EXPLORING DIGITAL SOLUTIONS TO ENABLE END CONSUMER PARTICIPATION IN GREEN ENERGY ADOPTION

by

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Dedication

I, Prakhar Chaudhary, declare that this thesis titled, "**EXPLORING DIGITAL SOLUTIONS TO ENABLE END CONSUMER PARTICIPATION IN GREEN ENERGY ADOPTION**" presented work in this report is my own. I ensure that:

- The entirety or most of this work was completed during my doctoral studies at the Swiss School of Business and Management, Geneva.
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- I have always provided clear attributions when consulting published works by others.
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- I have duly acknowledged all primary sources of assistance and support.

Signed: Prakhar

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Date: **March 22, 2025**

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ABSTRACT

EXPLORING DIGITAL SOLUTIONS TO ENABLE END CONSUMER PARTICIPATION IN GREEN ENERGY ADOPTION

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Utilities are driving energy transition projects aiming for carbon-free generation and promoting green energy initiatives globally. To achieve these goals, utilities must have a socioeconomic perspective and a multifaceted strategy involving stakeholders like investors, customers, competitors, and regulatory agencies. Active customer involvement can help develop innovative plans to reduce carbon footprint. However, there are limited options available for involving customers in these efforts. This research study enables us to comprehend why it is very crucial to enhance end-consumer participation in the net zero target globally.

The study employed a mixed-method approach, combining statistical analysis of quantitative data with qualitative insights to provide a well-rounded evaluation. It analysed the key dimensions, including technological, economic, social, environmental, and institutional support. The key areas that were considered are residential, EV charging parking lots, commercial (malls/offices), industrial, and emergency backup systems. The data analysis for this study was done, using SPSS (Statistical Packages for Social Sciences) Software.

The research found that through the implementation of **Power Bank on Cloud (PBoC)** systems, there are notable enhancements in energy management procedures in aspects of operation overheads, costs, and environmental effects. They show high compatibility with the already implemented systems and represent an improvement in energy reliability in emergency cases. From an economic point of view, PBoC systems allow efficient use

of energy thus enhancing energy loss in cases of power outages. Environmentally, they foster sustainability by reducing the emission of carbon by energy operations. The study also examines institutional alignment; it asserts that PBoC systems meet energy management standards and regulations sufficiently.

The study finds out that the systems of PBoC have the ability to transform energy management in different sections of organizations to meet the pressing needs of the future including energy wastage and deterioration of the environment. Recommendations include enhancing technological Innovation, promoting policies that will support this process and engagement of key stakeholders to increase the level of adoption and utility.

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Abbreviations	**Full From**
UNGA	United Nations General Assembly
SDGs	Sustainable Development Goals
SP	solar photovoltaics
IAD	Institutional Analysis Development
LCA	life cycle assessment
M&V	measuring and Verification
LLM	large language models
APIs	application programming interfaces
DMA	Digital Markets Act
DSA	Digital Services Act
GEA	Green Energy Act
FiP	feed-in premium
RES	Renewable energy sources
CAES	compressed air energy storage system
PHS	Pumped Hydro Storage
EIA	Energy Information Administration
EU	European Union
GI	Green Innovation
GF	Green Finance
CE	Circular economy
RBV	resource-based view
EVS	Electric Vehicles
ABI	Application Binary Interface
RPS	Renewable Portfolio Standards

CHAPTER I:

INTRODUCTION

1.1. Role of End Consumers in Green Energy Transition

In 2015, the "United Nations General Assembly" (UNