of its power generation. New Zealand and Sweden generate 65% and 54% of their power from renewables, respectively (Islam, Mekhilef and Saidur, 2013).

Solar hot water plays a significant role in the utilisation of renewable heat throughout various nations, with China emerging as the primary contributor, accounting for 70% of the worldwide aggregate of 180 GWth (Gigawatts Thermal). These systems provide a small portion of China's estimated 50-60 million households' annual hot water needs and are mostly found in multi-family apartment buildings (Kumar, Pal and Sharma, 2021). More than 70 million houses' water heating needs have been met in worldwide total of installed solar water heating systems. There has been an uptick in the number of households who utilise biomass heating. Sweden uses biomass energy more than oil. Heating using direct geothermal energy is growing quickly.

1.3 Types of Renewable Energy

Conventional energy sources, such as oil, coal and natural gases have shown significant efficacy in facilitating economic advancement. Nevertheless, due to the accelerated exhaustion of traditional energy resources and the escalating global energy requirements, the global primary energy consumption had a growth rate of 1.8% in the year 2012 (BP, 2022). As a result of various environmental concerns, several affiliated institutions have advocated for extensive research aimed at developing more efficient and environmentally friendly power plants via the use of new technology. With the growing awareness and importance placed on environmental conservation, there has been a significant surge in the pursuit and investigation of clean fuel technologies and alternative energy sources. There is a significant gap between the social and environmental costs of using fossil fuels and the costs of using RE. Markets for RE systems that are both sustainable and widely adopted are now in the early stages of rapid growth, as are the accompanying economic and legal frameworks. It is evident that the forthcoming expansion in the energy industry mostly lies within the emerging domain of renewable sources. Consequently, transitioning towards RE sources may effectively enable the achievement of two key objectives: reducing greenhouse gas emissions to mitigate adverse consequences of severe weather events and climate change and guaranteeing the dependable, prompt, and economically viable provision of electricity. Allocating funds to RE might provide significant advantages for strengthening the energy independence.

It is projected that there will be a 2.7-fold increase in global power output derived from RE sources from 2010 to 2035. The projected increase in biofuel use throughout the selected time period is projected to be more than three times as large as the increase in use between 2010 and that year, from 1.3 mboe/d to 4.5 mboe/d (Million barrels of oil equivalent per day). The predominant use of biofuels is now seen in the domain of road transport, with a notable shift anticipated towards the adoption of aviation biofuels by the year 2035. The utilisation of contemporary RE sources for heat generation is projected to see an almost twofold increase, rising from "337 million tonnes of oil equivalent in 2010 to 604 Mtoe (Million tonnes of oil equivalent) by the year 2035." The proportion of RE sources used in Electricity generating surpasses that of heat production or vehicle transportation (IEA, 2021).

1.4 Overview of Alternative Energy Resources

Biomass energy

Biomass encompasses plants, tree and agricultural materials, serving as a collective term for these organic entities. It functions as a reservoir for the solar energy harnessed via the process of photosynthesis. The process of harnessing various forms of energy from biomass, including thermal energy, electrical energy, and liquid fuels (biofuels), is often referred to as biomass energy (bioenergy).

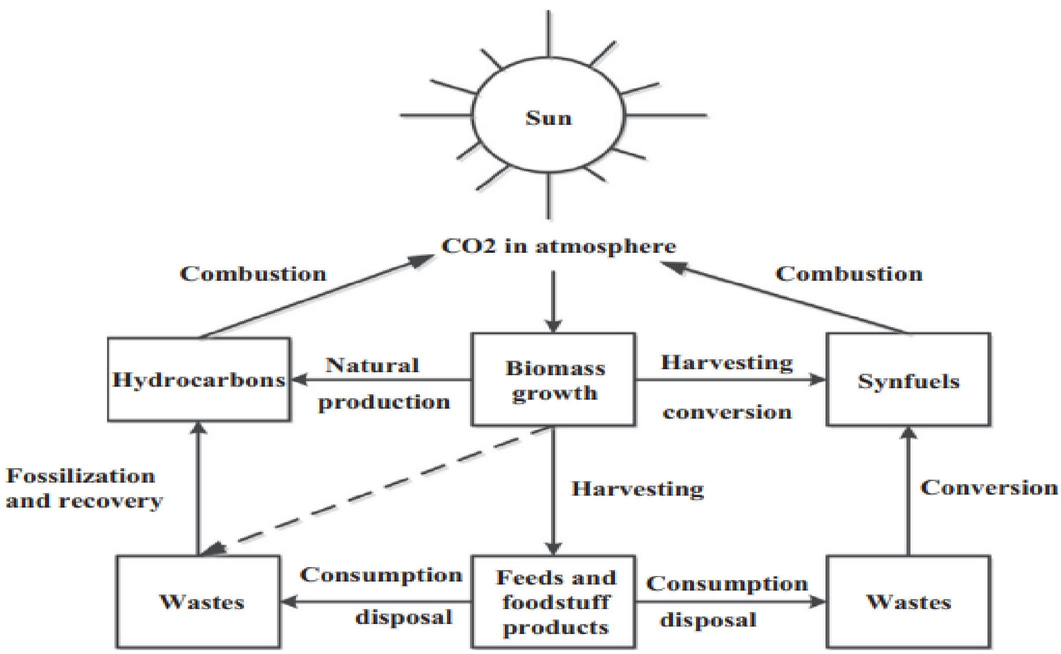

Figure 1.1 Schematic Presentation of biomass energy (Ellabban, Abu-Rub and Blaabjerg, 2014).

Energy crops grown specifically for their biomass content are one source of biomass for bioenergy, while residues left over after processing food and other crops are another (Sriram and Shahidehpour, (2005); Reddy and Srinivas, (2013); Ellabban, Abu-Rub and Blaabjerg, (2014)).

Biomass energy is considered to be a viable and environmentally friendly alternative. However, it has certain disadvantages with fossil fuels. Biomass has utility due to its potential as a source for the production of various forms of liquid or gaseous fuels, often referred to as biofuels. Alternatively, it may be directly combusted to generate energy. An energy mix based on intermittent sources like wind requires the ability to transport and store biofuels and generate heat and electricity on demand. In light of these parallels, (Hall and Scrase, 1998) predict that biomass will play a crucial role in future energy scenarios. To convert biomass feedstock into clean energy sources, the notion of biorefineries and biotransformation has just recently emerged. The aforementioned figure Klass, (2004) illustrates the idea of transforming bio-mass into several types of energy within the carbon cycle. A variety of biochemical and thermochemical conversion processes could be used to convert biomass feedstock into biofuels. Among these processes, gasification and combustion are the most prominent. Utilizing biomass as a fuel source has the potential to foster socioeconomic development in several nations, while concurrently enhancing energy security and bolstering trade balances (Ruiz *et al.*, 2013).

The disadvantages of biomass-to-energy plants are substantial in comparison to the advantages. The gathering and distribution of biomass fuels may be prohibitively expensive and the fuels themselves have poor energy densities. While the technology to convert biomass into power is mature, the price of electricity seldom covers the entire cost of the biomass fuel. There is an opportunity cost associated with the utilisation of inputs including water, crops, land and fossil energy to produce bioenergy fuels.

The total installed capacity of the world's biomass power plants will increase from 66 GW in 2010 to 148.9 GW by the year 2022. Long-term, it is possible that the 62 GW of electricity generated by biomass and garbage in 2010 will increase to 270 GW in 2030 (Skoczinski *et al.*, 2023).

Geothermal Energy

Geothermal energy (GE) extraction uses Earth's internal heat and pressure to produce electricity. Smaller-scale geothermal heat pumps may be used to heat homes, while larger-scale geothermal power plants can be used to generate electricity. It's commonly known that GE is the cleanest, most affordable, and least taxing way to generate electricity (Muraoka, 2022).

GE resources include thermal energy released from the Earth's core and trapped in mountains, as well as contained steam or liquid water. Geothermal systems have reservoir temperatures and depth profiles that vary by geological context. Continental ecosystems have intermediate-temperature (100–180 1C) and low-temperature (below 100 1C) systems. These systems are influenced by heightened heat generation resulting from the decay of radioactive isotopes, which subsequently elevates terrestrial heat flow. Additionally, the presence of aquifers charged with heated water can be attributed to the circulation along extensively penetrating fault zones. Under certain circumstances, geothermal areas with high, moderate and low temperatures may be harnessed for the purposes of generating electricity and directly using heat (Fridleifsson, 2001; Yan *et al.*, 2010).

The three main categories of GE sources are “hydrothermal systems, conductive systems and deep aquifers.” There are two types of hydrothermal systems: those in which liquids predominate and those in which gases prevail. Geological phenomena with a wide temperature range, such as hot rock and magma, are examples of conductive systems. In addition, fluid circulation inside porous media or fracture zones is a hallmark of deep aquifers, which are often located at depths more than 3 kilometres. It's vital to remember, nevertheless, that deep aquifers don't have a concentrated core’s heat source.

Strategies for harnessing geothermal energy resources broken down in a variety of buckets, such as those for generating electricity, using the heat directly, or using both heat and electricity in cogeneration systems. One possible category of direct use applications is geothermal heat pump (GHP) systems. Only hydrothermal systems are now employed commercially for power generation and direct use in the geothermal industry (Ellabban, Abu-Rub and Blaabjerg, 2014).

Hydropower Energy

Hydropower is electricity produced from the kinetic energy of flowing water. The kinetic energy created by flowing water is utilized to drive turbine generators. Hydropower that comes from dams is the most common type, but wave and tide power are also becoming more popular.

The hydrological cycle, which is propelled by the sun's rays, is the source of hydropower. Hydroelectricity is created by harnessing the energy of river water as it flows downhill from higher elevations, following the force of gravity. From a few watts to several gigawatts, HPPs may have a wide range of power outputs. Together, Brazil's Itaipu (capacity 14K MW) and China's Three Gorges (capacity 22K MW) produce between 80 to 100 TW h/yr. of electricity. Site-specific river systems are usually taken into account when developing a hydropower plant. Russia, China, Brazil, and the US produce more than half of the world's hydropower. (Wang and Yang, 2011). If all goes according to plan, hydropower's installed capacity will grow by almost 180 GW over the next decade. About a fourth of the existing capacity would be added with this upgrade. One-third of this growth will originate in China, while Turkey will experience the most capacity expansions.

There are primarily three different kinds of hydropower plants, each with its own unique way of harnessing the force of moving water to produce energy. The size range of run-of-river, storage and HPPs is determined by the hydro study and geography of the water flow. In a RoR, HPP the river's flow is harnessed to provide electricity. Hydroelectric plants that can store water in a reservoir are known as storage hydropower plants. As a result of the downstream pipe connection to the reservoir, the producing stations are less dependent on the variability of the inflow. The shape and purpose of reservoirs are determined by their natural setting. Pumped-storage hydroelectric facilities are not power plants but rather energy banks. When demand is low, water is pumped from a lower reservoir to a higher one to generate electricity; when demand is high, the process is reversed. Due to pumping losses, a pumping plant is a net energy consumer, but it may still help an energy storage system on a large scale. The capacity of pumped storage is greater than that of any other kind of grid-scale energy storage now available.

Hydropower has been used successfully for over a century, making it a highly developed and reliable technology. Since hydropower directly converts hydraulic energy to electrical, it is one of the most adaptable power technologies available today. It also has one of the highest conversion efficiencies. There is still opportunity for development via the implementation of more efficient procedures, the lessening of negative effects on the environment, the meeting of emerging social and ecological standards, and the creation of more resilient and cost-effective technology answers.

Marine energy

There are six distinct categories of renewable marine energy, each characterized by its source and technological prerequisites. These categories include “wave energy, tidal current energy, tidal range energy, ocean current energy, ocean thermal energy conversion and salinity gradient energy.” Except for tidal barrages, all ocean energy methods are either nearing or reaching commercialization. Ocean energy technologies provide a theoretical capacity of 7400 petajoules per year, a quantity that surpasses the current and anticipated global energy requirements. Limited research has been conducted to ascertain the technical capacity of various tidal energy technologies and this capacity is subject to alteration with the advent of new technologies (Ben Elghali, Benbouzid and Charpentier, (2007); Bhuyan, (2010); Aly and El-Hawary, (2011)). Between 2004 and 2009, the yearly construction of wave power and tidal current energy capacity was less than 3 MW. This limited progress may be attributed to the nascent stage of development within these sectors of ocean energy.

Solar energy

Thermal solar systems use the sun's heat to generate hot water, whereas "photovoltaic" (PV) and "concentrated solar power" (CSP) systems use the sun's heat to generate electricity. Many systems have been implemented across the globe using these technologies over the last few decades, attesting to their technological reliability (Byrne *et al.*, 2014).

Photovoltaic

Direct conversion from sunlight to electricity is made possible by solar PV systems. The PV cell is the fundamental component of a PV system; it is a semiconductor device that transforms DC power from sunlight. Each PV module may generate anywhere from 50 to 200 watts of power thanks to its linked PV cells. PV system consists of PV modules and a variety of other parts that are required for certain applications. PV systems may generate only a few watts to dozens of megawatts by adding panels.

Silicon-based solar PV systems are the most well-established options now available. Recently, these modules may be made of any semiconductor material, not only silicon. Thin films' efficiency is often lower than that of silicon modules, but their cost per watt is cheaper. The market for concentrating photovoltaics, which concentrate sunlight over a smaller area, is almost ready to take off. The efficiency of concentrating PV cells may reach 40%. Organic photovoltaic cells are one alternative; however, they are in initial phase of development.

The solar PV system has two benefits. One positive is that modules can be mass-produced in factories, therefore production costs can be kept low. However, PV is a very modular system. Solar PV has the benefit of producing energy even when the sky is cloudy, unlike concentrating solar power (CSP), which only utilizes the direct component of sunlight. This allows effective deployment in more areas than CSP (Marks, Summers and Betz, 2012).

There are two main types of solar systems: Grid-connected and Standalone. Recently, off-grid centralized PV mini-grid systems have emerged as a feasible solution for powering communities in poor countries where commercial usage of off-grid PV systems has great promise. Advantages from a technical standpoint may be seen in the increased electrical performance, decreased storage needs, increased energy availability and more flexibility of operation that come from using centralised systems to distribute electricity to local communities. For a given service level, centralised PV mini-grids with a diesel generator set as an optional balancing mechanism or hybrid PV-wind-diesel systems may be the most cost-effective. Diesel generators are no longer necessary in remote areas because to these installations (Branker, Pathak and Pearce, 2011).

In order to send the energy generated by a grid-connected PV system into the grid, the system's inverter must first convert the DC current into AC. Since the grid already acts as a buffer, the costs associated with grid-connected systems are lower than those of off-grid installations owing to the elimination of the need for energy storage. Distributed and centralised photovoltaic (PV) systems are two unique applications for grid-connected PV systems. Installing a grid-connected distributed PV system powers a grid-connected client or the grid. There are several advantages to using these systems. First, since they are often set up at the end user's home, they aid in lowering electric distribution losses. Second, they don't call for any extra space to house the PV equipment. Mounting expenses may also be reduced by having the system attached to an already existing building. Finally, building-integrated PV allows the PV array to double as a cladding or roofing material. Roofs on public and industrial buildings generally have sizes ranging from 10 kW to several MW, compared to residential systems that normally vary in size from 1 kW to 4 kW.

The functions and responsibilities often associated with central power plants may be met by grid-connected centralised photovoltaic (PV) systems. This system's principal goal is to offer a large-scale power supply rather than perform particular tasks inside the electrical grid and the electricity it generates is not bound to any one energy consumer. Centralised systems typically have a capacity of more than 1MW and are installed on the ground. Cost-effectiveness of photovoltaic elements and balance of systems, as well as the capacity to reduce installation and operating expenditures via bulk purchase, are two primary drivers of the economic advantages associated with these systems. In addition, with the addition of maintenance systems with monitoring devices, centralised photovoltaic (PV) systems may be more reliable than scattered PV systems. This may account for a negligible portion of total system costs (Sheikh and Kocaoglu, 2011).

In the ten years leading up to January 2022, solar power capacity increased dramatically, perhaps exceeding 800 GW worldwide. Countries like China, the USA and India were among the top solar capacity markets during this time period. Several European countries, including Germany and Italy, were also major contributors.

Concentrating Solar Power

CSP uses concentrated solar radiation to heat a liquid, solid, or gas for another process to generate electricity. Mirrors rather than lenses concentrate sunlight in large-scale

CSP systems. The focus of a trough or linear fresnel system is more along a line than that of a central receiver or dish system. Systems as little as tens of kilowatts (kW) in size and as large as megawatt-scale centralised power plants may both benefit from CSP. The California solar power plants that generate 354 MW were the world's first commercial concentrated sun power (CSP) plants and are still running today. Thanks to the early plants' accomplishments and lessons learned, trough systems are increasingly being adopted as the CSP industry grows (Machinda *et al.*, 2011).

In 2009, there were more over 7 hundred MW of grid-connected CSP plants operating, with another 15 hundred MW in the planning stages or under construction across the world. Parabolic trough arrays are widely used in operating plants. Every day, it seems like a new facility is being planned or constructed with plans to install a central receiver.

Wind energy

Wind power refers to the practice of capturing wind energy for useful uses, such as electrical generation, mechanical power, water pumping/drainage, and ship propulsion. In the early 20th century, the first wind turbines were developed to generate electricity. Since the 1970s, technology has been on an upward trend of steady development. As the 1990s came to a close, wind power once again emerged as a potentially game-changing source of renewable energy (Kaygusuz, 2009).

Wind energy must be converted into mechanical and electrical energy to create power. Thus, it is incumbent upon businesses to create wind turbines and power plants that are both cost-effective and efficient in effecting this energy conversion. Potential wind energy extraction is proportional to the cube of the wind speed, at least in theory. However, it is essential to remember that wind turbines can only capture a small percentage (often between 40 and 50 percent) of the wind's energy. Consequently, the design of wind turbines has been primarily centred upon optimising energy capture throughout a wide range of wind speeds encountered by these turbines. Simultaneously, efforts have been made to minimize the overall cost of wind energy, taking into consideration various factors involved in the process. Wind turbines are designed with the goal of minimising costs, which is accomplished by minimising the amount of materials used. The operations of wind power plants may be optimised and there is pressure to increase the size of turbines, the reliability of their parts and their overall efficiency.

From the 1970s to the 1980s, researchers examined different wind turbine designs. The horizontal axis design became more commonplace throughout time, however there were still design distinctions, recognition in the number and orientation of blades. Wind farms are large-scale collections of onshore wind turbines used to generate electricity. Wind farms vary from 5 to 300 MW, however smaller and larger exist. The offshore wind energy technology has a lesser degree of maturity in comparison to its onshore counterpart and necessitates a greater level of financial commitment. The rationales for the pursuit of offshore wind energy include many factors. Firstly, offshore locations provide superior wind resources in terms of quality. Secondly, the use of bigger wind turbines becomes feasible in offshore settings. Thirdly, the construction of larger power plants is made possible due to the absence of spatial constraints seen on land (Islam, Mekhilef and Saidur, 2013).

Electric system reliability, the electrical conversion system of a wind turbine is of crucial significance. Large-scale turbines that are linked to the grid may use one of three distinct electrical conversion technologies. In preceding years, fixed-speed induction generators were extensively used in wind turbines that included both stall regulation and pitch control mechanisms. In the given arrangements, wind turbines functioned as consumers of reactive power, hence requiring the provision of reactive power from the electric grid. The use of variable-speed machines has replaced these concepts in contemporary turbine technology. In this area, doubly fed induction and synchronous generators with power electronic converters dominate. Both architectures are often used in tandem with pitch-controlled rotors in real-world applications. Power quality is improved over conventional turbines in a number of ways by variable speed designs, which have the inherent ability to isolate the turbine's rotating masses from the ES. Electric network operators need turbines to possess the capability of generating both actual and reactive power, in addition to having fault ride-through capabilities.

1.5 Opportunities & barriers of RE

Various kinds of renewable resources are globally accessible, such as solar radiation, wind energy, tidal waves, and heat derived from biomass. Certain types, such as solar energy, possess endless and practically boundless potential. The amount of SE that reaches Earth's surface in a year is more than enough to cover the world's energy needs for more than 10,000 years. Furthermore, it should be mentioned that even utilizing 25% of the solar energy that falls on Earth's paved surfaces has the potential to adequately fulfil the present global energy demands. Some technologies can transform various resources into electricity and energy and these technologies are now undergoing significant advancements (Sen and Ganguly, 2017).

Opportunities

There are four primary industries in which RE is particularly suitable and these sectors will now be examined as potential areas of opportunity. Growth in society, availability of energy, protection against blackouts, and limiting global warming are major concerns.

Socio-economic development

The escalating cost of energy crises poses a significant threat to the economic progress of industrialized nations that possess limited resources (Velasco-Fernández, Dunlop and Giampietro, 2020). Certain rising economies that possess abundant resources have encountered a range of issues due to their over-dependence on the use of fossil fuels (Oró *et al.*, 2015). After the oil crises of the 1970s, there has been a noticeable global pattern indicating that certain developed nations have experienced positive effects on their GDP growth as a result of enhanced energy efficiency. However, many developing nations that are rich in natural resources continue to depend significantly on this sector of economy. The global demand for energy in both consuming and production sectors has been increasing, which has been exacerbating the well-documented pressure on energy supply and its impact on the global economic system (Lei *et al.*, 2022). The fast utilization of fossil fuels has resulted in the emergence of several social and political challenges, including energy fragility and the escalation of carbon emissions, due to the heightened demand for energy resources. According to Kaygusuz (2012), fossil fuels continue to dominate as the primary energy source, representing about 80% of world consumption in 2008 and 78% in 2030.

Both the Human Development Index and the amount of energy used per person are positively related to national wealth. In recent decades, economic expansion has emerged as the predominant determinant of the escalating energy demand and consumption. As the economy expands, there is a corresponding rise in the need for energy that is both intelligent and adaptable. The phenomenon of economic development has been linked to a transition from the utilisation of traditional fossil fuels to the use of more advanced forms of power. The need for this has been widely recognised in emerging nations, where significant social and economic progress is underway. The availability of clean and dependable energy is considered a fundamental need for human progress, since it has the potential to positively impact several aspects of society. It may play a significant role in generating revenue, improving the quality of health and education and reducing poverty levels. RE technologies, due to their decentralised nature, have the potential to significantly contribute to rural development. RE's long-term benefits in emerging and industrialised economies include employment generation. Government entities and officials have also extended their support to the home market in the RE technology sector via the provision of tax incentives, flexible regulations and investment-friendly policies, among other measures (B. Li *et al.*, 2023).

Energy access

According to Cozzi *et al.* (2022), a total of 774 million individuals lacked access to electricity in the year 2022, with about 85% of this population residing in rural regions. The concept of transitioning to contemporary energy access entails the process of ascending the energy ladder, wherein individuals and communities shift from reliance on conventional fuels to adopting new, environmentally sustainable and cleaner energy sources. Numerous endeavours have been undertaken, particularly within developing nations, to enhance the availability of power and promote the use of cleaner cooking facilities. According to Khatib (2011), the use of small and freestanding RE systems, such as solar photovoltaic (PV), hydropower and bioenergy, has shown to be very efficient and beneficial in rural regions. These systems effectively address the energy needs of local people in a more cost-effective and environmentally friendly manner. Photovoltaic (PV) technology is a very appealing solution for meeting fundamental requirements such as illuminating spaces and providing access to safe drinking water. Biomass combustion may serve as a viable method to address the issue of increased local demand. Transitioning from utilising cow dung and agricultural waste to using contemporary biomass cook stoves or biogas systems based on RE sources is an example of energy progression in the bioenergy sector (UN-Energy, 2005).

Energy security

Energy has acquired the status of a "strategic commodity" and any ambiguity over its availability has the potential to jeopardise the operational efficiency of the economy, especially in emerging nations. Energy security is the state in which the supply of energy is safeguarded and uninterrupted. The primary considerations in this context are to the accessibility and dissemination of diverse and dependable resources. The predominant source of energy to meet current demands is fossil fuels, which is accompanied by a notable issue of price instability (Sen *et al.*, 2016). The field of geopolitics assumes a significant role in influencing the price of oil and gas. Increasing energy security is possible through the use of local RE choices by decreasing dependence on traditional energy sources and increasing supply diversification. In this manner, foreign cash may be effectively allocated towards the importation of items that are not feasibly produced within the domestic market, as opposed to its use for energy imports. This might potentially provide significant benefits for nations that rely on oil imports. Developing nations, which rely largely on fossil fuels, are faced with the substantial financial burden of importing crude oil, necessitating significant foreign currency expenditures. The occurrence of an unanticipated import crisis has the potential to push the country perilously close to a state of catastrophe. The increasing energy demand, driven by economic expansion, poses significant challenges for current resources. This expanding need, both in industrial and home sectors, may lead to a substantial imbalance between supply and demand, resulting in a severe shortage of energy (Sen *et al.*, 2016).

Climate change mitigation

The increasing demand for RE is primarily driven by the significant importance placed on climate change mitigation. It is essential to undertake measures aimed at mitigating the effects of climate change. The potential ramifications of the fast increase in global temperatures are extensive and catastrophic for both human populations and the natural environment unless immediate and comprehensive measures are implemented worldwide to mitigate greenhouse gas emissions. To reach an all-inclusive worldwide agreement on climate change, the 21st session of the UNFCCC COP21 held in December 2015 might prove to be a watershed event. The primary objective of this conference was to mitigate the most severe consequences of climate change by imposing restrictions that would prevent the average global temperature from exceeding a 2 °C increase by the conclusion of the 21st century. The mitigation of global temperature increase necessitates collaborative efforts on a worldwide scale. During the “Conference of the Parties” held in Warsaw (COP19), participating countries were extended an invitation to provide a collection of policy commitments, often referred to as “Intended Nationally Determined Contributions” (INDCs). These measures would contribute to the fulfilment of the aim outlined in Article 2 of the UNFCCC), which emphasises the need to stabilise greenhouse gas concentrations in the atmosphere at a level that would effectively mitigate harmful human-induced interference with the climate system (United Nations, 1992). Based on an analysis conducted by Climate Action Tracker (2015), the INDCs that have been observed so far demonstrate a greater potential for emissions reduction compared to previously declared commitments. When the INDCs filed by October 1, 2015 are combined and expanded to include the whole globe, the cumulative greenhouse gas (GHG) emissions are projected to reach a range of 53-55 gigatons (Gt) of CO2 by the year 2030. Despite the notable progress made, there is a shortfall of 15–17 gigatons of carbon dioxide equivalent emissions to achieve the 2-degree Celsius objective. If all INDCs are effectively executed, it is projected that there would still be a predicted elevation in the average world temperature by around 2.7 °C by the conclusion of the 21st century.

The decarbonization of the energy sector via the deployment of RE is a fundamental component of several governments' efforts to mitigate climate change. Approximately 67% of the total yearly greenhouse gas emissions are attributed to energy use. Upon further examination, it becomes evident that the primary contributor to these emissions is electricity generation, with industry and transport following closely after. RE sources are now playing a significant role in mitigating emissions within the power industry. At now, renewable power plants constitute around 22% of the overall worldwide energy output. In the year 2012, it is projected that the utilisation of RE sources resulted in the avoidance of about 3.1 gigatons of carbon dioxide equivalent emissions. This figure represents the difference between the emissions that would have been released into the atmosphere from power generation reliant on fossil fuels and the emissions observed due to the adoption of RE. The decrease in emissions mentioned mostly stems from the utilisation of hydropower. However, there has been a remarkable surge in the generation of electricity from wind, solar and bioenergy sources in the last ten years. This growth may be attributed to the implementation of supportive policies and significant reductions in costs. According to estimates conducted by the IRENA utilizing data from "Intergovernmental Panel on Climate Change", the absence of power production derived from renewable sources would have resulted in a 20% increase in overall emissions from the power sector (Edenhofer *et al.*, 2011).

To reduce the increase in global temperatures, it is imperative to expedite the implementation of RE sources. To attain further reductions in absolute emissions within the electrical sector, a significant reduction in emissions intensity of power production is necessary. The emissions intensity, on average, has shown little variation throughout the course of the last two decades. According to prevailing regulations and national strategies, there is an anticipated decrease in emissions from 575 g/kWh in 2010 to 488 g/kWh by the year 2030. A further decrease in emissions intensity to 362 g/kWh, which corresponds to a 40% drop from the levels seen in 1990, might potentially be accomplished with the expansion of RE implementation. There are more possibilities for reducing emissions in other areas related to energy use, such as heating/cooling and transportation. These prospects strengthen the argument for expediting the transition towards sustainable energy sources (Ajadi *et al.*, 2019).

In order to meet climate goals while also fostering economic growth and protecting social well-being, it is crucial to speed up the use of RE sources. IRENA's REmap 2030 research shows that to keep global temperature increases at 2 °C, renewable sources must account for 18% of total final energy consumption in 2010 and 36% by 2030. It is predicted that by 2030, the share of TFEC met by RE sources would have risen to a meagre 21%, based on the current trajectory of legislation and those under consideration. Under this scenario, it is predicted that annual global energy-related CO2 emissions would increase significantly, from 30.3 to 41.4 gigatons per year between 2010 and 2030.

Barriers

The phrase “barriers to RE development” is used to describe the various obstacles that stand in the way of developing and implementing renewable energy. New legislation, initiatives, or technological advancements may be able to successfully remove these obstructions (Verbruggen *et al.*, 2010). In this section, we discussed some of the major challenges and worries connected to using RE for environmental sustainability.

Market failures

Market failures often arise as a consequence of externalities that emanate from human actions. In instances when an agent assumes a role of involvement and responsibility, the company may experience adverse consequences if such agent fails to fulfil their obligations or satisfy the established standards of performance and accountability. External variables may have both beneficial effects, known as external benefits and negative consequences, referred to as external costs. The presence of external advantages results in a reduction in the supply of commodities due to a fall in price. The presence of external costs incentivizes an increased demand for activities that have detrimental effects, since consumers are not fully burdened with the associated costs. When considering the growth of RE, the following considerations may be relevant:

- Research and development of RE technology is underfunded. This arises because those who come up with ideas often fail to get legal protections for their creations (Foxon and Pearson, 2008).
- Unquantifiable environmental effects (Clawson, 1989). Incorrect prices are being applied to the external costs of GHG emissions.
- When there is monopoly in the energy industry, there is less competition between providers and consumers and fewer opportunities to enter or leave the market. Regulatory integrated network enterprises (such as gas, electric and thermal energy grids) within a certain area are natural monopolies due to the economies of scale that allow for the provision of network services by a single operator (Perrakis *et al.*, 1982).
- Most prospective consumers, especially in underdeveloped countries, may be unable to acquire RE systems because to the prohibitively high initial investment cost.
- Financial risks are inherent in all power projects as a result of the presence of uncertainty around future energy pricing. According to (Bazilian and Roques, 2008), The private capital market seeks bigger returns on risky technology than established ones. This raises RE project costs. One instance of a financial risk

associated with real estate development outside the electricity sector is to the utilisation of biofuel in the aviation industry.

Informational and awareness barriers

RE exhibits a characteristic of being site-specific, which sets it apart from fossil fuels. For instance, the output of a wind turbine is contingent upon wind speed and other associated characteristics. Consequently, wind-based RE systems are economically viable only in places that possess favourable conditions for harnessing wind power. While there may be access to comprehensive wind regime data on a large scale, particular data relevant to local areas is often lacking in many instances. The inclusion of local topography data is a significant factor to consider in the context of wind technology. This is due to the observation that a wind turbine situated on a topographic high, such as a hill, is capable of generating a greater output compared to an identical turbine positioned on a topographic low, even if the two locations are near, separated by just a few hundred metres. The crux of the matter is the availability of very specific and thorough quality data, as well as the use of enhanced modelling techniques, to get a more accurate understanding of the output of the system. When considering solar energy, a significant challenge arises from the absence of dependable irradiation data. This absence hinders the accurate calculation of the produced output and subsequently affects the assessment of return on investment (Sen *et al.*, 2016). The challenge associated with geothermal RE systems is to accurately define the boundaries of the reservoir. Consequently, the absence of comprehensive datasets remains a significant obstacle to advancement of RE, regardless of specific technology used.

Another difficulty that arises in this context is the need for qualified human resources who have received particular training in RE. According to (Martinot, 1998), possessing the necessary skills to effectively operate and maintain RE gear is crucial for the successful implementation of RE projects. According to (Alam Hossain Mondal, Kamp and Pachova, 2010), the aforementioned issue poses a significant obstacle in the context of developing nations. Developing the workforce and ensuring efficient and timely access to replacement parts necessitates the establishment of new infrastructures.

Socio-cultural barriers

Barriers might potentially emerge due to a lack of adequate consideration towards social and cultural considerations. Farmers often exhibit a favourable disposition towards the installation of wind turbines, seeing them as an additional revenue stream. Underneath the turbines, individuals have the ability to engage in agricultural endeavours and several other things. However, it has been argued that alternative RE resources may impede the utilisation of land for various purposes (Kotzebue, Bressers and Yousif, 2010). Hydropower projects including the construction of dams may result in the conversion of agricultural lands, hence limiting the available space for urban expansion (Hynes and Hanley, 2006). In the context of Papua New Guinea, it is observed that local inhabitants may seek recompense for the use of their land in the establishment of small hydropower systems, despite being the primary beneficiaries of such initiatives. The concept of social acceptability has significant significance in this context. Over time, there has been a progressive increase in the level of acceptability. There is already a widespread enthusiasm among individuals for the installation of solar panels on their roofs. There is a need for improved communication pertaining to the social and cultural dimensions of the society, as well as an increased awareness of religious education.

Policy barriers

The presence of a monopoly within a certain sector and infrastructure might be seen as an institutional obstacle. The energy sector in the majority of nations is characterised by a limited number of key industrial participants. When there are fewer participating organisations, the system tends to become more centralised. This concentration of power might lead to a lack of openness for smaller supply technologies that are dispersed in nature (Besant-Jones, 2006). Numerous nations continue to uphold rules and regulations that are tailored to accommodate the presence of monopolistic or quasi-monopolistic service providers. The implementation of these laws serves to safeguard the prevailing centralised energy production, transmission and distribution systems, hence posing significant challenges to the adoption and integration of RE sources. Market liberalisation in the energy industry was seen in several nations throughout the period of 90s. The implementation of liberalised and favourable regulations has resulted in the entry of several independent power producers into the market. However, it is worth noting that in the US, some minor RE project ideas have not been considered due to regulatory requirements pertaining to size (Markard and Truffer, 2006). The first step towards the introduction and promotion of RE technologies, particularly for the integration of RE with the electric power system, necessitates the change of current laws and regulations (Casten, 2012).

Most RE technology is available by public sector channels, which might reduce private investment. The protection of patents for new technical discoveries and advancements in RE technologies has the potential to attract increased private expenditures in research and development (Clawson, 1989). Intellectual property rights may significantly impact investor perspectives.

Governments in developed nations have allocated substantial public funds towards research and development initiatives about energy. To date, substantial investments have been seen in the field of nuclear energy. The global financial crisis that occurred in 2008-09 prompted several governments to advocate for the adoption and promotion of RE systems. RE sources get tax advantages and incentives, as stated by Lior (2012). The effective distribution of government financial assistance, the implementation of rules that promote investment and the adoption of liberalised market policies have the potential to facilitate the development of RE technology.

1.6 Research Problem

While most of the previous studies on RE management mainly focused on solar power and revolved around the benefits of installing solar panels, etc., other RE resources like wind, hydro and bio were also studied to an extent from an independent energy production point of view. The lack of adaptation of these studies in an industrial environment is higher from a practical point of view due to the absence of proper planning and implementation. Most industries fall short of utilizing and integrating these resources available at their work premises from the inception phase and get the best out of it.

More specifically, the following research objectives were the main focus of this study:

1. To identify the key challenges and barriers that hinder the effective integration of RE solutions into industrial facilities.
2. To assess the viability and potential of various RE sources (including wind, hydro and solar) for meeting the energy needs of industrial sectors in different regions of India.
3. To develop a comprehensive roadmap for industrial organizations in all sectors to plan their facility layouts and operations for optimal utilization of RE sources, considering both economic and ecological benefits.
4. To develop practical recommendations and guidelines for industrial organizations to navigate the planning, implementation, and management of RE systems effectively.

1.7 Purpose of Research

A more sustainable and ecologically responsible future for the industrial sector is the purpose of this research. It aspires to solve and relieve the major issues preventing the successful integration of RE solutions into industrial facilities. To help industrial organizations make the switch to cleaner, greener energy practices, this work aims to identify the main obstacles and bottlenecks and provide practical answers and strategies.

The purpose of this study is also to evaluate the practicability and potential of various RE sources for satisfying the energy needs of the industrial sector in different geographical locations. The research intends to shed light on the most promising and context specific RE solutions via this evaluation, providing businesses with the information they need to make choices that strike a balance between economic benefits and ecological responsibility. This, in turn, has the potential to revolutionise energy management in the industrial sector, leading to smaller carbon footprints, less environmental impact and an overall more sustainable and climate-resilient industrial landscape. The ultimate goal of this research is to give detailed plans and useful suggestions for industrial organisations to follow as they navigate the complex process of designing, deploying and monitoring RE systems. This not only contributes to global sustainability goals but also establishes the path for a cleaner, more sustainable and economically resilient in industry.

1.8 Significance of the Study

The significance of this research is diverse, which includes crucial areas of energy sustainability and environmental responsibility within the Industrial sector.

Primarily, in the context of global need to decrease greenhouse gas emissions and address climate change, this study assumes a crucial role in advancing environmental stewardship. The industrial sector plays a substantial role in the generation of carbon emissions as a result of its energy-intensive activities. The study endeavours to investigate the incorporation of RE solutions, therefore aligning with international endeavours aimed at transitioning towards more sustainable energy practices. The transition not only results in a decrease in the industry's carbon emissions but also serves as evidence of industrial organizations’ commitment to a more environmentally sustainable future.

The study has great significance from an economic perspective. Industrial facilities have a dual role in the economy as both substantial users of energy and significant providers to economic development. The study provides practical advice and guidelines that enable industrial organisations to make educated choices about the integration of RE into their operations, therefore empowering them in this regard. The process of integrating various components may result in financial benefits such as cost reductions, improved energy efficiency and less reliance on volatile fossil fuel costs, hence boosting overall financial sustainability.

The study has significance on a global scale, notably within framework of the SDGs established by the UN. This study makes a valuable contribution to global sustainability goals by aligning with two particular SDGs, namely SDG 7 (Affordable and Clean Energy) and SDG 13 (Climate Action). The study is important for the progress of technology. Industrial organizations are now engaging in the exploration of RE solutions, which in turn stimulates innovation in creation and use of environmentally friendly technology.

Significantly, this study underscores the need of ensuring fair and just distribution of energy resources. Assessing viability of RE sources in diverse places opens the way for the delivery of long-term energy solutions to underserved areas. The research emphasizes the possibility of strengthening living circumstances, alleviating poverty and growth overall quality of life in areas that have restricted availability of power.

In summary, the importance of this research is extensive. The subject matter encompasses urgent global issues such as climate change, economic sustainability, international sustainability objectives, technological progress and fair energy availability. By providing in-depth analysis, suggestions and a strategic plan for industrial enterprises, this study not only contributes to the wider discussion on energy sustainability but also presents practical measures to synchronize industrial activities with a more environmentally conscious, economically feasible and socially equitable future.

1.9 Research Purpose and Research Questions

The purpose of this study is to examine and assess the incorporation of RE management in the industrial sector, specifically examining its viability, difficulties and possible impact on sustainability. The purpose of this work is to provide significant insights and actionable suggestions for industrial organisations that wish to optimise their energy resources and shift towards ecologically sustainable and economically feasible energy alternatives. The study is also consistent with global environmental objectives, namely within the realms of climate action and ensuring fair access to energy. Based on these objectives the following questions are answered in this study.

1. What are the specific challenges and barriers that industrial facilities encounter when attempting to integrate renewable energy solutions into their operations effectively?
2. How do the viability and potential of renewable energy sources (such as wind, hydro, and solar) vary across different regions of India in meeting the energy needs of various industrial sectors?
3. What factors should be considered in the development of a comprehensive roadmap for industrial organizations across sectors to optimize the utilization of renewable energy sources in their facility layouts and operations, with a focus on achieving both economic and ecological benefits?

4. What practical recommendations and guidelines can be formulated to assist industrial organizations in planning, implementing, and managing renewable energy systems efficiently within their operations?

1.10 Structure of the Thesis

This research will be separated into 6 chapters, the description of these chapters are as follows:

- **Chapter 1 – Introduction:** Chapter 1 establishes the context for the study being conducted. The provided text offers a comprehensive summary of the study, presents the research subject matter, delineates the objectives of the research and research questions.
- **Chapter 2- Literature Review:** This chapter will explore the body of current research, publications and academic works related to the management of renewable energy in the industrial sector. This part aims to provide a full comprehension of the present status of the field, including fundamental principles, obstacles, and new trends.
- **Chapter 3- Methodology:** The present chapter will provide a comprehensive overview of the research methodologies, tactics and instruments that will be used in the execution of the study. The work discusses the methodology for data collection, analysis, and interpretation, focused on the relevant dimensions of the study.
- **Chapter 4- Results:** In this chapter, we will go over the study's findings and conduct an in-depth analysis and interpretation of the data we gathered. The many difficulties and potentials of renewable energy management are explored in this research. It assesses the practicality of various renewable energy sources and offers useful insights for using them into the industrial sector.

- **Chapter 5- Discussion:** In discussion chapter, the main results will be summed up and compared to the research goals. It will explain what the results mean and how they fit in with previous studies.
- **Chapter 6- Conclusion:** The last section provides an in-depth summary of the study's most important findings, consequences, and recommendations. In addition to providing a solid foundation for everything that follows, the preceding chapters provide invaluable insight into the research's practical consequences in the specific field of RE management within the industrial sector.

CHAPTER II:

REVIEW OF LITERATURE

2.1 Introduction to Renewable Energy Management

The increasing need for energy in the face of growing global populations and economic progress necessitates a crucial transition towards sustainable alternatives. Non-renewable sources, burdened by rapid expansion, are on the edge of exhaustion. Introducing the collection of RE sources - the solar power expert, consistent hydropower, the intangible winds, the natural biomass, the age-old geothermal energy, and the rhythmic movement of the seas. These sources not only guarantee dependability but also demonstrate efficiency in terms of cost, harmony with the environment, and little waste, providing a pathway towards sustainable growth. The review examines the orchestration of renewable energy, arguing that these sources can provide around 66% of the world's energy requirements. They transcend being ordinary performers and instead emerge as steadfast guardians against greenhouse gases, skilfully coordinating a choreographed spectacle in the face of the phenomenon of global warming. As we fully embrace this comprehensive work on energy, they recognize both its importance and constraints, looking forward to a future where renewable energy serves as a guiding light, revealing a more environmentally friendly and sustainable road to growth.

2.2 Theory of Reasoned Action

The Resource-Based View (RBV)

To apply the "Resource-Based View" (RBV) theory to renewable energy management in the industrial sector, special resources and capabilities that can offer a long-term competitive advantage must be found and leveraged. Reduced energy consumption and emissions of greenhouse gases are possible outcomes of switching to renewable energy sources and implementing energy management practices. while also providing economic benefits. Energy management strategies involve implementing measures to reduce energy consumption and improve energy efficiency. These strategies can include the utilized of energy-efficient technologies, adopting energy-efficient practices, and implementing energy management systems that monitor and control energy usage (Stennikov *et al.*, 2022). This is how an RBV framework for managing renewable energy in the industrial sector is conceptualized.

1. **Valuable Resources:**

Advanced Renewable Technologies: The industrial sector benefits greatly from the presence of state-of-the-art RE technology, such as highly efficient solar panels, sophisticated wind turbines, and creative energy storage systems. With these advancements, we can produce more energy with less waste and rely less on traditional power plants. Electric utility sector restructuring initiatives push for greater usage of renewable energy. Notwithstanding financial obstacles, developing wind power technology is essential. It is advised to use demand-side policies to foster innovation and expand markets (Loiter and Norberg-Bohm, 1998).

Strategic Land Holdings: A valuable resource is having or securing key land holdings appropriate for large-scale RE projects, such as wind or solar farms. A competitive advantage in terms of size and resource availability is ensured by having access to large areas for the development of RE infrastructure. With changes in EU policy, Spain saw a boom in renewable energy. Andalusia gave priority to the growth of solar and wind power. Strategic landholdings and state assistance were key success factors. Integration of spatial planning is one of the challenges (Prados, 2010).

2. **Rare Resources:**

Skilled Workforce: It is uncommon to find staff with specific expertise in project management, maintenance, and renewable energy technology. Businesses that give their staff members ongoing training and development opportunities might give them a clear competitive edge. The study looks at skill trends in the RE industry to address global energy challenges. The results show that there is a need for a trained workforce with an emphasis on subject-specific expertise, especially in technical professions (Baruah *et al.*, 2018).

Exclusive Partnerships: Forming unique alliances with top suppliers of renewable energy technologies, academic institutions, and government agencies can be an uncommon and beneficial asset. These collaborations provide access to the newest developments, regulatory knowledge, and a competitive advantage in putting cutting-edge solutions into practise. Canada's remote Indigenous communities confront social and environmental issues due to their heavy reliance on fossil fuels. To promote cooperation and sustainability, this study highlights the value of exclusive partnerships for efficient renewable energy solutions (Fitzgerald and Lovekin, 2018).

3. Inimitable Resources:

Customized Energy Management Software: A distinctive resource is the creation of proprietary energy management software suited to the particular requirements of industrial clients. By integrating with different renewable energy systems, this software can offer real-time monitoring, predictive analytics, and optimization features that are difficult for rivals to match. Using a Genetic Algorithm, a Home Electric Energy Management System (HEEMS) is creatively designed while taking user activity levels and the availability of renewable energy into account. With Customized Energy Management Software, the algorithm runs more quickly and efficiently thanks to its Matlab® implementation (Gutierrez-Martinez *et al.*, 2019).

Regulatory Compliance Expertise: Developing internal knowledge of the intricate regulatory frameworks surrounding renewable energy is a unique asset. Businesses who are well-versed in the constantly changing environmental laws and incentives are at a distinct advantage when it comes to guaranteeing adherence to regulations and optimising advantages.

4. **Non-Substitutable Resources:**

Brand Reputation for Sustainability: A non-replaceable resource is building and sustaining a solid brand reputation for sustainability and dedication to renewable energy techniques. Credibility is increased and environmentally conscientious industrial clients are drawn to companies with a positive public image and a history of environmentally mindful operations.

Comprehensive Renewable Energy Portfolio: For industrial clients, a broad range of renewable energy solutions, such as wind, solar, and energy storage, are offered as non-substitutable options. With this all-inclusive strategy, enterprises may accommodate different energy requirements and preferences.

5. **Competitive Advantage:**

Utilizing these rare, valuable, unique, and non-replaceable resources, businesses can gain a long-term competitive edge in the industrial sector's management of renewable energy. Being able to offer dependable, effective, and eco-friendly energy solutions establishes the company as a market leader. According to the RBV, organizations can develop capabilities and gain competitive advantage through the set of resources they possess (Vachon and Klassen, 2008).

6. **Dynamic Capabilities:**

Adaptive R&D and Innovation: Organizations that consistently invest in R&D are better prepared to adjust to new trends and technological advancements in the renewable energy industry. Long-term competitive advantage is sustained by the company thanks to this dynamic skill, which guarantees it stays at the forefront of innovation. This research applies the two-factor learning curve model to the analysis of R&D support in wind turbine farms located in Denmark, Germany, and the UK, with a focus on innovative and adaptive R&D to reduce costs (Klaassen *et al.*, 2005).

In summary, identifying and developing distinctive resources and capabilities that contribute to a sustainable competitive advantage is a key component of applying the RBV theory to REM in the industrial sector. The aforementioned framework places significant emphasis on the value of ongoing innovation, strategic collaborations, and profound knowledge of renewable energy technology and regulations.

- **Wind Energy**

In this research Kaygusuz (2009) examined the notable progress in wind energy, which is acknowledged as the fastest-growing technology for producing power on a worldwide scale. In the last ten years, it has become common for the industry to exceed its goals, highlighting the business's fast-paced development. Given the increasingly severe impact of climate change, that is essential to attaining sustainable development, there is a pressing need for a significant overhaul of our energy infrastructure. The aim is to migrate from using fossil fuels to using renewable energies and substantially increase energy efficiency during the next decades. This essay looks at the latest developments in wind energy and considers its enormous global potential. Based on Denmark's and Germany's experiences, the report emphasises how wind energy has developed into a reliable and affordable technology with major advantages in decreasing CO2 emissions.

deCastro et al. (2019) examined offshore wind energy development in the EU, China, and US. The research aims to analyse the range of activities performed in these locations, including extensive studies, legislative measures, and strategic planning for offshore wind farm building. Europe leads the world with 84% of worldwide installations, technological competence, economic maturity, and a growing zero-subsidy culture, exemplified by the first floating wind farm. Despite significant expansion since 2005, China has untapped potential for improvement via legislation, quicker licencing procedures, and higher feed-in tariffs. Strategic decisions will determine the US offshore wind future. A simplified licencing regime and long-term economic incentives may help the US dominate offshore wind.

In this study Zhang et al. (2023) examined the historical background, present difficulties, and future possibilities of wind energy advancement in New Zealand, taking into account its abundant renewable energy resources. The obstacles, which are impacted by issues related to two different cultures, the environment, and the economy, are examined. Seven popular wind energy storage systems are examined to find the best suited solution for New Zealand's specific setting, taking into account the unpredictable nature of wind power. The research evaluates the practicality of incorporating small-scale residential wind turbines in urban areas of New Zealand, showcasing three specific instances as case studies. The results demonstrate the significant capacity for power production and the enduring economic advantages of small-scale turbines, which enhance the overall efficiency of wind energy utilization in New Zealand.

- **Biomass Energy**

In this work, Buffi et al. (2022) The European Union's goal to achieve a transition to RE sources and meet the carbon neutrality targets of European Green Deal by 2050 is supported by hydrogen, a crucial element of the decarbonization plan in Europe. The electrolysis of biomass to produce hydrogen can significantly enhance incorporation of sustainable hydrogen sources into industrial processes on a large scale. By explicitly resolving the issue of irregular green hydrogen production from solar and wind energy, industrial sectors that require a consistent supply may be provided with an alternative solution. Through direct or indirect photolysis, biological water-gas shift reaction, photo- and dark fermentation, or thermochemical processes such as pyrolysis, liquefaction, and gasification, hydrogen can be extracted from biomass. Several techniques for producing hydrogen from biomass or substances derived from biomass are investigated, including liquid bio intermediates, biogas, and polysaccharides. Moreover, it provides a comprehensive evaluation of the most cutting-edge technologies that have the potential to be implemented within the sector. Several strategies, although steam bio-methane reforming and biomass reforming are both technically mature enough to be implemented commercially, biomass gasification is still considered to be in the low technical readiness stage. The assessment of the energy and environmental performances of the various production pathways highlights the limitations and deficiencies of the state-of-the-art life cycle assessment study. Based on the research, it seems that techniques for generating hydrogen from biomass are a promising option that might soon be able to supplement electrolysis.

A study conducted by Shahzad et al. (2023) attempts to close a knowledge gap by addressing the issue of how to get beyond the obstacles in the way of increasing Pakistan's production of biomass power by using the Pythagorean fuzzy analytic hierarchy technique. With a weight of 0.2281, the political and institutional barriers rank highest among the obstacles, followed by financial and economic barriers, weather-related obstacles, technological and infrastructural barriers, and cultural and behavioural barriers, which rank second through sixth, respectively. Furthermore, the results show that, with a global weight of 0.0471, political instability is the most significant sub-obstacle. The study's findings recommend that decision-makers, stakeholders, and regulatory bodies coordinate their efforts to guarantee the availability of suitable incentives, increase feedstock supply, and provide locals with training in order to accelerate the currently slow growth of Pakistan's biomass industry.

In this work Gul et al. (2023) advises that academics should look into the possibilities of renewable energy sources and suggest a cutting-edge new grid-connected energy system design in order to boost the medium-sized Municipality of Perugia's (Central Italy) dependency on renewable energy. Using state-of-the-art mathematical models and innovative dispatch methods, the energy system model that is being presented optimises and mixes solar, biomass, and hydroelectric energy. The developed model optimises each source's power production according to the lowest Net Present Cost and Levelized Energy Cost, and it employs integrated dispatch algorithms to regulate the fluctuating load demand. Effective energy management also makes use of demand-side load control strategies. The consequences of the suggested system have been evaluated while accounting for environmental and economic concerns. A substantial amount of renewable energy (33.2 GWh/year) is generated at the lowest Levelized Cost of Energy (0.067 €/kWh), according to the data. Furthermore, renewable energy sources fulfil as much as 78% of the community's energy needs, resulting in an annual reduction of 13,452 tonnes of carbon dioxide emissions.

The purpose of a study conducted by Calvo-Saad et al. (2023) This study identifies which Colombian communities could potentially benefit from the renewable and sustainable production of electricity using agricultural, animal, and urban residual biomass. The objective was accomplished through the utilization of a geostatistical multi-criteria decision-making strategy that incorporated analytical hierarchy techniques algorithms including Rank-Sum and Weighted Linear Combination, along with a suite of sustainable development metrics applied to official data from Colombia. For comparison, two options are taken into consideration. The first is based on professional norms, while the second takes into account the UN's Sustainable Development Goals. It was discovered that 127 municipalities were eligible for producing electricity from agricultural-urban residual biomass in the two scenarios that were put forward, while 162 municipalities were acceptable for producing power from livestock-urban residual biomass. The requirement that municipalities possess adequate production capacity to meet their own energy needs is a significant obstacle to widespread adoption of urban biomass. To evaluate the "Multi-Criteria Decision Methodologies" (MCDM), it is recommended to conduct an additional comparative analysis with previous research.

In Alola & Adebayo (2023) look at changes in the following sectors between 1990 and 2019: "greenhouse gas emissions from agriculture" (AGHG), "industrial greenhouse gas" emissions (IGHG), "waste management greenhouse gas emissions" (WGHG), and overall GHG emissions (GHG). The main information source for this topic is the utilisation of native resources, or DMC, particularly metals ores, biomass, and fossil fuels. By using Fourier function techniques, the study discovers that whereas DMC from metallic ores initially increases greenhouse gas emissions, DMC from biomass and fossil fuels eventually reduces greenhouse gas emissions. Additionally, biomass DMC has similar elasticities of 0.04 and 0.025 and over time lowers AGHG and WGHG. Using domestic fossil fuel materials decreases the IGHG over time with an elasticity of 0.18 for fossil fuel DMC, but it has minimal influence on the AGHG or WGHG. Furthermore, the elasticity of ~0.24 in metallic ores DMC spurs only IGHG. All things considered, the data suggests that to maintain environmental sustainability and keep the country on track with the CAP 2020, tougher resource circularity and material consumption laws are required, especially for metallic ores and fossil fuels. Analysing Iceland's usage of metallic ores, biomass, fossil fuels, and greenhouse gas emissions from industry and agriculture

To power both cascaded adsorption- Gado et al. (2022) In contrast to a conventional compression system of similar nature, evaluate the energy and financial feasibility of a hybrid renewable biomass, solar, and wind energy system that operates on the same input energy. Compressed refrigeration systems constitute the primary focus of this research. In scenarios I and II, two alternatives for autonomously powering the cascaded adsorption-compression system are proposed: systems comprising bi-batteries, solar, wind, and biomass are incorporated, respectively. By way of biomass and thermal residual heat derived from photovoltaic/thermal collectors, the adsorption system is operated. Conversely, the compression apparatus is operational on electricity generated by collectors powered by solar and wind energy. Therefore, excess power that is not needed for the recharge of the battery bank is transformed into thermal energy via the functioning of an electric heater. The mean meteorological data from the Egyptian city of New Borg El-Arab is compared to the aforementioned conditions. In summary, Scenario-I is a more economically viable option compared to Scenario-II, given that Scenario-II's refrigeration consumes 0.237 $ kWh−1 instead of 0.235 $ kWh−1. Scenario I involve the provision of an additional 16.6 kWh of electricity by photovoltaic and thermal collectors, which represents the full one hundred percent of the required electric demand. The design of Scenario-II, which contains 15 kWh fewer solar and thermal collectors, generates 15 kWh more electricity. Conversely, biomass energy provides the majority of the necessary thermal demand in both scenarios. Furthermore, when renewable resources are utilised, a compromise between the conventional compression cycle and the proposed cascaded adsorption-compression cycle has been identified. This document presents two proposed systems, namely photovoltaic-wind-battery (Scenario-IV) and photovoltaic-battery (Scenario-III), for the standard compression cycle. The research findings indicate that the cascaded system would entail an annual expenditure of at least $4045, with Scenario-I resulting in the maximum cost of $2714. The overarching goals encompass the reduction of ongoing energy consumption and mitigation of the effects of climate change and global warming by utilising a variety of RE sources for the operation of refrigeration and air conditioning systems.

In a study conducted by Le (2022) The idea of data mining and Hadoop-based technology are used in the development of the biomass energy engineering data resource management platform, which addresses the challenging issues of mass data gathering, storing, processing, and analysis. The high temporal complexity of the Apriori method is its bottleneck for analysing large amounts of data. To address this issue of Apriori, this study merges the Apriori algorithm with the Hadoop framework, tests the data mining of the resulting Apriori algorithm, and so on. Outcomes The test successfully identified the huge database's ideal storage mode, and the Apriori algorithm's performance was 40% better than that of the original Apriori method.

In this work, Tun et al. (2019) designed to provide a comprehensive overview of biomass energy in Southeast Asian countries, highlighting the benefits that the region's biomass resources offer to the economy and ecology. To do this, the study gathered and assessed the biomass resources, energy potential, use, and management in the area. This was made possible by looking through national reports, review papers, and research articles that had been published. It was discovered that fuelwood, wood waste, rice husk, rice straw, sugarcane residues, oil palm leftovers, and coconut residues were the main sources of biomass in this area. An estimated 500 million tonnes of biomass, or 8000 million gigajoules of potential energy, are produced annually by the region's forestry and agricultural industries combined. The study described the challenges and barriers related to utilising biomass sources in these countries and, by contrasting them with the traditional approach, proposed a workable strategy for generating biomass energy.

- **Geothermal Energy**

A study conducted by Alcaraz et al. (2016) proposes a method to enhance resource management by establishing a market for the rights to use shallow geothermal energy. In order to define the fundamental unit of management, a novel concept known as the thermal plot was developed. It deals with a registered piece of land's shallow geothermal potential. To do this, the study gathered and assessed the biomass resources, energy potential, use, and management in the area. This was made possible by looking through national reports, review papers, and research articles that had been published. It was discovered that fuelwood, wood waste, rice husk, rice straw, sugarcane residues, oil palm leftovers, and coconut residues were the main sources of biomass in this area. An estimated 500 million tonnes of biomass, or 8000 million gigajoules of potential energy, are produced annually by the region's forestry and agricultural industries combined. The study described the challenges and barriers related to utilising biomass sources in these countries and, by contrasting them with the traditional approach, proposed a workable strategy for generating biomass energy.

In Noorollahi et al. (2019), An overview of Iran's geothermal energy development during the last 20 years is provided. An overview of Iran's geothermal operations is provided, along with an analysis of the advantages of these advancements in the National Development Plan (NDP). The logistical advancement of geothermal projects worldwide, and the first geothermal project in Iran (NW Sabalan) in particular, is hindered by several administrative, technical, and regulatory obstacles. The primary issues and barriers in the first geothermal project include inadequate human resource management, a lack of municipal and federal laws, and a failure to transfer technology. One may implement policy changes by creating new local and national laws, develop human resources by sending scientists and engineers to other countries for training, and convince them to stay involved in geothermal projects in order to achieve a proper geothermal resource development.

In this work, Piselli et al. (2020) For the purpose of energy retrofitting historical buildings, integrate the modelling, monitoring, administration, and maintenance of a new geothermal system using Historic Building Information Modelling (HBIM). Adsorption heat pumps are linked to the horizontal ground source heat exchangers (GHEXs) of the system. A preliminary case study is undertaken on a rural structure situated within a mediaeval complex in the Central Italian province of Perugia. The study demonstrates how the incorporation of Facility Management (FM) functions from HBIM into the building monitoring and supervisory system can function as a human-cantered operational management control mechanism for the interior comfort and energy efficiency of the structure. As a result, this HBIM integration strategy has the potential to enable the user-centric re-operation of older structures.

In this work, Ruef et al. (2020) conducted an empirical investigation of varying interpretations of the project managers' and the residents' viewpoints, which are fundamental to a participatory process. Project managers tend to perceive participatory forms in a somewhat traditional way, while residents search for formats that they can incorporate into their daily routines. When combined, these viewpoints broaden the accepted definitions of participation found in the literature and make it possible to identify blind spots. The results, which are based on actual data from the geothermal energy industry, demonstrate that expectations and perceptions of involvement differ and may even be erroneous, which causes misconceptions about the kind and extent of engagement. Thus, energy initiatives may be postponed or maybe blocked.

In this work, Y. Wang, Liu, et al. (2020) outlines the current state of geothermal energy in China and examines issues pertaining to financial investment, scientific advancement, policy and regulation, and environmental protection. A few policy suggestions are made to encourage the use of geothermal energy in China. This essay makes the case that geothermal energy development has an opportunity during the "13th Five-Year Plan" timeframe. As interest in geothermal energy grows, a number of laws to support its growth and use may be developed, and China may see a scaled-up development of this resource.

The primary objectives of a study conducted Gong et al. (2021) examines the political, economic, social, and technical (PEST) aspects of China's geothermal energy business to identify its strengths, weaknesses, possibilities, and dangers. The SWOT–PEST study shows that China's geothermal energy sector has the necessary resources, market, and technology base to grow on a massive scale. However, it faces challenges such uneven resource distribution, unfinished government regulatory development, unfinished national policy execution, ambiguous authority across governmental administrative systems, and a lack of standardised technical standards and codes. As a result, plans for future growth have been made to provide geothermal energy development technical assistance and policy instruments. Enhancing policy direction and financial support, streamlining administrative processes, developing geothermal expertise, and improving resource discovery are some of the measures made to guarantee its healthy and sustainable growth.

In Shortall & Kharrazi (2017) investigates cultural shifts towards sustainable energy using a case study of Icelandic and Japanese geothermal development. They emphasise cultural factors pertinent to sustainable transitions using Hofstede’s framework for cultural theory, focusing in particular on the difficulties associated with managing geothermal energy resources, handling associated disputes, and involving the public. They provide the conclusions, which are supported by a thorough literature analysis and were gleaned from conversations with influential figures in the energy sector in both nations. It is ascertained that the advancement of geothermal energy in both countries is substantially impacted by cultural factors. Furthermore, study enumerate the advantages and disadvantages of various approaches to resolving shared challenges and obstacles.

In this work, Pellizzone et al. (2015) give the findings of a survey asking people what they think about Sicily's potential use of geothermal energy. The study was conducted as part of larger VIGOUR research project, which looked at the viability of using geothermal energy in southern Italy. The present investigation aims to accomplish two principal goals: firstly, to examine the perspectives and attitudes of nearby communities towards the possible uses of geothermal energy; and secondly, to add to the growing corpus of knowledge on public involvement in energy-related matters. They used both qualitative and quantitative methodologies to perform a case study to investigate public perceptions of geothermal technology. Despite Italy's vast geological potential for producing geothermal energy, the general public's awareness of this energy source is rather low. The findings show that there is a general lack of confidence in decision-making processes among Sicilians and that the subject is surrounded by ambiguity. When combined, these elements should have a significant influence on any future advancements in this field. The findings unequivocally demonstrate that the initial step in a public involvement process should be further social discussion backed by a strong communication action plan.

In this work, F. Sun et al. (2018) explains To simulate the movement of CO2 in the geothermal well's descending, horizontal, and ascending portions, a model is created. Additionally, the ideas of critical position and effective distance are offered as two novel ways to accurately assess the efficacy of geothermal recovery. The findings of the simulation indicate that: (a) The working fluid temperature and formation temperature are equivalent at a key point in the ascending wellbore. (b) When gravity is disregarded, the impact of mass flow rate on pressure drop becomes more apparent, particularly when mass flow is greater. (c) The performance of geothermal recovery is not improved by the working fluid temperature rising quickly. The effective distance should now be used as an extra point of reference.

In this study, by Moya et al. (2018) A comprehensive review of scholarly literature is undertaken concerning the evolution of power plant technology, direct heat utilization, and geothermal energy development. An examination is conducted on the architectural designs of dry-steam, single-flash, advanced, binary, and double-flash power plants. To be taken into consideration for future assessments of geothermal power plants, the thermodynamic properties are looked at. Also included are the direct applications of geothermal heat that are most common. The findings suggest that the use of Binary – Organic Ranking Cycle Power Plants may be necessary for the extraction of geothermal resources that have temperatures below freezing. Hybrid solar-biomass systems research is also needed for applications that use poly-generation. The geothermal reservoir's lifespan is extended by these designs, which also improve energy production and thermal efficiency. Likewise, direct applications of geothermal heat provide fantastic opportunities to increase a geothermal plant's revenue. The optimal use of geothermal resources is contingent upon both the particular geographic zone and the cascade design. Further research is warranted to assess the environmental, financial, regulatory, and drilling aspects of geothermal projects, in addition to their geophysical, chemical, geophysical, and drilling characteristics. The primary objective of addressing these issues is to furnish the most current information regarding geothermal development to geothermal energy-interested communities, policy officials, academics, and developers.

- **Marine Energy**

A study conducted by X. Li et al. (2023) Apart from its eco-friendliness, the electric propulsion ship with a “hybrid energy storage system” (HESS) offers notable benefits in terms of reduced fuel usage. Due to boats' high manoeuvrability and load variation, the marine HESS design issue is multi-objective and nonlinear. The “adaptive multi-objective joint optimization framework” (AMJOF), which considers “energy management strategy” (EMS), is proposed in this research for HESS design. This framework's objective is to address the intricate working circumstances that emerge during the actual operation of vessels as well as the close relationship between power allocation and HESS. A multi-objective joint optimization approach is included in the framework to achieve high operating condition adaptability and get the most appropriate energy management for maritime HESS design with the lowest investment cost and least amount of battery deterioration. Furthermore, a brand-new energy-saving system (EMS) is being put forward that uses adaptive segmentation and frequency management to allocate power optimally. Furthermore, an evaluation indicator is provided to measure the effectiveness of various optimisation techniques. The outcomes show how effectively the AMJOF can function and choose the best course of action for ship operating.

In this work X. Sun et al. (2023) focuses on the variable weighted decision model predictive control (VWDMPC) for maritime hybrid energy management. The primary goal of this approach is to properly allocate energy and dynamically adjust weight in order to achieve the best possible trade-off between fuel consumption, power output, and energy allocation. The study simplifies the optimisation process by compressing the optimum energy management issue and the weight tuning procedure into one by using the KKT condition, which improves the real-time and flexibility of VWDMPC. Real-time hardware execution platforms and test benches are used for performance research. The suggested VWDMPC's improved power performance and comparable fuel consumption were assessed using a variety of weighting choice comparison situations, and the optimal proportionate weights (0.33,0.27,0.2,0.2) were determined by taking both factors into consideration. Additionally, this study offers validation and feedback based on evaluation results, which indicate that, based on the radar plot created from performance index parameters, the ideal weight combination taking economy and dynamics into account ranges from (0.3,0.3,0.2,0.2) -(0.33,0.27,0.2,0.2).

According to a study conducted by Jiang & Khattak (2023) investigates the correlation between South Korea's carbon dioxide emissions (CO2e) and the IMET (1990Q1-2018Q4). The expansionary commercial policy (ECP), international cooperation in green technology development (ICGD), and gross domestic product per capita (GDPPC) are all examples of control variables. Initially, the results corroborated the enduring correlations among CO2e, ICGD, GDPPC, ECP, REC, and IMET. Additionally, the findings indicated that a rise in IMET was correlated with the generation of renewable energy sources that generated reduced carbon emissions, consequently leading to an enhancement in environmental conditions. In addition, the computations unveiled a positive correlation between GDPPC and ECP increases and CO2e levels. Furthermore, the data illustrated that ICGD's assistance in the advancement of co-green technologies resulted in a decrease in carbon dioxide emissions. Fifth, there was a negative correlation between REC and a reduction in CO2e. In order to advance the green economy, this essay suggests that governments enact legislation that incentivizes academic institutions and businesses to participate in IMET, based on current estimates.

In this work, Duan et al. (2023) explains how the scalable rolling-structured TENG (SR-TENG) was designed, including the calibration of its exterior form and interior particulate loading quantity to produce an average power density of 10.08 $W \cdot m^{-3}$ when activated routinely. The SR-TENG achieves peak power densities of 80.29 $W \cdot m^{-3}$ and an average of 6.02 $W \cdot m^{-3}$, which are substantially higher than the power densities of conventional water wave-driven TENGs. Ultimately, it was demonstrated that a power supply consisting of an eight-unit SR-TENG array could effectively sustain portable electronic devices employed in marine environment monitoring. By promoting the production and utilisation of ocean blue energy, the SR-TENGs could offer an innovative strategy for achieving carbon neutrality.

In this work, Lazaar et al. (2020) provides the ideal dimensions for a hybrid microgrid that uses marine current energy. Using Matlab software, a particle swarm optimisation (PSO) has been created for this reason. To fulfil demand all year long, an energy management plan that considers the availability of RE sources and energy usage at all times has been put into place. To assess the efficacy of the PSO, the results were contrasted with those generated by the genetic algorithm (GA). To simulate the diversity in home loads on an island, the conventional household load profile is used. Because the Alderney Race (also known as Raz-Blanchard in French) location has some of the greatest currents in the world, it is selected as a case study for our maritime energy system.

In, Akbarzadeh et al. (2022) focus on optimizing the battery system's capacity for the battery HESS of an electric harbour tender. An evaluation was conducted on three crucial performance metrics—namely battery weight, system efficiency, and cost—about the implications of battery hybridization. In battery systems that have been designed to last for a duration of 10 years, NMC and LTO cell technologies are employed as high-energy (HE) and high-power (HP) cells. The HESS design is comprised of a parallel full-active architecture and a rule-based energy management method. The study's findings indicate that battery hybridization has the potential to decrease system costs by around 28% and 14%, respectively, in comparison to monotype batteries that utilise LTO and NMC cells. When compared to monotype designs, hybridization of batteries reduces battery cell weight by approximately 30%, even when the efficiency difference between the monotype system and HESS is negligible. The findings of the research indicate that substantial battery packs for electric vessels might experience a reduction in both weight and cost through the process of hybridization.

In this work, Hernández-Fontes et al. (2019) Performs an insightful theoretical examination of marine energy sources in the vicinity of Mexico with the purpose of identifying potential locations for future comprehensive technical evaluations and the execution of projects. A multitude of energy sources, including thermal gradients, ocean currents, waves, and salinity, are considered. Using global databases, the percentages of energy availability for the aforementioned characteristics were computed to identify potential locations with the longest-lasting power availability. By selecting this approach instead of simply calculating the mean values of the data, more illuminating results were obtained. Furthermore, several social and environmental considerations that were mandatory for subsequent evaluations of the marine energy potential of Mexico were integrated. The results indicate that the northwest region of Mexico exhibits the greatest capacity for wave energy, with estimated values ranging from 2 to 10 kW/m more than fifty percent of the time. Furthermore, more than fifty percent of the time, the state of Quintana Roo derives electricity from ocean currents (approximately 32–215 W/m2). 70% of the time, the thermal gradient power in the southwestern and southeast regions of the country remains relatively constant, averaging between 100 and 200 MW. Southeast Mexico has the greatest concentration of salinity gradient energy. This methodology has the potential to be applied in the future to resource evaluations in areas with limited data availability.

In this work, Trabelsi et al. (2022) The integration of a supercapacitor-based energy storage system (SC-ESS) with a tidal turbine has the potential to mitigate substantial fluctuations in power generation. The purpose of connecting the SC-ESS to the tidal turbine unit in an islanded microgrid is to meet requirements regarding the fluctuation of injected tidal power. For the ESS, a novel intelligent power management strategy is proposed. By integrating a tidal turbine with a supercapacitor-based energy storage system (SC-ESS), this methodology mitigates substantial variations in power production. Additionally, the study puts forth a proposal for the thorough modelling of the overall operation of the system. The system model is implemented using the Energetic Macroscopic Representation (EMR) tool, whereas the control methods are deduced using the inversion-based control concept. By employing this worldwide methodology, the islanded grid of Ushant in France is linked to the test tidal turbine, which is constructed upon a tangible 1 MW prototype. Empirical evidence suggests that a compact, inexpensive SCs pack might possess the ability to withstand significant fluctuations in tidal force. The present scenario utilises a collection of SCs as opposed to the current method, which employs a bank of resistors to prevent excessive power fluctuations. An energy loss reduction of 18.2% is illustrated for a single tidal cycle, providing the Ushant's Island microgrid with a substantial advantage.

Renewable Energy in Industrial Sector

In this paper, Jahanger et al. (2023) At the 26th Conference of the Parties to United Nations Climate Change, deliberations were held regarding the consequences of achieving carbon neutrality by 2050 or 2060. To facilitate the realization of SDG 7, which aims to establish a habitable environment that is both economical and ecologically sound, the study further examines the energy efficiency contributions of renewable energy and technologies in the ten foremost manufacturing countries, concentrating on the carbon neutrality breakeven point. This research employs the “Moment Quantile Regression” (MMQR) technique to generate predictions for the period 1990–2020. The study's findings indicate that energy efficiency and renewable energy represent two pragmatic and consequential approaches to mitigating greenhouse gas emissions in the chosen nations. Once more, the data suggests that greenhouse gas emissions are positively influenced by the industrial sector. Conversely, the term that exhibits an interaction between energy efficiency and industrial expansion diminishes emissions in every quantile, suggesting that manufacturing energy efficiency may have the capacity to offset the ecological repercussions of industrial expansion. Ongoing and beneficial technological progress consistently contributes to the mitigation of GHG emissions. Moreover, the results about the ten foremost nations in the manufacturing sector provide support for the EKC theory. The study's findings will furnish the legislators of these countries with vital policy recommendations in their quest to attain carbon neutrality.

The main issue of the research conducted by Lin & Huang (2023) Between 2000 and 2019, the multi-regional input-output table was utilized to calculate the impact of digital industries on the power sector in 33 countries. To assess potential moderating influence of digitalization on the causal connection between renewable energy installation and production, a two-way fixed effect panel model was developed. The findings of the inquiry have been substantiated via robustness testing. The findings indicate that digitalization appears to exert a beneficial influence on the integration of RE. Even more so is the inconsistency of the moderating effect. It is expected that additional progress will be made in the integration of renewable energy once the digital input surpasses 4.2659%. Moreover, established countries are still experiencing the moderating effects of digitalization, whereas developing countries have yet to exhibit any statistically significant outcomes. The study's results provide legislators and stakeholders with empirical information, policy suggestions, and a practical tool to facilitate the expansion of RE sources and the achievement of carbon neutrality.

In this work, Raihan (2023) The present study investigated the dynamic effects of urbanization, economic growth, utilization of renewable energy sources, tourism, industry, agricultural output, and forest area in the Philippines to achieve carbon dioxide emission reduction and environmental sustainability. The researchers employed the "Dynamic Ordinary Least Squares" (DOLS) method and the "Autoregressive Distributed Lag" (ARDL) bounds testing strategy to analyse annual time series data spanning the years 1990 to 2020. It is projected that CO2 emissions in the Philippines will increase by 0.16%, 1.25%, 0.66%, and 0.26%, respectively, for every one percent rise in economic development, urbanization, industry, and tourism. Furthermore, it is worth noting that a 1% increase in the implementation of renewable energy sources, forest area, and agricultural productivity could potentially lead to respective decreases of 1.50 percent, 0.20 percent, and 3.46% in carbon dioxide (CO2) emissions. To ascertain the factors that contribute to the association between the variables, the paired Granger causality test was applied. This study provides guidance on the implementation of policies aimed at promoting environmental sustainability via emission reduction in low-carbon economies. The aforementioned initiatives promote policies such as sustainable urbanisation, environmentally sympathetic tourism, climate-smart agriculture, and green industrialization.

In this work, Fang et al. (2022) investigates the correlation between industrialization, R&D, and the expansion of the green economy. Green finance could potentially facilitate the development of novel technologies, fund environmentally sustainable initiatives, and foster the expansion of the green economy. Therefore, it significantly contributes to the expansion of the green economy and the reorganisation of the industrial sector. This study looks at how industrialization, R&D, and renewable energy affect the expansion of the green economy in South Asia between 2008 and 2020. This connection's endogeneity is handled using a two-step ordinary least square (O.L.S.). The results demonstrate how R&D and upgrading industries may both lead to a green economic rebound and a decrease in carbon emissions. Consequently, 35.2% less emissions were produced, and 33.4% more energy was conserved. The influencing framework of the policy is shown by the partial mediation effect results. The empirical findings demonstrated that, along with advancements in the transformation of the industrial structure, technological spill over bore the most responsibility for reducing CO2 emissions at different levels. According to the research, developing countries benefit more from the industrialization push than do developed ones because the former has more economic effects.

In a study conducted by Ge et al. (2022) examines how China's industrial structure is affected by technology advancements in renewable energy and green financing. It was discovered that RETI has made a substantial contribution to the restructuring of the industrial structure. The Panel Vector Autoregressive (PVAR) model research results further demonstrate this ongoing and dynamic positive promotion. As green finance improves, the results of the threshold regression indicate a non-linear relationship between RETI and industrial structure. In locations where green funding is relatively low, RETI may restrict the upgrading of industrial structure. The impact of RETI on industrial structure is notably good when the level of green finance development is reasonably high. According to heterogeneity study, technical progress in renewable energy has greatly aided in the upgrading of the industrial structure in eastern China. Policymakers should thus take some actions to hasten the growth of green financing and bolster its support for technological advancements in renewable energy. The Chinese government must keep putting relevant green credit laws into practice and broaden the pool of available green money.

In this research Raihan et al. (2022) Analysed the potential benefits of urbanisation, industrialization, technological advancement, the use of renewable energy, economic expansion, forest area, and industry in Bangladesh, Through the mitigation of carbon dioxide emissions, this research aspires to attain ecological sustainability. ARDL bounds was testing done on time series data from 1990 to 2019 before the DOLS approach was used. The available empirical evidence indicates that economic expansion, urbanisation, and industrialization all contribute to the escalation of CO2 emissions in Bangladesh. Nevertheless, these aforementioned factors also foster technological progress, facilitate the growth of forested regions, and encourage implementation of RE alternatives. The cumulative effect of these favourable outcome's aids in the mitigation of CO2 emissions and achievement of ecological sustainability. To investigate the causal relationships between the variables, the paired Granger causality test was applied. To reduce emissions and advance environmental sustainability in Bangladesh, this study proposes policies that will facilitate the development of a low-carbon economy. Among these objectives are the promotion of sustainable forest management, encouragement of RE use, sustainable urbanisation, and green industrialization.

This study Fotio et al. (2022) Between 1985 and 2017, this study analyses the effect of renewable energy on value-added in the agricultural, industrial, and service sectors in a sample of twelve Sub-Saharan African nations. The findings sourced from the PMG-ARDL model suggest that the value-added generated by renewable energy sources exhibits a consistent upward trend across diverse sectors, with the most significant benefits being observed in the service industry. However, the extent to which renewable energy directly influences value-added in sectors is limited. In addition, even though capital and labour are the primary value-added generators in all three sectors, data indicate that the use of non-renewable energy sources significantly increases service value-added. In conclusion, the causality test demonstrates that renewable energy has no influence on value-added in the industrial sector, but rather has a unidirectional impact on value-added in the agricultural sector. According to these results, consistent investments in renewable energy are prevalent.

In this work, Hu et al. (2020) An examination of the effects of the pilot programme for China's CO2 ETS in 2011 on energy conservation and emission reduction. They apply the difference-in-differences (DID) model to panel data from the two-digit industry at the provincial level for the period 2005 to 2015 to assess the impact of the CO2 ETS on energy conservation and emission reduction. The findings indicate that the adoption of the CO2 ETS in pilot regions leads to a notable decrease of 15.5% in CO2 emissions and 22.8% in energy consumption for regulated businesses in comparison to nonpilot regions. Upon further investigation, it becomes evident that the transformation of the sector's structure and the improvement of technological efficacy are the principal determinants of policy outcomes. In addition, the study establishes a correlation between enhanced functionality of CO2 ETS systems and increased levels of environmental regulation and marketization. The data indicates that the CO2 ETS has been successful in developing countries in reducing emissions and promoting energy conservation.

Abu-Rumman et al. (2020) looked at Jordan's current energy situation and assessed whether direct investments in renewable energy sources would be feasible. The real contribution of clean energy, at around 7% of total energy consumption, is still small despite the efforts made to develop alternative energy sources. The supply and demand for power in the country are shown, and the policies, grants, and tax breaks that the government has put in place to promote clean energy projects are also covered. Together with its ambitious $20 billion energy goals, the renewable energy policy creates potential for investors in the future, as does its aim to increase energy efficiency. Prospective developers and clean energy investors may find this report useful as plans for 2,000 MW of solar and wind energy projects are up for bid. Such an endeavour and example would also be beneficial to neighbouring countries in the region.

Maradin (2021) The objective of this essay is to assess the advantages and disadvantages of utilising renewable energy sources in a broad sense, excluding particular renewables such as wind and solar power. Environmental protection through reduced emissions of greenhouse gases and technical and innovative progress are two of the many advantages of generating electricity from renewable sources that the study cites. Certain drawbacks of using RE sources to create power are also discussed, including their reliance on the weather, poor energy efficiency, and limited capacity.

Pietrzak et al. (2021) is authors that set out to investigate the opportunities for the RE sector to grow in Poland, as well as the industry's impact on certain social and economic factors. To achieve the goal of this study, a critical situation assessment of RE in Poland was carried out, along with a survey of a group of subject-matter specialists. The impact of psychological, physical, and legal factors on the real estate industry was examined. It was determined that simplifying relevant legislative acts in Poland was necessary in the framework of legal determinants. Some laws need to be improved, the Distance Act being among them. It was discovered that biomass, solar, and wind energy have the best prospects for growth in physical determinants. The writers of Mental Determinants took into consideration the need to teach the public about getting and utilising energy. It's also critical to educate people about the good effects that the RE industry has on the low-emission economy. This will increase the number of new employments created and lower the amount of toxic chemicals released into the environment.

In this work, Gielen et al. (2019) investigates the financial and technical implications of an accelerated energy transition till 2050 using recently released information on renewable energy. The pillars of this transition, according to the report, are energy efficiency and renewable energy technologies, and their synergies are also crucial. Such a shift is encouraged by favourable economic circumstances, a wealth of resources, scalable technology, and substantial societal advantages. Until 2050, when a significant decrease in greenhouse gas emissions will be required to keep the average rise in global surface temperature below 2 °C, two thirds of the world's energy needs can be met by renewable energy. In order to achieve the necessary six-fold acceleration in renewable energy output, changes must be made to enabling policies and regulatory frameworks. When combined with a high level of energy efficiency, wind and solar PV technologies are expected to increase at the fastest pace. However, in order to completely eradicate carbon dioxide emissions, it will be crucial to implement novel technologies and foster innovation, particularly in the transportation and industrial sectors—areas that are presently receiving limited attention in international discourse. Emerging infrastructure concerns that require additional attention include charging infrastructure and other repercussions of sector coupling.

In this study Kyritsis & Serletis (2019) Conduct an analysis of the effects that volatility and uncertainty surrounding crude prices have on the stock returns of technology and renewable energy companies. A bivariate structural VAR model is utilised, which has been modified to account for GARCH-in-mean errors. The utilised dataset for this purpose comprises monthly observations from May 1983 to December 2016. Furthermore, the study investigates the disparity in the way stocks respond to oil price disruptions of varying magnitudes when oil price uncertainty is present versus when it is absent. The findings of the research suggest that a symmetrical relationship is present between stock returns and hydrocarbon prices. In addition, no correlation between oil price uncertainty and stock returns is statistically significant. Taking into account the model's parameters and fluctuations in the stock prices of renewable energy companies, robustness of the results is readily apparent.

Bagheri et al. (2019) posit in 2019 that an optimal and methodical approach to designing neighbourhood-scale solar, wind, biomass, and natural gas systems can be devised by utilising actual real-time hourly electric demands. They developed three electricity scenarios to accomplish this: natural gas alone, natural gas combined with renewables, and renewable energy sources (solar, wind, and biomass). They determined which hybrid systems exhibited the least NPC under each power condition. Based on the investigation, the expense associated with supplying renewable energy to the industrial sector for neighbourhood sizes is 0.385 USD/kWh. The aforementioned data illustrates a decrease of 4% and 5%, respectively, when compared to the residential and commercial sectors (0.318% and 0.399% USD/kWh). The increased COE associated with the residential system can be primarily attributed to the greater proportion of larger batteries about solar PV. Furthermore, in comparison to the equivalent system, the biomass/wind/solar power facility demonstrated a threefold decrease in COE. Similarly, the integration of the low emission “natural gas” (NG) generator into the hybrid solar, wind, and biomass facility led to an estimated threefold increase in annual GHG emissions and a 30% reduction in the COE of the system. Furthermore, a sensitivity analysis was performed to determine how alterations to the discount rate and the capital cost of the PV panels and batteries would affect the COE of the systems. This was done to assess the model's accuracy in light of the input variables' inherent uncertainty and variability. Therefore, it was demonstrated that fluctuations in battery prices had a greater impact on the COE of systems compared to solar panels. The results of this research could potentially assist policymakers in formulating regulations and policies that promote urban hybrid renewable energy systems more efficiently. This article's objective is to compute the monetary consequences of renewable energy implementation in Croatia. The indirect and induced repercussions of an input-output model were employed to assess the process of initiating and sustaining these facilities. The closed input-output model incorporates induced consequences linked to the rise in household sector income, while the open input-output model examines indirect effects. Independent parties have conducted an assessment of the combined impacts of the investment channel and the intermediate consumption channel. The results indicate that the installation and operation of renewable energy facilities in Croatia generate favourable multiplier effects. Equal investments in biogas and lesser hydropower facilities generate the greatest employment and gross value added; conversely, wind power plants have diminished multiplicative effects due to the substantial reliance on imported equipment.

The purpose of the research conducted by Anton & Afloarei Nucu (2020) to examined, between 1990 and 2015, the relationship between financial growth and use of renewable energy using panel data from 28 EU member states. In the panel fixed effects model of this study, the quantity of renewable energy utilised is determined by financial development, income, energy prices, and foreign direct investments. According to empirical research, each of the three financial development dimensions—the capital market, bond market, and banking sector—has a positive effect on the proportion of renewable energy use. Furthermore, this research indicates that the impact of the capital market expansion in the recently established EU Member States on the uptake of RE sources is negligible. The empirical research conducted yields significant insights regarding the optimal approaches to capital allocation within the RE industry. The primary objective is to provide clients with cost-effective alternatives and supplementary services that add value.

Chaichaloempreecha et al. (2017) examines the fluctuations in greenhouse gas emissions from 2005 to 2036. The population, GDP, and cost of fuel all affect how much energy is needed. To evaluate the GHG reduction in various scenarios, one tool that may be utilised is the “Long-range Energy Alternative Planning System” (LEAP). “Business-as-usual” (BAU) scenarios may be thought of as static situations without the use of new technologies or improved energy efficiency. On the other hand, the AEDP2015 (MIT_RE scenario) and EEP2015 (MIT_EE scenario) use the existing mitigation (MIT) scenarios. This study encompasses eleven industries, including construction, manufacturing, food and beverage, textiles, timber and furniture, chemicals, non-metallic, basic, and produced metals, paper and pulp, and additional sectors. Fossil fuels constitute the predominant source of greenhouse gas emissions within this industry, contributing to 86% of total emissions. Greenhouse gas emissions increased from 77.6 Mt-CO2eq in 2005 to 222.5 Mt-CO2eq in 2036. The non-metallic sector was found to be the primary source of GHG emissions. Under the MIT_EE and MIT_RE scenarios, full implementation of the EEP2015 and AEDP2015 could reduce greenhouse gas emissions by 36% and 9%, respectively, by 2036. Potentially aiding in the attainment of these GHG reductions is the implementation of EEP2015, which provides financial incentives to particular businesses that satisfy energy performance targets and uphold energy standards.

Strielkowski et al. (2021) Evaluating renewable energy's role in the electrical power industry's sustainable expansion is the review's main goal. It does this by focusing on energy providers and consumers, who are mostly residents and businesses that are gradually transitioning to prosumer status in the electric energy industry. Additionally, it highlights the benefits of RE for the system and utilities. Moreover, it outlines the main forces behind the sustained expansion of the electrical power sector.

Liu et al. (2019) This research utilises the "social accounting matrix" (SAM) multiplier model to examine the financial ramifications of coal and renewable energy in China. Using "structural path analysis" (SPA), the transmission mechanisms of coal and renewable energy on production variables are also investigated from the perspective of the sector industrial chain. The research indicates that renewable energy can facilitate faster economic growth in US than coal energy. Renewable energy may, in the interim, facilitate the modernization of the industrial infrastructure more efficiently than coal energy. Moreover, regarding economic growth, the transportation, warehousing, electrical equipment manufacturing, and service sectors are the intermediate industries most significantly impacted by renewable energy. Implications for the responsible design and construction of future energy development projects are substantial. These results enhance our understanding of the impact pathway associated with renewable energy.

The goal of the research of Tanu Rizvi (2022) is to concentrate on how renewable energy sources are used in various businesses. Their potential for industrial applications has received little attention up to this point. According to research, the bulk of processing will be done using renewable energy sources until 2050. Until 2050, they are probably going to provide around half of the total at a cost that is competitive with other sources. Solar energy sources will ultimately replace all other renewable energy sources as the main source since they are compatible with a broad variety of devices. This study conducts a comprehensive analysis of prospective technological developments to investigate the economic feasibility of renewable energy sources. In addition, the principal conclusions and strategies for further development of these types of frameworks are discussed.

Hansen et al. (2019) The goal of this research is to increase our understanding of how to move Germany's energy system to 100% renewable energy by 2050. This study presents a road map for the comprehensive transformation of the German energy system, which includes sectors such as transportation, industry, heating, and electricity. It takes into consideration the expenditures of the energy system, the potential of renewable resources, and the primary energy supply. From a technical and financial aspect, the study reveals that this change is achievable, with specific stages being required to achieve this aim inexpensively. The primary barrier to this change is the availability of resources, especially biomass resources, which are scarce and under threat. They conclude by discussing the key policies needed to implement the green transition.

Rangel-Martinez et al. (2021) study offers a thorough rundown of the state-of-the-art in machine learning applications currently used in manufacturing sectors that significantly affect sustainability and the environment, such as smart grids, the catalysis industry, biomass, solar, wind, and hydropower, and power storage and distribution. Because of their ability to generalise, artificial neural networks are the most recommended methods above other machine learning algorithms. Since there is a rising need for academic courses connected to artificial intelligence in science, math, and engineering, there will be a significant rise in demand for machine learning methods in the energy sectors in the next years. The effective use of machine learning algorithms that can be shared by significant players in the energy sector is anticipated to be contingent upon the collection, management, and safety of data. This will facilitate the advancement of ambitious energy management initiatives. The flow of information between ML and systems will be improved by new algorithms for generating trustworthy data and the inclusion of additional information sources (such innovative sensors).

Kamran et al. (2020) Pakistan's renewable energy business is being evaluated for viability in its present condition and for its future development using the Strengths, Weaknesses, Opportunities, and Threats (SWOT) framework. The conclusions, which examine advantages, disadvantages, opportunities, and threats from a local perspective, are explicit and categorised to emphasise the effects on the environment, society, and economy that will affect the renewable energy industry's ability to expand sustainably. Consequently, the sector's merits—specifically, its capacity for renewable energy, resource maps that have been independently verified, environmental sustainability, and the increasing presence of private investors—are subject to critical examination. On the contrary, deficiencies such as technology-related environmental risks, developing institutional structures, inefficient technologies, and high capital expenditures are perceived as intrinsic defects that require remediation. Utilising unrealized potential, small- and micro-scale installations, off-grid energy systems, and efficiency improvements are the primary avenues for sustainable growth. The sustainability of the renewable energy industry faces many challenges that need to be avoided, such as grid connection issues, regulatory consequences, and competing energy supplies.

In this study, Bouraiou et al. (2020) explains that A synopsis of the energy profile and the possibilities for renewable energy has been examined. The existing body of research suggests that the integration of renewable energy sources might experience a postponement, in contrast to the considerable capacity of wind and photovoltaic power plants to produce 354.3 MW as of June 2018. This is in stark contrast to the enormous potential of solar and wind energy. This contrasts with the goals set by the government. The Algerian government has encountered significant challenges in its endeavours to diminish the nation's economic dependence on hydrocarbon revenues and greenhouse gas emissions (with 135.5 MT of carbon dioxide emissions in 2018). This study provides valuable insights into the state of renewable energy in Algeria, serving as a scientific forum for business organisations and academics alike to explore viable strategies for progressing the field.

The aim of this study of Seetharaman et al. (2019) aims to look at how barriers to renewable energy adoption are affected by legal, technological, social, and financial issues. An online survey was used to gather data, and 223 experts worldwide who work in the energy business answered it. Moreover, this research demonstrates that the adoption of renewable energy sources is significantly influenced by social, technological, and legal barriers in addition to economic constraints, which exert a substantial indirect influence. By lowering obstacles to research and development, organisations will have the capacity to allocate substantial resources towards the advancement of state-of-the-art technologies. These technologies possess the capacity to augment the efficacy of utilising renewable energy sources and enhance their overall perceived viability. All parties involved will be happy when locals have access to energy alternatives that are less polluting and have cheaper tariffs, as well as when manufacturers make more money.

The present research of Ramzan et al. (2022) Analyses the relationships between information and communication technologies (ICT), trade openness, fossil fuel energy, and Pakistan's expanding ecological footprint. Additionally, this research demonstrates that there is a moderating effect of ICT on the relationship between financial development and ecological footprint. This innovative study employs non-parametric causality-in-quantiles methods to examine quarterly data from 1960Q1 to 2019Q4 for causality-in-mean and causality-in-variance. It recognises that instantaneous causation is not possible, but that higher-order interdependencies do exist. Uneven predictions regarding ecological distribution were uncovered by the study's results, while the predictive power of financial development, ICT, and fossil fuels for ecological footprint was found to be substantial. Furthermore, in the context of predicting pollution on a national scale, a noteworthy association was discovered between financial development and advancements in information and communication technologies. The study's overall conclusions highlight how vital it is that more money be allocated to innovative industrial sector environmental adjustments and cleaner, renewable energy sources (SDG-7: less expensive, greener energy).

Poudyal et al. (2019) The goal of the research is to provide a contemporary viewpoint on Nepal's ongoing energy dilemma. This study specifically investigates the patterns of current energy production and consumption in order to identify the main factors contributing to the increasing imbalance between energy supply and demand. Hydropower projects that are overpriced and delayed, energy infrastructure that is outdated and inadequate, transmission and distribution losses, energy theft, inadequate energy management, low equipment efficiency, inadequate energy conservation, and unsatisfactory regulations in the energy market are a few of these factors. Certain geographical and geopolitical reasons, a heavy reliance on energy imports, and insufficient use of the abundant renewable energy sources all contribute to the worsening of the energy crisis. An overview of the main hydroelectric projects that are planned and currently under progress is given. The focus is on the government of Nepal's recent investments and policy measures to boost green and renewable energy sources. Furthermore, with the energy modelling programme LEAP, a long-term projection of Nepal's energy status is given, demonstrating how to take use of the country's enormous potential for renewable energy. The findings indicate that renewable resources are crucial for easing the present energy crisis as well as for the ultimate development of reliable and secure energy sources that would provide Nepal energy independence.

Pickl (2019) By examining the renewable energy policies and investments of the oil giants, the research contributes to the resolution of this question. Additionally, a thorough measurement and classification of oil giants into leaders or laggards in renewable energy is offered. The findings indicate that five of the eight oil giants have made significant investments in renewable energy. The data also shows a high correlation between the renewable energy plans of the oil giants and their proven oil reserves.

Solaymani (2021) demonstrates that the research examines patterns in energy consumption, legislation, and the rise of renewable energy sources, in addition to the correlation between economic development and renewable and non-renewable energy sources. It utilises two methodologies to accomplish this. A review of the current energy landscape and energy policy is conducted prior to examining the correlations between the variables using Granger causality analysis. The findings indicate that the integration of renewable energy technology into Iran's energy supply is presently insufficient and not of sufficient magnitude. Policy measures were enacted in the late 2000s and early 2010 to promote the utilisation of renewable energy sources, particularly in the electricity generation sector. These measures included the implementation of fuel diversification policies and development plan targets. Iran has incorporated energy source diversification as a pivotal component of its novel approach. Furthermore, energy and renewable sources can be generated from biomass derived from agricultural products, including fruits, as well as from municipal refuse in major cities. Balance must be restored regarding the consumption of fossil fuels, despite the fact that existing regulations promote the adoption of renewable energy sources. Additionally, 4.8 billion litres of bioethanol from crop residues and 526 thousand tonnes of biodiesel from oilseeds are projected to be produced annually in 2018, according to the study, which is based on agricultural output capacity. By employing Granger's causality analysis, the unidirectional causal relationship between economic growth and the utilisation of renewable and non-renewable energy sources is further established. Despite the fact that renewable energy consumption is a by-product of non-renewable energy consumption, its growth is propelled by gross fixed capital formation and labour force.

This research of Cheng et al. (2019) explains the evolution of per capita CO2 emissions in the BRIICS countries from 2000 to 2013, taking into consideration economic development, renewable energy, and environmental patents. Through the utilisation of panel ordinary least squares (OLS) and panel quantile regression techniques, it is determined that the effects of the determinant variables vary across all quantiles. Renewable energy sources have significantly contributed to a decline in CO2 emissions per capita, with the greatest impact observed at the 95th quantile. Per capita carbon emissions increase as a consequence of environmental patent generation; however, this effect is predominantly observed at the far end of the conditional distribution. CO2 emissions increase in tandem with GDP per capita, with the most substantial surge observed in the fifth quantile. The asymmetric inverted U-shaped effect on carbon emissions per capita can be attributed to exports. Foreign direct investment reduces carbon emissions per capita, but only in the upper and intermediate regions of the conditional distribution. Providing domestic financing to the private sector causes an initial increase in per capita carbon emissions. However, in the end, these effects diminish in magnitude across every quantile. The research outcomes produce an extensive array of policy recommendations.

The current research of Raza et al. (2020) is exploratory and is based on the introduction of new development policies and RETs for Pakistan's rural regions. The research demonstrates the interdependence between clean energy, fossil fuel energy, rural population density, energy potential, national and international policies, and programmes aimed at revitalising Pakistan's off-grid regions. The results indicate that families in rural regions consume less power than those in urban areas, and that the agricultural industry is the most profitable. Therefore, it is recommended that in order to boost jobs, living standards, and the economy, the government fund renewable energy projects in rural areas.

Electricity-consuming appliances constantly contribute in some little manner to the needs of homes and businesses. As a consequence, the government should employ best practices and promote the use of renewable energy technology in order to limit or reduce power demand, as China and the United States have done.

The purpose of the research of Naderipour et al. (2020) seeks to illustrate the potential environmental and renewable energy output growth advantages of COVID-19 in Malaysia. With the aim of impeding the transmission of the disease, Malaysia enacted the Movement Control Order (MCO) legislation in March 2020. Particularly air pollution, the country's environmental pollutants decreased as a consequence of the law's implementation. From January to March 2020, greenhouse gas (GHG) emissions decreased from 8 Mt CO2 equivalent to less than 1 Mt CO2 equivalent in April and May 2020. As a consequence of the decrease in greenhouse gas emissions and deleterious pollutants, photovoltaic panels received more sunlight, which in turn increased the generation of renewable energy.

Bashir et al. (2022) The principal aim of the present investigation is to provide policy recommendations that efficiently address the challenges presented by climate change and advance the cause of environmental sustainability. Furthermore, this study examines the purpose of environmental levies and regulations pertaining to the implementation of renewable energy sources. The primary aim of this study is to conduct a correlation analysis between environmental legislation, renewable energy, environmental technology, and environmental taxes in 29 OECD countries from 1996 to 2018. They analysed the precise impact of technological advancements and environmental regulations on the utilisation of renewable energy sources. The authors employ FMOLS, quantile regression, the panel Wester Lund co-integration test, CIPS and CADF unit root tests, and FMOLS in their econometric study. Econometric research indicates that the implementation of renewable energy sources in OECD economies is hindered by environmental regulations. As stated in the report, environmental policy efforts should prioritise the implementation of environmental policies so as to support the growth of the renewable energy sector and the advancement of environmental technology in industrialised nations.

In this review, Ahmad et al. (2020) evaluate electricity and renewable energy prediction models used as a tool for energy planning in a methodical and rigorous manner. Three portions comprise the forecasting intervals, namely: I) brief; ii) intermediate; iii) and extended. Three renewable energy sources—wind, solar, and geothermal energy—as well as the required electrical load demand are included for the forecasting study. They analysed three main categories of state-of-the-art forecasting: I) artificial neural networks; ii) ensemble-based techniques; and iii) machine learning algorithms. The predictive application, temporal and geographical forecasting accuracy, and planning and policy goals relevance of these systems are examined. Large volumes of data may be handled by machine learning models with precise forecasting analysis. Applying ensemble approaches helps us to gain improved forecasting accuracy by merging diverse models. When used properly, artificial neural networks may aid in making a strong judgement since they can extract and mimic previously unknown connections and features. Furthermore, unlike these conventional techniques, artificial neural networks do not impose any limitations on the input and residual distributions. Professionals and researchers would benefit from the review's findings as they would be able to identify prediction methodologies and choose appropriate techniques to meet their forecasting needs and intended goals.

Godil et al. (2021) from within This study examines how technological advancement, economic expansion, and renewable energy may reduce CO2 emissions in the Chinese transportation sector using annual data from 1990 to 2018. The CO2 emissions of China's transport sector are significantly impacted by technological innovation, economic development, and the use of renewable energy sources, as demonstrated by the QARDL method. The implementation of renewable energy sources and innovation negatively impact carbon dioxide emissions associated with transportation. It illustrates how increased innovation, and the use of renewable energy are anticipated to reduce CO2 emissions in the transport sector; conversely, a country with a higher GDP will experience an increase in CO2 emissions in the transport sector. To further reduce CO2 emissions, China should still enact new legislation encouraging innovation in the transportation sector.

Potrč et al. (2021) from within This report details the sustainable renewable energy supply networks and a phased energy transition strategy for the power and transport sectors to achieve carbon neutrality by 2050 for the EU-27. A diverse range of technologies is employed to construct a multi-period mixed-integer programming model for the production of biofuels, renewable energy, hydrogen, sustenance, and bioproducts. It optimises the net present value of sustainability while taking into consideration various biomass and refuse resources. The findings indicate that, with the current state of technology, it is viable to attain the objective of a carbon-neutral European Union without compromising the provision of sustenance. Since solar photovoltaics are expected to account for 43% of electricity production from renewable energy sources (RES) by 2050 and have gained prominence over time, wind farms have emerged as the most viable alternative thus far for the rapid increase in electricity generation from renewable energy sources. Within the European Union, the energy transition could generate approximately 1.5 million new jobs over the next three decades. It may also substantially enhance the economic, social, and environmental dimensions of sustainability.

In this study, Matsuo & Schmidt (2019) In order to advance conventional input-intensive industrialization strategies, it is necessary to emphasise the trade-off between cost reductions associated with low-carbon energy production and the potential investment in local enterprises that utilise low-carbon energy technologies. Notably, the study examined how the national priorities of Mexico and South Africa for these two objectives resulted in distinct RE auction structures and outcomes by analysing the cases of these two countries. Through the examination of policy documents, interviews with public and private stakeholders in the two countries, and data on the participation of foreign and domestic actors in RE initiatives in South Africa and Mexico, study demonstrate the influence of policy design in each nation on bid price and RE market developments, as well as the establishment of local RE value chains. Prioritising low-cost renewable energy generation over regional capacity building could potentially result in increased reliance on foreign value chains and capital, which could have a favourable long-term effect on the market, according to this research.

In this study of Bagherian & Mehranzamir (2020) it is explained that This study investigates the utilisation of renewable energy sources, including solar, wind, and geothermal energy, in the context of energy production. The analysis encompasses both cogeneration systems and integrated heat and power systems. This study's main goals are to evaluate the performance of the most recent cutting-edge designs and to provide an extensive overview that highlights the most current developments in the geothermal and, wind, and solar energy. This study goes into great depth on how combined heat and power systems may integrate one or more renewable energy sources. Accordingly, early research projects are categorised according to how renewable resources are used in single and multiple integrations. Further categories are based on the most referenced research trends in that particular field of renewable energy in order to realise the current research goals and the problems that every renewable industry is facing today. Every system that is offered is assessed in terms of its implemented elements, techniques used, goals, and important discoveries. Three primary research areas are identified as a consequence of this classification process: developing and using models for solar-integrated systems, optimising thermos economics for geothermal-integrated systems, and planning and limiting curtailment for wind-integrated systems.

The purpose of this research of Smirnova et al. (2021) aims Find out what factors influence Russia, China, and India's governments' support for the production of renewable energy. The research methodology is based on a survey of 57 experts to determine the variables that have led to the expansion of renewable energy. Next, regression models are used to show how renewable energy affects national data. The proposed methodological approach provides an opportunity to assess the governments' assistance in both qualitative and quantitative terms for the growth of renewable energy in the countries that are the subject of the study. The most important elements influencing the renewable energy market, according to the study's conclusions, are securing public-private support for renewable energy projects, reducing the share of conventional energy sources, and increasing financing possibilities for renewable energy sources. The number of renewable energy business groups, facilities, and their total installed capacity—the primary indicators of the development of renewable energy—and the socioeconomic indices of the countries under study were found to be correlated, according to link-regression modelling. Regression equation-based modelling demonstrates that, although businesses and governments must make deliberate and concerted efforts to install renewable energy, it offers favourable development circumstances in the countries under study.

The purpose of the study of Aghahosseini et al. (2019) Assesses the advantages of the integrated energy grid of the Americas. In accordance with the selected scenario, the levelized cost of energy (LCOE) fluctuates between 48.8 and 59.0 €/MWh. The outcomes demonstrate a reduction of 15% in the total annualised cost and 14% in the LCOE of a centrally powered system, respectively. Energy storage requirements are diminished when transmission networks operate at their optimum capacity. Sector coupling offers additional advantages through the reduction of the LCOE by 4%, contingent upon the fulfilment of energy demands in the non-energetic industrial gas, electricity, and saline desalination sectors. When the connected Americas are compared to North and South America separately, the total annual system cost and LCOE are reduced by 1.6% and 4.0%, respectively. Although global grid connections have resulted in reduced energy system costs, the primary benefits of a Pan-American energy system remain elusive. In addition, a scenario has been disclosed that involves the exchange of synthetic natural gas (SNG) through a liquefied natural gas value chain. Costs associated with producing SNG locally in the presumed consumption centre are comparable to costs associated with producing SNG elsewhere, according to the findings.

Przychodzen & Przychodzen (2020) provides fresh empirical information on the main political and economic forces influencing post-socialist nations' shifts to renewable energy production and a low-carbon economy. It has been discovered, via the use of comprehensive data from 27 transition economies between 1990 and 2014, that increased economic development, as well as growing rates of unemployment and public debt, stimulated the process of creating renewable energy. The Kyoto Protocol's implementation made it possible for the use of renewable energy sources to rise significantly. In addition, the generation of power from renewable sources was severely constrained by rising CO2 emissions per person, the enforcement of antitrust laws, and a declining level of market competitiveness. Moreover, since the start of the previous global financial crisis in 2007, the findings suggest that public financing increases and energy sector competition have played a major role in promoting the use of renewable energy sources.

The goal of Q. Li et al. (2021) The aim of this research is to examine the relationship between the utilisation of renewable energy sources and the economic development of South Asian Association for Regional Cooperation member nations (SAARC).Three primary renewable energy sources are utilised in this study: wind, hydropower, and geothermal energy. The SAARC nations supplied the data set for this research between 1995 and 2018. For data analysis, the panel vector error correction model (PVECM) and the fixed effect test were used. The combined results show that the use of all three renewable energy sources has significantly boosted the economies of the SAARC member nations. Additionally, compared to the other two combined, hydropower is a renewable energy source that has a bigger effect on economic growth.

This research of Pitelis et al. (2020) evaluates how well various forms of renewable energy policy (REP) have worked to promote innovation in the OECD's electrical industry between 1990 and 2014. More precisely, from 1990 to 2014, they gathered and examined information on 21 OECD nations' performance, innovation activity (counting patents for each kind of renewable technology), and governmental interventions. They identify all of the REP in the sample using the unique features of each policy, and they classify them into three different policy types: systemic policy instruments, both technology-push and demand-pull policies. Next, they examine how policy intervention affects innovation, taking into account the kind of technology and policy tools used. The findings unequivocally demonstrate that one size does not fit all. Only for certain technologies (like geothermal), is it discovered that innovation activity is more sensitive to demand-pull policy instruments; for other technologies (like wind), a more mixed strategy may be more beneficial. Additionally, policies that focus only on a single technology might sometimes promote innovation more successfully than those that address many technologies (as in the case of solar). In general, demand-pull strategies have been shown to be more successful in promoting innovation in renewable energy technology than any other kind of governmental intervention.

The research of Y. Wang, Zhang, et al. (2020) permits the creation of a thorough procedure and a quantitative assessment framework. Based on the body of existing research, five features of factors—institutions, capacity for technical development, energy security and environmental protection, and the state of the RE sector today—have been chosen for the framework. In this study, data covering 29 provinces from 2008 to 2014 were analysed using dynamic principal component analysis. Significant variations in the evolution of RE among Chinese regions are indicated by the results. Greater economic development may be found in places like Beijing, Shanghai, and Guangdong, which rank higher on the list and provide clear benefits in almost every regard. The empirical findings offer policy implications and suggestions for promoting more equitable development throughout China. This methodology can also be applied to investigate analogous matters in different nations.

In this research work Y. Wang, Zhang, et al. (2020) use the latest advancements in AI adoption for the European Union's (EU) renewable energy industry. In this regard, they examined the following: (I) the efficiency of the procedures used to convert gross onshore use of renewable energy sources (RE) into final energy consumption; (ii) the effects of these processes on the energy content of renewable resources (such as biomass, wind, and solar power); (iii) the worker productivity in the real estate industry in comparison to the economy as a whole and how that productivity relates to investment levels; and (iv) the implications for future smart city research of utilising AI for RE. This study's primary contribution is the formulation of a conceptual framework that elucidates the role of artificial intelligence in the real estate industry of Europe. Furthermore, this study makes a bold contribution by delving into the implications for future directions in smart city research.

Lu et al. (2020) This study focuses on the energy policies of five nations: Denmark, Germany, the United States, the United Kingdom, and China. An overview of sustainable energy policy with regard to renewable energy promotion is given in this article. A thorough literature assessment is conducted in order to support the development of sustainable energy policy and modelling. One of the most common methods for designing energy-efficient buildings is to use energy-efficiency standards, which are often updated to reflect the most recent developments in technology. Numerous nations have reaped the benefits of feed-in tariffs, which are widely implemented to incentivize the use of renewable energy. In order to facilitate the progress towards net-zero energy buildings and smart cities, it is imperative to enhance building energy performance certification programmes through the incorporation of more transparent data and a dependable database system.

The research of Jafarinejad et al. (2021) examines how technology is being used in RE, the demands of the RE sector for workers, and the accreditation of engineering programmes. It then makes recommendations for potential ways to improve undergraduate engineering students' exposure to RE at universities, along with some theoretical RE ideas. Technology skills, such as those related to analysis, science, and modelling, are very important for the RE industry. This study focuses on these RE modelling and analysis tools, which may be used for planning, designing, planning, training, techno-economic analysis, optimisation, and other purposes.

Erdiwansyah, Mamat, et al. (2019) The principal aim of this study is to investigate the development of renewable energy and evaluate governmental initiatives aimed at significantly increasing the share of renewable sources in the production of electricity.

Legislative suggestions for promoting the broad use of sustainable renewable energy sources are also included in the paper. In order to meet the ambitious objective of attaining a primary energy mix comprising 23% renewable energy by 2025, it is imperative that the ASEAN countries take prompt action to eliminate subsidies for fossil fuels, integrate regional markets, and accelerate the completion of ongoing projects. Achieving success will ultimately require robust political determination, steadfast guidance, and concrete measures from all parties involved, including increased cooperation within the region.

Qudrat-Ullah (2022) created and assessed two scenarios: one centred on the utilisation of local resources and low-carbon technology, and the other on present policies and local circumstances. In contrast to what policymakers had anticipated, the reference scenario does neither alleviate power consumers' problems nor assist Pakistan in meeting its 2030 compliance year CO2 emissions reduction goal. In contrast, in a different scenario, Pakistan could stably meet its pollution goal while saving almost 23% annually on power expenditures for its consumers. Lastly, policy ramifications are discussed, along with suggestions for legislators that are equally applicable to other nations with comparable electrical system dynamics.

In this study Khan et al. (2021) In 69 nations that are a part of the "Belt and Road Initiative (BRI)" from 2000 to 2014, the study seeks to assess the short- and long-term effects of financial support, foreign direct investment, and technology improvements on carbon dioxide emissions, non-renewable energy, and renewable energy. The results showed that economic growth, technological development, and foreign direct investment (FDI) all had a detrimental effect on renewable energy. In order to quantify these effects, dynamic GMM estimators and robust standard error regression were utilised. However, scholarly investigations have demonstrated that financial progress substantially enhances the renewable energy sector in the analysed area. It seems that perceptions of technical innovation, economic expansion, and foreign direct investment have a beneficial effect on carbon emissions and energy consumption in the BRI countries. Funding, renewable energy, technological innovation, and foreign direct investment have a reciprocal causal link, according to the results of the Granger non-causality test.

Pradhan et al. (2020) This illustrates the extensive ramifications that COVID-19 has had on the renewable energy sector in India. India has demonstrated its prowess and ability to anticipate future developments in the realm of sustainable development solutions. It details the current effects of the pandemic on the industry as well as projections for how it may continue to harm it for as long as the epidemic continues to spread worldwide. To reduce or mitigate the effects of the COVID-19 pandemic on their company, the authors have compiled a list of suggestions that they believe the Indian government and renewable energy sector representatives should implement.

Rather than investigating the connection between economic growth and the RES, this study of Simionescu et al. (2020) places emphasis on the actual gross domestic product (GDP) and the fulfilment of the nation's objectives regarding renewable energy. A panel data model is employed to analyse the EU-28 scenario from 2007 to 2017. The results indicate a moderately positive correlation between per capita GDP and the proportion of final consumption derived from renewable energy sources. The study's results show a significant causal association between real GDP per capita and the percentage of final consumption that comes from renewable energy sources (RES). This highlights the opportunity for developed nations to increase their adoption of RES. Cluster analysis is employed to define numerous nation types in accordance with these parameters. The 2020 scenarios were formulated using the proposed panel data models, accounting for diverse percentages of renewable energy sources and EU Member States. Policies that establish a correlation between the achievement of national objectives and financial incentives for countries that achieve significant progress in incorporating substantial amounts of renewable energy into their overall energy consumption appear to require more attention in general.

Dagar et al. (2022) Using panel data from 1995 to 2019, the effects of financial development, natural resource, industrial production, consumption of renewable energy, and total reserve on environmental degradation were examined in thirty-eight OECD nations. The one-step difference, two-step system, and one-step system GMM models were the dynamic panel data models used in the study. The differences between a one-step, two-step, and single-step system the main drivers of environmental degradation in OECD countries, according to the GMM research results, are total reserve, industrial production, financial development, and environmental deterioration; however, the use of natural resources and renewable energy sources helps to ameliorate this issue. Based on the data analysis, significant policy recommendations are developed with the aim of improving the environmental quality in OECD member states.

Atif et al. (2021) looked at how gender diversity on boards affects the amount of energy used for renewables. With a panel of 11,677 firm-year data from the United States from 2008 to 2016, they discover a favourable correlation between the percentage of renewable energy used by the board and girl diversity. Moreover, boards need two or more women for women to have a meaningful influence on renewable energy usage, consistent with the critical mass hypothesis. The study further shows that the positive impact of female directors on the use of renewable energy comes from female independent directors, not from female executive directors. In the end, it is found that the company's financial success is positively connected with the use of renewable energy sources and the gender diversity of the board. The findings are robust to different identifying and estimation techniques.

Mrabet et al. (2019) The research contributes to the body of literature by concentrating on a sample of industrialised and developing countries. In this study, author examine the effects of urbanisation and other significant factors on the demand for non-renewable energy in those nations between 1980 and 2014.Additionally, sophisticated heterogeneous panel methodologies like Augmented Mean Groups (AMG) are used in this empirical study. The empirical findings demonstrate that the demand for non-renewable energy rises by 0.72% for every 1% increase in urbanisation. Compared to the impact of variables like the GDP and the price of oil, we find that urbanisation has the most impact on the demand for non-renewable energy.

Salem et al. (2023) This research aims to investigate the factors that influence the adoption of renewable energy sources (RESs) by the Palestinian industrial and commercial sectors, evaluate the ensuing effects on sustainable performance, and ascertain whether government participation can function as a moderator in the relationship between RES adoption and sustainable performance. In order to achieve this, a quantitative method of gathering data from 100 top managers in the economic and industrial sectors of Palestine was used via the use of questionnaires. The data was analyzed, and the resultant hypotheses were assessed using the Smart PLS programme. The results corroborate the idea that there is a favourable correlation between the deployment of RES and sustainable performance. Additionally, there is a clear link between the use of renewable energy sources and government involvement. Although there isn't a clear relationship between the government's role and sustainable performance, it has been found that the government serves as a middleman between the use of renewable energy sources (RES) and sustainable performance.

McPherson & Stoll (2020) In order to reflect more realistic demand response operational restrictions, such as uptimes and downtimes, daily starts, acceptable power limits, and necessary recovery intervals, the study presents a suite of constraints. Real-world load data for Bangalore, India is used to evaluate the suggested demand response installation. The findings demonstrate that demand response mainly lowers production costs by enabling the near-zero marginal cost replacement of thermal generators with high marginal costs with renewable energy sources. Demand response utilisation rates are primarily limited by their maximum permitted daily deployment; however, their operational behaviour is controlled by intraday recovery limits. Demand response aggregators stand to gain significantly from price arbitrage in addition to the grid's huge benefit from demand response.

Busu (2019) By examining how renewable energy companies (RES) employ total quality management (TQM) strategies, this study seeks to enhance RES management performance. TQM is a contemporary strategy used by businesses to raise the performance of their management teams. The study begins by providing a summary of the many stages of Edwards Deming's conceptualised model's development as they are reported in the literature. Then, an application is sent to the RES in Romania using the TQM approach. Both the impact of applying TQM practises on obtaining a competitive edge and the efficiency of project management in the RES are examined using a quantitative model. Managers and employees of RES were given a questionnaire, which served as the basis for the survey used to gather the data. Partial least squares (PLS) analysis was used in addition to structural equation modelling (SEM) to evaluate the study hypotheses. The data analysis was carried out using the statistical programme SmartPLS 3.2.8. The main contribution of this study is an evaluation of the relationship between TQM process indicators and the management effectiveness of Romanian businesses involved in the RES sector. In order to improve managerial effectiveness, the results highlight the importance of a motivated workforce, integrated operational processes, policies and trading strategies, and corporate social responsibility (CSR) as essential elements of a total quality management (TQM) approach. Consistent with the latest findings the study's conclusions show how different parts and processes—like integrated operational management, corporate social responsibility (CSR), trade strategies and policies, and skilled and informed employees—relate to one another.

Inês et al. (2020) The regulatory frameworks of nine countries and regions—Belgium (including the Flanders region), Croatia, France, Germany, Italy, Portugal, Spain, the Netherlands, and the United Kingdom—are compared cross-nationally in this study to determine the main advantages and disadvantages that these have brought about for cooperatively acting renewable self-consumers, citizen energy communities, and collective RE prosumers. For collective prosumers, the Netherlands, Germany, France, and the UK are the four nations with superior frameworks. The findings show that collective prosumers are a viable alternative within the EU's present legislative framework. In 2019, Portugal and Spain both moved from a framework of limited regulation to one of collective law. The research provides a basis for policy implications analysis aimed at improving frameworks relevant to European collective RES prosumers.

The Long-range Energy Alternative Planning System (LEAP) model is utilised in this study to ascertain the best course of development for China's power industry between 2015 and 2050. The analysis takes into account the effects of goals for renewable energy, as explained in detail by Liang *et al.* (2019). Three scenarios—a base scenario, a policy scenario for renewable energy, and a technical progression scenario—are created in order to evaluate the benefits and drawbacks of producing renewable energy and advancing technology. The study estimates that if energy development proceeds as anticipated, CO2 emissions will drop by 35.8 billion tonnes between 2015 and 2050, but the cost of providing power will rise by at least 2.31 trillion RMB. Moreover, a 1% increase in renewable power's capacity factors would save 5.56 RMB/tCO2 in CO2 abatement expenses in addition to reducing total CO2 emissions by 979 million tonnes annually. Several policy recommendations regarding the expansion of China's electrical industry are formulated in light of the findings of this study. The government may decide to review the current planning of nuclear and gas-fired electricity in order to attain low-carbon energy production. Secondly, adjusting the price of carbon may offset the additional cost of generating electricity from renewable sources. Thirdly, developing cutting-edge technology in combination with the generation of renewable energy has additional benefits for the environment and the economy. Finally, lowering the price of solar energy should be the present priority in order to facilitate future expansion.

Mohd Chachuli et al. (2021) described the methodology used in this research, which combines static and dynamic analytic tools to examine the consequences of Malaysia's transition to operational policies centred upon renewable energy. The efficacy of the nation's operational policies for the expansion of renewable energy, such as feed-in tariffs (FiT), net energy metering, large-scale solar photovoltaic (LSSPV), and small renewable energy power (SREP), is also examined in this research. This research employs two outputs (renewable energy production and gross domestic product) and three inputs (employment, electricity generation, and renewable energy licenced capacity). This research uses the panel dataset and the Malmquist productivity index to look at changes in productivity, efficiency, and technology in four Malaysian locales between 2010 and 2017. The results showed that the East Malaysian area produced renewable energy with the highest degree of efficiency over the aforementioned time. The data also indicate that Malaysia saw a decline in renewable energy efficiency in 2017 during the first policy shift from the SREP project to the FiT programme. On the other hand, efficiency increased with the subsequent policy shift in 2017 from the FiT project to the integrated plan.

J. Wang et al. (2021) from within Panel data from 1997 to 2017 are utilised to analyse the short-term and long-term effects of economic growth and financial development on China's national and regional adoption of renewable energy. Long-term relationships indicate that while financial development has an adverse effect on the adoption of renewable energy, economic expansion in western China and on a national scale promotes its utilisation. Conversely, short-term correlations indicate that economic expansion and financial development have contrasting yet favourable impacts on the adoption of renewable energy. The Granger causality test can be used to determine whether there is and is not causality between variables. The causality test results show that, in both eastern and national China, there are unidirectional causal linkages between financial growth and the adoption of renewable energy sources. In both the eastern and western parts of China, the use of renewable energy sources is driving economic growth simultaneously. The empirical research suggests a few measures that should be put into place to encourage the growth of the renewable energy industry.

In this paper, Lahiani et al. (2021) Using the nonlinear autoregressive distributed lags (NARDL) model, examine the relationship between financial development and the adoption of renewable energy in the United States from 1975Q1 to 2019Q4.In particular, the three financial development metrics that are considered are the overall financial development index, the financial development index pertaining to banks, and the financial development index concerning equities. In order to incorporate the effects of real crude prices, real GDP, and trade openness, the model is expanded. The findings from the empirical analysis indicate that stock-based metrics and overall financial development indicators have distinct long-term impacts. Changes in financial development metrics, whether favourable or unfavourable, affect the amount of energy consumed by renewable sources. Changes that are harmful to stock-based and general financial development indicators are the main factors that will negatively affect the adoption of renewable energy in the near future. The latter impact has implications for the one-lagged period that are both positive and negative. Short-term changes in bank-based funding have no effect on the uptake of renewable energy sources.

Schmidt & Sewerin (2019) study fills this vacuum by offering a first examination of the temporal dynamics of intricate policy combinations. In order to do this, author provide a conceptualization and assessment of the balance of the policy mix across instrument types as well as elements of the policy mix design (such as technology specificity as a technology-focused design feature and intensity as a general feature). This enables us to respond to the query of how the balance and design elements of policy mixtures vary over time across national boundaries. The methodology for measuring is bottom-up, meaning that policies are evaluated separately before being methodically combined at the policy mix level. This makes it possible to solve the issue of measuring policy output, often known as the "dependent variable problem in the study of policy change." More precisely, they created an OECD-wide comparison dataset of 522 renewable energy initiatives. The data indicates that although there is less variation in the dynamics of policy mixes for certain factors (like balance), there is a significant variation for others (like technological specificity). They also examined the impact of these mixed dynamics on policy outcomes in the form of the dissemination of renewable energy technologies as a validity check.

Current research of Udeagha & Muchapondwa (2023) examines the connection between the amount of natural resources and carbon dioxide (CO2) emissions. The study looks at annual panel data for each of the BRICS countries from 1990 to 2015. Even with issues like heterogeneity and cross-sectional dependence, the enhanced mean group (AMG) panel method is still a reliable method that may be used to infer different effects of natural resources on CO2 emissions in the BRICS countries. South Africa's abundant natural resources increase pollution, while Russia's reduce CO2 emissions. Moreover, the Environmental Kuznets Curve (EKC) concept emerged as a consequence of the abundance of natural resources in Brazil, China, Russia, and South Africa. In conclusion, a feedback hypothesis concerning natural resources and CO2 emissions was formulated via causality analysis.

Erdiwansyah, Mahidin, et al. (2019) reveals that the report contains details regarding the condition of renewable energy as an all-out substitute for fossil fuels in Southeast Asian countries. This contains details on the region's present and future possibilities for renewable energy sources. Additionally, the report offers a short overview of renewable energy objectives, issues related to Southeast Asia's energy needs, and the potential of renewable energy. Furthermore, this study offers a number of suggestions for renewable energy in Southeast Asian nations.

Abbasi et al. (2022) This research examines the relationship between GDP, renewable energy, and fossil fuel energy from 1980 to 2018 using unique dynamic ARDL simulations and Frequency Domain Causality (FDC) models. In both the short and long run, CO_2 emissions are significantly increased when energy is generated using fossil fuels, according to the available empirical evidence. In the near term, meanwhile, the environment suffers greatly from the small but noticeable rise in carbon emissions caused by China's GDP. In contrast, there is a short-lived negative impact on greenhouse gas emissions from using renewable energy sources. In addition, the FDC lends credence to the short-term, medium-term, and long-term causality theories. If we want to accomplish environmental sustainability targets, the study shows that we need to increase the proportion of renewable energy in the energy balance. This is because renewable energy inhibits the use of fossil fuels. The study advises China to consider empirical data and adopt long-term plans to cut carbon emissions in order to protect the environment.

Shahbaz et al. (2020) The relationship between the amount of renewable energy used by 38 nations and their economic growth between 1990 and 2018 is reexamined in this study. Heterogeneous non-causality, dynamic ordinary least squares (DOLS), and fully modified ordinary least squares (FMOLS) are some of the techniques used. Utilizing renewable energy sources has been positively correlated with economic development, according to empirical studies. In addition, the study found that labor, capital, renewable energy, and nonrenewable energy all had a favorable impact on economic growth. It is noteworthy that in 58% of the examined countries, the use of renewable energy sources had a favorable effect on economic growth. Governments, energy organizers, international cooperation organizations, and relevant agencies should collaborate to increase investments in renewable energy so that the majority of these nations can achieve low-carbon growth, according to the empirical findings.

Simionescu et al. (2019) This article's goal is to assess the contribution of GDP per capita and the share of renewable energy to the achievement of these goals. In contrast to alternative research endeavours, the correlation between economic development and renewable energy sources (RES) is not investigated in this report. On the other hand, this study looks into a possible relationship between the real GDP per capita and the percentage of renewable energy sources that are in use. The analysis of panel data models spanning from 2007 to 2017 indicated a marginally positive correlation between GDP per capita and the percentage of electricity generated from renewable sources in all European Union member states, excluding Luxembourg, which exhibited outlier GDP per capita figures. However, there was no evidence to establish a causal relationship between the two variables. These criteria were used to characterise various groups of countries using cluster analysis. Subsequent research endeavours need to focus on broadening this model to include more noteworthy elements, such the RES potential that is available in countries with certain geographic conditions.

In nine wealthy nations, the research of examines Ponce & Khan (2021) The long-term connections between GDP, property rights, renewable energy, energy efficiency, and fossil fuels from 1995 to 2019. The results show that, in contrast to developed European countries, developed non-European countries do not have long-term equilibrium relationships. The main conclusions show that there is a negative association between CO2 emissions, renewable energy, and energy efficiency. A 0.03% decrease in carbon dioxide emissions is linked to every 1% increase in the utilisation of renewable energy sources in industrialised Europe. In conclusion, several policy proposals are presented with the aim of attaining environmental sustainability.

Based on comprehensive hourly energy systems simulations, the study of Sorknæs et al. (2020) examines the energy and economic implications of switching from 3GDH (3rd generation district heating) to 4GDH (4th generation district heating) for the particular instance of Aalborg Municipality, Denmark. The evaluations take into account the impacts of variations in grid losses, variations in surplus heat potentials, and variations in the efficiency of the district heating conversion units. All things considered, the analyses of the Aalborg example demonstrate that when moving from 3GDH to 4GDH, the whole energy system's primary energy consumption is decreased by around 4.5% and the system expenditures are decreased by 2.7%.

Given this, This research of Usman & Balsalobre-Lorente (2022) Environmental impacts of industrialization, total reserves, and the expansion of natural, financial, and renewable resources are analyzed. This investigation makes use of panel data from recently industrialized nations spanning the years 1990 to 2019. Despite heterogeneity, the outcomes produced by the enhanced mean group (AMG) panel technique are reliable. Moreover, cross-sectional dependence suggests that the three main drivers of environmental degradation in the aforementioned nations are financial development, industrialization, and total reserves. On the other side, over time, the availability of renewable energy sources and natural resources lessens environmental damage. In addition, predictions made at the aggregate level and for the long run are in agreement with these findings. In addition, the panel Dumitrescu and Hurlin causality test results demonstrated a one-way causative relationship between industrialization and renewable energy, ecological footprint, natural resources, and environmental impact. The results also showed that overall reserves, ecological footprint, and financial development are all causally related. Finally, significant policy recommendations for protecting the integrity of the environment in newly industrialized nations are presented.

The purpose of this research of Amin et al. (2020) An investigation of the impacts of urbanisation, economic expansion, and the usage of renewable energy sources on CO2 emissions from the European transportation sector using the Environmental Kuznets Curve (EKC) paradigm. The 1980–2014 dataset is subjected to non-causality testing and second-generation panel long-run estimations in order to overcome this problem. According to empirical data, increased renewable energy usage reduces carbon emissions associated with transportation, whereas urbanisation has a statistically insignificantly positive effect on pollution. The adoption of renewable energy sources leads to an approximate 12% reduction in carbon dioxide (CO2) emissions through transportation. The EKC hypothesis is validated. Moreover, a direct causal connection can be established among urbanisation, emissions associated with transportation, and renewable energy. Suggestions from the study include increasing the general awareness and concern of urban residents regarding the environmental issues caused by transportation and promoting energy and environmentally favourable modes of transportation to strengthen the sustainable transportation system. This study demonstrates the influence of the European transport sector on greenhouse gas emissions and provides reliable information to policy makers in European countries, specifically regarding renewable energy initiatives within the sector.

According to a research of F. Li et al. (2022), t A lack of potential for green development is a hidden problem that prevents most rising countries from developing sustainably, leaving them in a state of high green levels and slow growth. The development of green infrastructure, investments in renewable energy, employment rates, and R&D expenditures are important transmission channels for the power and emission reduction technologies, industrial restructuring, and economic agglomeration effect that foreign direct investment brings to developing countries. With short- and long-term effects on the host country's industry, energy, and economy, foreign direct investment is a significant node in the causal network. This research helps developing countries transition to green development and offers insights into the investment inclination and selectivity of investing nations.

Usman & Radulescu (2022) From 1990 to 2019, This study looks into how natural resources, nuclear energy, renewable and non-renewable energy sources, and technical developments affect carbon emissions in nations that produce nuclear power. They accomplished this by combining a broad and exhaustive empirical investigation with contemporary econometric instruments. Long-run cointegration of the second generation for panels creates long-term connections between series. The results show that the use of nuclear and renewable energy sources significantly improves environmental quality. But the ecosystem's survival is seriously threatened by non-renewable energy sources and technological breakthroughs. The exploitation of natural resources could have unfavourable long-term effects. The results of the panel causality test showed that there is a one-way causal relationship between carbon footprint and nuclear energy. Moreover, there is a causal connection between natural resources with a carbon footprint, renewable energy sources, non-renewable energy sources, and technological improvements. This suggests that for the purpose of promoting a well-calibrated energy structure, these nations should coordinate their energy policy initiatives and develop coherent energy plans by harmonising the fundamental aspects of nuclear energy on a global scale.

Masud et al. (2020) highlights Bangladesh's present energy status and looks at the country's renewable energy potential and prospects. Although the government has previously made initiatives to create power from renewable energy sources, it has been shown that 62% of Bangladesh's electricity comes from natural gas. The current laws and regulations in Bangladesh pertaining to the production of renewable energy have been openly addressed. Lastly, certain recommendations have been made to address both renewable energy and the nation's chronic energy issue.

Sidik & Akbar (2021) The study proposes defining the potential of emerging renewable energy sources in the Conjure region in order to support the government's goal of achieving the national energy balance and to facilitate energy diversification in the electrical system. According to the study's conclusions, the Cianjur area has a great deal of potential for generating renewable energy from a range of energy sources that might be converted into electrical energy.

Hailu & Kumsa (2020) The study offers a thorough and in-depth analysis of Ethiopia's potential for renewable energy. Additionally, the present status of renewable energy resources is discussed, along with the energy regulations in place. There are many measures that are suggested that could encourage the usage of energy technologies in rural Ethiopia. Finally, this document helps government officials and researchers choose the appropriate renewable energy technology to suit the energy needs of rural areas by drawing attention to the country's energy potentials, the current state of renewable energy, and providing practical recommendations.

This study of Mastoi et al. (2022) examines the effects of COVID-19 on China's energy output and consumption in the first two quarters of 2020 and 2021. Investigations were also conducted into the opinions of various nations about the impact of COVID-19 on the development of renewable energy, including solar PV and offshore wind generation. This piece demonstrates how COVID-19 impacts electricity. China produced and used 1.4% and 1.3% less energy in the first two quarters of 2020, respectively, despite a 5.3 GW increase in power plant capacity and a 3.6 g/kWh decrease in coal usage. Power generating investments grew 51.5 billion yuan and power grid investments surged 0.7 billion. 2020 saw a 378 GW decline in new generating capacity in the first two quarters. 2021 saw increases in power generation and consumption of 16.2% and 13.7% in the first two quarters. While coal use decreased by 0.8 g/kWh, power plant capacity grew by 9.5 GW. 8.9 billion was acquired for power production projects and 4.7 billion for power grid projects. Compared to the previous year, 14.92 GW more capacity was installed. Due to lockdown strategies like working from home or studying, domestic power usage increased by 6.6 and 4.5 percent in the first two quarters of 2020–2021. To lessen COVID-19's effect on solar PV systems and support the establishment of offshore wind power plants, financial and economic measures have been implemented.

X. Ma et al. (2021) demonstrated a correlation between real GDP, CO2 emissions, renewable and non-renewable energy consumption, tourism growth, and labour force density, given that France and Germany are spearheading the push to promote the Paris Agreement both within and beyond the E.U. The time periods have been executed from 1995 to 2015, contingent upon the accessibility of data. Several unit root evaluations of the first and second generations support the unit root theory in the presence of cross-sectional dependence. Pedroni and Westernlund, on the other hand, support the cointegration theory. The results provide credence to the environmental Kuznets curve, which suggests that, for the combined economy of Germany and France, real GDP and CO2 emissions have a long-term, inverted U-shaped connection. The results show that although using non-renewable energy sources raises carbon emissions, using renewable energy sources significantly lowers then. The tourism industry has demonstrated its efficacy in mitigating carbon emissions through its commitment to energy conservation and emissions reduction initiatives within large corporations. Consequently, this fosters an increase in the number of visitors and aids in the development of a sustainable tourism economy.

Fang et al. (2022) The primary focus of the research is an examination of the correlation between R&D, industrialization, and the expansion of the green economy. Green finance could potentially facilitate the development of novel technologies, fund environmentally sustainable initiatives, and foster the expansion of the green economy. Therefore, it significantly contributes to the expansion of the green economy and the reorganisation of the industrial sector. This study looks at how industrialization, R&D, and renewable energy affect the expansion of the green economy in South Asia between 2008 and 2020. This connection's endogeneity is handled using a two-step ordinary least square (O.L.S.). The results demonstrate how R&D and upgrading industries may both lead to a green economic rebound and a decrease in carbon emissions. Consequently, 35.2% less emissions were produced, and 33.4% more energy was conserved. The influencing framework of the policy is shown by the partial mediation effect results. The empirical findings demonstrated that, along with advancements in the transformation of the industrial structure, technological spill over bore the most responsibility for reducing CO2 emissions at different levels. According to the research, developing countries benefit more from the industrialization push than do developed ones because the former has more economic effects.

Energy Management Practices in The Industrial Sector

In this work, Bosu et al. (2023) explains that A special energy audit and analysis road plan has led to an investigation of possible causes of energy waste in the facility. Furthermore, for the first time, particular energy efficiency recommendations and useful energy management strategies for the various kinds of industrial equipment have been made available. Additionally, the suggested action plans' environmental benefits are analysed in accordance with their economic evaluation, which is conducted using the payback approach. The results show that an extension of the PV system would produce 676.62 MWh yearly, or over 50.95 percent of the factory's entire yearly power usage. The renewable energy system has an appealing three-year repayment plan and requires an initial expenditure of $124,115. It lowers CO2 emissions by 293 tonnes yearly. The variable speed drivers in the motor systems would also reduce annual CO2 emissions by approximately 21 metric tonnes and generate savings of 48.477 megawatt-hours with a repayment period of 1.73 years. However, an estimated 319 MWh of yearly energy savings were obtained by designing the mould assembly with an air space and using thermal boards to protect it from heat. Compensators, fans, and lighting energy management save 121,461 MWh, 14,88 MWh, and 32,154 MWh of energy annually, respectively. But compared to fossil fuel-powered forklifts, buying electric forklifts would be more expensive and take longer to pay for ($32,220 versus 5.74 years, respectively). The energy audit and management methods mentioned above save 535,971 megawatt-hours of energy and 232 metric tonnes of CO2 emissions this year, respectively. Significant decision-makers will undoubtedly reduce carbon emissions and improve energy efficiency by adhering to the energy audit and management process.

In this work, Iqbal et al. (2023) aims to investigate the key success factors (CSFs) for EESC in the building sector of Pakistan. This study used the Delphi approach, ISM, and MICMAC to provide a novel paradigm for CSF analysis for EESC. CSFs were first discovered in past studies and were removed using the Delphi method. Following examination, CSFs were categorised using MICMAC and ISM. The findings indicate that pressure from environmental legislation, top-level management support, and global demand for EESC are the key factors determining the efficacy of EESC adoption. The least significant elements impacting the adoption of EESC in Pakistan's construction sector include also risk identification and management, EESC expertise, sustainable strategic planning, R&D projects, competitive advantage, green manufacturing, and supplier management. These results will assist managers in taking the necessary steps to guarantee a seamless implementation of EESC. Governments and lawmakers would also benefit from using eco-friendly construction practices.

In a study conducted by Kayacık et al. (2022) explains to determine important sustainability standards using a unique fuzzy decision-making process in order for the firms to be included in this index. The analysis's findings enable the businesses to take action without having to bear excessive expenditures. It is established that the utilization of renewable energy has a substantial influence on all other criteria, and when utilizing clean energy, the enterprises have an opportunity to enhance other criteria of SI. Furthermore, the usage of renewable energy is the most important requirement to be included in SI, according to the weighted findings. Similar to this, resource recovery also contributes significantly. Finally, the ranking data indicates that the IT and communication sector is the most successful one for SI. As such, it makes sense for companies to give the adoption of renewable energy sources top priority. Similar to this, resource recovery also contributes significantly. Finally, the ranking data indicates that the IT and communication sector is the most successful one for SI. As such, it makes sense for companies to give the adoption of renewable energy sources top priority. This would mitigate the concern regarding carbon emissions while simultaneously enhancing the businesses' standing among investors and consumers. Under this paradigm, businesses may integrate microgrid energy management systems to address the expensive issues associated with investment projects including renewable energy. Because microgrid energy applications allow renewable energy expenditures to be shared with other businesses, it will be feasible to expand the usage of renewable energy because the cost per unit may be lowered.

In this work, S. Ma et al. (2022) aims to provide big data and digital twin technologies to energy-intensive industries (EIIs) for a sustainable smart manufacturing strategy that leverages information management systems throughout the lifecycle of the product. The integration of digital twins and big data enables critical technologies such as data collection in energy-intensive industrial settings, prediction and mining in unforeseen scenarios, and real-time control in complex working environments. To clarify and demonstrate sustainable smart manufacturing, additional materials include an operational mechanism driven by digital twins and a basic framework for the integration and cleaning of large data. The effectiveness of the approach is demonstrated by two case studies from northern and southern China. The results demonstrate how implementing the suggested actions allowed Companies A and B to save money and energy. Company A's unit energy consumption and energy costs of production were both at least 3% lower after using an energy management system. Additionally, the big data analysis of the "cradle-to-gate" lifecycle reveals a significant decrease in Company B's environmental protection costs. Finally, a number of managerial takeaways for EIIs in China are evaluated and examined, along with the effectiveness of the suggested approach.

In this research Fernando et al. (2022) seeks to provide a theoretical framework for the WTE supply chain by examining how value chain analysis (VCA), economic potential cycle (EPC), and life cycle assessment (LCA) support the circular economy capacity (CEC). This research aims to explore the present waste-to-energy (WTE) supply chain management methods in Malaysian agricultural and agro-based industries. Survey data was gathered from businesses who actively practise sustainable waste management and convert waste products into bioenergy. According to this research, WTC supply chain procedures and CEC are significantly and favourably impacted by the enablers. The findings suggest that the straight route from LCA to CEC has been mediated by WTC supply chain practices. The research has expanded the theoretical-mediating effect of the CEC to explain how waste is converted into clean energy in the agro-based and agricultural sectors. The study suggest that the agricultural industry closely monitor WTE practices and consciously look for ways to benefit from renewable energy while protecting the environment. Thus, in order to sustain business operations and generate new income, the abundant agricultural biomass waste in growing countries has to be strategically converted into clean energy.

Breyer et al. (2022) concentrating on energy storage, grid congestion, sector coupling, the electrification of industry and transportation, the integration of natural and artificial carbon dioxide removal (CDR) approaches, power-to-X and hydrogen-to-X indicators, and energy storage. The end product is a thorough strategy plan that outlines how to achieve a net-negative economy, which is defined by zero greenhouse gas emissions. This plan allows the energy sector to construct energy systems that rely only on renewable energy sources in order to economically and sustainably limit global warming to 1.5°C. It does this by having a clearly defined carbon budget. Concentrating on energy storage, grid congestion, sector coupling, the electrification of industry and transportation, the integration of natural and artificial carbon dioxide removal (CDR) approaches, power-to-X and hydrogen-to-X indicators, and energy storage. The end product is a thorough strategy plan that outlines how to achieve a net-negative economy, which is defined by zero greenhouse gas emissions. This plan allows the energy sector to construct energy systems that rely only on renewable energy sources in order to economically and sustainably limit global warming to 1.5°C. It does this by having a clearly defined carbon budget. Initially, the subject was met with considerable scepticism. This study thus examines the institutional resistance that hinders the adoption of 100% renewable energy systems by the Intergovernmental Panel on Climate Change and the International Energy Agency. It also addresses significant criticisms of such systems, potential disadvantages for energy equity, and community acceptability. The study concludes by contemplating the potential societal benefits of the development of this nascent field of study.

To assess the ideal behaviour of energy consumption parameters to clean the environment under the application of green technology, Lee et al. (2022) designed a simulation-based optimization model. The results demonstrate that using renewable energy sources, such as coal, wood, and maize cobs, has a positive effect on adopting green technology. It's interesting to note that at this time of scarcity, industry shifts towards renewable resources have a good influence on energy shortages as well (gas and electricity). Due to its easy availability, they discover a bigger amount of wood in optimum behaviour analysis rather than coal and cobs. Because of its larger shortage, an optimum subsidy for electricity is shown to be bigger than one for natural gas. This research assists the government in determining the ideal energy shortage for reducing energy use and in managing the ideal number of subsidies to address issues with energy usage. In terms of implementing green technology, it also helps the textile sector determine the ideal amount of energy consumption to maintain a clean atmosphere.

Chen et al. (2022) This study expands the scope of this argument by taking into account other potential energy efficiency elements and the US economy. Regarding the USA, research has been conducted on the impact on energy efficiency between 1990 and 2020 of trade openness, industrial production, financial inclusion, and investments in renewable energy resources. By examining the causal relationship between variables and considering the temporal dimension, this research contributes even more to the body of knowledge. By examining the causal relationship between variables and considering the temporal dimension, this research contributes even more to the body of knowledge. findings emphasize the significance of industrial output, financial inclusion, trade liberalization, public energy research and development, and energy efficiency in the US. All the other variables have a positive link with energy efficiency, except industrial output. It has been shown that trade openness, industrial productivity, financial inclusion, and public RD&D funding for renewable energy are all caused by energy efficiency. The findings indicate that the frequency at which an energy efficiency shock affects each variable varies. Legislators ought to enact the requisite regulations to enhance the financial system, given the substantial ramifications that this will impose on renewable energy.

In this context, Simionescu et al. (2023) highlights that this article's primary goal is to evaluate how this kind of energy usage has affected economic development in 23 EU member states between 1990 and 2020. In addition to the overall quantity consumed, numerous applications of renewable energy are taken into account, including transportation, industry, public and commercial services, and domestic usage. Panel data models, which are founded on the Cobb-Douglas function, serve as the methodological foundation. One crucial component that should encourage economic growth is the use of renewable energy sources. While it is true that economic development is the primary driver of renewable energy usage in industry, a panel data approach using causality analysis, and the Mean Group and Common Correlated Effects Mean Group estimators reveals that this is not necessarily the case. Moreover, increased transportation energy consumption fuelled by renewable sources stimulates economic expansion. The industrial sector's increased adoption of renewable energy sources could potentially be stimulated by the swift growth of the economy. Consequently, industrial enterprises will have the capacity to allocate additional financial resources towards the advancement of renewable energy sources and implement them economically viable. Through renewable investments, the EU will be able to attain sustainable transportation.

In this study, Mokhtar & Nasooti (2020) To address these issues and help plant management choose and finance the most relevant initiatives, an integrated three-phase approach is offered. The suggested technology would help the cement management meet their energy-saving goals as it is founded on a multi-criteria decision approach the tool is tested in three scenarios to show its use with real data, and the result is a prioritised list of opportunities for each facility.

Ben Jebli et al. (2020) The study investigated the connections between CO2 emissions, economic expansion, utilization of renewable energy, industrial value addition, and service value addition from 1990 to 2015. The four income classes that people fall into are poverty, lower middle class, upper middle class, and high income, based on annual statistics from 102 countries. Global CO2 emissions decreased as a result of a rise in the usage of renewable energy, except lower-middle-income countries, according to the Granger causality test and the generalized technique of moments. According to the estimation, high-income and low-income (or upper-middle-income) countries' industrial and service value-added are negatively and favourably impacted, respectively, by the adoption of renewable energy sources. The usage of renewable energy increases or decreases industrial value added in low-income countries (or service value added). Only a small portion of the industrial and service values to which the global council contributes are positively impacted by the use of renewable energy.

In this study, Korberg et al. (2020) Using the energy system analysis programme EnergyPLAN, investigate the role of biogas and biogas-derived fuels in a renewable energy system that is entirely based in Denmark. The end-fuels that are now under investigation include biogas, electro methane, and biomethane. It all starts with establishing a hypothetical situation devoid of biogas. Then, biogas, biomethane, and electro methane take the role of dry fuels derived from biomass in many areas of the energy system. The findings show that whether used for electricity, heat, or industrial sectors, biogas and biomethane may cut dry biomass utilisation by as much as 16%. Biogas and biomethane nevertheless lead to lower energy system costs whether used in the heating, power, or industrial sectors. However, the savings are reduced when the feedstock for biogas is paid for by the energy sector. This is especially true if the feedstock is provided free of charge for energy purposes. While utilising biomethane instead of liquid bio-electro fuels for transportation results in some cost savings, employing electro methane results in much higher expenses. Regardless of the cost of dry biomass, electro methane is not economically viable for transportation, industry, electricity, or heat. Either biomethane or direct usage of biogas is recommended. Although it is a finite resource that depends on how the agriculture industry is organised, it may support other renewable energy sources.

In this work, Hu et al. (2020) An analysis of the 2011 carbon dioxide (CO2) ETS pilot programme in China's impact on energy conservation and emission reduction. Using panel data pertaining to the two-digit industry at the province level from 2005 to 2015, the author used the difference-in-differences (DID) model to evaluate the effect of the CO2 ETS on energy conservation and emission reduction. When compared to regulated enterprises in nonpilot locations, the CO2 ETS lowers CO2 emissions by 15.5% and energy consumption by 22.8 percent in pilot districts. According to further study, the main factors influencing policy results seem to be improving technology effectiveness and changing the structure of the industry. Furthermore, the study demonstrates a connection between increased levels of environmental marketization and regulation and improved CO2 ETS functioning. According to analysis, the CO2 ETS has been effective in reducing emissions and encouraging energy conservation in developing nations.

Dudin et al. (2019) The purpose of this study is to perform a comprehensive examination of the theoretical and empirical progress made in advanced technologies within the energy industry, with a focus on the energy trilemma encompassing environmental sustainability, energy efficiency, and energy security. The growth of the global energy business is accompanied by shifts in the fuel types that dominate the energy balance, organisational and technical breakthroughs, supply chain expansion, and optimization. Increased demand for energy, a greater dependence on renewable energy sources, and improved energy efficiency characterise this phase of the global energy market transition. The growth of the global energy business is accompanied by shifts in the fuel types that dominate the energy balance, organisational and technical breakthroughs, supply chain expansion, and optimization. Increased demand for energy, a greater dependence on renewable energy sources, and improved energy efficiency characterise this phase of the global energy market transition. Therefore, the main areas of focus for investment in the energy sector should be the development of conventional and renewable energy resource infrastructure, making up for the decrease in energy supply production from existing oil and gas fields, and creating and implementing solutions to meet the growing demand. This study primarily focuses on the technological advancements and purportedly more efficient utilisation of renewable energy sources (RES) and non-traditional hydrocarbons (shale gas and oil sands). To investigate these developments, the study employs content, analytical, statistical, and functional research methods. It examines the most recent developments in the global energy sector's transition. The following deductions have been made in light of the data provided in the article: It is anticipated that second-order renewable energy sources will become more widely used than first-order renewable energy sources throughout time. Technology for energy resource extraction will evolve concurrently with the implementation of new energy service technologies built on the smart grid idea. Over the next several decades, the energy industry will use unconventional hydrocarbon resources more and more. In addition, new technologies specifically designed for energy resource development and use will be put into practise.

Butturi et al. (2019) An industrial-urban energy symbiosis may result from the study on energy synergies in eco-industrial parks, which might make it easier for businesses to use renewable energy sources. To facilitate a literature review on the subject of potential energy symbiosis within eco-industrial parks, the energy-related data was classified into issue categories. In order to achieve the urban-industrial energy symbiosis, it focuses on technology solutions, design and optimisation models, and organisational strategies. The study provides potential strategies to persuade the industrial sector to use renewable energy sources and outlines four key approaches for putting energy synergy into practice. The energy symbiosis networks that integrate renewable energy systems throughout industrial and urban regions are poorly understood, as shown by a number of recognised research gaps.

Challenges and Barriers in Industrial Renewable Energy Management

In this work, Siraj et al. (2023), It ranks, examines, and investigates the connections among the various obstacles to sustainable boiler operation in the apparel manufacturing sector using an integrated MCDM technique. Fuzzy theory is merged with the DEMATEL (decision-making trial and assessment laboratory) technology. This is accomplished with a developing economy in mind. The obstacles were initially identified through a visual inspection of 127 factories and a review of the relevant literature. Thirteen obstacles in total were finally selected for analysis using the fuzzy DEMATEL methodology following expert validation. The study's conclusions state that "high groundwater usage," "burning fossil fuels and greenhouse gas emissions," and "lack of water treatment facilities" are the three key obstacles to sustainable boiler operation. The cause-and-effect interactions among the barriers show that "Inadequate compliance with safety and hazard legislation" is the main obstacle, while "Fossil fuel burning and GHG emissions" is the barrier that is most impacted. In order to aid policymakers and managers in the garment manufacturing industry in their efforts to attain the Sustainable Development Goals (SDGs), this research aims to effectively resolve the obstacles that impede sustainable boiler operation and thereby reduce operational risks.

In this research Abdul et al. (2023) shows how, in spite of many challenges, business owners in the renewable energy (RE) industry support and foster the creation of innovative ideas and solutions. By using a fuzzy multiple-criteria decision-making (MCDM) strategy to address the entrepreneurial barriers that restrict the expansion of energy production in poor nations, this study seeks to close a research gap. The study, which is split into two halves, aims to investigate the ecopreneur ship barriers to RE development by means of an extensive investigation carried out in an unpredictable environment. First, a study of the literature and discussions with experts were utilised to identify probable obstacles. Second, a special Spherical Fuzzy Analytical Hierarchical Process was used to finalise the obstacle weights. "Inadequate government or policy support" is the most important of the major categories, according to the data, followed by "inadequate access to institutional finance" in second place. The results' ultimate weight was (0.2093). The proposed method takes into account additional information due to the uncertain nature of the decision-making environment, while Pythagorean fuzzy AHP does not. Conversely, the worldwide rankings of hurdles indicate that "Accessing credit," with a final weight of (0.0737), is more crucial than the other twenty-six difficulties.

In this research Almutairi et al. (2023) focuses on outlining the conditions and challenges associated with using blockchain technology to renewable energy supply networks. Additionally, it rates the impediments according to the likelihood that they may disturb processes. The Iranian renewable energy supply chain is used as a case study to evaluate the suitability of the proposed structure. This study employs the concept of grey numbers to rank and analyse the problems utilising the grey sequential weight assessment ratio analysis and the grey evaluation based on distance from average solution (EDAS-Gray) (SWARA-Gray). WSM-Gray, COPRAS-Gray (grey complicated proportional assessment), and TOPSIS-Gray (grey methodology for order of preference by likeness to ideal solution) are among the additional hybrid processes that are used to validate the results (grey weighted sum method). There is a significant level of agreement across the rankings generated using different approaches". Out of all the obstacles mentioned, "high investment cost" is the biggest one that prevents blockchain technology from being used in supply chains for sustainable energy.

In this research Amir & Khan (2022) concentrating on the implication of COVID-19 on the African energy market. Also, analysing current breakthroughs in African renewable energy production that contains the great ability for improvisation. This report highlights the suggestions made for the African renewable energy industry in response to the COVID-19 epidemic. This study is the outcome of a thorough investigation focused on the main concerns guiding sustainable solutions for Africa. Effective conclusions are drawn in this review study to handle the difficulties posed by the present epidemic. Africa has a plethora of resources that have enormous potential for electricity production.

Nevertheless, due to its inability to use its vast renewable energy resources, Africa is now going through a period of severe crisis. Restructuring the electricity system, developing energy storage technologies, and concurrently mitigating environmental causes with seasonal changes are so imperative. The suggested review analysis would improve the chances for all problems to have sustainable solutions, which will improve Africa's situation with regard to renewable energy. It has been noted that focusing on having robust legislative frameworks and appropriate rules is unavoidably necessary. The different proposals are necessary to swing towards renewable energy development. To attract foreign investments and tackle practical concerns like goal setting, joint efforts are needed. This research presented a machine learning-based framework for improving PV forecasts and upgrading existing technologies to create a smart energy system.

In Polleux et al. (2022) demonstrates a comprehensive understanding of these obstacles through an exhaustive review of the scientific literature, which includes a wide range of subjects such as the thermodynamics of fossil fuel engines and the application of control system theory to industrial systems. An analysis is conducted on state-of-the-art research pertaining to diverse industrial sectors, with an emphasis on oil and gas microgrids. This analysis serves to illustrate the concept of reliability-constrained microgrids and identify their defining attributes. After providing an account of the difficulties associated with elucidating the dynamic characteristics of fossil fuel equipment, storage systems, and solar systems, several areas of research are highlighted. In conclusion, appropriate management strategies are proposed.

In Madurai Elavarasan et al. (2020) investigate the factors supporting or hindering the growth of renewable energy sources. Every nation, including US, China, India, Sweden, and Iceland, has a particular edge when it comes to renewable energy sources. A SWOT analysis will be used in this research to provide a descriptive image of the country's renewable resource base and environmentally friendly future. Four criteria will be used to analyse each country: renewable resource-related strengths, weaknesses, opportunities, and dangers. This study aims to evaluate each nation's potential for producing renewable energy. These countries were chosen because of their proven success in producing and using renewable energy sources. Several factors that this research will look at are responsible for their positive results. In addition, a method based on math was developed to determine whether countries will be able to achieve Sustainable Development Goal 7. (SDG 7).

In this research Almutairi et al. (2023) focuses on outlining the conditions and challenges associated with using blockchain technology to renewable energy supply networks. Additionally, it rates the impediments according to the likelihood that they may disturb processes. To assess the suitability of the proposed structure, a case study of the Iranian renewable energy supply chain is conducted. To analyse and rank the issues, the "evaluation based on distance from average solution" grey (EDAS-Gray) and the "sequential weight assessment ratio analysis" grey (SWARA-Gray) are combined with the grey numbers concept. Within this research, an extra set of hybrid processes is used to verify the findings, including WSM-Gray, COPRAS-Gray (grey complex proportional assessment), and TOPSIS-Gray (grey technique for order of preference by resemblance to ideal solution) (grey weighted sum method). There is a significant level of agreement across the rankings generated using different approaches. Out of all the barriers mentioned, "high investment cost" is the biggest one that prevents blockchain technology from being used in sustainable energy supply chains.

A study conducted by Lawrence et al. (2019) The energy-intensive Swedish pulp and paper industry (PPI), which has the most international experience implementing EnM systems and has been operating in accordance with the standards since 2004, is the best source for information about EnM practises, the most significant perceived drivers and barriers for EnM, and the relationships between them. Overall, the findings indicate that the PPI and EnM engage in a consistent, methodical collaboration with clearly delineated tasks. Subsequent in order of maturation in EnM practice were investments, organisation, performance monitoring, and energy policy. Additionally, the study emphasises the necessity for enhanced communication to occur between operational personnel and intermediate management. The predominant type of barriers identified were organisational in nature, whereas economic factors comprised the majority of the motivating elements. However, it is worth noting that knowledge-related obstacles and motivators ranked highly, indicating that there is potential for enhancing the ability to comprehend energy-related challenges.

Environmental Impacts and Renewable Energy

In this work X. H. Chen et al. (2023) Within the context of China's 14th Five-Year Plan, this research looks at the relationship between carbon emissions and the use of renewable and non-renewable energy sources (2021-2025). The five-year plan places significant emphasis on the implementation of a "Dual control" approach, which involves not only limiting energy consumption but also decreasing the energy intensity of the “gross domestic product” (GDP). The study examined the correlation between the quantity of air pollution and the sources of energy using a Granger causality analysis on a large dataset of energy and macroeconomic data from China spanning the years 1990 to 2022. The research indicates that air pollution and both renewable and non-renewable energy sources have a one-way relationship. Despite substantial government investment in renewable energy, the analysis indicates that China's economy continues to rely heavily on conventional energy sources, including fossil fuels. This study examines in-depth, for the first time, the connection between energy use and carbon emissions in the Chinese environment.

Important new information from the study may be used to guide market and policy policies that support technology innovation and carbon neutrality in both the public and commercial sectors.

In Rahman et al. (2022) To assess the environmental implications of RES-based power plants, a comprehensive analysis is conducted on a range of energy sources including wind, biomass, solar thermal, hydroelectric, tidal, ocean current, oceanic wave, and osmotic impacts. The expression "concentrated solar power" is frequently applied to solar thermal energy. Each RES-based power plant is subsequently subjected to a SWOT (strengths, weaknesses, opportunities, and threats) analysis. Concentrated solar power plants and solar photovoltaic plants are compared using SWOT analysis. A summary of the comparative environmental impact assessments of all operational RES-based power plants is provided, taking into account a variety of criteria. These encompass a range of adverse environmental effects, such as deforestation, noise pollution, eutrophication, ozone layer depletion, toxification, flooding, and human-induced consequences. The study concludes that electrical power facilities should exercise caution when selecting renewable energy sources (RES), as improper utilisation of RES can potentially result in adverse environmental consequences.

The purpose of the research conducted by Lanre Ibrahim et al. (2022) to Undertake research in the five most carbon-intensive African nations (South Africa, Algeria, Nigeria, Egypt, and Morocco) concerning the ramifications of structural change, reliance on renewable energy, environmental technologies, and dependence on natural resources from 1990 to 2019. The study applies several second-generation estimators, including "quantile regression" (QR), "augmented mean group" (AMG), "common correlated effects mean group" (CCEMG), and "cross-sectional auto-regressive distributive lag" (CS-ARDL). Because the model's cross-sectional dependency and slope variability directly affected the selection of second-generation estimators, the long-run assessment used the Wester Lund cointegration test. The empirical results that have been published are based on CS-ARDL. The structural change indicators significantly lower carbon emissions. Likewise, renewable energy sources and environmental technology contribute to reducing the rate of increase in carbon emissions. On the other hand, a high reliance on natural resources causes carbon emissions to rise significantly. The trustworthiness of the results is further supported by the results of CCEMG, AMG, and QR tests. Furthermore, the empirical support for nexus is provided by the causality derived from the Dumitrescu Hurlin test, which considers both unidirectional and bidirectional causalities. Prominent policy recommendations encompass those that advocate for investments in renewable energy, environmental technical practices, and service-led structural transformation.

Bogdanov et al. (2021) in A methodology that enables the full hourly resolution modelling of complex energy system transitions for the transportation, industrial, electricity, and heat sectors—which collectively account for over 75% of CO2 emissions—is presented and tested in this paper. The technology is evaluated for the instance of Kazakhstan. The findings demonstrate that, even in the event of extreme climatic conditions and an energy-intensive economy, as found in Kazakhstan, a transition towards a system that is entirely sustainable and reliant on renewable energy by 2050 is feasible. Because of the stronger electrification that results in increased sector coupling, the power sector becomes the foundation of the whole energy system. The results indicate that although sectoral integration presents unique benefits, greater flexibility is offered by both electrification and sector integration, leading to more efficient systems and more affordable energy delivery. The levelized cost of energy in a completely integrated system could potentially decline from 62 €/MWh in 2015 to 46 €/MWh in 2050. While the cost of heat is mostly stable at 30-35 €/MWh, the energy system costs 40–45 €/MWh. The transition to entirely RES is expected to decrease these businesses' CO2 equivalent emissions by 90% by 2040 and eliminate them by 2050.

In a study conducted by Shahbaz et al. (2020) From 1990 to 2018, the relationship between the economic performance of 38 nations that utilized renewable energy is analysed. Among the methods employed are “fully modified ordinary least squares” (FMOLS), “dynamic ordinary least squares” (DOLS), and heterogeneous non-causality. Utilizing renewable energy sources has been positively correlated with economic growth, according to empirical studies. In addition, they found that labour, capital, renewable energy, and non-renewable energy all had a favourable impact on economic development. It is noteworthy the adoption of renewable energy sources positively impacted economic development in 58% of the countries under examination. Governments, energy organizers, international cooperation organizations, and relevant agencies must collaborate to increase investments in renewable energy, according to the empirical findings, if the majority of these nations are to achieve low-carbon development.

Evidence of The Connection Between the Adoption of Renewable Energy and Economic Growth from The Renewable Energy Nation Attractiveness Index

A study conducted by Usman & Balsalobre-Lorente (2022) This research analyses the effects on the environment of total reserves, industrialization, and the growth of renewable, financial, and natural resources. Using panel data from 1990–2019, this study examines nascent industrialized nations. Even though there is a lot of variation, the results from the "enhanced mean group" (AMG) panel method are solid. In addition, according to cross-sectional dependency, the three main factors contributing to environmental degradation in the specified countries are total reserves, financial development, and industrialization. On the flip side, renewable energy sources and natural resource availability reduce environmental damage. Not only that, but these results are in line with the aggregate-level and long-term predictions. Furthermore, industrialization was found to have a unidirectional causal relationship with renewable energy, natural resources, and ecological footprint according to the panel Dumitrescu and Hurlin causality test results. There was also demonstrated to be a two-way causal relationship between ecological footprint, total reserves, and financial progress. Finally, the study concludes with some crucial policy recommendations for environmentally conscious nations that have only just begun to industrialize.

Fais et al. (2016) clarifies that literature looks at how important industry is to achieving long-term policy objectives related to decarbonization, renewable energy, and efficiency. A process-oriented modelling strategy, based on a vast technology database specifically designed for the industrial sector, is employed in one methodologically novel national energy system model for the United Kingdom (UKTM). This method enables the decarbonisation of upstream energy vectors in the industrial sector and the measurement of the contribution of mitigating alternatives. Subsequently, a comparative policy scenario analysis is carried out at the national and European levels, using this enhanced model, to examine several objective elements associated with energy efficiency, renewable energy, and carbon mitigation. The results show that the industrial sector's ambitious target of cutting emissions by up to 77% from 2010 levels by 2050 can be achieved. Moreover, given the sector's capacity to reduce industrial energy consumption by as much as 31% from 2010 to 2050, its implementation is critical to reaching the overarching efficiency goals. An additional factor encouraging the adoption of renewable energy sources is the industrial sector, which mostly relies on biomass for low-temperature heating services. Sub-targets pertaining to renewable energy and energy efficiency should be given particular consideration since they have the potential to greatly affect the long-term mitigation route's cost-effectiveness.

Sustainability and Renewable Energy Adoption

A study conducted by Asif et al. (2023) seeks to closely examine the relationships between collectivism, value orientation, utilitarian advantages, adoption motivation, attitude towards renewable energy (RE), and adoption intention in the context of renewable energy. The research examines survey information from 359 Pakistani customers who had solar panels installed in their homes. To assess hypotheses, a method known as structural equation modelling is used. Based on empirical evidence, value orientation has a positive and substantial impact on the motivation behind the adoption of RE as well as the attitude towards RE. In a same vein, attitudes about RE are significantly and favourably impacted by the utilitarian advantage. Additionally, attitudes towards RE are significantly and favourably correlated with collectivism and adoption motivation. The results of the research further demonstrate that RE attitudes positively and significantly affect customers' inclinations to utilise renewable energy. Future directions for researchers and professionals are enhanced by the study, which is supported by the literature on sustainable practice.

In this study, Al-Emran & Griffy-Brown (2023) goal to identify and analyse the major possibilities and difficulties connected with technology adoption in sustainable development. In addition, the study suggested a number of research topics and noted a number of research gaps that will need further investigation. These study subjects have been divided into four primary areas. The first three categories focus on the three pillars of sustainability: society, the economy, and the environment. Research agendas that are applicable to all three of the sustainability aspects are included in the fourth category, which is a generic category. The information gathered from this study contains significant theoretical contributions, practical implications for developers, practitioners, and lawmakers, and broadens the corpus of knowledge.

In this work, Poshnath et al. (2023) seeks to establish flat owners' "Energy Entitlement" as a crucial research idea to encourage the use of RES in MOBs. The author emphasize the need of "Energy Entitlement" while conducting a comprehensive analysis of the elements impacting the adoption of RES in MOBs and the current energy allocation frameworks put forth in the literature in order to position the notion. The literature that is currently accessible mostly focuses on the obstacles and facilitators of RES adoption in MOBs. The "RES" and "Land Administration" synergy, however, is one of the least concentrated. While some studies have presented controversial energy allocation methods, research on the energy-spatial dilemma in MOBs is still in its early stages. The study wraps up by emphasising how "Energy Entitlement," which advocates for an equal division of energy ownership along with land management principles, has implications for business, academia, and policy regimes.

In this work, Qamar et al. (2022) seeks to identify the essential components that Pakistan's MSMEs in two tehsils in the district of Multan, Punjab province, must take into account in order to adopt and disseminate solar energy technology (SET). In order to ascertain the essential components, surveys and literature reviews are employed. Path modelling based on partial least squares is then implemented. The findings indicated that the three primary impacting variables are the size of the organisation, the SET's perceived reliability, and its reported ease of use. Widespread adoption and utilisation of SET is hindered by the energy cost intensity of MSME, the perceived cost of SET, and the perceived level of competitive pressure. The absence of technical comprehension regarding SET is an unbiased concern. (3) Perceived SET price, energy cost intensity of MSMEs, and firm size are significant determinants according to the impact size and path coefficients; eco-labels and green decals, consumer preferences, and a deficiency in technical SET competence are comparatively less influential. To encourage more Pakistani

MSMEs to adopt and disseminate SET, it is recommended that the price of SET be decreased. This is because SET adoption is a logical progression that is particularly contingent on financial incentives.

Future Prospects for Renewable Energy in The Industrial Sector

In this work, Rauf et al. (2023) thoroughly examines the condition of solar resources now, the solar PV sector's potential for development in the future, and the key elements influencing the industry's steady expansion. The study focuses on the following five main areas: technological R&D, project incentive programmes, electricity pricing recommendations, laws and regulations, and industrial planning. A thorough approach is used to investigate these characteristics, including statistical data collection, legislative analysis, regulatory and policy analysis, and literature review. Development route models may be expanded by the analysis of typical events, the development process, and the characteristics of the five components. The study's conclusions provide light on the PV power industry's present state and potential future growth in India. In the current dynamic social, economic, and technical spheres, policymakers possess the chance to enhance their comprehension of the constantly changing practices and novel developments in the business paradigm.

2.3 Summary

An extensive body of research devoted to the subjects of renewable energy management and sustainability has yielded significant findings regarding challenges and strategies in a variety of industries. Identified causes of energy waste in a specialized industrial energy audit prompted the implementation of individualized efficiency measures, including the expansion of photovoltaic (PV) systems, the installation of variable speed drivers, and the evaluation of electric forklifts. These implementations not only yielded substantial energy conservation but also played a role in diminishing carbon dioxide emissions. An investigation into the construction industry in Pakistan employed methodologies such as the Delphi approach and MICMAC to ascertain critical success factors for Energy Efficiency and Sustainable Construction (EESC). The study emphasized the significance of recognizing and mitigating particular determinants of success in the construction sector in order to effectively advocate for sustainable practices. An independent study was carried out to create sustainability standards for businesses using a novel fuzzy decision-making process, emphasising the importance of renewable energy incorporation in the IT sector. The integration of microgrid energy management systems was proposed as a viable solution to the financial obstacles associated with investing in renewable energy. This development presented a practical strategy to improve sustainability across multiple sectors. Big data and digital twin technologies were introduced into sustainable smart manufacturing to help energy-intensive companies save money and use less energy. An examination of a theoretical framework that centres on the "Waste-to-Energy" (WTE) supply chain with agricultural sectors in Malaysia revealed the favourable effects that WTE implementations have on the capacity for a circular economy. To tackle more extensive energy concerns, a comprehensive strategic plan for attaining a net-negative economy incorporated measures such as carbon dioxide removal, energy storage, grid congestion, and sector coupling. Institutional opposition to 100 percent renewable energy systems was investigated alongside societal benefits. A simulation-based optimization model was used to assess the ideal energy consumption characteristics, highlighting the benefits of switching to renewable energy sources, particularly for the textile sector. In analysing energy efficiency components of the U.S. economy, industrial output, financial inclusion, trade liberalization, and public energy research and development were given particular attention. A complex association between the use of renewable energy and CO2 emissions was found, which varied across income levels, in the assessment of the impact of RE usage on economic development in EU member states. In addition, research investigated obstacles within the cement sector by implementing a three-phase integrated strategy for energy-conservation endeavours grounded in multi-criteria decision-making. The research as a whole enhances comprehension of energy management and sustainability by emphasizing customized methodologies, cutting-edge technologies, and regulatory structures as means to attain a sustainable renewable energy future.

CHAPTER III:

RESEARCH METHODOLOGY

3.1 Overview of the Research Problem

Renewable power systems, into cities characteristic as a significant component of sustainable improvement and climate change adaptation. Cities where more than 78% of energy is used and contribute 60% to carbon emission need to move away from conventional and outdated sources of energy to clean technologies such as solar, wind and geothermal power (United Nations, 2019). However, there are still some challenges in implementation of renewable energy. The challenges are technical, financial, regulatory, and social challenges that affect the use of these technologies in urban areas.

Altogether, one of the major concerns is the absence of a reliable source of data and information on how well renewable energy is integrated into the urban setting. This means knowing the level of integration, and the effect of integration on urban sustainability, defined by the three pillars of environment, economy, and society, as well as the effectiveness of existing policy and strategy in furthering this integration (Hmouda, Orzes and Sauer, 2024). In addition, perspectives drawn from practical contextual factors including, but not limited to, city planning, architecture, engineering, and policy-making remain largely uncharted thus denying the formulation of context-specific recommendations or strategies that would help address factors inhibiting the adoption of renewable energy solutions in cities (Abou Jaoude, Mumm and Carlow, 2022; Menon, 2017).

Therefore, the research problem defining this study is the absence of an accurate assessment of current state and effects of RE in the integrated infrastructure of cities, as well as a lack of clear recommendations on improving the overall performance of RE systems used in urbanization (Dey, Sreenivasulu, G. T.N. Veerendra, *et al.*, 2022).

Assessing these aspects will offer information to policy makers, urban designers, and other stakeholders which will enable the construction of sustainable cities.

3.2 Operationalization of Theoretical Constructs

The theoretical constructs of this study are operationalized through a multi-faceted approach that addresses the diverse challenges and barriers to renewable energy integration, alongside a detailed assessment of the renewable energy potential across different climatic regions in India. Challenges and barriers encompass the technical, financial, regulatory, and social factors that hinder the widespread adoption of renewable energy sources (Charles Rajesh Kumar and Majid, 2020). For the viability assessment, the study categorizes regions into hot, dry, and humid areas; coastal and hilly regions; and regions with high rainfall. Each category is evaluated for its specific renewable energy potential, taking into account factors such as solar irradiance, wind speeds, and hydropower potential (Tramontin, Loggia and Trois, 2012).

Furthermore, the development of a comprehensive roadmap for industrial organizations is operationalized by considering general perceptions, economic considerations, and ecological impacts of renewable energy use. This includes assessing the cost-benefit analysis, return on investment, and sustainability metrics relevant to industrial operations. (Pachar, Singh and Wahid, 2021). The ecological considerations involve the study of environmental impacts, such as carbon footprint reduction and resource conservation, thereby ensuring that the adoption of renewable energy contributes to broader environmental goals (Kumar et al., 2010; Mittal, Ahmed and Koli, 2018).

3.3 Research Purpose and Questions

The present study aims to identify key challenges and opportunities connected with the management of renewable energy in the industrial sector. This study aims to generate a multitude of benefits and impacts through its pursuit of solutions to the research problem.

These include but are not limited to enhanced comprehension, increased productivity, improved sustainability, and economic prosperity. The present investigation concentrates on the subsequent research questions:

1. What are the specific challenges and barriers that industrial facilities encounter when attempting to integrate renewable energy solutions into their operations effectively?
2. How do the viability and potential of renewable energy sources (such as wind, hydro, and solar) vary across different regions of India in meeting the energy needs of various industrial sectors?
3. What factors should be considered in the development of a comprehensive roadmap for industrial organisations across sectors to optimise the utilisation of renewable energy sources in their facility layouts and operations, with a focus on achieving both economic and ecological benefits?
4. What practical recommendations and guidelines can be formulated to assist industrial organisations in planning, implementing, and managing renewable energy systems efficiently within their operations?

3.4 Research Design

The research design of this study was based on the Saunders' research onion. Crossley (2021) Research Onion details the many interrelated choices you'll need to make when you're crafting your research methodology.

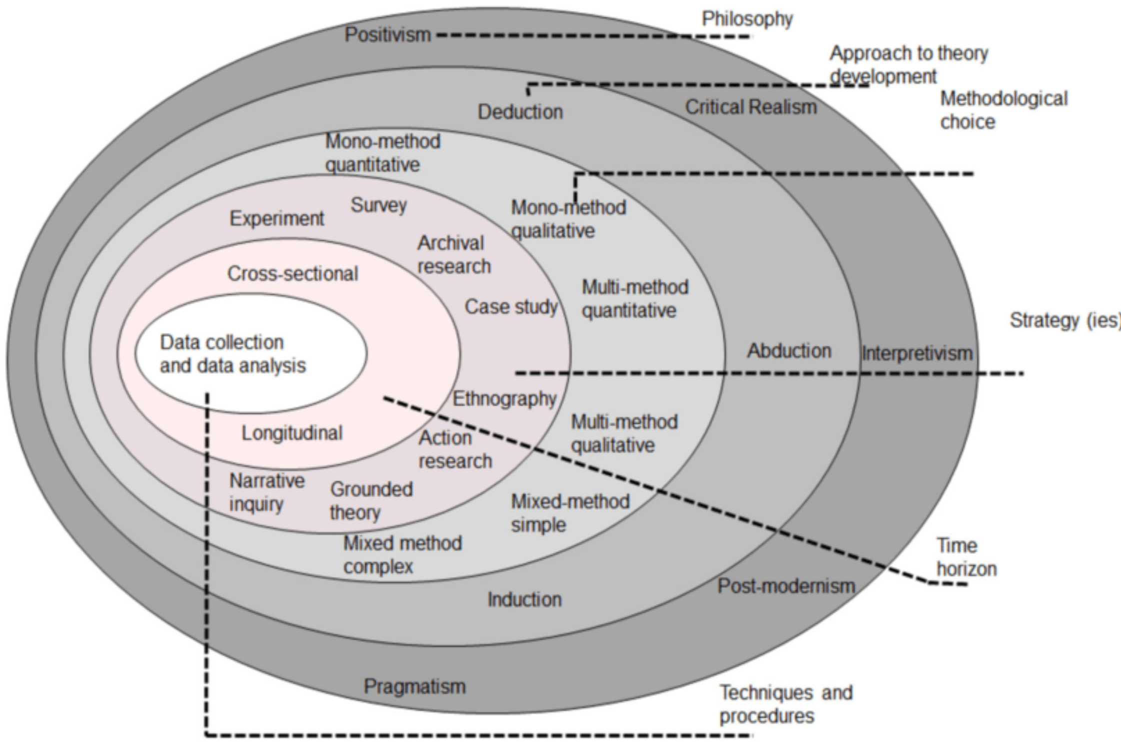

Figure 3.1 Saunders' Research onion

Research Philosophy

The research philosophy underpinning this study is grounded in positivism, which emphasizes an objective reality that can be measured and quantified. This approach aligns with the study's aim to investigate renewable energy management in the industrial sector using a quantitative research design (Guba and Lincoln, 1994). Positivism is a research philosophy that uses measurement and reason to study the world through a neutral lens. It's based on the idea that knowledge is revealed through objective observation of activity, action, or reaction. Positivism is closely linked to quantitative methods of data collection (Bonache and Festing, 2020).

Approach to Theory

The research has used a deductive method and draws upon well-established ideas (Soiferman, L.K., 2010). The first assumptions, derived from prior literature, serve as a framework for collecting empirical data in order to assess and confirm these ideas. The primary objective is to enhance or create theories via empirical observations in the dynamic field of managing renewable energy in industrial settings.

Methodological choice

This study was based on the quantitative research approach to assess various aspects of 'Renewable Energy Management in the Industrial Sector' (Dixon-Woods *et al.*, 2005). Quantitative data was collected through surveys to measure energy consumption, cost savings, environmental impact, and operational efficiency in industrial settings.

Strategy

The study was based on the survey strategy. A survey can be used as a research strategy to collect quantitative data that can be analysed statistically. The results of a survey can be used to produce both quantitative and qualitative results.

Time horizon

A cross-sectional study is conducted to examine the current state of renewable energy management in the industrial sector. This work is cross-sectional in that it seeks to sample or select some industrial facilities at one point in time (Kesmodel, 2018). The assessment involves the analysis concerning integration of renewable energy, like the energy type, technology, and issues. Different industries are targeted at the same time and data is collected through opinion polls or other research instruments. It also presents a current state of development analysis, which enables the researchers to see patterns, relationships, and causations within the renewable energy management practices that work across various industries.

3.5 Population and Sample

There are different methods of selecting the sample. However, a basic use of random selection, as noted by Singh (2003), was adopted to get a total sample of 300 respondents from 300 unique industries; the study administered the questionnaires to employees in each of the selected industries. This survey was conducted online, in the various websites and social media forums where the target respondents were found. The questionnaire survey was mailed to the email addresses, LinkedIn accounts or any other account that may be provided by the respondents. In this case, barriers to the integration of renewable energy were determined, and probabilities of profitability of various renewable energy sources were determined (Frey, 2017).

3.6 Participant Selection

The participant selection of this study survey was based on the following inclusion and exclusion criteria:

Table 3.1 Inclusion and Exclusion Criteria

Criteria	Inclusion	Exclusion
Industry Sector	Participants from the industrial sector are involved in renewable energy management.	Participants from non-industrial sectors or not involved in renewable energy.
Job Role	Managers, engineers, and decision-makers in energy management.	Employees without decision-making roles or unrelated job roles.
Experience	Minimum of 2 years of experience in energy management.	Less than 2 years of experience in energy management.
Geographical Location	Participants based in India.	Participants based outside India.
Knowledge Level	Adequate knowledge of renewable energy practices.	Limited or no knowledge of renewable energy practices.
Consent	Willingness to participate and provide informed consent.	Unwilling or unable to provide informed consent.

3.7 Instrumentation

The survey on **Renewable Energy Management in the Industrial Sector** employed a number of research instruments. Oben (2021) To gather a wealth of information. In order to receive accurate information on the instigation of renewable energy techniques, structured questionnaires were distributed and completed by key stakeholders. Further, internet surveys and email questionnaires which were tailored for specific groups were employed so as to increase the coverage and responses. These tools allowed for the collection of diverse information such as measurements of energy use and changes, technical acceptance rate and issues faced by the industrial segments along with the adoption of renewable energy options.

3.8 Data Collection Procedures

While researching this study, a broad approach of data collection was used. Data collection was done through questionnaires that were filled by the stakeholders containing questions that would elicit the current state of renewable energy management in the industrial sector (Sadan, 2017). An online survey thus extended the coverage; participation derived from diverse industrial scenes, which works from different parts of the world. However, to ensure that response rates were achieved, the email surveys were focused on specific organisations. This approach is intended to obtain integrated data on energy consumption profiles, trends in new technologies, and issues associated with the adoption of renewable energy by enterprises. In structured questionnaires, internet polls, and email surveys, a diverse and wide-ranging set of data was accumulated. One could analyse various methods applied in industrial renewable energy management, using the data set developed. (Manstein, Shiah and Laikhter, 2023).

3.9 Data Analysis

From the analysis of the case study "Renewable Energy Management in the Industrial Sector", several discoveries were made by purposely integration of tools and methods. The study employed the Descriptive analysis approach (*Descriptive Sensory Analysis in Practice*, 2004) that showed the existence of patterns in the adoption of renewable energy practices in the several businesses cases. More so, specific statistical studies to identify possibilities of relationships and hypothesis testing would not have been possible without the application of the IBM SPSS programme. Analytical techniques included in the study were regression analysis which provided a deeper understanding of industrial renewable energy data. This kind of approach ensured the exhaustive approach, which gave valuable insights on the efficiency of management of the renewable energy supply chain, which may be beneficial for analysing the employment of sustainable energy in various industrial segments.

3.10 Research Design Limitations

The approach that was adopted in the quantitative study had inherent disadvantages. However, the use of sampling might limit the ability to generalise some of the findings, whereas, using self-data has the following biases, socially desirable reporting. The quantitative method on the other hand offers statistical validity but at the same time the complex processes cannot be elaborated to the required depth. Another criticism made on descriptive approaches, especially the cross-sectional ones, is the ability to miss out on temporal changes that may already be emerging. Making causal relation is problematic and perhaps there will be dismal chances of accurately measuring qualitative features of the renewable energy techniques. In addition, factors like the reliability of the instruments used, the limitation of resources which are time and money, and other practical limitations affect the internal validity of the study. Acknowledging these limitations ensures first and foremost that the results are analyzed in a way which is beyond reproach.

3.11 Conclusion

In essence, this study on “Renewable Energy Management in the Industrial Sector” charts the web of energy technology in light of the energy trilemma. Driven by technical progress and a worldwide transition to sustainable sources, the analysis predicts the rise of non-traditional hydrocarbons, renewable energy, and secondary renewable sources integrated with smart grid technologies. The study investigates microgrid systems and highlights the crucial role of renewable energy in mitigating climate change. It promotes efficient information exchange and recognises the significance of energy storage. The methodology chapter ensures the study's legitimacy by providing a clear plan for future research, while the use of quantitative methods and the operationalisation of theoretical constructs provide a strong and reliable basis. The study aims to clarify obstacles, evaluate feasibility, and provide practical suggestions for effective management of renewable energy, making a substantial contribution to the discussion on sustainable energy practices in the industrial sector.

CHAPTER IV:

DATA ANALYSIS AND INTERPRETATION

4.1 Reliability

Table 4.1 Reliability Statistics

Cronbach's Alpha	N of Items
.842	33

The reliability data for the scale is shown in table 4.1 above, which is based on 33 items and has a Cronbach's Alpha of 0.842. This number shows that scale has strong internal constancy and reliability. Values of Cronbach's Alpha exceeding 0.70 are commonly regarded as satisfactory, whereas values beyond 0.80 indicate exceptional dependability.

4.2 Frequency Table

Table 4.2 Your present or past company or professional experience belongs to which industry sector?

	Frequency	Percent
Manufacturing	176	58.7
Service	80	26.7
Other	44	14.7
Total	300	100.0

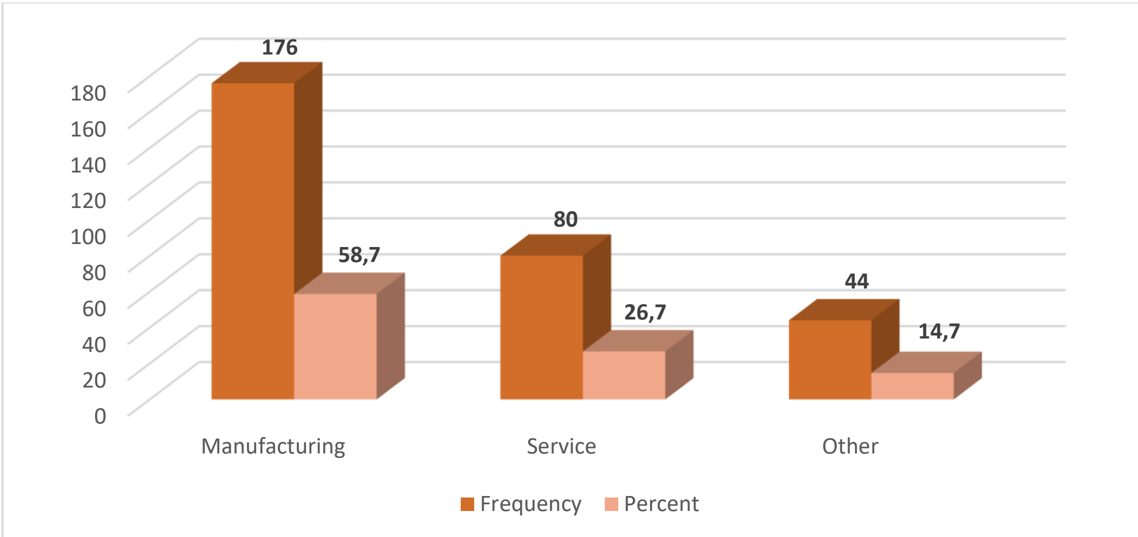

Figure 4.2 Your present or past company or professional experience belongs to which industry

The majority of respondents, or 58.7%, are from the manufacturing sector, while 26.7% are from the service sector, according to Figure 4.2 above. Just 14.7% of respondents said they had prior expertise in other industries.

Table 4.3 Name of your Department/Current Role/Area of specialization

	Frequency	Percent
Academics	1	.3
Account Manager	3	1.0
Administration	5	1.7
Advisory, Supply Chain and Cloud	2	.7
Applications Sales	2	.7
Architecture/ Principal Architect	3	1.0
Associate Director (Sales/BD)	2	.7
CEO	6	2.0
Channel Leader	7	2.3
Civil & Structural / Senior Manager / structural Engineering	4	1.3
CMD	2	.7
Construction	6	2.0
Consultancy for Accounts and Tax	3	1.0

Coordinator	1	.3
Creative head	1	.3
Customer care	2	.7
Delivery Head	2	.7
Designer	2	.7
Development of commercial and residential buildings	1	.3
Director and Head of Client Partner	23	7.7
Electricity Generation (Thermal)	6	2.0
Employee Health & Safety	1	.3
Engineering /HOD/ Utility (energy savings)	3	1.0
Estate management	1	.3
HR	15	5.0
Industrial Engineering	2	.7
Interior Decoration Fit out And Modernization of Commercial Spaces	2	.7
IT Consulting	9	3.0
Lecturer in English	1	.3
Logistics	2	.7
Management	64	21.3
Mentor	2	.7
New Product Development	2	.7
Online Commerce	20	6.7
Plant Head / Production	21	7.0
Principal Engineer	1	.3
Procurement	2	.7
Production Manager	14	4.7
Program Director	1	.3
Project Management	4	1.3
Proprietor	4	1.3
Purchase Head	9	3.0
Relationship Channel	1	.3
Safety In charge	4	1.3
Sales Service & Installation	12	4.0
Scientist	1	.3
Software Engineer/Compiler-System Verification	2	.7

Solution Engineering	2	.7
Stores	1	.3
Strategic	2	.7
Survey	1	.3
Technology Advisory	10	3.3
Total	300	100.0

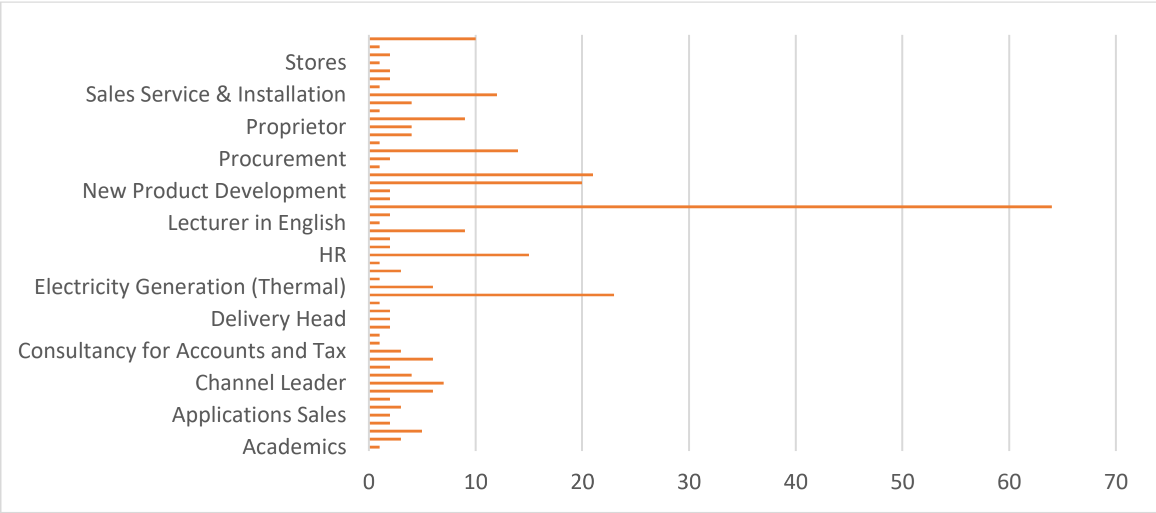

Figure 4.3 Name of your Department / Current Role/Area of specialization

The majority of respondents, or 21.3%, are in management jobs, followed by directors and heads of client partnerships, or 7.7%, according to Figure 4.3 above. 6.7% work in online commerce, while a sizeable percentage, 7.0%, are Plant Heads or involved in production. Production managers comprise 4.7%, and HR specialists make up 5.0%. 3.3% of occupations are in technology advisory roles, while 4.0% of roles are in sales, service, and installation. Heads of purchasing, procurement, and IT consulting each account for 3.0%. The CEO (2.0%), the construction (2.0%), and the channel leaders (2.3%) have additional roles. The percentages of several specialised roles, such as engineering, consulting, and advice, are smaller.

Table 4.4 Organization size (Number of Employees)/worked with/have been associated with

	Frequency	Percent
Small (1-100 employees)	110	36.7
Medium (101-500 employees)	61	20.3
Large (501+ employees)	129	43.0
Total	300	100.0

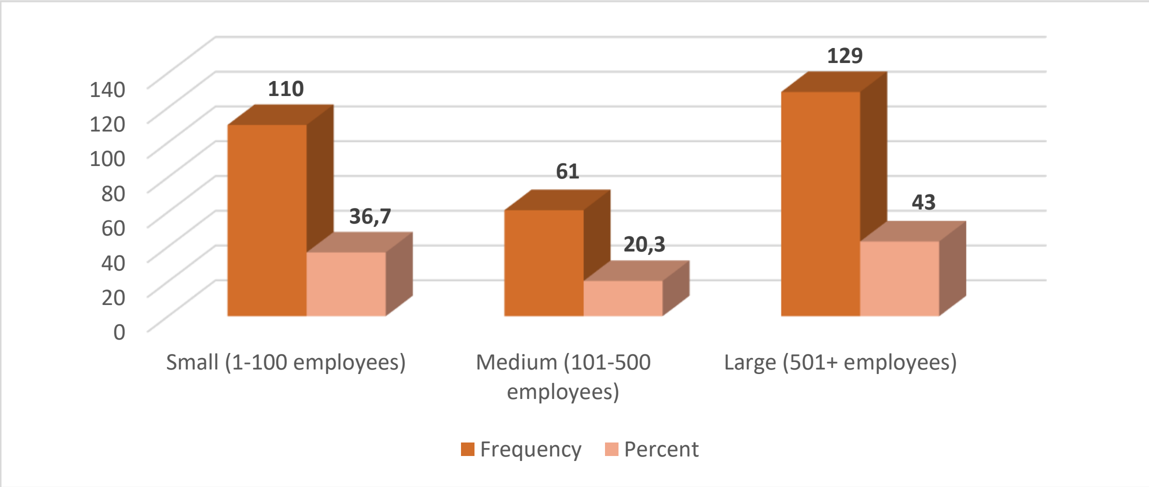

Figure 4.4 Organization size

The data on organization size is shown in Figure 4.4 above. The largest group of respondents, with over 501 employees, comprised 43.0% of the total respondents. 20.3% of the sample has worked for medium-sized companies with 101–500 employees, while another 36.7% has worked for small businesses with 1–100 employees.

Table 4.5 Geographic Location (City/State)

	Frequency	Percent
Assam	13	4.3
Chhattisgarh	3	1.0
Chennai	6	2.0
Goa	10	3.3
Gujarat	3	1.0

Gurgaon	4	1.3
Haryana	4	1.3
Himachal Pradesh	5	1.7
Jharkhand	15	5.0
Karnataka	15	5.0
Kerala	2	.7
Kharagpur	4	1.3
Kolkata	90	30.0
Maharashtra	31	10.3
Meghalaya	3	1.0
MP	3	1.0
New Delhi	35	11.7
Odisha	11	3.7
Rajasthan	2	.7
Telangana	3	1.0
Uttar Pradesh	6	2.0
West Bengal	32	10.7
Total	300	100.0

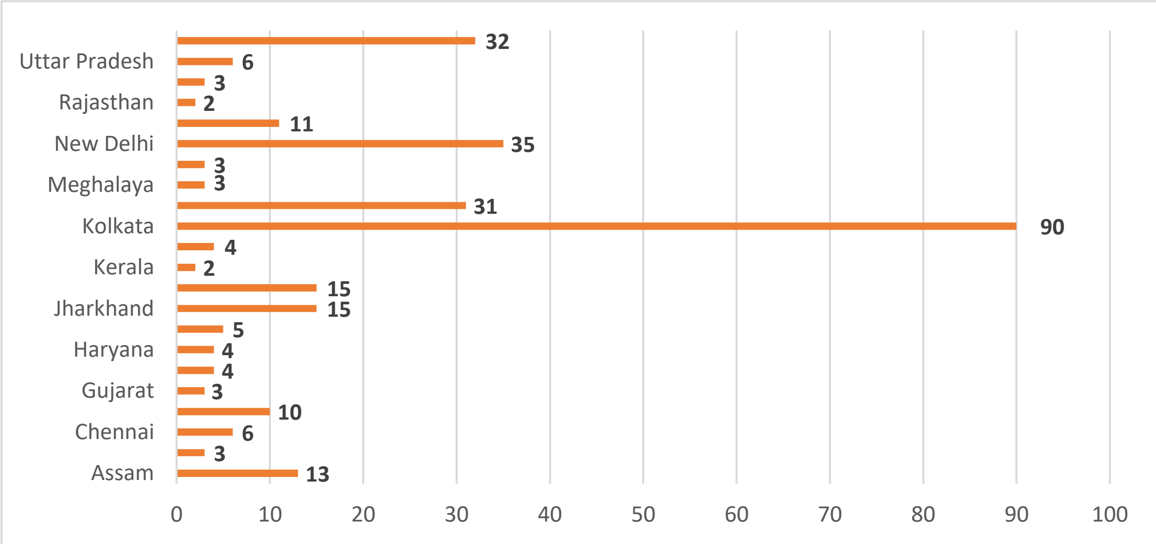

Figure 4.5 Geographic Location (City/State)

The distribution of respondents' geographic locations is presented in Figure 4.5 above. The majority of respondents, 30.0%, are from Kolkata, followed by 11.7% from

New Delhi and 10.7% from West Bengal (which excluding Kolkata). 10.3% of responders are from Maharashtra, while 5.0% are from each of Karnataka and Jharkhand. Insignificant shares of the sample originate from Goa (3.3%), Odisha (3.7%), and Assam (4.3%). Between 1.0% and 2.0% of responders are from many states, including Haryana, Gurgaon, Kharagpur, Himachal Pradesh, and Chennai. States with fewer than 1% participation are Kerala, Rajasthan, and Meghalaya.

Table 4.6 Are/were you directly involved in renewable energy management within your organization/professional association?

	Frequency	Percent
Yes	99	33.0
No	201	67.0
Total	300	100.0

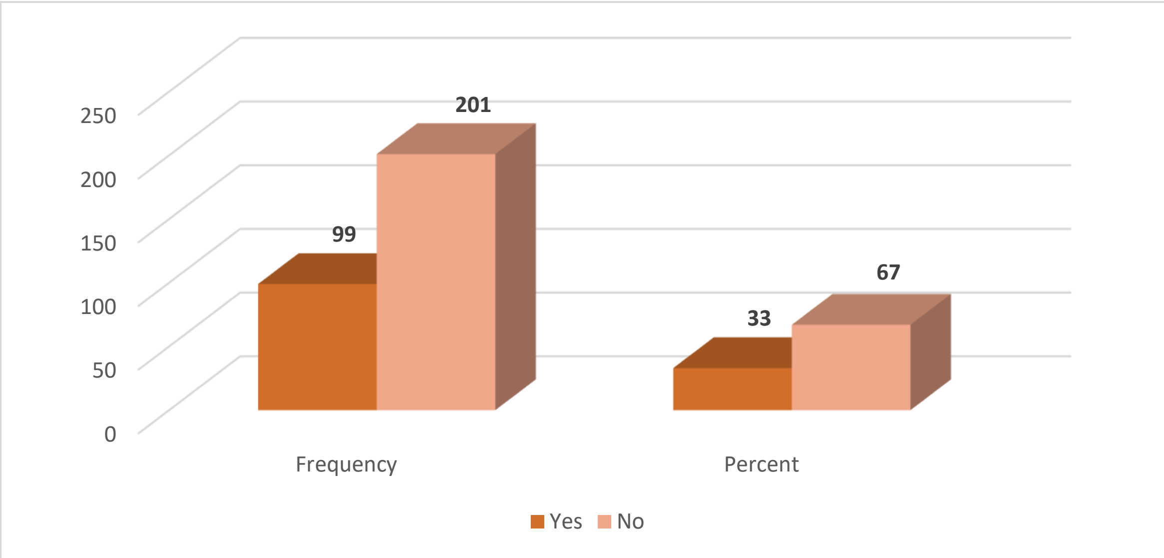

Figure 4.6 Are/were you directly involved in renewable energy management within your organization/professional association?

The above figure 4.6 shows that 33.0% of respondents were directly involved in renewable energy management within their organization, whereas the majority, 67.0%, were not.

Table 4.7 Is your organization or the association/s you are involved with actively utilizing renewable energy sources in its operations?

	Frequency	Percent
Yes	121	40.3
No	179	59.7
Total	300	100.0

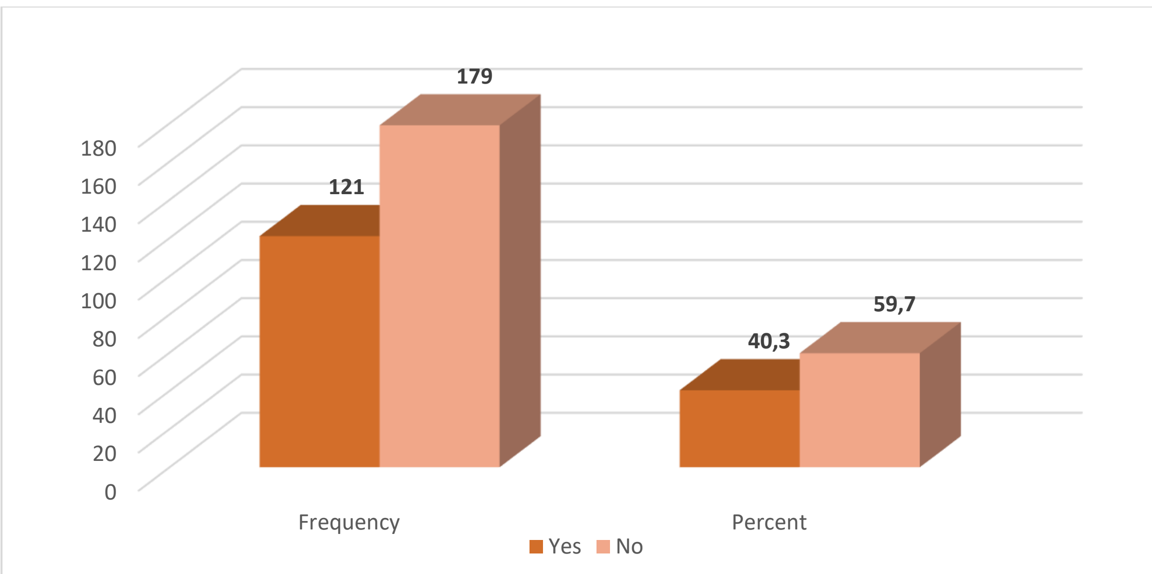

Figure 4.7 Is your organization or the association/s you are involved with actively utilizing renewable energy sources in its operations?

According to Figure 4.7 above, 40.3% of the associations or organisations who responded actively use renewable energy sources in their activities, whereas 59.7% do not.

Table 4.8 Is your organization or the association/s you are involved with actively utilizing renewable energy sources in its operations?

	Frequency	Percent
Low	118	39.3
Moderate	119	39.7
High	63	21.0
Total	300	100.0

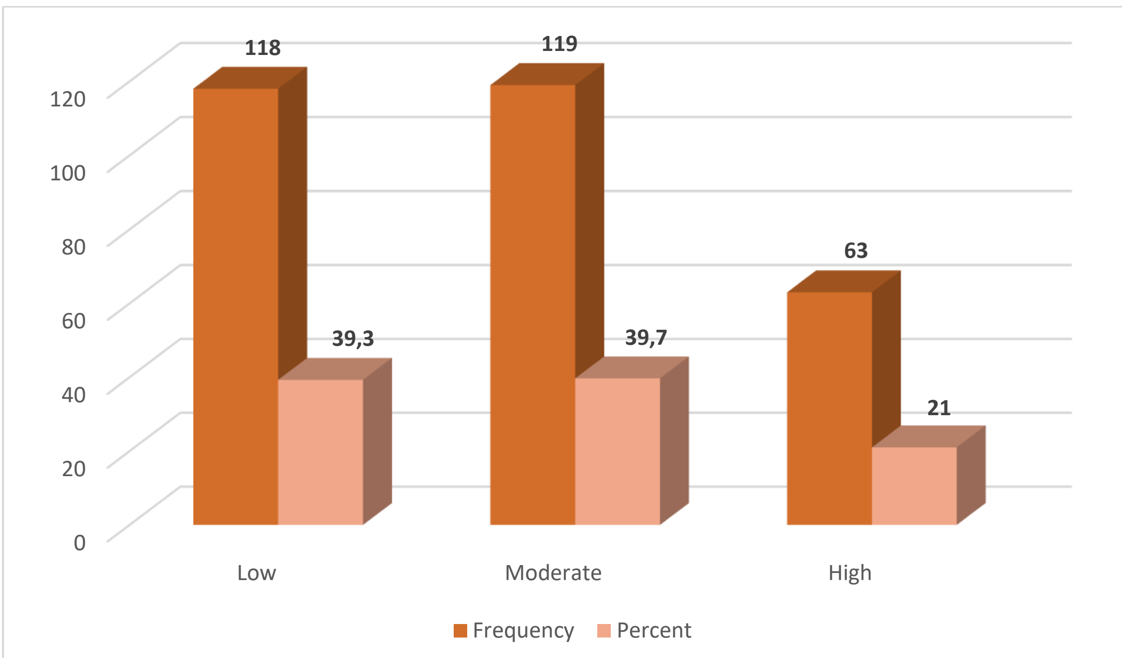

Figure 4.8 Is your organization or the association/s you are involved with actively utilizing renewable energy sources in its operations?

The above figure 4.8 shows the data of organizations or associations utilizing renewable energy sources at a moderate level, according to 39.7% of respondents are moderate, while 39.3% report a low level of utilization. A smaller portion, 21.0%, indicates a high level of utilization.

Table 4.9 The initial capital cost of setting up a renewable energy system is a significant barrier.

	Frequency	Percent
Strongly Disagree	9	3.0
Disagree	20	6.7
Neutral	95	31.7
Agree	99	33.0
Strongly agree	77	25.7
Total	300	100.0

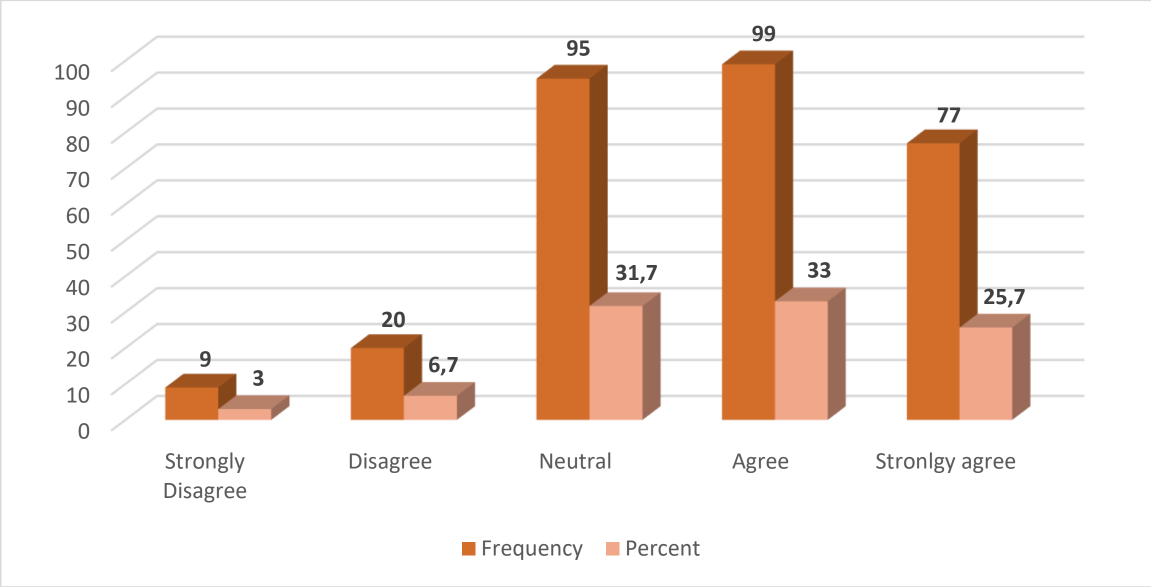

Figure 4.9 The initial capital cost of setting up a renewable energy system is a significant barrier.

The aforementioned figure 4.9 shows that the initial capital cost of installing a renewable energy system is a barrier. A sizable percentage of respondents, 33.0% agree, with an additional 25.7% strongly agreeing. On the other hand, 31.7% of respondents are neutral, while a lower proportion disagrees (6.7%) or strongly disagrees (3.0%).

Table 4.10 The lack of available government incentives or subsidies hinders renewable energy adoption.

	Frequency	Percent
Strongly Disagree	9	3.0
Disagree	28	9.3
Neutral	77	25.7
Agree	129	43.0
Strongly agree	57	19.0
Total	300	100.0

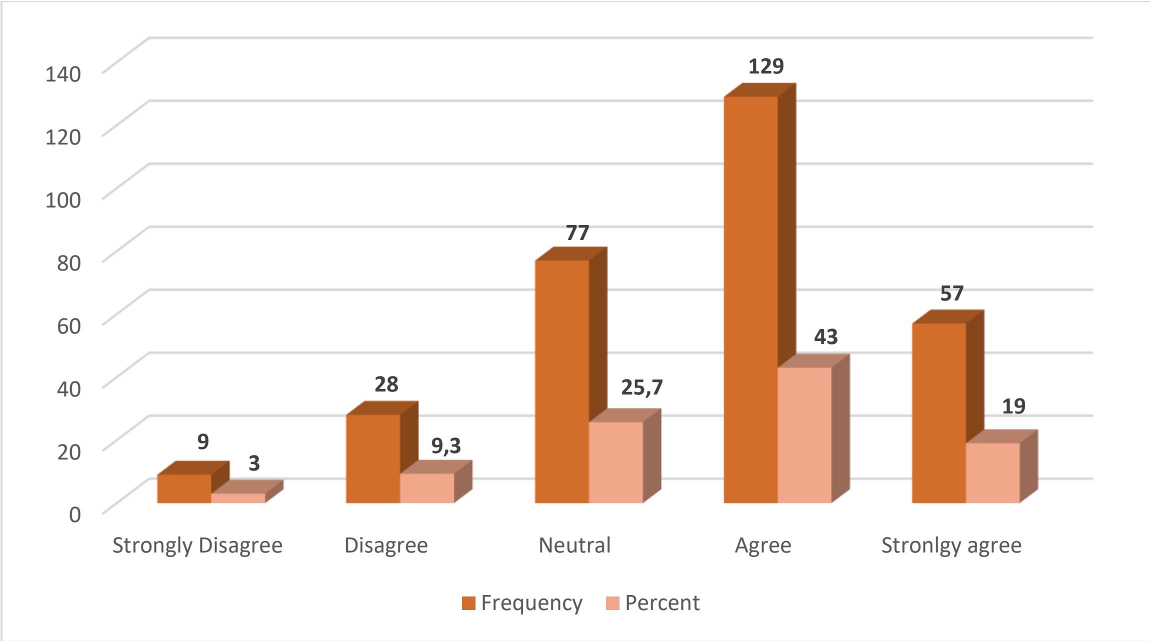

Figure 4.10 The lack of available government incentives or subsidies hinders renewable energy adoption.

The data in Figure 4.10 above indicates that while 43.0% of respondents agree and 19.0% strongly agree, the lack of government incentives or subsidies prevents the use of renewable energy. On the matter, 25.7% of respondents are neutral, 9.3% disagree, and 3.0% strongly disagree.

Table 4.11 The complexity of integrating renewable energy into existing infrastructure is a major challenge.

	Frequency	Percent
Strongly Disagree	2	.7
Disagree	44	14.7
Neutral	65	21.7
Agree	136	45.3
Strongly agree	53	17.7
Total	300	100.0

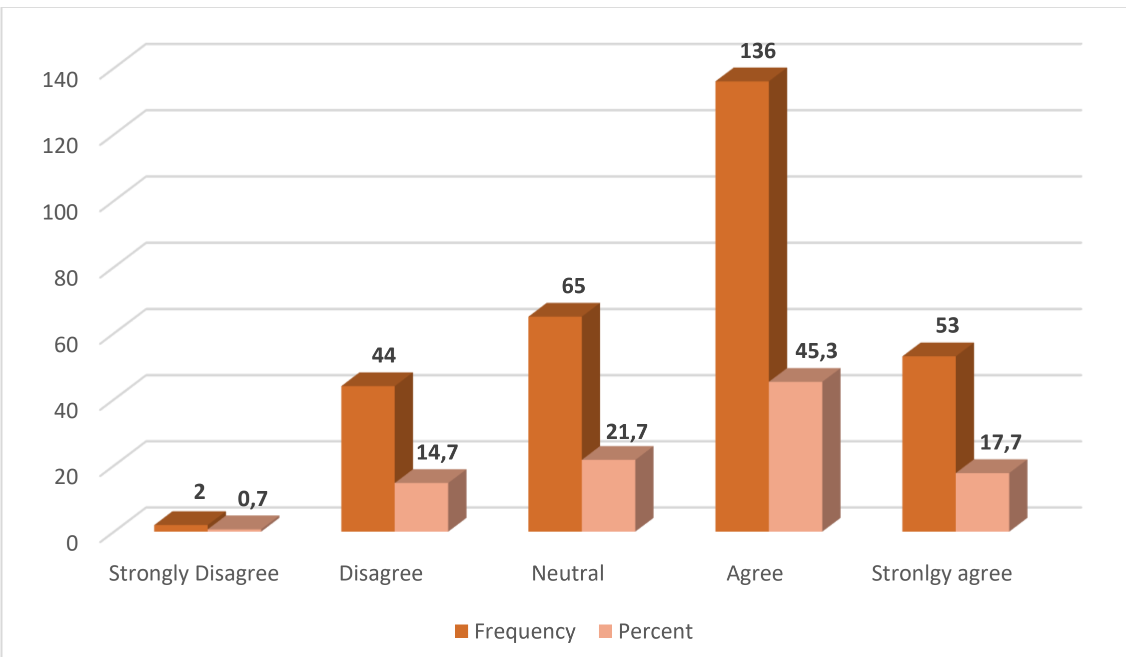

Figure 4.11 The complexity of integrating renewable energy into existing infrastructure is a major challenge.

According to Figure 4.11 above, 45.3% of respondents agree that it is a significant problem to integrate renewable energy into the current infrastructure, and an additional 17.7% strongly agree. The majority, 21.7%, are neutral, followed by 14.7% who disagree and 0.7% who strongly disagree.

Table 4.12 Uncertainty about the long-term cost savings of renewable energy solutions is a barrier.

	Frequency	Percent
Strongly Disagree	15	5.0
Disagree	56	18.7
Neutral	80	26.7
Agree	115	38.3
Strongly agree	34	11.3
Total	300	100.0

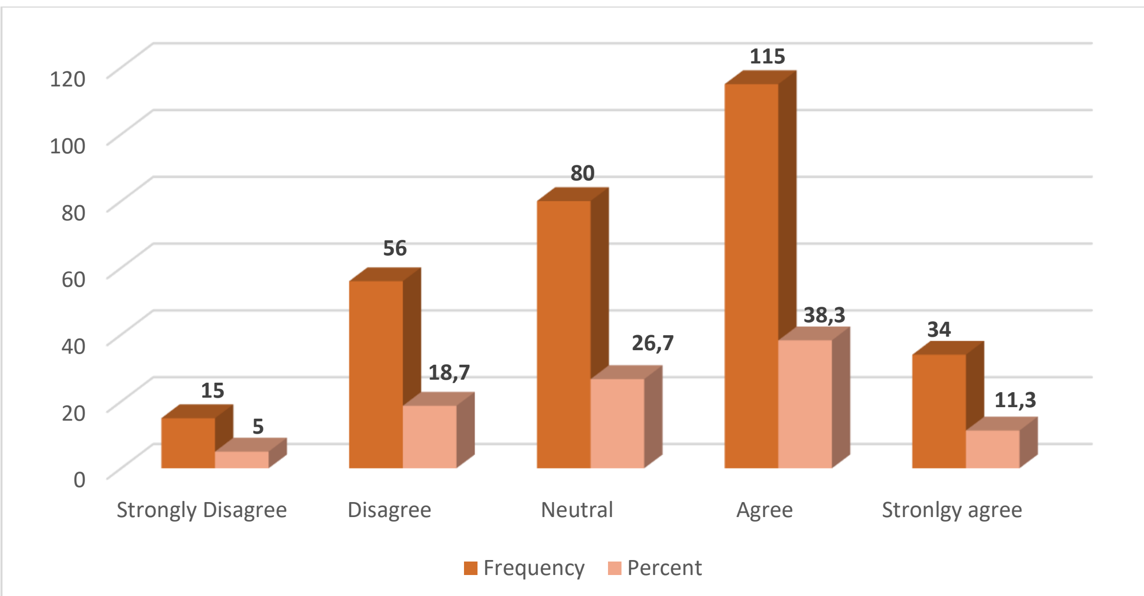

Figure 4.12 Uncertainty about the long-term cost savings of renewable energy solutions is a barrier.

The distribution of respondents' uncertainty about the long-term cost savings of renewable energy solutions as a barrier is depicted in Figure 4.12 above. Of them, 38.3% agree, and 11.3% strongly agree. On this matter, however, 18.7% disagree, 5.0% strongly disagree, and 26.7% are neutral.

Table 4.13 Concerns about the reliability and consistency of renewable energy sources/vendors are barriers

	Frequency	Percent
Strongly Disagree	5	1.7
Disagree	33	11.0
Neutral	75	25.0
Agree	157	52.3
Strongly agree	30	10.0
Total	300	100.0

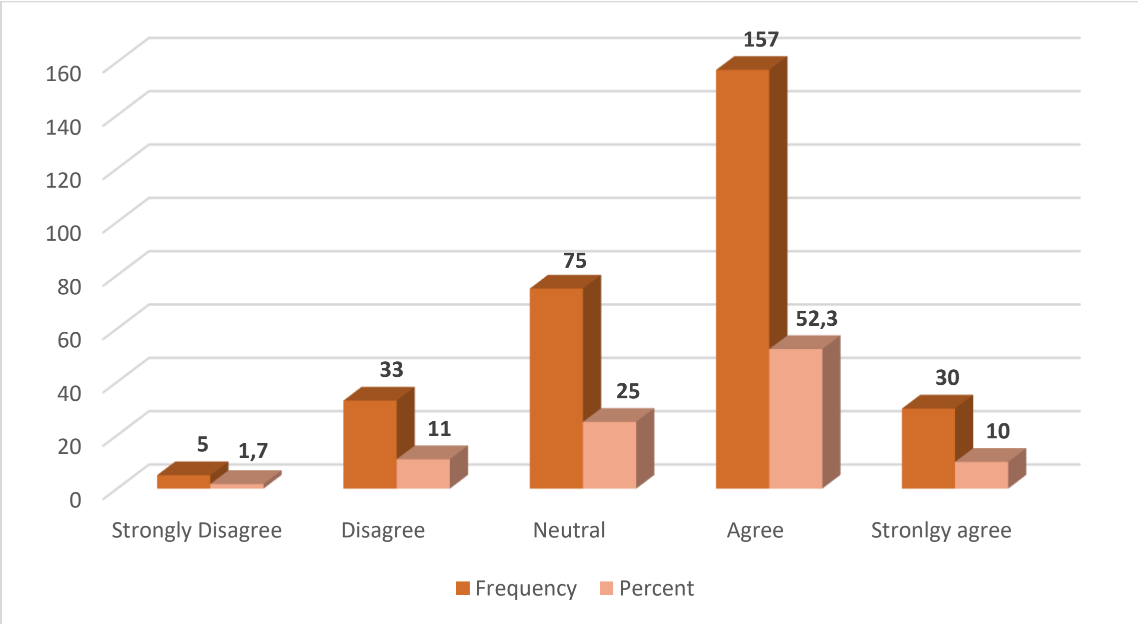

Figure 4.13 Concerns about the reliability and consistency of renewable energy sources/vendors are barriers

The concerns about the reliability and consistency of renewable energy sources or vendors are barriers. The above figure 4.13 shows that 52.3% of respondents agree, with an additional 10.0% strongly agreeing. A quarter of respondents (25.0%) are neutral on this issue, while 11.0% disagree and 1.7% strongly disagree.

Table 4.14 Resistance from stakeholders or management within the organization impedes renewable energy adoption.

	Frequency	Percent
Strongly Disagree	17	5.7
Disagree	70	23.3
Neutral	99	33.0
Agree	92	30.7
Strongly agree	22	7.3
Total	300	100.0

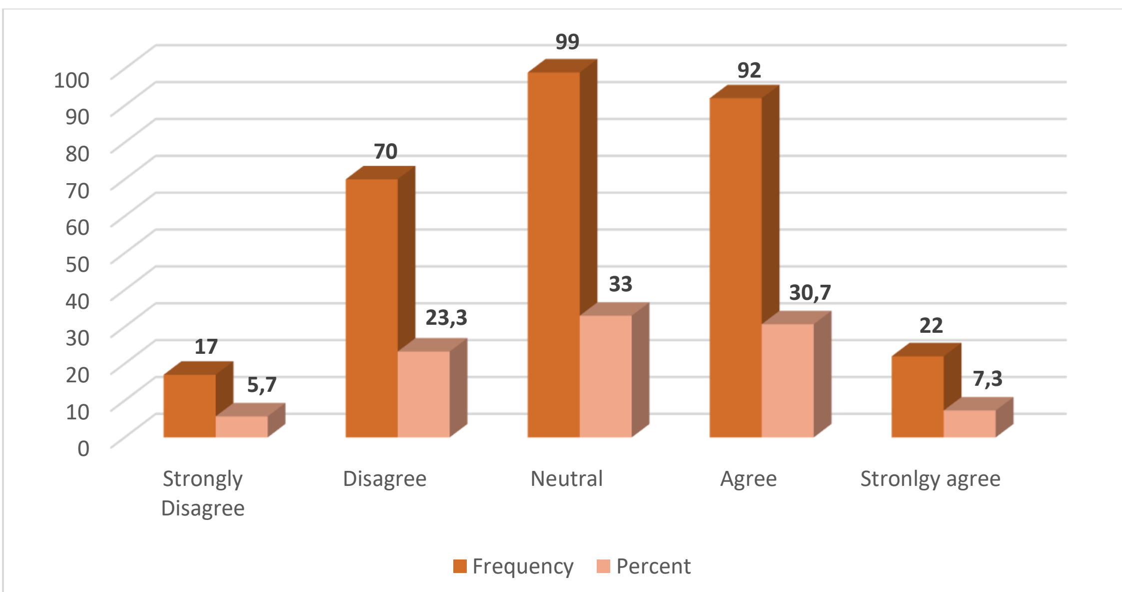

Figure 4.14 Resistance from stakeholders or management within the organization impedes renewable energy adoption.

According to the above figure 4.14, 30.7% of respondents agree with 7.3% strongly agreeing that resistance from stakeholders or management impedes renewable energy adoption. 33.0% of respondents are neutral about the matter, compared to 23.3% who disagree and 5.7% who strongly disagree.

Table 4.15 General Perception-Renewable energy sources are crucial for the sustainable future of industrial organizations.

	Frequency	Percent
Strongly Disagree	6	2.0
Disagree	4	1.3
Neutral	27	9.0
Agree	126	42.0
Strongly agree	137	45.7
Total	300	100.0

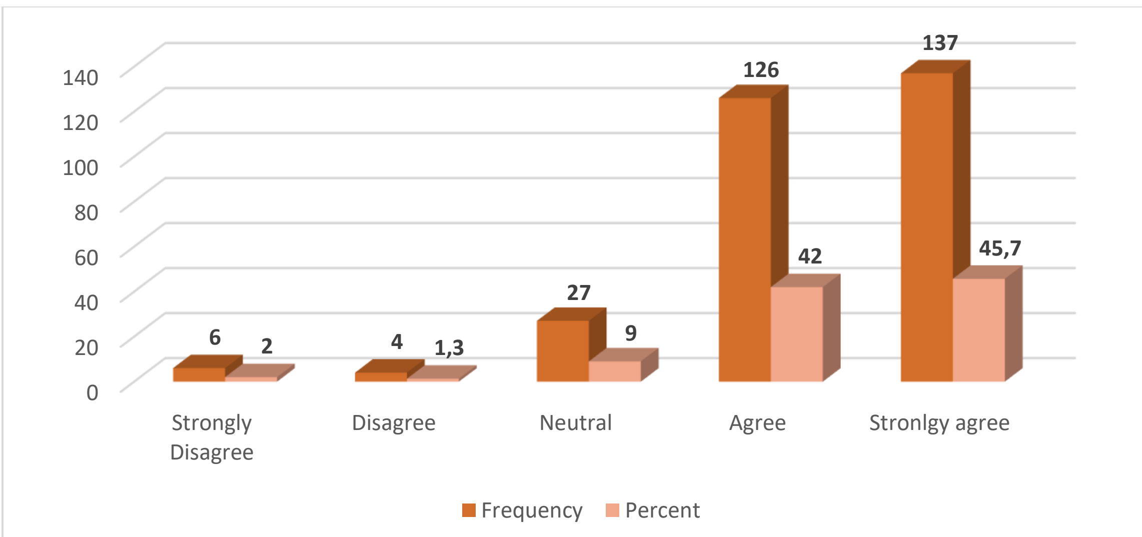

Figure 4.15 General Perception-Renewable energy sources are crucial for the sustainable future of industrial organisations.

According to the above figure 4.15 shows the data, 42.0% of respondents agree and a significant majority of 45.7% strongly believe that renewable energy sources are crucial for the sustainable future of industrial organisations. 1.3% disagree and 2.0% strongly disagree, while the remaining 9.0% are neutral.

Table 4.16 General Perception believes that integrating renewable energy sources into facility layouts and operations is economically viable.

	Frequency	Percent
Strongly Disagree	2	.7
Disagree	15	5.0
Neutral	65	21.7
Agree	148	49.3
Strongly agree	70	23.3
Total	300	100.0

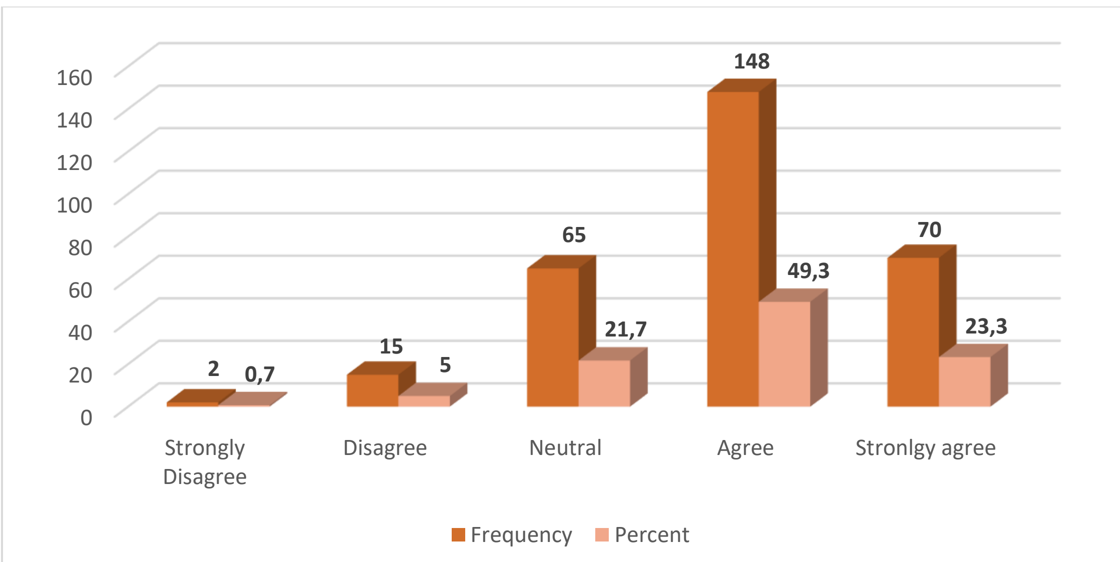

Figure 4.16 General Perception believes that integrating renewable energy sources into facility layouts and operations is economically viable.

The renewable energy sources in facility layouts and operations are economically viable, as appears in Figure 4.16 above, with 49.3% of respondents agreeing and 23.3% strongly agreeing.

In contrast, just 5.0% or 0.7% strongly disagree or disagree, while 21.7% are neutral.

Table 4.17 General Perception organization recognizes the importance of renewable energy in achieving sustainability goals.

	Frequency	Percent
Strongly Disagree	2	.7
Disagree	11	3.7
Neutral	71	23.7
Agree	140	46.7
Strongly agree	76	25.3
Total	300	100.0

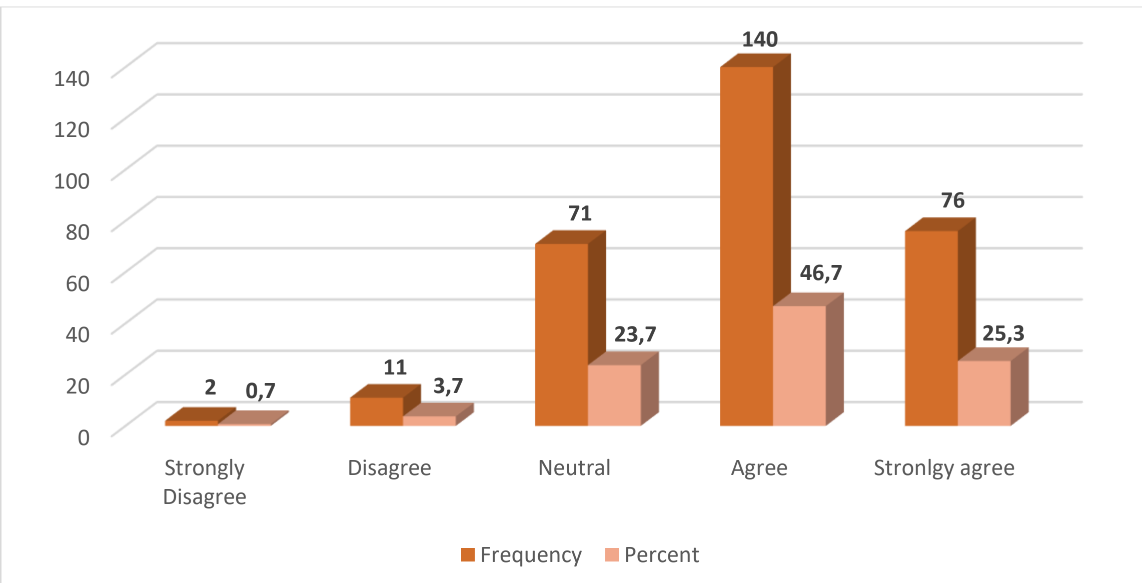

Figure 4.17 General Perception organization recognizes the importance of renewable energy in achieving sustainability goals.

As seen in Figure 4.17 above, 46.7% of respondents agree and 25.3% strongly agree that their organisation recognises the importance of renewable energy in achieving sustainability goals. Notably, 23.7% of respondents are neutral, 3.7% disagree, and just 0.7% strongly disagree.

Table 4.18 General The adoption of renewable energy sources aligns with our corporate values and mission.

	Frequency	Percent
Strongly Disagree	3	1.0
Disagree	23	7.7
Neutral	84	28.0
Agree	124	41.3
Strongly agree	66	22.0
Total	300	100.0

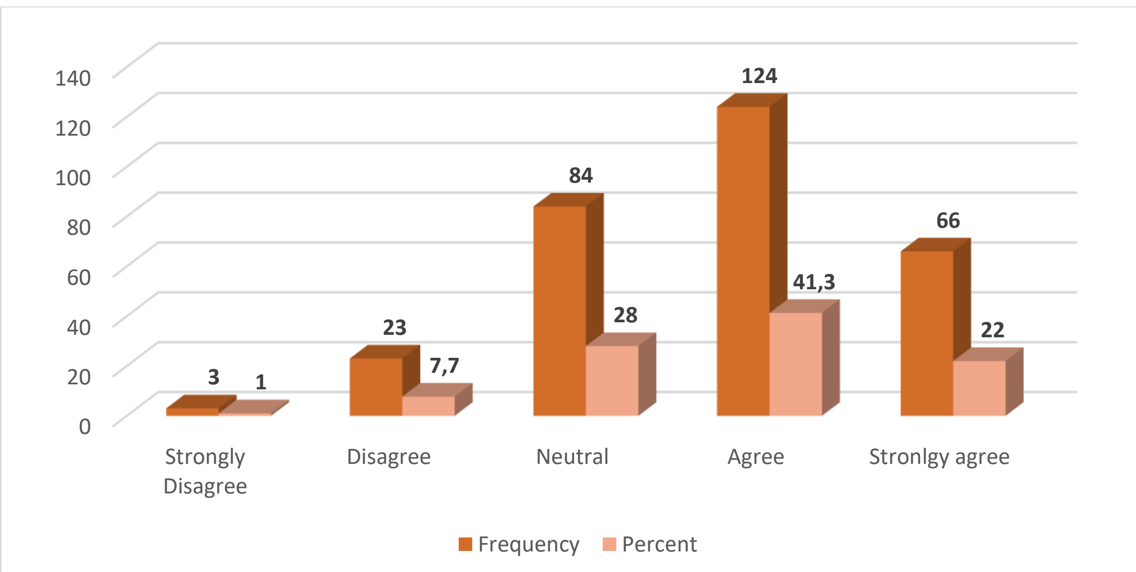

Figure 4.18 General The adoption of renewable energy sources aligns with our corporate values and mission.

The above figure 4.18 shows that, of the individuals surveyed, 41.3% agree that using renewable energy sources aligns with their company's mission and values, and another 22.0% strongly agree. 28.0% are significant parts that are neutral, 7.7% disagree, and 1.0% strongly disagree.

Table 4.19 Economic Considerations-Using renewable energy sources in facility operations will lead to cost savings for my organization

	Frequency	Per cent
Strongly Disagree	8	2.7
Disagree	10	3.3
Neutral	59	19.7
Agree	149	49.7
Strongly agree	74	24.7
Total	300	100.0

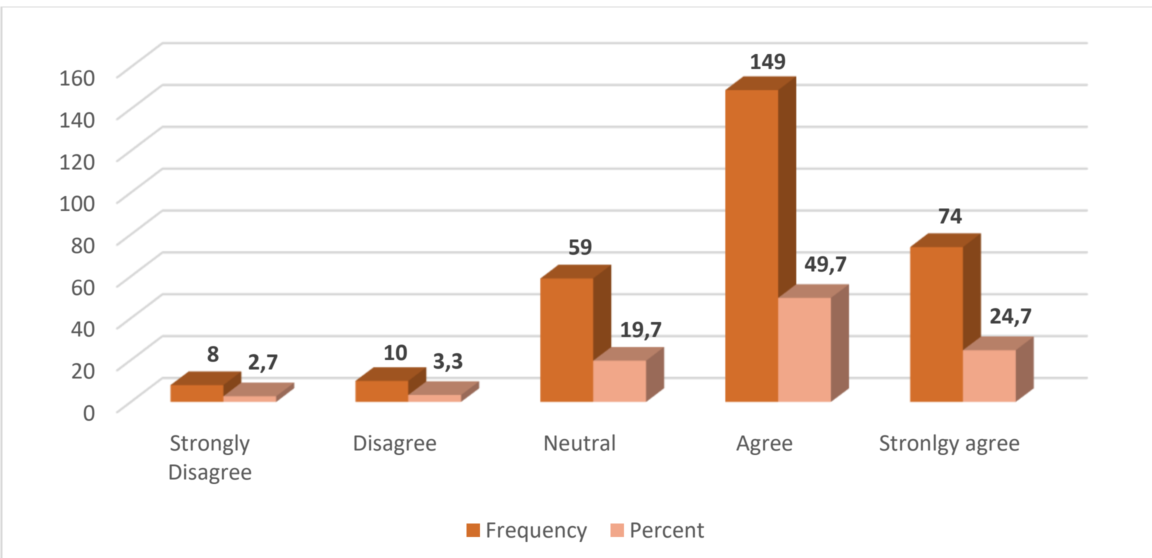

Figure 4.19 Economic Considerations-Using renewable energy sources in facility operations will lead to cost savings for my organization

According to Figure 4.19 above, 24.7% of respondents strongly agree that their renewable energy sources in facility operations will lead to cost savings for their organization, while 49.7% of respondents agree. A sizeable percentage (19.7%) are neutral, 3.3% disagree, and 2.7% strongly disagree.

Table 4.20 Economic Considerations-Government incentives and subsidies for renewable energy make it an attractive option for our organization

	Frequency	Percent
Strongly Disagree	6	2.0
Disagree	12	4.0
Neutral	84	28.0
Agree	143	47.7
Strongly agree	55	18.3
Total	300	100.0

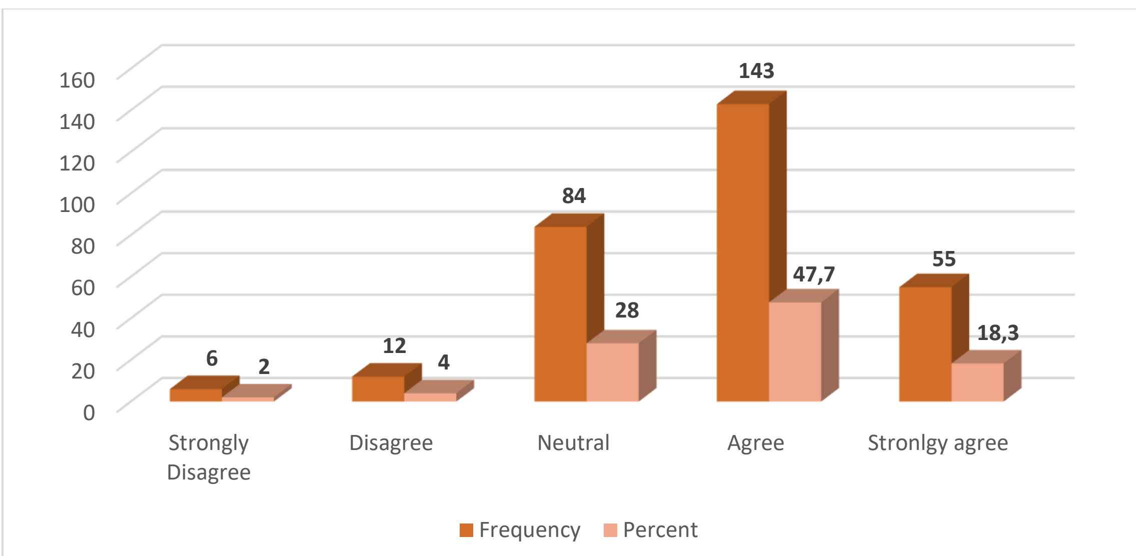

Figure 4.20 Economic Considerations-Government incentives and subsidies for renewable energy make it an attractive option for our organization

The above figure 4.20 shows that a significant portion of respondents view government incentives and subsidies for renewable energy as making it an appealing option for their organization. Specifically, 47.7% of respondents agree, and an extra 18.3%

strongly agree with this statement. Comprising 6% who strongly disagree and 4% who disagree and hold a less favourable view. The common respondents are neutral (28%).

Table 4.21 Economic Considerations organization actively seeks opportunities to invest in renewable energy technologies.

	Frequency	Percent
Strongly Disagree	6	2.0
Disagree	33	11.0
Neutral	107	35.7
Agree	108	36.0
Strongly agree	46	15.3
Total	300	100.0

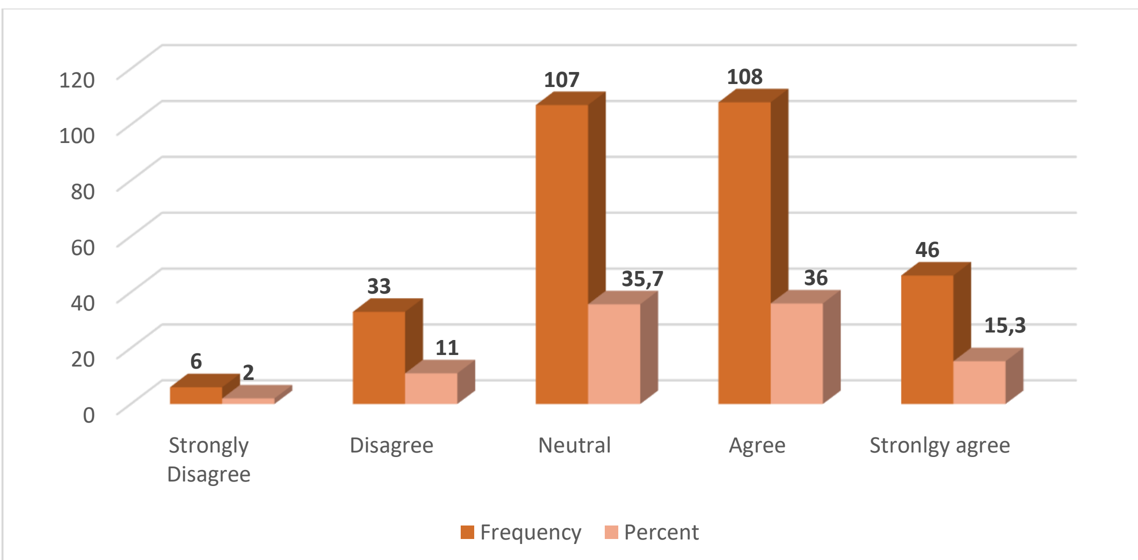

Figure 4.21 Economic Considerations organization actively seeks opportunities to invest in renewable energy technologies.

According to Figure 4.21 above, most of the responders are organizations in active pursuit of renewable energy investments. In particular, 36% of respondents agree and 15.3% strongly agree that their company looks for such prospects; 35.7% of respondents are neutral, suggesting doubt or lack of strong opinion on the subject. 11% disagree and 2% strongly disagree, on the opposing side.

Table 4.22 Economic Considerations have a clear strategy for financing renewable energy projects within our organization.

	Frequency	Percent
Strongly Disagree	12	4.0
Disagree	56	18.7
Neutral	111	37.0
Agree	74	24.7
Strongly agree	47	15.7
Total	300	100.0

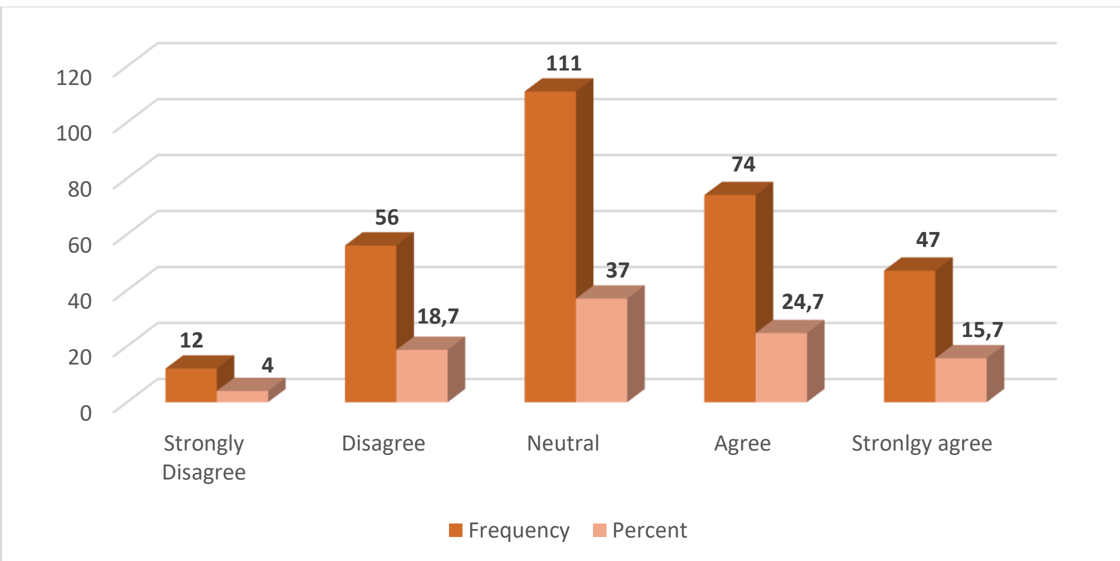

Figure 4.22 Economic Considerations have a clear strategy for financing renewable energy projects within our organization

According to Figure 4.22 above, 37.0% of respondents wonder whether their organization has a clear strategy for financing renewable energy projects. Meanwhile, 24.7% of respondents agree and 15.7% strongly agree that this kind of approach is implemented. Still, 18.7% of respondents disagree and 4.0% strongly disagree with the assertion.

Table 4.23 Ecological Considerations- Reducing carbon emissions through the use of renewable energy is a top environmental priority for our organization.

	Frequency	Percent
Strongly Disagree	9	3.0
Disagree	4	1.3
Neutral	75	25.0
Agree	122	40.7
Strong agree	90	30.0
Total	300	100.0

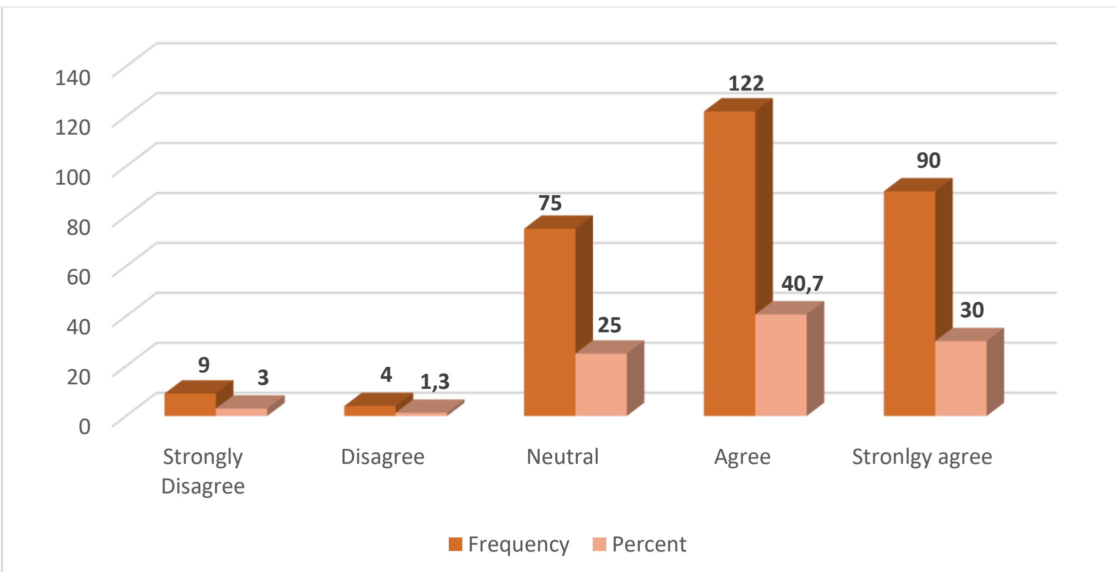

Figure 4.23 Ecological Considerations- Reducing carbon emissions through the use of renewable energy is a top environmental priority for our organization.

According to the above figure 4.23, 30 % of respondents strongly agree, and 40.7% of respondents agree that reducing carbon emissions through the use of renewable energy is a top environmental priority for their organization, 25% are neutral, 1.3% disagree, and 3.0% strongly disagree.

Table 4.24 Ecological Considerations organization is committed to reducing its environmental footprint through renewable energy adoption.

	Frequency	Percent
Strongly Disagree	8	2.7
Disagree	12	4.0
Neutral	80	26.7
Agree	130	43.3
Strongly agree	70	23.3
Total	300	100.0

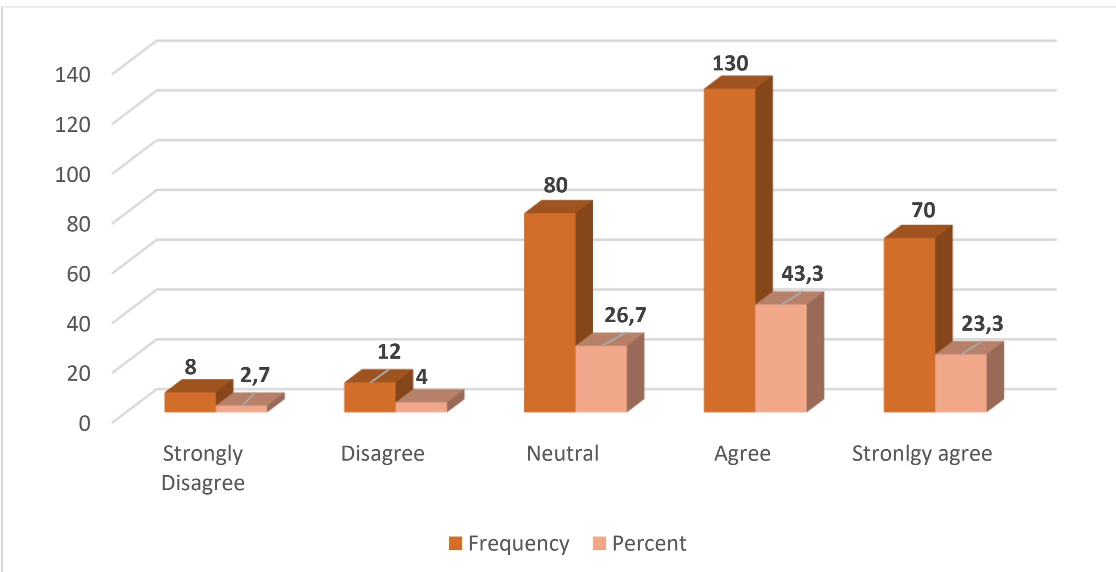

Figure 4.24 Ecological Considerations organization is committed to reducing its environmental footprint through renewable energy adoption.

The above Figure 4.23 shows that 43.3% of respondents agree, with 23.3% strongly agreeing, that their organization is committed to reducing its environmental footprint through renewable energy adoption. A significant percentage, 26.7%, are neutral, compared to 4.0% disagree and 2.7% strongly disagree.

Table 4.25 Ecological Considerations actively monitor and report on the environmental impact of our energy consumption

	Frequency	Percent
Strongly Disagree	11	3.7
Disagree	46	15.3
Neutral	93	31.0
Agree	93	31.0
Strongly agree	57	19.0
Total	300	100.0

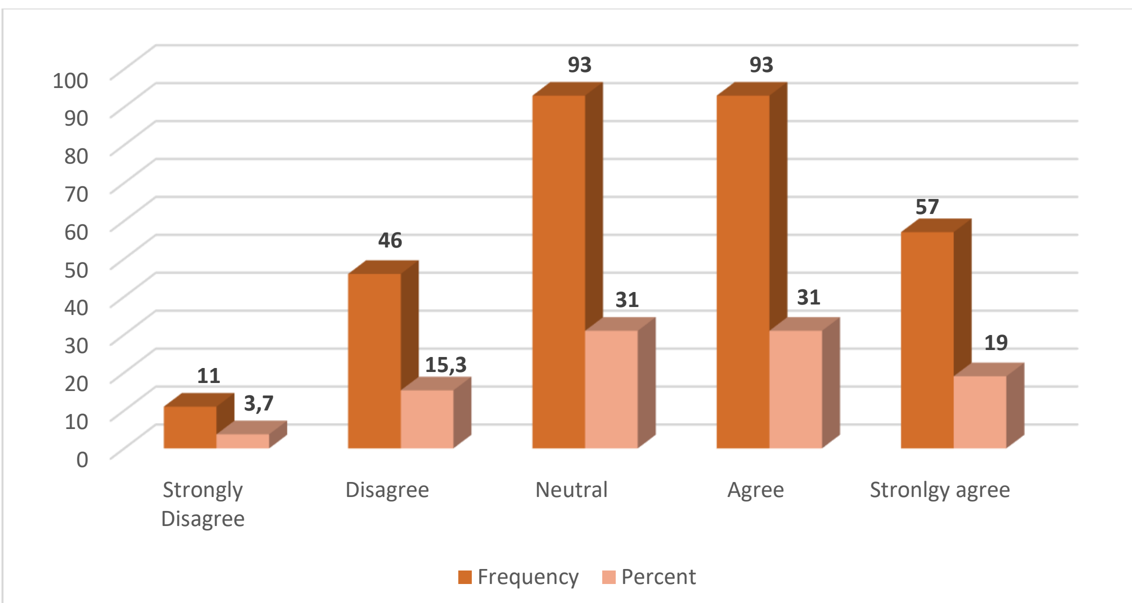

Figure 4.25 Ecological Considerations actively monitor and report on the environmental impact of our energy consumption

The response to monitoring and reporting the environmental impact of energy consumption is not uniform, as seen in Figure 4.25 above. Regarding this environmental impact, a total of 50% of respondents agreed (31%) or strongly agreed (19%). In contrast, 3.7% strongly disagree and 15.3% disagree. Furthermore, 31% of respondents are neutral.

Table 4.26 Ecological Considerations-Sustainability practices, including renewable energy, are integrated into our corporate culture.

	Frequency	Percent
Strongly Disagree	10	3.3
Disagree	48	16.0
Neutral	95	31.7
Agree	87	29.0
Strongly agree	60	20.0
Total	300	100.0

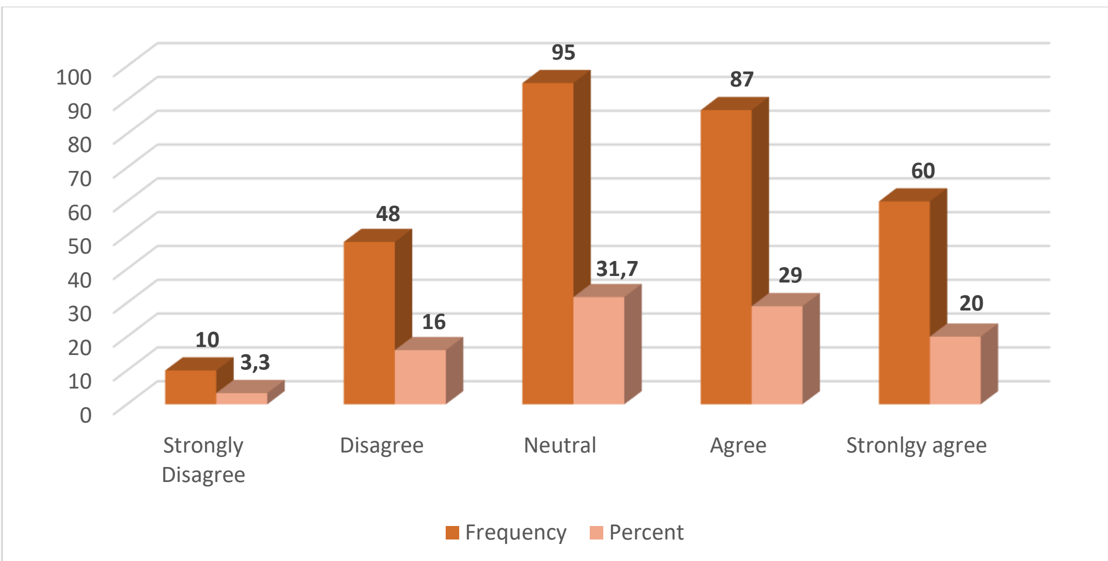

Figure 4.26 Ecological Considerations-Sustainability practices, including renewable energy, are integrated into our corporate culture.

The distribution of sustainable practice integration including renewable energy into corporate culture is shown in Figure 4.26 above for corporations. Well-integrated practices are agreed upon by 29% of respondents, with 20% strongly agreeing. In contrast, 16% disagree and 3.3% strongly disagree, while 31.7% are neutral.

Table 4.27 Hot, Dry, and Humid Region-Wind energy can effectively contribute to the energy needs of industrial sectors in hot, dry, and humid regions of India.

	Frequency	Percent	Chi-Square Test Statistics
Disagree	21	7.0	240.720[a]
Neutral	87	29.0	
Agree	180	60.0	
Strongly agree	12	4.0	
Total	300	100.0	

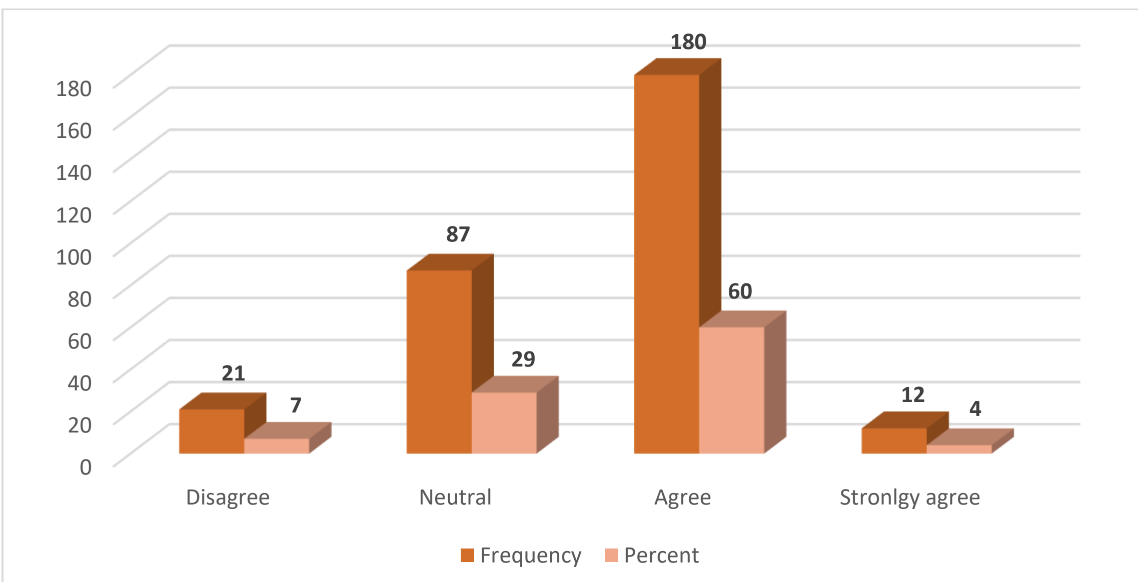

Figure 4.27 Hot, Dry, and Humid Region-Wind energy can effectively contribute to the energy needs of industrial sectors in hot, dry, and humid regions of India.

According to the above figure 4.27, 60.0% of respondents, with 4.0% strongly agreeing, believe that wind energy can effectively contribute to the energy needs of industrial sectors in hot, dry, and humid regions of India. 7.0% disagree with this statement, while a significant portion, 29.0%, are neutral. The Chi-Square Test value of 240.720 was obtained.

Table 4.28 Hot, Dry, and Humid Region-Solar energy has substantial potential to meet the energy demands of industrial sectors in hot, dry, and humid regions.

	Frequency	Percent	Chi-Square Test Statistics
Disagree	17	5.7	134.720[a]
Neutral	57	19.0	
Agree	155	51.7	
Strongly agree	71	23.7	
Total	300	100.0	

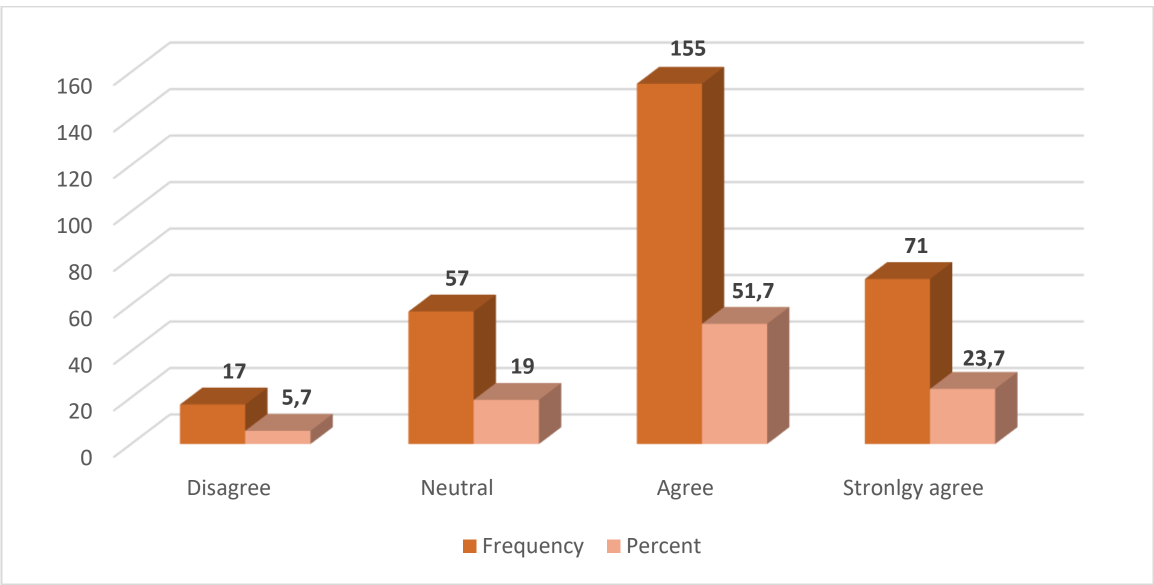

Figure 4.28 Hot, Dry, and Humid Region-Solar energy has substantial potential to meet the energy demands of industrial sectors in hot, dry, and humid regions.

The above figure 4.28 shows that 51.7% of respondents agree that solar energy has substantial potential to meet the energy demands of industrial sectors in hot, dry, and humid regions, with 23.7% strongly agreeing. A notable portion, 19.0%, are neutral, while 5.7% disagree. The Chi-Square Test statistic is 134.720.

Table 4.29 Hot, Dry, and Humid Region-Biomass energy can be a sustainable and reliable source of energy in hot, dry, and humid regions.

	Frequency	Percent	Chi-Square Test Statistics
Disagree	19	6.3	
Neutral	111	37.0	
Agree	139	46.3	139.520[a]
Strongly agree	31	10.3	
Total	300	100.0	

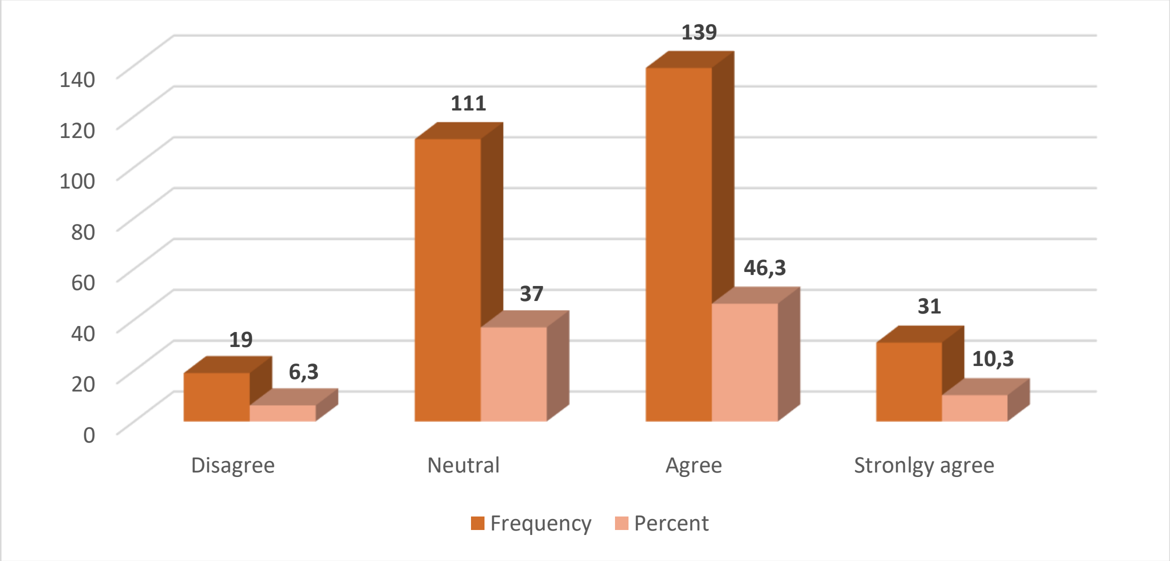

Figure 4.29 Hot, Dry, and Humid Region-Biomass energy can be a sustainable and reliable source of energy in hot, dry, and humid regions.

The distribution of biomass energy as a practical and sustainable energy source for hot, dry, and humid environments is shown in Figure 4.29 above. Particularly, 10.3%

strongly agree and 46.3% agree; 37% of respondents are neutral. Just 6.3% of respondents disagree with the statement. The chi-square test statistic of 139.520 was obtained.

Table 4.30 Hot, Dry, and Humid Region-Geothermal energy is a feasible option to explore for meeting energy needs in hot, dry, and humid regions.

	Frequency	Percent	Chi-Square Test Statistics
Strongly Disagree	2	.7	276.033[a]
Disagree	22	7.3	
Neutral	127	42.3	
Agree	133	44.3	
Strongly agree	16	5.3	
Total	300	100.0	

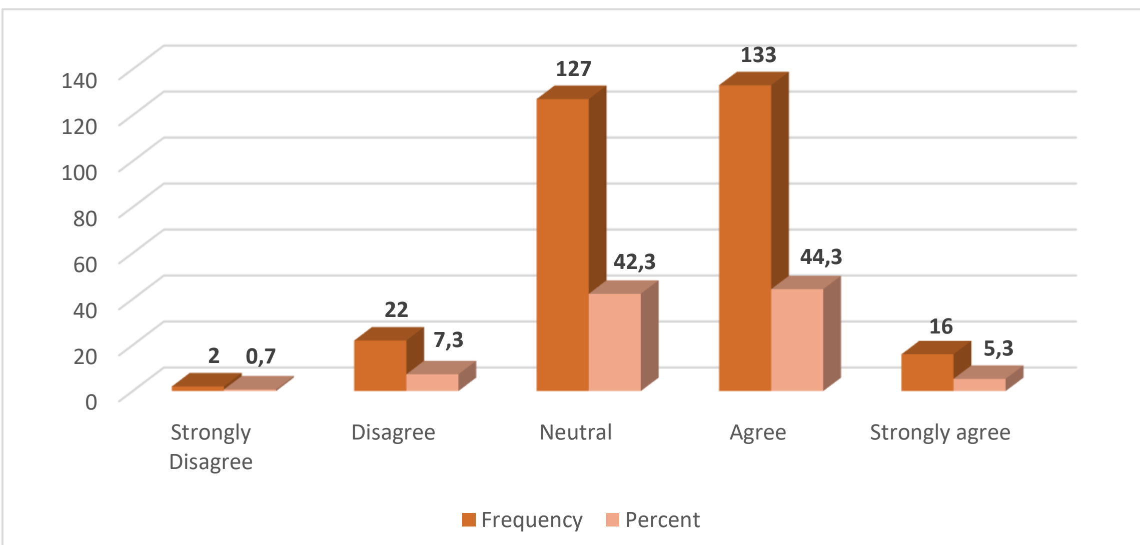

Figure 4.30 Hot, Dry, and Humid Region-Geothermal energy is a feasible option to explore for meeting energy needs in hot, dry, and humid regions.

The information in Figure 4.30 above shows that geothermal energy is considered a feasible option for meeting energy in hot, dry, and humid climates. More specifically, 5.3% strongly agree and 44.3% agree. In contrast, just 7.3% disagree, with a minimal 0.7%

strongly disagreeing. Furthermore, 42.3% of responders are neutral. The chi-square test statistic of 276.033 was obtained.

Table 4.31 Hot, Dry, and Humid Region-Energy storage technologies, such as batteries, can effectively support renewable energy sources in ensuring a stable power supply in these regions.

	Frequency	Percent	Chi-Square Test Statistics
Strongly Disagree	1	.3	260.267[a]
Disagree	27	9.0	
Neutral	86	28.7	
Agree	157	52.3	
Strongly agree	29	9.7	
Total	300	100.0	

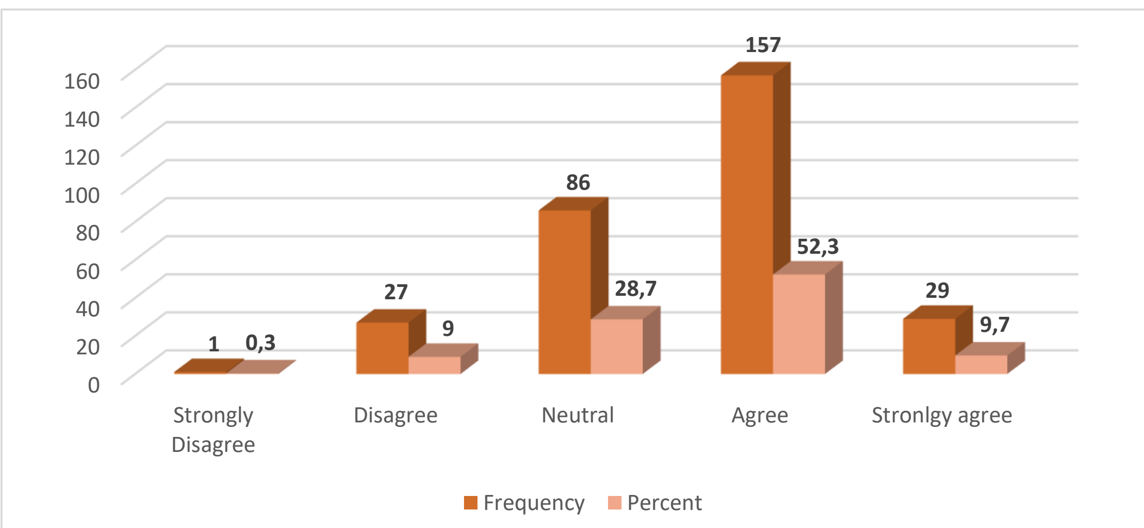

Figure 4.31 Hot, Dry, and Humid Region-Energy storage technologies, such as batteries, can effectively support renewable energy sources in ensuring a stable power supply in these regions.

Responses of the following questions- "The effectiveness of energy storage technology, such as batteries, in sustaining renewable energy sources and ensuring stable power supply in hot, dry, and moist regions" is shown in Figure 4.31 above. In particular, this statement is agreed upon by 52.3% of respondents agree and strongly agreed upon by 9.7%. Just 9% of respondents disagree, and just 0.3% strongly disagree. The remaining 28.7% of respondents are neutral. The chi-square test value of 260.267 was obtained.

Table 4.32 Coastal and Hilly Regions-Hydropower is a reliable and efficient source of renewable energy for coastal and hilly regions of India

	Frequency	Percent	Chi-Square Test Statistics
Strongly Disagree	4	1.3	291.600[a]
Disagree	6	2.0	
Neutral	72	24.0	
Agree	166	55.3	
Strongly agree	52	17.3	
Total	300	100.0	

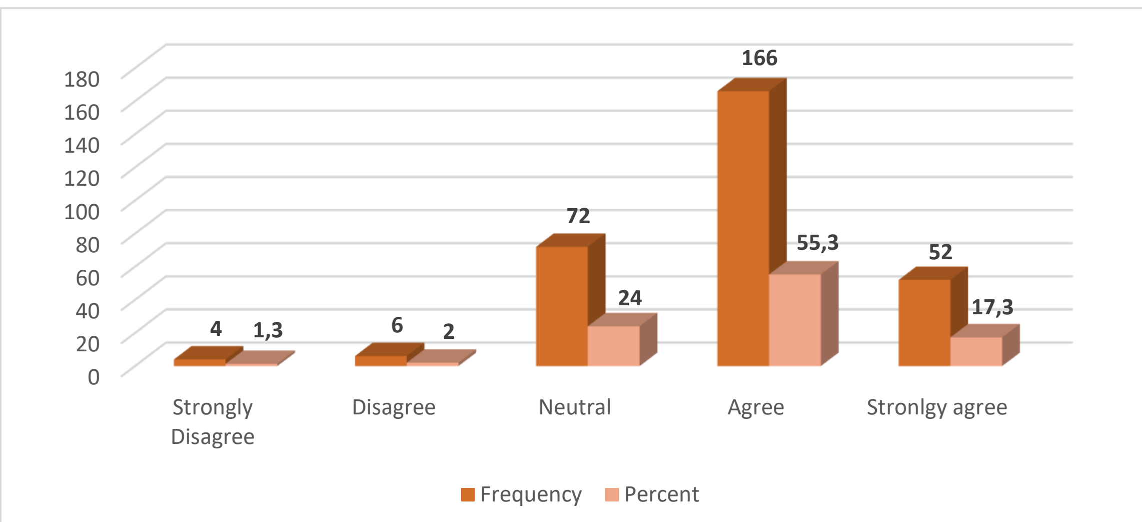

Figure 4.32 Coastal and Hilly Regions-Hydropower is a reliable and efficient source of renewable energy for coastal and hilly regions of India

The India's hilly and coastal regions, hydropower is a dependable and effective source of renewable energy, according to 55.3% of respondents agree, with 17.3% strongly agreeing, as seen in figure 4.32 above. 2.0% disagree and 1.3% strongly disagree, although a sizable portion, 24.0%, are neutral. 291.600 is the Chi-Square Test value.

Table 4.33 Coastal and Hilly The combination of wind and solar energy is a suitable solution for coastal and hilly regions to meet energy demands effectively.

	Frequency	Percent	Chi-Square Test Statistics
Strongly Disagree	2	.7	309.300[a]
Disagree	14	4.7	
Neutral	87	29.0	
Agree	167	55.7	
Strongly agree	30	10.0	
Total	300	100.0	

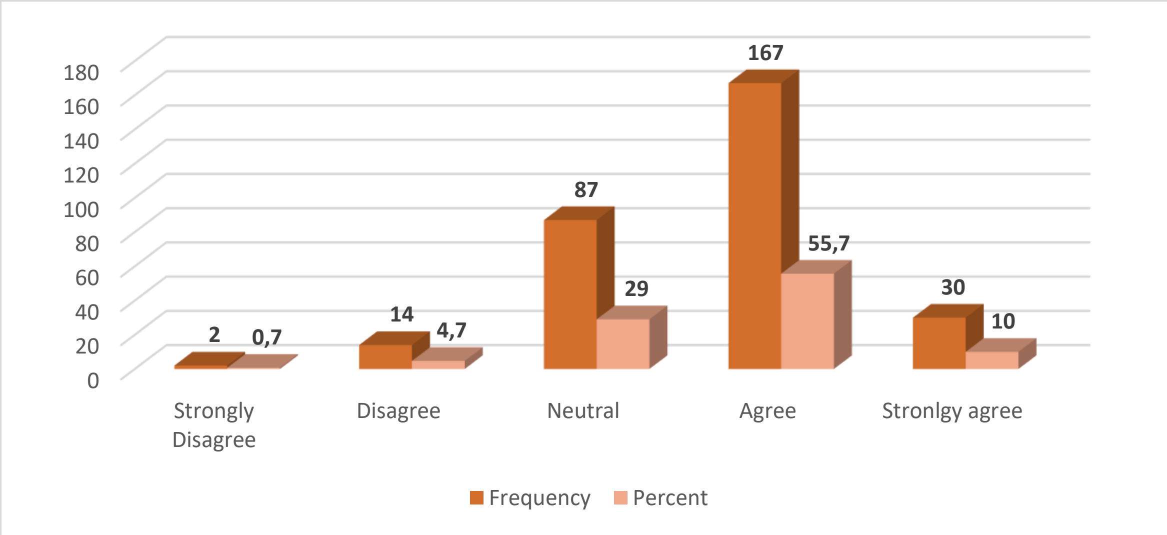

Figure 4.33 Coastal and Hilly The combination of wind and solar energy is a suitable solution for coastal and hilly regions to meet energy demands effectively.

The combination of solar and wind energy is widely regarded as a suitable solution for meeting energy demands in coastal areas, as shown in Figure 4.33 above. Only a tiny minority of respondents disagree (4.7%) or strongly disagree (0.7%) with this statement, whereas the majority of respondents agree (55.7%) and strongly agree (10%) with it. But 29% are neutral. The chi-square test statistic of 309.300 was achieved.

Table 4.34 Coastal and Hilly Regions-Tidal and wave energy can be harnessed efficiently in coastal regions to supplement the energy mix

	Frequency	Percent	Chi-Square Test Statistics
Strongly Disagree	2	.7	249.733[a]
Disagree	8	2.7	
Neutral	104	34.7	
Agree	142	47.3	
Strongly agree	44	14.7	
Total	300	100.0	

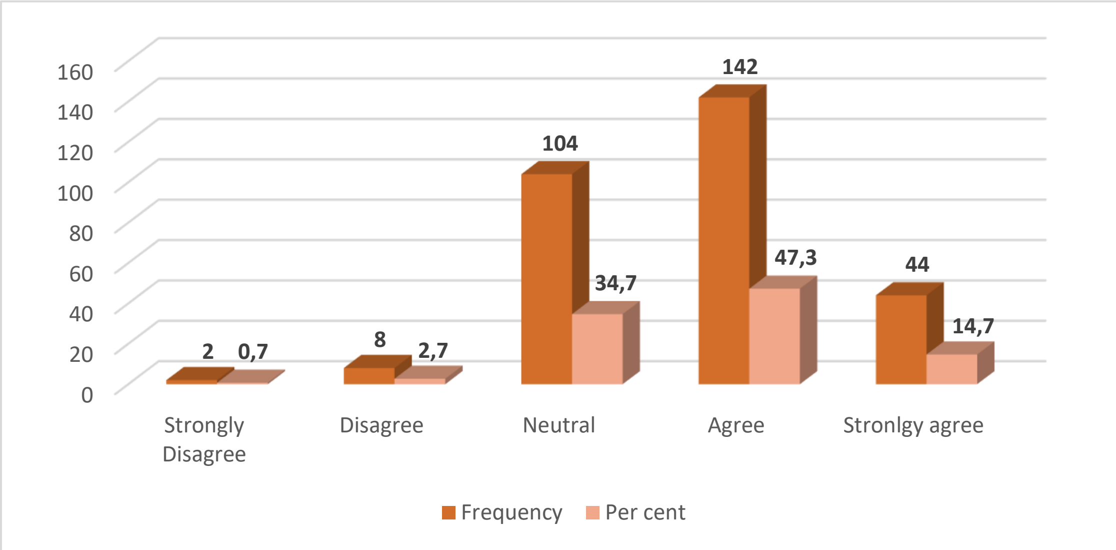

Figure 4.34 Coastal and Hilly Regions-Tidal and wave energy can be harnessed efficiently in coastal regions to supplement the energy mix

The Tidal and wave energy can be effectively harnessed in coastal places to complement the energy mix, as shown in Figure 4.34 above. Of the respondents, 47.3% agreed and 14.7% strongly agreed. Remarkably, 34.7% remain neutral, 2.7% disagree, and 0.7% strongly disagree. The results of Chi-Square Test value of 249.733 was achieved.

Table 4.35 Coastal and Hilly Regions-Geographically challenging terrains in hilly regions might pose difficulties for renewable energy infrastructure deployment.

	Frequency	Percent	Chi-Square Test Statistics
Strongly Disagree	6	2.0	255.900[a]
Disagree	32	10.7	
Neutral	83	27.7	
Agree	158	52.7	
Strongly agree	21	7.0	
Total	300	100.0	

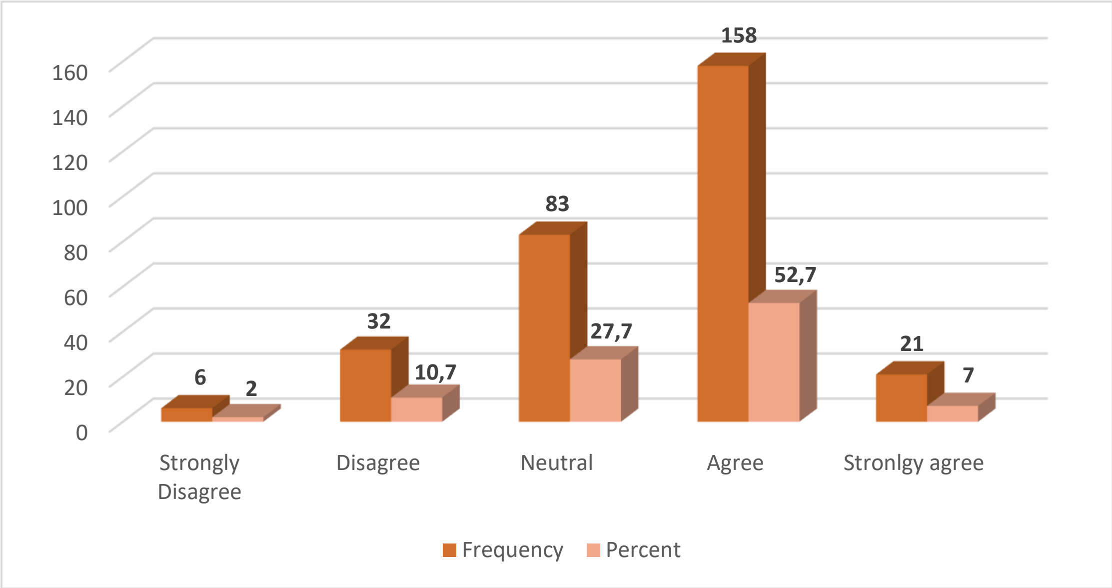

Figure 4.35 Coastal and Hilly Regions- Geographically challenging terrains in hilly regions might pose difficulties for renewable energy infrastructure deployment.

The Geographically challenging terrains in hilly regions might pose difficulties for deploying renewable energy infrastructure according to 52.7% of respondents are agree, with 7.0% strongly agreeing, as shown in figure 4.35 above. 10.7% disagree and 2.0% strongly disagree, while a significant portion, 27.7%, is neutral. The Chi-Square Test result of 255.900 was obtained.

Table 4.36 Coastal and Hilly Regions-Energy storage solutions are crucial to ensuring a stable and continuous energy supply in coastal and hilly regions.

	Frequency	Percent	Chi-Square Test Statistics
Strongly Disagree	4	1.3	319.500[a]
Disagree	4	1.3	
Neutral	84	28.0	
Agree	169	56.3	
Strongly agree	39	13.0	
Total	300	100.0	

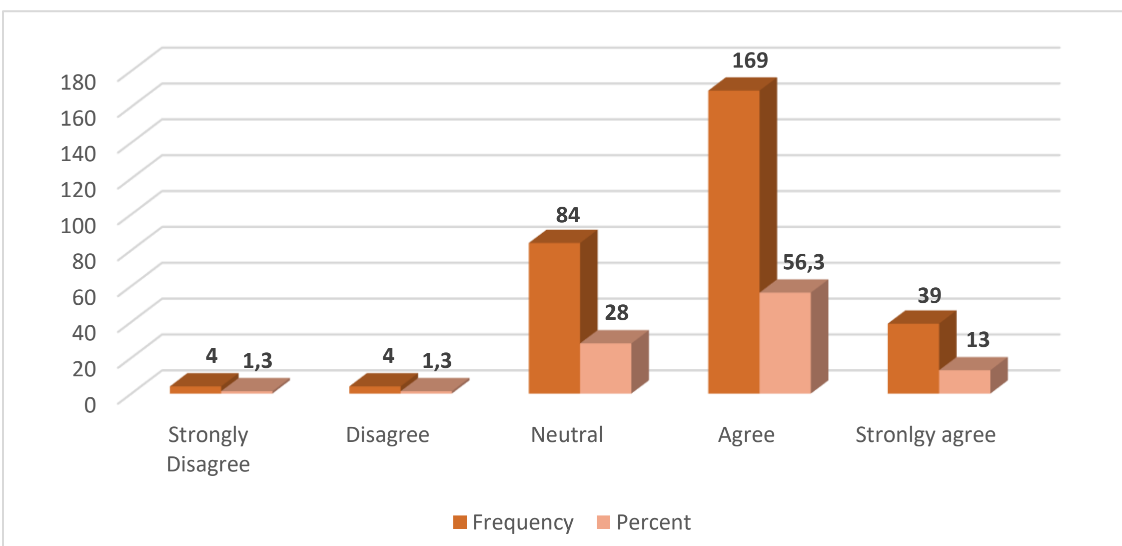

Figure 4.36 Coastal and Hilly Regions-Energy storage solutions are crucial to ensuring a stable and continuous energy supply in coastal and hilly regions.

The storage solutions are crucial to ensuring a stable and continuous energy supply in coastal and hilly regions are shown in Figure 4.36 above. There are just 1.3% strongly disagree and another 1.3% disagree, while 28% of respondents are neutral. A majority of respondents either agree (56.3%) or strongly agree (13%). The chi-square test statistic of 319.500 was obtained.

Table 4.37 Regions with High Rainfall-Hydropower are the most promising and efficient renewable energy source in hilly regions with rivers.

	Frequency	Percent	Chi-Square Test Statistics
Strongly Disagree	6	2.0	312.633[a]
Disagree	16	5.3	
Neutral	63	21.0	
Agree	176	58.7	
Strongly agree	39	13.0	
Total	300	100.0	

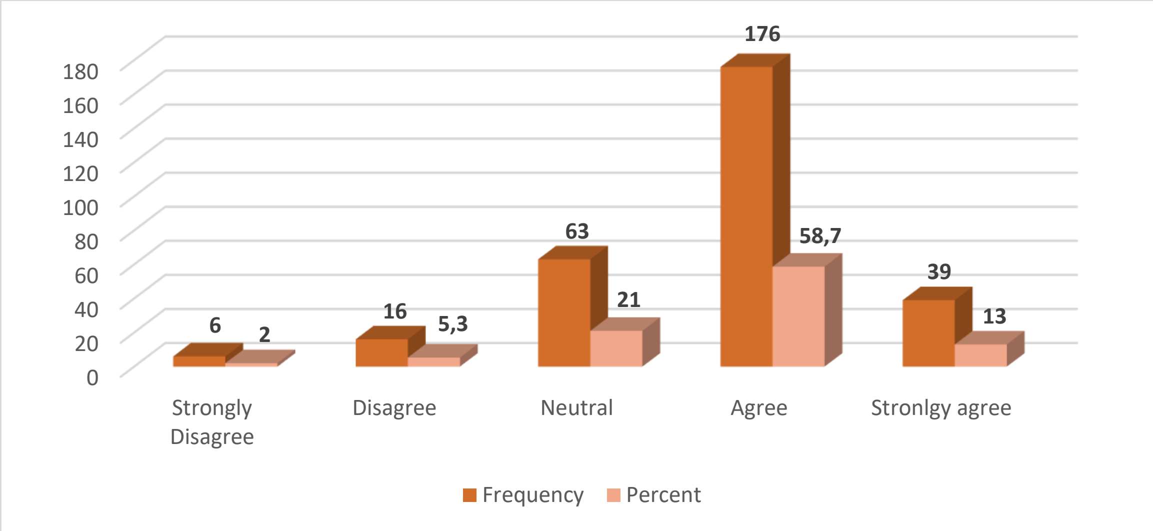

Figure 4.37 Regions with High Rainfall-Hydropower are the most promising and efficient renewable energy source in hilly regions with rivers.

According to Figure 4.37, the data shows that 58.7% of respondents agree and 13.0% strongly agree that hydropower is a potential renewable energy source in mountainous areas with rivers. A significant proportion of 21.0% maintains a neutral, while 5.3% disagree and 2.0% strongly disagree. The Chi-Square Test score of 312.633 was obtained.

Table 4.38 Regions with High Rainfall-Wind energy could supplement hydropower in hilly regions with rivers to ensure a reliable energy supply

	Frequency	Percent	Chi-Square Test Statistics
Strongly Disagree	2	.7	309.867[a]
Disagree	22	7.3	
Neutral	98	32.7	
Agree	162	54.0	
Strongly agree	16	5.3	
Total	300	100.0	

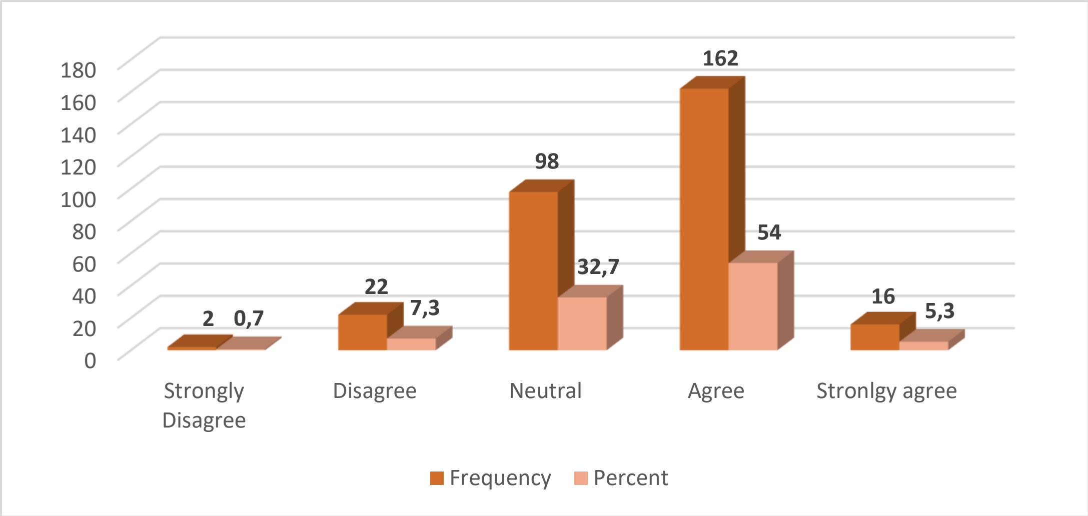

Figure 4.38 Regions with High Rainfall-Wind energy could supplement hydropower in hilly regions with rivers to ensure a reliable energy supply

The energy could supplement hydropower in hilly regions with rivers to ensure a reliable energy supply, as shown in Figure 4.38 above, with 54.0% of respondents agreeing and 5.3% strongly agreeing. Furthermore, 0.7% strongly disagree, 7.3% disagree, and 32.7% are neutral. The Chi-Square Test result of 309.867 was obtained.

Table 4.39 Regions with High Rainfall-Geothermal energy exploration is practical and worth considering in hilly regions with rivers.

			Chi-Square Test Statistics
	Frequency	Percent	308.533[a]
Strongly Disagree	2	.7	
Disagree	18	6.0	
Neutral	142	47.3	
Agree	126	42.0	
Strongly agree	12	4.0	
Total	300	100.0	

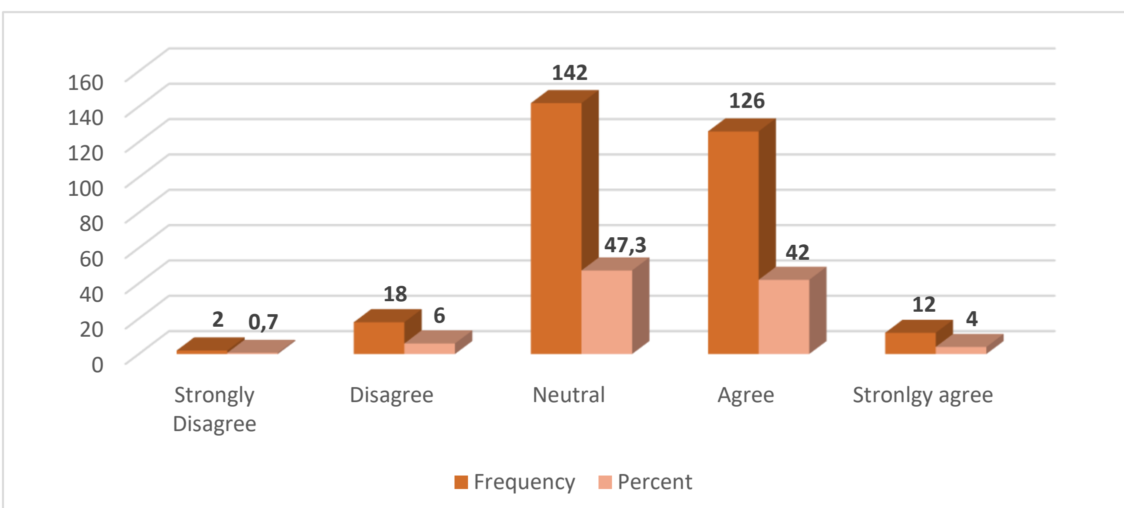

Figure 4.39 Regions with High Rainfall-Geothermal energy exploration is practical and worth considering in hilly regions with rivers.

Geothermal energy exploration is practical and worth considering in hilly regions with rivers as shown in Figure 4.39 above. Of the respondents, 42.0% agreed and 4.0% strongly agreed that it is an option worth taking into account. But a significant percentage, 47.3% remains neutral, compared with 6.0% disagree and 0.7% strongly disagree. The Chi-Square Test value of 308.533 was obtained.

Table 4.40 Regions with High Rainfall-The terrain in these regions might require specialised infrastructure for renewable energy projects

	Frequency	Percent	Chi-Square Test Statistics
Strongly Disagree	4	1.3	355.767[a]
Disagree	2	.7	
Neutral	97	32.3	
Agree	171	57.0	
Strongly agree	26	8.7	
Total	300	100.0	

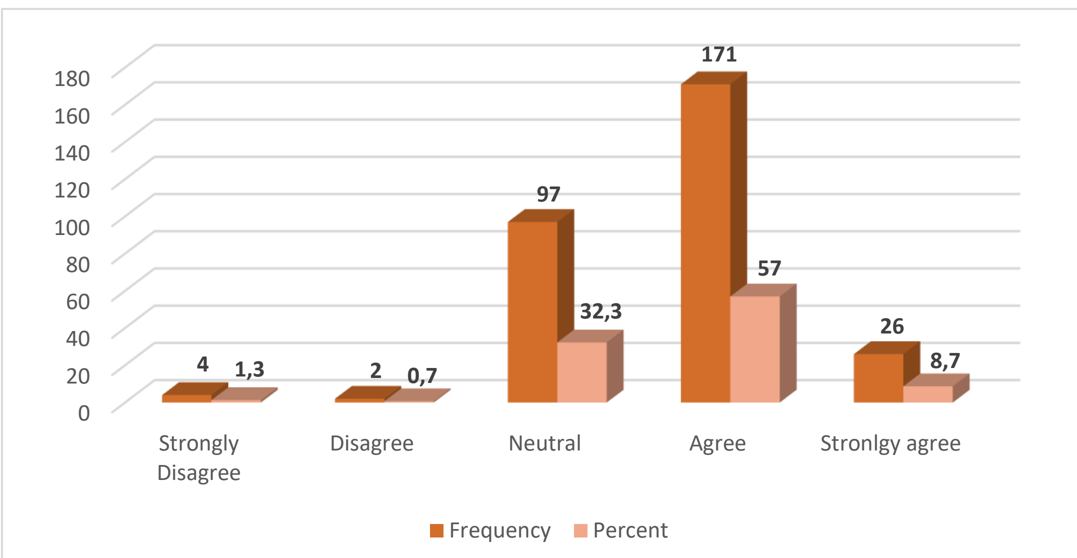

Figure 4.40 Regions with High Rainfall-The terrain in these regions might require specialised infrastructure for renewable energy projects

The majority of respondent's terrain in these regions might require specialized infrastructure for renewable energy projects shown in figure 4.40 above. Specifically, 57% agree and 8.7% strongly agree with this statement, and 32.3%, are neutral. Only a small portion of participants expressed disagree (0.7%) or strongly disagree (1.3%). 355.767, the chi-square test score was obtained.

Table 4.41 Regions with High Rainfall- Collaboration between regional governments and energy companies is crucial for realising the renewable energy potential in hilly regions with rivers.

	Frequency	Percent	Chi-Square Test Statistics
Strongly Disagree	2	.7	243.033[a]
Disagree	3	1.0	
Neutral	76	25.3	
Agree	147	49.0	
Strongly agree	72	24.0	
Total	300	100.0	

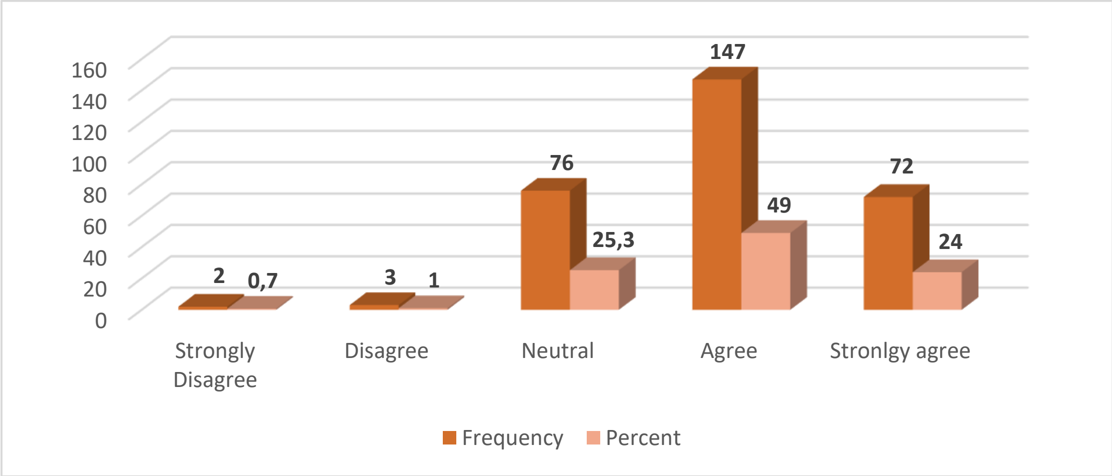

Figure 4.41 Regions with High Rainfall- Collaboration between regional governments and energy companies is crucial for realising the renewable energy potential in hilly regions with rivers.

The distribution of cooperation between regional governments and energy companies to realise the potential of renewable energy in hilly regions with rivers is shown in Figure 4.41 above. Of the respondents, 49.0% agreed and 24.0% strongly agreed that such collaboration is essential. In the meanwhile, 1.0% disagree, 0.7% strongly disagree, and 25.3% remain neutral. The Chi-Square Test statistic of 243.033 was obtained.

4.3 Hypothesis

PLUM - Ordinal Regression Hypothesis 1

H0: There is no impact of key challenges and barriers of renewable energy solutions in industrial facilities.

H1: There is an impact of key challenges and barriers of renewable energy solutions in industrial facilities.

Table 4.42 Model Fitting Information

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	66.309			
Final	46.619	19.690	1	.000
Link function: Logit.				

The above Table 4.42 shows that the model outperforms the intercept-only model, with a Chi-Square value of 19.690, 1 degree of freedom (df), and Sig. of.000 in Model Fitting Information table. The -2 Log Likelihood dropped from 66.309 to 46.619, improving the model's fit. Under the Logit link function, the model fits data well due to the substantial p-value.

Table 4.43 Goodness-of-Fit

	Chi-Square	df	Sig.
Pearson	25.497	8	.001
Deviance	15.864	8	.044
Link function: Logit.			

In Goodness-of-Fit Table 4.43, the Pearson Chi-Square value of 25.497 with 8 degrees of freedom (df) is statistically significant (p =0.001), suggesting that the model may not fit the data well. A Deviance Chi-Square score of 15.864 with 8 df is statistically significant (p =.044), showing some variation from predicted values.

Table 4.44 Pseudo R-Square

Cox and Snell	.064
Nagelkerke	.074
McFadden	.033
Link function: Logit.	

The above table 4.44 gives pseudo-R-Square values, which reflect how much of dependent variable's variation the model explains. Cox and Snell values of. 064 and Nagelkerke values of.074 indicates that the model explains 6.4% to 7.4% of the variation. The McFadden R-Square of.033 suggests that the model explains 3.3% of the variation.

Table 4.45 Parameter Estimates

		Estimate	Std. Error	Wald	df	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
Threshold	[R = 1.00]	-8.060	1.000	64.920	1	.000	-10.021	-6.099
	[R = 3.00]	-4.909	.715	47.171	1	.000	-6.310	-3.508
	[R = 4.00]	-2.146	.658	10.644	1	.001	-3.436	-.857
Location	CB	-.748	.169	19.607	1	.000	-1.080	-.417
Link function: Logit.								

The parameter estimates in Table 4.7 show that the key challenges and barriers (CB) to renewable energy solutions in industrial facilities have a statistically significant impact, as shown by the negative estimate of -.748 with a standard error of.169 and a highly significant p-value (Sig. =.000). The Wald Chi-Square score of 19.607 reinforces this effect. A 95% confidence band of -1.080 to -.417 supports the robust CB estimate. The null hypothesis (H0), which states no impact, should be rejected in favor of alternative hypothesis (H1), which states that key challenges and barriers significantly impact industrial facility renewable energy solution adoption.

CHAPTER V:

DISCUSSION

5.1 Discussion of Results

Efficient implementation and control of RE in the industrial sector of the current society plays a central role in tackling environmental as well as business issues (Jaiswal *et al.*, 2022). With growing trends toward sustainable energy solutions, the integration of renewable resources— including wind, solar, and hydroelectric power — is crucial in a bid to achieve low carbon footprints and optimal operations. But the shift to renewable power source is not easy going for many industrial plants because they meet various technical, financial and logistical issues (Mirzania *et al.*, 2023). For these RE systems to be managed optimally there is need to consider the various aspects that come with them so that the industrial demeanour can consider ecological objectives, profitability, and sustainability.

Findings of the study demonstrate that the key challenges and barriers play remarkable role in renewable energy solutions of industrial facilities. To a large extent, the improvement of the coefficients in the estimation results from the current model compared with the intercept-only model suggests that these challenges and barriers help to improve the goodness-of-fit and amplify the strength of the model used in explaining the outcomes. This has an implication that the challenges and barriers are among the most vital determinants that affect the decisions on renewable energy implementation (Olabi *et al.*, 2023).

However, the goodness-of-fit tests, failed to produce encouraging findings in some cases. Some of the tests suggest that the model might not fit the data optimally while another test shows that there is some variance in the values that have been predicted and those observed. However, given the overall impact of the findings, it can be stated that the model reflects certain regularities in data that are, perhaps, not taken into account by the model.

The derived pseudo R-squared values indicate that the suggested model accounts for a moderate degree of variance in the dependent variable. Although the explained variation is limited, the analysis indicates that challenges and barriers are significant and partially influence CE (Consumer engagement) decisions regarding renewable energy. However, this also implies that other factors, not accounted for in the model, may affect adoption.

Last of all, the parameters estimate shows that challenges and barriers have a negative influence on the adoption of RE in industrial facilities. Thus, the negative correlation implies that as these challenges rise, there is reduced ability to implement RE solutions. These results are statistically significant, thus making it possible to reject the null hypothesis and conclude that these barriers do have an impact on possibility of integrating RE in an industrial environment.

5.2 Discussion of Research Question One

What are the specific challenges and barriers that industrial facilities encounter when attempting to integrate* renewable *energy solutions into their operations effectively?

High First Cost Renewable energy technologies for instance; wind, solar, and hydroelectric power have large capital requirements. Among the most significant challenges is the initial cost that embodies the investment required to purchase and incorporate renewable energy systems and the necessary changes to technological manufacturing and equipment (Paraschiv and Paraschiv, 2023). In most industries particularly those that operate in the industrial sector with thin profit margins, these initial costs pose a major financial challenge on the ability of organizations to meet them. With the increased adoption of renewable energy solutions, most of them are cheaper in the long run but the payback periods take over a decade. This uncertainty coupled with the vulnerability of the energy prices and the economic cycles make renewable energy projects less appealing to industries that are result-oriented and with a focus on short-term returns (Gielen *et al.*, 2019). Furthermore, the development of RE projects seems to have certain difficulties with the financing process. The perception of risk could be a reason why lenders and investors shy away from backing such projects especially when there is ambiguity on the future policy frameworks and the financials of RE technologies (Motyka, 2020). Some of the segments that may benefit from renewable energy are constrained by capital to invest in these projects, especially the SMEs.

Interoperability with current systems Industrial facilities are also another challenge faced in the adoption of RE because it is challenging to incorporate it with the current systems in use. A large number of industrial plants are optimized with conventional energy systems, thus, integrating RE with industrial plants calls for major changes in the energy networks (Ellabban, Abu-Rub and Blaabjerg, 2014). These changes often involve capital costs which are time-consuming and may lead to higher initial investment needed to allow the integration of renewable energy into the existing systems. At times industries require a complete change within the energy system, this is disruptive and causes a shutdown which many organizations cannot allow (Liczmańska-Kopcewicz, Pypłacz and Wiśniewska, 2020). The uncertainty and variability of RE sources especially wind and solar energy further complicate integration process. While the power plants that rely on fossil fuels are very reliable, renewable sources of energy are those that depend on the weather conditions and geographical characteristics (Ssekulima *et al.*, 2016). Some renewables such as solar energy is limited by time but more so by unpredictable output; the energy generated depends on the time of the day and weather conditions. Wind energy is also fluctuating and depends on the wind speed that is not constant during the year. Therefore, manufacturing plants and similar establishments that require a reliable source of power experience high levels of vulnerability in their operations if renewable energy is used as the main source of power without affordable storage mechanisms or standby systems.

Energy Storage and Backup Systems As much as renewable energy sources may be fashionable in the industrial world, energy storage systems or conventional energy backup have to be used to counter unpredictability. The flexibility of energy storage technologies like batteries is that they can store energy from periods of excess renewable generation and discharge it during periods of low renewable generation. However, these storage solutions are not only costly but also, need technologies that are not easily available and may not be possible for large-scale industries. The costs of energy storage systems together with the demand for backup power generators add to the financial expenses of industries especially in areas where RE sources are less reliable.

Policies and Regulations The use of RE in the industrial sector has a close relationship with government policies and regulations in the sectors. As revealed in some developing countries, including India, a lack of standard and proper policies could act as the major hindrance for RE integration. While some governments come up with incentives like tax credit, subsidies, and grants to support renewable energy, some may not offer enough support and this may cause industrial firms to lack adequate capital to support their change (Fernando and Siani, 2016). However, fluctuations in government policies that may change often may lead to unpredictability in policies, and this makes industries lack consistent policies to follow while investing in renewable energy (Gielen *et al.*, 2019).

Another challenge is the high regulatory hurdle that emanates from the various permits that are needed in order to install renewable energy systems. In some of these regions, industrial firms experience long approval from permits required for the renewable energy infrastructure, which is significantly influenced by bureaucratic procedures and regulations. These delays can also lead to additional costs of a project and discourage industries from using renewable energy integration. Moreover, in the places where the grid structure remains primitive or requires upgrade, the industries may face difficulties in connecting renewable energy systems with the grid; thus, the integration process may prove to be challenging as well.

Inadequate training and education in renewable energy technology is a major obstacle that industrial facilities face when seeking to integrate renewable energy in their facilities. According to Jafarinejad et al., (2021), many industrial firms need either the retraining of the incumbency or the hiring of new employees with the professional knowledge of renewable energy systems. Sometimes, industries are unable to find a qualified workforce to design, install, and maintain renewable energy systems, hence time is wasted and costs are raised.

This skills deficit is especially important in developing countries where there can be a shortage of educational and training programs in renewable energy technologies (Favour Oluwadamilare Usman *et al.*, 2024). There is also a skills gap that requires governments and industry stakeholders to invest in workforce development programs so that industrial firms can obtain the talent and skill set they require to assimilate renewable energy into their operations (Burke and Stephens, 2018).

Technological Barriers Although there is improvement in renewable energy technologies over the last few years, the technology barriers remain as some of the constraints to the industrial deployment of renewable energy. For instance, there are those manufacturing processes that demand high heat or electrical energy that present contemporary renewable technologies cannot deliver effectively (Ellabban, Abu-Rub and Blaabjerg, 2014). In such scenarios, industries may have to use systems that mix renewable energy with the traditional energy systems; this in the long run makes integration complicated, expensive, and time-consuming.

Further, renewable energy technologies are in a state of development and the constant improvement of technology on an industrial scale can be challenging. Some of the organisations may shy away from adopting renewable energy systems in the belief that the technology will get outdated before they get their investment back. Thus, there are certain technological barriers industries have to face in adopting the renewable energy sources, and they have to keep themselves updated on the new technology available and also coordinate with the technology suppliers to ensure that the systems are scalable.

The issues and obstacles in adoption of RE sources in industrial facilities are equally complex and can be categorized in terms of financial, legal, technical, and human capital. Although RE sources such as hydro, solar, wind, and geothermal offer long-term advantages for industries in terms of costs, sustainability, and the environment, the following barriers must be addressed so that industries can reap the benefits from renewable energy. Both governments, industrial firms and renewable energy providers need to find appropriate solutions to these challenges as part of designing effective strategies on how to promote usage of renewable energy in the industrial sector. Based on the financial solutions, changes of the regulation policies, technological advancement, and training of the human resource, the incorporation of the renewable energy in the industrial buildings can be made more effective and common so that the creation of the sustainable and strong industrial economy can be fostered.

5.3 Discussion of Research Question Two

How do the viability and potential of renewable energy sources (such as wind, hydro, and solar) vary across different regions of India in meeting the energy needs of various industrial sectors?

Regional Viability and Potential of Wind Energy

The wind resource potential of India is affected greatly by the large geographical area of the country: the wind energy density varies considerably across the country. High wind speeds are favourable for wind power generation which are being received consistently in the coastal states of Tamil Nadu, Gujarat as well as Maharashtra (Irfan *et al.*, 2019). Tamil Nadu for instance, accounts for nearly 25% of the wind energy in India and is an important player in manufacturing and textile industries that require reliable power most especially in meeting their production targets (Ghosh, Roy and Chakraborty, 2023). Gujarat has the second largest wind power installations in the country and its coastal region the state's wind farms provide power to several industries, ports, chemical industries and ship building factories (Sharma *et al.*, 2023).

On the other hand, wind energy is less feasible in inland and hilly topographical zones like, Madhya Pradesh and some districts of Uttar Pradesh due to low wind intensity. The inconsistency in the wind power potential in different areas is one of biggest challenges to equal adoption of wind energy. Such areas therefore do not warrant investment in wind infrastructure since their energy production is volatile (Luthra *et al.*, 2015). In addition, wind capacity factor can fluctuate with seasons and the monsoonal influence, which limits its usefulness for constant industrial application.

To address these challenges, integrated renewable energy systems including wind integrated with solar, biomass or other energy systems have been recommended for areas of low to moderate wind power densities. The current studies also reveal that hybrid systems could enhance the total system efficiency of generating energy and provide energy dependability throughout various locations (Roy *et al.*, 2022). These systems can help to eliminate the geographical barriers and guarantee the stable power supply to the highly energy-consuming sectors such as manufacturing and steel industries.

Solar Energy: Regional Suitability and Industrial Applications

Solar energy is proving to be a very feasible energy solution for the majority of the states in India especially the states with high solar intensity that include Rajasthan, Maharashtra, and Andhra Pradesh. Rajasthan is situated in a desert zone that enjoys more than 300 sunny days a year, and thus is the most appropriate place for large-scale solar parks (Raghuwanshi and Arya, 2019). These regions have seen an increased deployment of both rooftop and utility-scale systems especially where organizations have large roof areas or large open grounds as in the case of mines and textile factories (Batool *et al.*, 2023). The utilization of solar energy is gradually increasing because of its ability to slash operational expenses as well as CO2 emissions in industries such as cement and car manufacturing industries which have constant and high energy consumption.

However, the major disadvantage of solar energy is the variation of intensity in the sun during the monsoon season which is an obstacle in the utilization of solar energy. Other places like Kerala and West Bengal have many days of cloud coverage which affects the use of solar energy during a particular period. In addition, operational expenditure of the solar systems is relatively high, especially because SMES have little capital to invest on the larger solar systems.

To address these issues, the Indian government has embarked on some policies on renewable energy including; National Solar Mission, which provides financial incentives/rewards and subsidies to industries on the use of solar energy. Also, new technologies like bifacial solar panels that can harvest the power from both faces of panels have the option of enhancing the efficiency of solar energy, especially in areas with intermittent sunshine.

Hydroelectric Power: Regional Constraints and Opportunities

Himachal Pradesh, Uttarakhand, and the north-eastern states like Sikkim & Assam are the states where hydropower is established to some good extent. They are blessed with the facilities such as fast-moving river zones and mountainous terrains which are favourable for hydro-electric power generation (Das, 2013). Hydroelectric dams of Himachal Pradesh also feed the heavy industries like aluminium industries and large industries and manufacturing sector where uninterrupted and stable energy is a must.

Nonetheless, problems of social equity, variability of water supply and climate change make hydropower generation an intermittent form of electricity production. For instance, reduced rainfall or decreased snow melt water in the Himalayas reduce water flow in the rivers and hence energy generation. Such factors show the associated dangers of using hydropower as the leading energy source in areas that are experiencing elevated climate volatility (Raina and Sinha, 2019). In addition, hydroelectric projects may result in environmental issues such as relocation of people and destruction of water bodies and hence, complicating their integration in industrial energy systems (Luthra *et al.*, 2015).

Nevertheless, small scale hydropower projects have been put forward as a more sustainable and adaptive to context solution than large dams. These micro-hydro installations can be used to supply energy for limited industrial applications especially in areas that are off-grid or in the rural areas (Balkhair and Rahman, 2017). Other current researches also stress the importance of using hydropower together with other types of renewables in order to minimize fluctuations in wind and solar energy (Kern, Patino-Echeverri and Characklis, 2014; Jurasz *et al.*, 2018).

Biomass and Emerging Technologies

Besides wind, solar and hydro, biomass energy has also proved feasible for industrial application in states which are endowed with agricultural waste products like

Punjab and Haryana. Biomass energy is obtained from crop residues, woods, animal dung etc, and is mostly applicable in the food processing, paper and pulp manufacturing industries. Biomass power plants have recently entered into the energy map of Punjab, a large agricultural state, that has resulted into the establishment of power loop where in agricultural waste is used to generate power for the industries which are into agriculture (Singh, 2017).

While biomass has high potential, it is currently used only in limited quantities in industrial sectors due to the availability and transportation of raw material which are seasonal in nature. Furthermore, emissions of particulate matter and other pollutants during burning biomass also raises environmental concerns over the use of biomass compared to wind or solar power (Kishore, Bhandari and Gupta, 2004). However, technological advancements in the future see biomass as a better and sustainable energy source as seen by the BECCS technology (Hanssen *et al.*, 2020).

Toward a Comprehensive Renewable Energy Roadmap

The geographical distribution of India requires different strategies for implementing renewable energy. A clear strategic plan in industrial energy management must also incorporate geography and differences in energy opportunities across different regions, the industry's energy demand. For instance, coastal states can opt for wind energy whereas landlocked areas can use solar or biomass (Irfan *et al.*, 2019). Additionally, integrating two or more RE sources makes it possible to provide a more stable and continuous energy supply (Roy *et al.*, 2022).

Towards achieving both economic and ecological objectives, policymakers and industrial players need to encourage investments in renewable energy, simplify processes that govern investment in this sector, and encourage technological advancement for these investments. Regional cooperation between states with similar energy supply and demand patterns also improves energy interchange and avoids interruptions in industrial consumption.

This study also highlights that possibilities and sustainability of RE sources in the Indian industrial sector are immensely affected by the regional geography and climate. Coastal areas provide enhanced wind energy prospects while areas with very high temperatures are most suitable for solar energy. It is still widely used today, especially in those areas that are mountainous and the most difficult challenge is the variation in flow of water in the seasons. By using regional strengths and overcoming certain challenges, a sustainable and effective approach for energy strategy of India based on the current industrial segmentation can be offered.

5.4 Discussion of Research Question Three

What factors should be considered in the development of a comprehensive roadmap for industrial organizations across sectors to optimize the utilization of renewable energy sources in their facility layouts and operations, with a focus on achieving both economic and ecological benefits?

Key Considerations for Developing a Comprehensive Roadmap

To provide a clear guideline of how the industrial sectors can adopt renewable energy, several factors must be put into consideration in the process, including both the short–term strategic considerations and long–term sustainable development considerations. When properly developed, a roadmap such as this one can be a strategic tool for organizations to deal with the challenges of integrating RE, and make sure they are getting both, economic and environmental value from their investments (Hassan *et al.*, 2023). Below are the expanded key factors that should be considered: Below are the expanded key factors that should be considered:

1. Economic Feasibility and Return on Investment (ROI)

The primary concern of any industrial organization is the feasibility of adopting renewable energy. The initial investment for renewable power plants including solar PV systems, windmills as well as hydro power plants, may be high (Chou, Ngo and Tran, 2023). These expenditures should be balanced against the benefits which are long-term costs such as use of energy and other operational costs. First, for example, solar and wind-generated electricity may be expensive to install, but it helps to reduce the costs of electricity consumption in the long run (Yang *et al.*, 2019). The payback period of renewable energy systems can be several years or more depending on the size of the installation, current energy prices within a certain region, and availability of incentives and grants.

2. Government Policies and Incentives

In India, several schemes launched by central as well as state governments provide financial incentives like tax credits, subsidies, and grants to industrial organizations for adopting RE (Elavarasan *et al.*, 2020). For instance, the AD for wind energy or the GBI for solar energy helps in lowering the costs of industries that are funding renewable sources. Others include the “Renewable Purchase Obligation” (RPO), which is another policy that compels a certain percentage of energy purchases to come from RE sources in the industrial sectors (Elavarasan *et al.*, 2020). These incentives and regulations are some of the key components in the economic assessment when organizations design their RE strategies.

3. Energy Storage and Grid Integration

Energy storage is central in making sure that renewable energy systems deliver power that is both dependable and continuous (Kalair *et al.*, 2021). Solar and wind power are unreliable; they provide power during the day or high winds respectively, and so there is a need for an efficient way of storing the power in batteries to cater for periods of low or peak production. For example, energy storage systems that enable excess energy produced at certain manufacturing periods to be stored for use during other high-consuming manufacturing periods can be incorporated into industrial facilities (Wei *et al.*, 2023). Besides storage, there is integration with the electricity grid that has to be addressed as well. The connection of renewable energy systems to already established industrial energy systems must be complementary particularly in voltage and frequency control (Mukhopadhyay *et al.*, 2020).

4. **Energy Intensity and Efficiency**

Therefore, energy intensity and efficiency need to be improved to reduce as much energy wastage as possible and harness the benefits from renewable energy systems. Energy conservation is critical for many industrial facilities, which use a lot of energy, therefore efficiency gains should be sought. Evaluating the performance of integrating renewable energy in a very efficient energy process also improves its efficiency and at the same time minimizes an organization's carbon impact (Klemeš *et al.*, 2019). The industrial energy audit serves as a tool for finding out whether renewable energy can complement or replace conventional energy like using heated solar energy for industrial purposes, or wind energy for electrical energy (Bhattacharyya, 2010). Conducting energy conservation measures along with promotion of renewable energy also works for the twin objectives of reducing cost and saving the environment.

5. **Site-Specific Considerations and Facility Layout**

The location of industrial facilities is a vital factor that defines the possibility of various types of renewable energy sources. For instance, wind energy is more feasible in the coastal and hilly areas of India and so the solar energy is more feasible in the hot and arid areas of the country. Industrial organizations require to undertake a comprehensive evaluation of the climate regime and the related weather conditions to determine the most optimal source of renewable power to adopt. Consequently, the way facilities are laid down or even rearranged has to incorporate renewable energy systems. It may involve providing space for solar panels on the roof or else in the open area, or designating land for wind power where wind intensity is higher (Strielkowski *et al.*, 2021).

6. Lifecycle Assessment and Environmental Impact

To emphasize, the long-term environmental friendliness of renewable energy sources makes the ecological benefits of integrating these sources quite clear. Land use and carbon footprint analyses (LCAs) of renewable energy systems are also important for understanding their true environmental implications (Gasparatos *et al.*, 2017). Photovoltaic panels, wind turbines, and other renewable energy technologies have consequences in their manufacturing and recycling processes, despite the fact that their application aims to reduce fossil fuel consumption and emissions of greenhouse gases. For example, some of the raw materials utilized in solar panels and batteries include toxic components, which require suitable recycling or disposal methods. Also, wind power generators may have impacts on the fauna and flora especially on birds in some areas. Therefore, when coming up with an industrial roadmap for renewable energy, these ecological factors should be taken into consideration, and it should also be made sure that renewable energy projects will not have negative impacts on the environment.

7. Regulatory Compliance and Corporate Social Responsibility (CSR)

Renewable energy systems are subject to regional, national and international environmental laws that must be met by adopting industries. Indian laws and norms of emissions and energy consumption, as well as sustainability protocols, are very strict and organizations involved in industries have to make sure that their renewable energy initiatives are in compliance with these laws. However, adopting renewable energy sources is strategic for implementing CSR policies since it shows firm’s concern towards sustainable development. Those strategies indicate that when organizations focus on the supply of renewable energy, they do not only meet the expectations of the law but also gain a reputation for being socially responsible (Us, Pimonenko and Lyulyov, 2023).

8. Technological Advancements and Innovation

The renewable energy industry is by nature one of innovation where there are constant innovations that enhance the efficiency in generation, output, and other factors that enable new opportunities in the industrial market. For instance, there is the evolution of bifacial solar modules which allows for generation of more electricity from the same area and this is very appropriate for industrial plants that have small footprints (Hassan *et al.*, 2023). Also, new technological developments in wind turbines give a possibility to input more energy into them even in cases with low wind velocity. Organizations need to monitor these innovations so that the strategies that they are adopting for renewable energy sources are the best and most effective ones.

9. Collaboration with Stakeholders

Renewable energy systems require stakeholders' coordination for successful implementation to be achieved. This includes engaging suppliers, regulators, people in the local communities and the financial backers of renewable energy projects so as to ensure that those projects have the right support and that they are sustainable. Strategic alliances should be established by industrial organizations intended for knowledge exchange and collaboration on issues regarding funding, technology implementation, and compliance with the rules and regulations. Other sources of information can also be used through partnerships with academic and research institutions that avail research findings, information, and expertise in management of RE.

The strategic plan to achieve the highest level of efficiency of RE integration in industrial processes entails a complex process that takes into consideration economic and environmental perspectives. By identifying and reviewing the concept of financial feasibility and taking advantage of government incentives, increasing the efficiency of energy, and including the aspect of environmental management, industrial organizations can achieve the goal of sustainable development and at the same time support the goals of environmental protection. Further, the improvement of technology solutions, adherence to the regulatory requirements, and engagement of stakeholders provide compounds for effective implementation of renewable energy systems in the industrial segments. With good planning and perfect execution, the industrial sector can be one of the biggest promoters of renewable energy in the world and at the same time be economically prosperous.

5.5 Discussion of Research Question Four

What practical recommendations and guidelines can be formulated to assist industrial organizations in planning, implementing, and managing renewable energy systems efficiently within their operations?

Research Question Four is therefore relevant as it seeks to establish effective strategies and policies that industrial organisations can adopt in organising, executing and managing renewable energy systems for their operations. One of the most important suggestions should be to start with the assessment of current energy use and potential savings as well as the definition of renewable sources that are applicable for the organization (Szakály *et al.*, 2021). This audit will inform decisions as to whether solar, wind, hydro or any of the renewable energy sources should be incorporated (Zakariazadeh *et al.*, 2024). Furthermore, organisations should focus on system solutions that can be gradually integrated into new organisations preventing disturbance of existing processes but enabling future development of the energy systems as new technologies emerge and energy requirements rise (Jasiūnas, Lund and Mikkola, 2021).

Another important guideline is formation of multi-disciplinary teams of engineers, financiers and environmentalists in order to meet organizational strategic goals and objectives of the renewable energy project (Elavarasan *et al.*, 2020). It will also help to create such teams to ensure that organization, technical, financial and environmental aspects are well addressed in the planning and implementation processes (Bibri, Krogstie and Kärrholm, 2020). Another area which is important would be on training and capacity building activities which are necessary to ensure that staffing is adequately equipped in order to manage the technical aspects of the renewable energy systems in the long-run and phase out the need for hiring outside experts to do maintenance work on the renewable energy systems (Briggs *et al.*, 2022).

Furthermore, effective management of RE systems requires the utilized of advanced monitoring and control technologies. Industrial organizations should invest in smart grid systems and energy management software that can track energy production, storage, and consumption in real-time. This will enable the optimization of energy use, reduce waste, and provide valuable insights for continuous improvement (Pandiyan *et al.*, 2023). Additionally, clear maintenance protocols should be established to ensure the longevity and reliability of renewable energy infrastructure (Gidiagba *et al.*, 2023). By following these recommendations and guidelines, industrial organizations can not only achieve greater energy efficiency but also create a resilient, sustainable energy management system that supports their long-term operational goals (Hafez *et al.*, 2023).

5.6 Sustainable Integration approach of Renewable Energy

Solar Power

Solar power plays a crucial role in the sustainable energy roadmap for industrial facilities, given its vast potential and decreasing installation costs. The study of solar energy harvesting involves proper planning of solar generation, which starts from strategic land acquisition of required amount of land to install solar installations and also to consider future expansion or the use of new technologies (Dincer and Acar, 2015). Most important is the way in which the industrial facilities are positioned, with a focus on flat roofs oriented to the true south to maximize solar energy capture. This orientation maximises solar radiation in the day along with increasing the energy output of photovoltaic panels (Hernandez, Hoffacker and Field, 2015).

In terms of factory planning, it is essential to incorporate sufficient space for the installation of solar panels, not just for immediate energy needs but also for future technological innovations in solar energy (Jacobson *et al.*, 2017). While our technology will continue to improve, and more efficient or novel solar systems may become available in the next two decades, it is prudent to reserve space for that. Integration of solar energy into industrial complexes involves the optimization of today's energy demands while simultaneously fortifying the facility's energy infrastructure to cope with future energy demands that will continue to be met by renewable energy technologies and innovation.

Wind Energy

To incorporate wind power into industrial energy planning, an assessment of geographic and meteorological conditions is needed so that wind energy can be effectively harvested. Land acquisition is also critically strategic because industries need to secure patches of land with the best wind conditions, in order to site the turbine. Wind speed, direction and consistency have been shown to be extremely important in the feasibility and output of wind energy systems (Blanco, 2009). Because wind turbines run at maximum efficiency, careful site selection and a supply of land in sufficient quantities are necessary. In addition, turbine wakes need to be sufficiently spaced apart to avoid turbine wake effects that can diminish overall energy generation.

As part of a long-term roadmap, industries should also plan for future advancements in wind energy technology. Industrial facilities can reserve additional land to allow them to grow into the most efficient turbines or other advanced renewable technologies. In the coming decades, next generation vertical-axis wind turbines, or hybrid systems, could be integrated into this same infrastructure. With these advancements, planning for such industrial energy systems helps to scale and adapt to the long-term growth in sustainable manner (Gholami and Naghmeh, 2023).

Factory planning should incorporate wind power in a way that complements other renewable energy systems, such as solar power. Given that both resources are abundant in these areas, rooftop wind turbines and vertical turbine installations could coexist with solar arrays as well, maximising the land area available for energy generation while increasing the efficiency of overall energy as a whole (Manwell, McGowan and Rogers, 2010).

Biomass Energy

Biomass energy offers a viable and sustainable renewable energy (RE) source from an industrial perspective, when combined with wider energy planning. To be able to take advantage of the possibility present in an organic waste streams existence within or close to an industry, industries should start by evaluating available organic waste streams existing inside or close to the industry that can be able to be converted to energy through processes such as anaerobic digestion or combustion (Velvizhi *et al.*, 2023). Small scale biomass digesters can be incorporated within factory premises where the waste materials can be used for energy generation and at the same time reduce the energy consumption and costs of waste disposal.

Land acquisition for biomasses digesters should be planned for to allow for future expansion and spaces should be allocated. Factory layouts should be designed for flexibility that can accommodate novel RE technologies that may be realised in the next

10–20 years. Future scalability is planned for, to guarantee that the facility can be resized in response to technological improvements without needing extensive structural alterations (Edenhofer *et al.*, 2011). In addition, biomass systems should be integrated into industrial complexes based on water usage, with the possibility of rainwater harvesting systems for digestion to meet the water demands of biomass systems. This holistic approach not only enhances energy resilience but also aligns with sustainable factory planning by reducing resource dependency and optimizing available land and energy resources.

Hydropower Energy

The feasibility of hydropower as renewable energy for industrial use is very strong, especially for industrial use in areas with abundant water resources. IRENA (2019) has emphasised that effective planning for hydropower integration starts with a thorough assessment of hydrological conditions of the local area, as well as environmental impact studies. In order to utilize hydropower effectively, industries should not pursue the efficiency of hydropower without adopting a phased approach, which includes small hydropower plants in areas where large scale installations may not be practical. Factory planning must include space for water reservoirs and diversion canals that can support micro-hydro systems, which can supply a consistent and renewable power source for industrial operations.

According to Kaunda et al., (2012) land acquisition strategies should be centred on areas near rivers or water bodies with least environmental damage. It will allow for the installation of hydropower facilities without losing the potential for future expansions or combination with new renewable technologies. Keeping industrial energy flexibility requires preserving space for future advancements in hydropower or other renewable sources, such as energy storage systems or floating solar panels on reservoirs. Furthermore, aligning hydropower projects with the broader renewable energy roadmap can ensure long-term sustainability, especially as industries aim to meet future energy demand with a reduced carbon footprint (Owusu and Asumadu-Sarkodie, 2016).

Geothermal Energy

Industrial facilities in regions with suitable geological features can dependably obtain a reliable and sustainable energy source from geothermal energy. This renewable energy (RE) has to be harnessed through careful planning. The first step of geothermal potential studies is exploratory drilling and resource mapping to identify geothermal potential of an area. It is Lund & Boyd, (2016) who argue that such assessments are important in determining feasibility of geothermal energy projects. After this, land acquisition should include both the needs of immediate geothermal energy installations, such as drilling sites, and needs for future technological advances. The land needed for the initial geothermal infrastructure should be sufficient not only to accommodate the initial installations but also enough to accommodate potential expansion, or integration with other renewable technologies as they come to market (Fridleifsson, Bertani and Huenges, 2008).

In terms of factory planning, geothermal energy systems can be integrated into the facility's overall energy management framework, providing a steady and continuous energy supply for heating, cooling, and electricity generation. Future upgrades or new novels geothermal technologies will likely have better efficiency and scale than exists today (DiPippo, 2016). By aligning geothermal energy adoption with a broader renewable energy roadmap, industries can future-proof their facilities and ensure long-term energy sustainability while reducing their carbon footprint.

Other Sources

There are many opportunities in marine, tidal and wave energy, and waste to energy (WTE) systems for industrial sectors to diversify their renewable energy portfolio. The integration of these resources demands an in-depth assessment of their geographic potential, technological readiness and integration challenges. Tidal and wave energy are location specific and need to be close to coastlines with high tidal ranges (or strong wave action). These projects require strategic land acquisition, which should be related mainly to coastal industrial complexes because these technologies can be effectively exploited there. Additionally, considerations for tidal turbines or wave energy converter installations must take into account potential capacity expansion due to technology advancing (Lewis *et al.,* 2009). Factory planning must also account for the unique infrastructure demands of marine energy systems, including energy transmission from offshore installations to onshore industrial facilities (Chen *et al.*, 2021).

Waste to energy (WtE) systems likewise provide a versatile renewable energy solution for industries that generate large amounts of waste. The integration of the WtE plants into the industrial complexes not only helps in cutting down the waste disposal requirements, but also engenders a circular energy system, as waste products are transformed into useful energy. When planning WtE facilities, acquisition of land, especially in locations close to waste producing industries and the provision of land for future technological upgrades such as advanced combustion technology or gasification technology are considered (Dijkgraaf and Vollebergh, 2004). In addition, there should also be space in industrial layouts for future integration of emerging WtE technologies in the coming decades, keeping the complex open to innovation. The roadmap for both marine and waste-to-energy technologies must remain flexible, allowing for phased development and the integration of novel RE technologies as they evolve over time (IRENA, 2020).

5.7 Conclusion of the Discussion

It is noted that the effective deployment of RE systems calls for integration of monitoring and control technologies. Industrial organisations ought to use smart grid systems and energy management software capable of analysing real-time energy generation, storage, and consumption. This will facilitate the enhancement of the utilization of energy, eliminate wastage, and get insights necessary for improvement. Further, implementation of various maintenance procedures must be set out to help provide long-term effectiveness of renewable energy sources. Stemming from the above set recommendations and guidelines, industrial organizations are not only able to optimize their energy utilization but also develop an effective and reliable energy management system that is in tandem with the organizational objectives.

Furthermore, the issue of establishing the strategy map of the extensions needed for the industrial organizations to embrace renewable energy has to consider the economic and ecological issues. This entails not only the effective investment on cash resources and energy conservation but also the proper handling of the effect that renewable systems have on the environment. Some of the important and basic guidelines include energy audit, use of modular systems, cross functional teams, as well as use of energy management system and technologies towards renewable energy usage. If these barriers are eliminated and the guidelines are applied, the industrial organizations can increase energy efficiency, sustainability and organizational resilience in the long run.

CHAPTER VI:

SUMMARY, IMPLICATIONS, AND RECOMMENDATIONS

6.1 Summary

This thesis's research examines the critical challenges and opportunities regarding renewable energy (RE) management in industrial sector, specifically related to planning, exploiting and optimising renewable energy resources from within industrial facilities. The global spotlight on sustainable practises and fighting climate change are making industries accountable for lessening their carbon footprint. The practical aspects of implementing diversified RE solutions in the industrial context, with specific focus on three different meteorological regions in India, is explored within the broader discourse on renewable energy integration. The research sought to address the pressing issues related to planning and harnessing renewable energy, developing a roadmap for industrial organizations to optimize their facility layouts, and ensuring the seamless integration of renewable energy sources to achieve both commercial viability and ecological benefits.

To investigate how to organise and utilise renewable energy in industrial settings, this study considered regional climatic conditions. The results indicate that industrial renewable energy integration has considerable potential but faces a number of obstacles. The first step to solve these problems is comprehensive planning at facility conception. The major reason that industrial facilities fail to use their renewable energy resources is poor planning and forethought in the building and layout design. Regions with abundant renewable energy resources such as solar, wind and hydro are underutilised as a result of lack of long-term energy strategy and renewable energy consideration in planning. This study demonstrates that an integrated and comprehensive approach to renewable energy planning is necessary for planning the facility's full energy needs, the renewable resources available in the region, and the technology infrastructure required to take advantage of them.

The study also aimed to develop a roadmap that industrial organizations across different sectors could follow to plan their facility layouts and operations to maximize renewable energy utilization. The findings suggest that this roadmap must be adaptable and tailored to the specific environmental, economic, and technological conditions of each industrial facility. For example, solar energy is a particularly feasible option to satisfy industrial energy requirements in hot dry and humid areas while wind energy seems a more promising option in coastal regions. On the other hand, hydropower has a potential in hilly and riverine areas. The roadmap proposed in this study emphasizes the need for industries to adopt a diversified energy portfolio that incorporates multiple renewable energy sources to ensure a stable and continuous supply of energy, mitigate risks associated with the variability of renewable energy, and enhance the resilience of energy systems within industrial settings.

A key component of the roadmap involves factory planning and the strategic positioning of renewable energy systems within the industrial facility. The research discovered that industrial facilities do not adequately configure their layouts to accommodate renewable energy installations, leaving a window for increased energy efficiency and lowered operational costs. For instance, in the initial design of the facility, roof mounted solar panels or strategically placed wind turbines could contribute at least considerable sums of money towards savings in energy. Yet, the installation of renewable energy systems still carries significant capital cost and retrofitting existing industrial infrastructure is highly complex. That means that such early-stage planning and financial incentives from governments to get industries to invest in renewable energy solutions matter.

The findings suggest that industries are more likely to adopt renewable energy solutions if there is a clear economic benefit, such as lower initial capital costs and long-term tax breaks for renewable energy investments. The lack of a regulatory structure for renewable energy usage in the industrial sector has also played a part in the slow uptake. This study recommends that policymakers foster supportive policies to reduce the financial and administrative costs of moving to renewable energy that will in turn attract more investment in clean energy practises.

An important finding of this research is also the technical challenges of integrating renewable energy into existing industrial infrastructure. It was reported by many respondents that the integration of renewable energy systems to conventional energy grids, and to machinery, have severe difficulties. In areas where industrial operations are energy intensive, the availability of renewable energy sources, wind and solar, make energy storage systems imperative to ensure a stable, reliable power supply. But because the costs of energy storage technologies like batteries are prohibitive for so many industries, the economic case is still not proven. It is suggested that the successful integration of renewable energy into industrial operations will rely upon further technological advancement and cost reduction in energy storage systems. Additionally, the study revealed that industrial managers don't have the technical knowledge to run complex systems of renewable energy, which only slows down adoption. This thesis proposes that industries invest in capacity building programmes to help their technical staff understand and respond to renewable energy systems.

The study finds that most of the industrial stakeholders accept the point that renewable energy is necessary from a point of sustainability and economic viability in the long run. Survey data shows that cost savings over time was high for organisations that had adopted renewable energy systems, despite the higher initial capital investment. In addition to this, industries that have adopted renewable energy into its operation have been known to be very committed with corporate social responsibility, as the business practise aligned itself with the global sustainability goals. Renewable energy use isn't just a way for industries to cut their carbon emissions; it also contributes to their public image and their competitiveness as business in a marketplace where consumers and stakeholders are increasingly demanding sustainable business practises.

Overall, this work finds that renewable energy integration in the industrial sector holds great potential but faces a number of barriers to reaching full potential. Renewable energy strategy for industrial facilities requires effective planning, government support, technological innovation and building capacity in managing and developing the strategy. The roadmap developed in this study provides a practical guide for industries looking to transition to renewable energy, offering recommendations on facility layout optimization, energy resource diversification, and the adoption of energy-efficient technologies. This research identifies the challenges that can be addressed through innovations that industries can adopt to increase energy security and cost savings while also contributing to global efforts to control climate change and support sustainable growth. These findings are crucial to policy makers, industrial stakeholders, and energy managers, and they add a necessary input to the debate about the management of renewable energy in the industrial sector.

6.2 Implications

The theoretical implications of this analysis are discussed in a broad context of energy policy, technological development, and sustainability. First, it reveals that the geographical dissemination of RE sources indicates that the conventional method of implementing the spread of renewable energy sources may not fit the country's regions. This is in line with the systems theory especially when considering adaptive systems that have to change depending on the localized environment/society. These results imply that the current theoretical frameworks of energy transition should include a better understanding of regional capabilities, resources, and socioeconomic factors to get accepted with high accuracy (Devine-Wright, 2009).

Based on the diffusion of innovation theory, it is noted that renewable energy technologies have varying levels of diffusion depending on the region and type of technology. For example, the usage of solar energy, particularly in hot and arid climates, may be close to or already reached the limit at which new generations become aware of the technology and deliberate on whether to take it up, whereas technologies such as geothermal or tidal energy may just be in their infancy in most locations because people are not very much aware of them. This supports the earlier assertion of the fact that not all renewable technologies go through the adoption curve in the same manner. What is suggested here is that, for targeted educational and outreach campaigns, these fewer familiar technologies remain at the ‘Innovators’ and ‘Early Adopters’ phases and need to be taken hastily to the ‘Early Majority’ phases.

The analysis also supports resource-based theories with great emphasis on the resource-dependence theory. Varying degrees of resource dependence are present in different regions, which gives preference and shapes preference and challenges towards renewable energy adoption. For instance, coastal areas can use hydropower since they have a sufficient water supply; that is a region-oriented approach toward renewable energy. This coincides with theoretical frameworks that call for the abandoning of an optimized approach to the transition suggesting instead that available regional resources and their interactions with the available technology and the environment should guide transition strategies (Klessmann, Nabe and Burges, 2008).

Another theoretical contribution involves the institutional theory as well. The diversified responses about the current regulatory policies and governmental support make it clear that the institutional factors within the form of, policies, regulations, laws and norms of the government significantly impact the implementation of renewable energy technologies. The deterrents for large-scale hydropower because of environmental factors and reluctance to invest in solar or biomass because of lack of ‘effective government support’ suggest that regulatory bodies are key actors in the diffusion process. In this context of institutional theory, the rollout of renewable energy sources shows several countries rushing through these technologies because of favourable policies while other nations are slow because of such institutions or conflicting policies.

It also borders with the aspects of stakeholder theory, based on the fact that the respondents always complained about the lack of cooperation between the government, private entities and the public. This indicates that the adoption of renewable energy sources requires collaboration of all stakeholders, who include: the local communities where the sources are tapped, businesses, environmental non-governmental organizations and the policy makers. In theoretical terms, it can be argued that a shift towards renewables has to be accomplished through the models of adoption that will take into consideration multi-stakeholder perspectives given the multiple value stakes that are implicated in energy transitions (Geels, 2014).

Moreover, there is an appeal to technological advancement and a call for upgrading aspects such as energy storage, grid, and infrastructural systems that seem to have theoretical implications for innovation systems theory. The issues that the respondents pointed out such as doubt about battery efficiency, and the practicality of grid connectivity in rural regions are indicative of the need to have innovative ecosystems to support the growth of renewable energy. Theoretical frameworks that deal with innovation and technology relationships and with policy will require the inclusion of this notion that renewable energy systems' success hinges on the speed and flexibility innovation ecosystems have to address regional issues (Zarębski and Katarzyński, 2023).

Finally, the theoretical implications of this analysis suggest the desirability of more context-specific models of renewable energy, where contextual factors are defined by resource endowment; technological literacy; institutions; and stakeholders. By elaborating of the existing theories, including diffusion of innovation, institutional theory, and resource-based views, we can extend the existing knowledge as to introduce more credible approaches to evaluating the challenges of transition to renewable energy across the distinct regions.

The managerial implications derived from this analysis are as follows, for the leaders in the renewable energy sector, policymakers and private organizations involved in clean energy transition: First, the analysis states that the given energy strategies should be regional. This means that managers need to understand that one common strategy in the adoption of renewable energy sources does not apply because of the differences in geography, environment, and socio-economic areas. For example, where it is hot and dry, or even hot and humid, solar energy should rank highly among the priorities of the management, with attention being paid to finding ways and means of developing solar energy technologies that will have lower initial costs than at present, and that will be relatively easy to maintain. This means that for organisations that are located in these regions, there is a need to undertake cost minimisation measures for solar-related infrastructure and also ensure adequate training of maintenance staff to avoid future operational problems (Obaideen *et al.*, 2021).

In coastal and hilly regions specifically, where hydropower is highly favoured, achieving the goal becomes challenging for the managers as they have to balance between the natural water resources and the environmental and social issues at the same time.

Various policies should be included in the projects such as non-degradation of the environment and appropriate remuneration to be provided to the affected persons displaced by the large hydropower projects. To enhance relations with the community as well as the success of the hydropower projects without negatively affecting the society managers in this sector are required to improve on the engagement in the community and the overall CSR.

These mixed perceptions of wind and solar energy in these regions alert managers to examine solutions when more renewable systems work together (de Jong *et al.*, 2013). However, there is a problem with grid connectivity particularly when it comes to the wind resources which can be intermittent. To overcome these, managers are required to concentrate on enhancing the grid structure as well as on the construction of energy storage techniques to avail constant power. It may be through strategic alliances with battery technology companies or engaging with the governments for financing that will address the need for enhancing the grid systems.

Where hydropower is dominant, such as in areas of high rainfall, but the problem of fluctuation of the rainfall pattern limits the consistency of the generated power, the managers must then concentrate on developing ways and means of storing the power during the rainy season for use during the dry season. This means that there is a need for a more extensive form of R&D that can help in enhancing battery life and efficiency. Additionally, the terrain classification makes it clear that the challenges of wind energy in these regions extend to the infrastructure development which has called for the use of varied solutions like the modular and/or flexible wind turbines that are best suited for such terrains.

Another trend that is visible in all areas is the low level of awareness of some technologies, like geothermal and tidal energies (Dey, Sreenivasulu, G.T.N. Veerendra, *et al.*, 2022). This presents a clear managerial challenge: enhancing the public and stakeholders' awareness. The stakeholders that are engaged in these relatively exotic technologies should step up on awareness creation, which may involve some form of advertisement or creating partnerships that help society embrace the less conventional energy forms. It could also range from partnering with governments in establishing policies that will encourage use of other forms of renewable energy that may not be popular among the populace, hence enhancing public acceptance.

Furthermore, the study also highlights there is a high tendency of patrons wanting governmental and corporate intervention. Top managers in renewable energy companies should therefore encourage policy changes that will allow for the use of renewable energy. This is in advocating for the development of new policies and laws, tax credits, and grants for renewable projects especially where initial costs remain high. That calls for closer collaboration with government agencies to obtain a favourable regulatory framework to support innovation and investment in renewable technologies (Dall-Orsoletta, Romero and Ferreira, 2022).

To private organisations, the implication of the research is in the aspect of coordination between the business models and sustainability objectives (Fobbe and Hilletofth, 2021). There is a need for better measurement and management of sustainability as CSR activities as more and more companies are develop sustainability metrics and reporting as part of their strategy as a general management control in the light of increasing regulation and investor demand for sustainable energy investments. In addition, managers should consider sectorial cooperation where energy incumbents could cooperate with technological companies to create new generation solutions in the sphere of renewable energy sources and their distribution and storage.

Finally, the financing of renewable energy projects is highlighted especially in the costs of implementation of renewable technologies and the return on investment (ROI).

System managers must ensure they design and implement proper financial models that factor in the costs of putting up the renewable energy infrastructure right from the start of development up to the time when the structures require maintenance and probably a technology change. There might be a need to undertake risk management activities to avoid the financial risks inherent in the promotion of renewable energy sources like the search for green bonds, carbon credits, and public-private partnerships (Gandhi, Hoex and Hallam, 2022).

Based on the managerial implications of this analysis, some recommendations advocate for the use of a regional targeted approach, enhancing public awareness and government partnership, and a constant provision of better financial and technological resources to overcome all barriers to the take-off of renewable energies. Managers have to take responsibility for the managerial efforts to promote the implementation of region-specific strategies, the innovations of technologies and social engagement to achieve the change towards sustainable energy systems.

6.3 Recommendation of research

In light of these results, a number of key recommendations are suggested for guiding industrial stakeholders in the planning, tapping, and maximising of renewable energy (RE) resources. The first thing for the successful integration of renewable energy systems in the industrial plants is comprehensive planning. The first step for industries is to evaluate the availability of renewable resources locally, including solar, wind, hydro and biomass, and match their energy strategy to what is most viable. A phased approach is warranted beginning with those technologies that are available given the relatively short time scale of 5 to 10 years, such as solar energy through true south facing flat roofs, and planning for integration of other emerging renewable technologies as they become available in the next decade. For example, factory designs should be designed with space for future installation of more advanced renewable technologies so that industrial complexes can maintain their adaptability to innovation without major and expensive retrofitting.

Industries also need to look at the land acquisition for the six renewable energy systems: solar, wind, hydropower, biomass, geothermal, and energy storage. Buying land with an eye to buy more land for future expansion, so you can grow your renewable energy installations as your energy demands grow. Solar panels should be installed on true south facing flat roofs that will maximise solar energy capture and save energy. The architectural designing of industrial complexes should also involve wind ventilation, which would help in the use of wind turbines and natural ventilation to reduce further dependence on non-renewable sources of energy.

The other important recommendation is for small scale biomass digesters to be integrated in industrial facilities. Biomass energy is a complementary energy source especially for industries with a lot of output waste. Digester that process this waste can be small and efficient, converting it to energy and helping to reduce the facility's waste disposal needs while providing additional energy production. Additionally, industrial facility designs must include rainwater harvesting systems. The creation of water reservoirs to capture and store rainwater is able to fulfil multiple roles, principally as a non-drinking water source (e.g., to cool, clean, etc.), and as an emergency fire suppression resource. Industrial operations can enhance resiliency with the addition of these water reservoirs and lower dependence on external water sources.

The roadmap developed in this study highlights the need for a long-term view when planning renewable energy integration. Furthermore, industries should save space for tomorrow's technologies, starting now, to accommodate today's RE technologies, as well as their emerging technologies for the next two decades. Doing so lets them maintain the relevant and efficient energy systems as technology advances to become commercially viable. Furthermore, these plans must be flexible enough to react to changes in the market, the regulatory environment, and the level of technological progress, and make sure the industrial complex keeps up with renewable energy utilisation.

Finally, industrial stakeholders are advised to interact with local authorities and policymakers to enable government incentives, subsidies and support for renewable energy projects. Such collaboration can take some weight off the financial burden of an initial investment in renewable technologies and ease the sloping transition towards more sustainable energy sources. If industries follow these recommendations, they won't only save energy and meet sustainability goals, but also make an important contribution to global efforts to slow down climate change and promote environmental stewardship.

6.4 Future Research Suggestions

To further the knowledge and application of renewable energy technologies the following research areas should be explored in future studies: First, they achieved a call for additional micro-level research looking into the individual effects of regional policies /incentives on the utilization of renewable energy. In line with the systems theory, it was mentioned that energy transition policies need to be contextualized to the country's circumstances (Clegg and Dunkerley, 2013). Policy studies should also investigate how regional variation in policy efficiency affects the adoption of renewable technologies especially about the offers of incentives that can be used to encourage the uptake of renewable technologies in different regions of the world.

Furthermore, the theory stating that the diffusion of innovation implies that the more novel renewable technologies such as geothermal, and tidal energy, need information promotion to spread in the fifth stage of the adoption curve(Dearing, 2021). Subsequent studies should examine the ways to increase the focus on and the pace of the adoption of these innovative technologies. This could occupy controlled and compare approaches for evaluating outreach techniques in influencing the perception and acceptability of the food-borne threat.

Resource-based theories also provide knowledge that understanding regional resource endowment might help to develop better transition strategies (Barney, 1991) . Future research should examine the impact of regional resources on the deployment of renewable energy and find out the best match of technologies for specific levels of the resource. This could comprise of success stories of the implementation of the models as well as the failure within giving the evaluator a preview of things to expect.

Mimetic, normative, and coercive forces as emphasized by institutional theory highlight the contextual variable, the regulatory environment as determining the extent of renewable energy (Schout and North, 1991). Further studies should be carried out on how institutional factors, policies and regulations, may impact the successful adoption of renewable energy and how the conflicting environmental protection laws can be aligned.

The application of stakeholder theory reveals the essentially cooperative aspects of renewable energy transitions (Freeman, 2010). Further studies should identify how all stakeholders, international, national, and global companies and local communities can collaborate more effectively to eliminate the barriers and enhance the utilization of renewable energy. Some of these are the analysis of public-private partnerships as well as community involvement in the implementation process.

Last, the innovation systems theory note that development of technology systems for renewables energy has to be progressed (Pavitt, 1995). Subsequent research efforts should concentrate on enhancing rechargeable battery technology, conversion of stand-alone grid systems and other such technologies that are important for RE systems. Research that can be done includes the advancements in battery technology, smart grid and distributed generation, examining their feasibility in the use of renewable energies as well as the effectiveness of the systems.

In conclusion, the research gaps identified in filling the gap as discussed below. The future development of research can raise more profound insights on how regional policies, diffusion dynamics, resource-based strategies, institutional impacts, stakeholder collaboration and technological advancements can contribute to the enhancement of the transition towards sustainable energy systems.

6.5 Conclusion

Finally, the conclusion of this study stresses the necessity of thorough planning, strategic implementation, and adaptive utilization of renewable energy (RE) for use in industrial facilities. This research investigates how industries can better integrate renewable energy sources, including solar, wind, and hydropower, with operations to create a more sustainable operation, reduce costs, and lessen an industry's impact on the environment. According to the research objectives and findings, planning contributes to proper adoption and use of renewable energy systems. If industries do not have a clear forward-looking plan, they will not optimize the available renewable energy resources to their advantage, thereby preventing a shift to greener, more efficient operations.

This study provides one of the basic insights that planning for renewable energy integration should start in the earliest stages of facility design and development. If industries consider renewable energy during their factories and operational facilities planning, it will be easier for them to find a match between the energies they need and the renewable resources that are available. The approach takes into account the conduct of detailed meteorological assessment of the conditions in the locality, identifying the most appropriate RE source for the area and designing layouts of facilities for the installation of RE systems like solar panels or wind turbines. Foresight is seen as important in planning because retrofitting existing industrial infrastructure for renewable energy is often much more costly and logistically challenging than integrating such systems from the beginning.

The study developed a comprehensive roadmap to guide industrial stakeholders in the transition to renewable energy. This roadmap is not a one-size-fits-all solution but rather an adaptable framework that industries can tailor based on their specific environmental, technological, and economic circumstances. A key component of this roadmap is the diversification of energy sources. Where there are plentiful amounts of sun, solar energy must be the primary focus whereas where the wind is abundant, wind energy becomes primary. Additionally, where there are water resources, hydropower will also provide an additional energy source for solar and wind. The diversification across multiple renewable resources helps reduce variability in the availability of renewable energy supplies, so that industrial operations can continue to receive a stable and steady inflow of energy, regardless of changing weather.

In addition to selecting the most appropriate energy sources, the roadmap emphasizes the importance of integrating renewable energy into the overall energy management system of the industrial facility. The bag also includes adopting energy storage solutions, for instance batteries, for storing excess energy created during high (production) periods. As renewable energy generation is more unstable due to changes in weather or other external factors it is especially important to store energy to ensure a reliable power supply. In addition, energy management systems must be designed that optimise how energy is used within the facility by favouring renewable energy sources over conventional fossil fuels and minimise the total energy used by efficiency measures. A holistic approach to energy management that enables industries to reap maximum benefits of renewable energy and minimise dependence on non-renewable sources.

Factory planning also plays a pivotal role in the effective harnessing of renewable energy in industrial settings. Renewable energy systems often have particular spatial and structural requirements that industrial facilities should be designed and laid out to accommodate. For instance, solar panels can be placed on roof space, or even open space for wind turbines. In addition, factories can be designed to be energy efficient and reduce the overall energy demand and the ease with which it can be supplied by the energy needs. Strategic factory planning also involves making provisions for future renewable energy installations as technologies evolve and become more cost-effective. If industries plan for future upgrades, they can be flexible enough to respond to technology in a renewable energy way over time.

Lastly, renewable energy planning and usage for the industrial sector needs both technical and economic as well as operational consideration. The roadmap developed in this study provides a practical guide for industries to adopt renewable energy technologies and manage their energy needs more efficiently. Factory planning, in particular, is critical for ensuring that facilities are designed to support renewable energy systems, both in the present and in the future. Industries can become sustainable for the long term, lowering their operational costs, and contribute to the global solution to counter climate change by adopting renewable energy solutions. However, the research also shows that challenges such as uncertainty in price and technology, as well as lack of both capital budgeting and regulatory mechanisms, are surmountable and that the viable path to renewable energy adoption in the industrial sector is also necessary to secure a sustainable future.

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APPENDIX A:

QUESTIONNAIRES

1. **Your Name (optional)**

   ____

2. **Contact Email and Phone Number (optional)**

   ____

3. **Company Name (optional)**

   ____

4. **Your present or past company or professional experience belongs to which industry sector?**
   a. Manufacturing
   b. Service
   c. Others
5. **(Please specify if Others)**

   ____

6. **Name of your Department / Current Role / Area of specialization**

   ____

7. **Indian Organization Size (Number of Employees):**
   a. Small (1-100 employees)
   b. Medium (101-500 employees)
   c. Large (501+ employees)
8. **Geographic Location (City / State)**

   ____

9. **Are / were you directly involved in renewable energy management within your organization / professional association?**
   a. Yes
   b. No

10. Is your organization or the association/s you are involved with actively utilizing renewable energy sources in its operations?

a. Yes
b. No

11. How would you describe your organization's / the association/s you are involved with on their current level of commitment to sustainability and renewable energy initiatives?

a. Low
b. Moderate
c. High

12. Challenges and Barriers

Please indicate your level of agreement with the following statements for each region by selecting the appropriate number.:

Statements	1	2	3	4	5
The initial capital cost of setting up a renewable energy system is a significant barrier.					
Lack of available government incentives or subsidies hinders renewable energy adoption.					
The complexity of integrating renewable energy into existing infrastructure is a major challenge.					
Uncertainty about the long-term cost savings of renewable energy solutions is a barrier.					
Concerns about the reliability and consistency of renewable energy sources / vendors are barriers.					
Resistance from stakeholders or management within the organization impedes renewable energy adoption.					

13. Renewable Energy Potential and Viability Assessment for Different Regions in India: Hot, Dry, and Humid Region.

Statements	1	2	3	4	5
Wind energy can effectively contribute to the energy needs of industrial sectors in hot, dry, and humid regions of India.					
Solar energy has substantial potential to meet the energy demands of industrial sectors in hot, dry, and humid regions.					
Biomass energy can be a sustainable and reliable source of energy in hot, dry, and humid regions.					
Geothermal energy is a feasible option to explore for meeting energy needs in hot, dry, and humid regions.					
Energy storage technologies, such as batteries, can effectively support renewable energy sources in ensuring a stable power supply in these regions.					
To what extent do you think there is awareness and education about the benefits and implementation of renewable energies in the Indian industrial sectors?					

14. Renewable Energy Potential and Viability Assessment for Different Regions in India: Coastal and Hilly Regions

Statements	1	2	3	4	5
Hydropower is a reliable and efficient source of renewable energy for coastal and hilly regions of India.					
The combination of wind and solar energy is a suitable solution for coastal and hilly regions to meet energy demands effectively.					
Tidal and wave energy can be harnessed efficiently in coastal regions to supplement the energy mix.					

Geographically challenging terrains in hilly regions might pose difficulties for renewable energy infrastructure deployment.					
Energy storage solutions are crucial to ensuring a stable and continuous energy supply in coastal and hilly regions.					

15. Renewable Energy Potential and Viability Assessment for Different Regions in India: Regions with High Rainfall

Statements	1	2	3	4	5
Hydropower is the most promising and efficient source of renewable energy in hilly regions with rivers.					
Wind energy could supplement hydropower in hilly regions with rivers to ensure a reliable energy supply.					
Geothermal energy exploration is practical and worth considering in hilly regions with rivers.					
The terrain in these regions might require specialized infrastructure for renewable energy projects.					
Collaboration between regional governments and energy companies is crucial for realizing the renewable energy potential in hilly regions with rivers.					

16. To develop a comprehensive roadmap for industrial organizations to optimize their facility / construction layouts and operations using renewable energy sources: General Perception

Statements	1	2	3	4	5
Renewable energy sources are crucial for the sustainable future of industrial organizations.					
I believe that integrating renewable energy sources into facility layouts and operations is economically viable.					
My organization recognizes the importance of renewable energy in achieving sustainability goals.					

The adoption of renewable energy sources aligns with our corporate values and mission.					

17. To develop a comprehensive roadmap for industrial organizations to optimize their facility / construction layouts and operations using renewable energy sources: Economic Considerations

Statements	1	2	3	4	5
Using renewable energy sources in facility operations will lead to cost savings for my organization					
Government incentives and subsidies for renewable energy make it an attractive option for our organization.					
Our organization actively seeks opportunities to invest in renewable energy technologies.					
We have a clear strategy for financing renewable energy projects within our organization.					

18. To develop a comprehensive roadmap for industrial organizations to optimize their facility / construction layouts and operations using renewable energy sources: Ecological Considerations

Statements	1	2	3	4	5
Reducing carbon emissions through the use of renewable energy is a top environmental priority for our organization.					
My organization is committed to reducing its environmental footprint through renewable energy adoption.					
We actively monitor and report on the environmental impact of our energy consumption.					
Sustainability practices, including renewable energy, are integrated into our corporate culture.					

APPENDIX B:

DATASET

Your p	Name of yo	Organi	Geogra	Are / v	Is your	How w	Challe	Challe	Challe	Challe	Challe	Challe	Renew	Renew	Renew	Renew
1	31	1	13	1	2	1	3	4	4	4	4	3	3	3	3	3
2	9	1	13	2	1	2	5	5	5	5	5	5	4	3	3	4
1	38	1	13	2	2	1	4	4	4	4	4	4	3	3	3	3
3	25	3	17	1	1	3	4	4	4	2	2	2	4	4	4	3
1	31	1	14	2	2	2	4	4	2	3	2	4	2	4	2	4
1	34	1	13	1	2	2	4	5	5	4	3	2	3	5	5	3
1	34	1	13	1	2	2	4	5	5	4	3	2	3	5	5	3
1	50	1	1	1	1	3	1	4	4	2	3	2	3	4	3	4
1	50	1	1	1	1	3	1	4	4	2	3	2	3	4	3	4
1	31	1	13	2	2	1	5	4	4	3	3	4	4	5	4	5
1	31	1	22	2	2	1	5	4	4	3	3	4	4	5	4	5
1	31	1	22	2	2	1	5	4	4	3	3	4	4	5	4	5
1	25	1	13	2	2	1	5	4	4	3	3	4	4	5	4	5
1	26	3	13	2	1	2	5	2	4	4	4	1	3	4	3	3
1	41	1	13	2	2	3	5	2	4	4	4	1	3	4	3	3
1	26	3	13	2	1	2	5	2	4	4	4	1	3	4	3	3
1	41	1	13	2	2	3	5	2	4	4	4	1	3	4	3	3
1	20	1	9	1	2	2	3	3	2	2	3	2	3	4	3	3
1	20	1	9	1	2	2	3	3	2	2	3	2	3	4	3	3
1	28	2	22	2	2	3	3	3	2	2	3	2	3	4	3	3
1	25	2	22	2	2	3	3	3	2	2	3	2	3	4	3	3
1	35	3	13	1	1	2	4	3	4	2	4	2	4	5	5	4
1	35	3	13	1	1	2	4	3	4	2	4	2	4	5	5	4
1	40	3	22	1	1	3	2	5	2	2	4	2	3	4	3	3
1	40	3	22	1	1	3	2	5	2	2	4	2	3	4	3	3
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1	8	1	13	2	2	1	4	4	4	3	4	3	4	5	3	3
1	31	2	22	2	2	3	3	5	4	4	1	3	4	4	4	4
1	31	2	22	2	2	3	3	5	4	4	1	3	4	4	4	4
1	31	2	12	2	2	1	3	5	4	4	1	3	4	4	4	4
1	31	2	12	2	2	1	3	5	4	4	1	3	4	4	4	4

Renew	Renew	Renew	Renew	Renew	Renew	Renew	Renew	Renew	Renew	Renew	To dev	To dev	To dev	To dev	To dev	To dev	To dev	To dev	To dev	To dev	To dev	To dev
4	2	3	3	2	4	3	2	4	3	2	2	4	4	4	2	3	4	2	3	2	4	2
5	3	5	5	5	5	5	5	5	5	5	5	5	5	4	4	2	3	3	5	5	5	5
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2	4	4	3	4	3	4	4	3	4	4	3	4	4	4	5	5	4	5	5	5	4	5
2	4	4	3	4	3	4	4	3	4	4	3	4	4	4	5	5	4	5	5	5	4	5
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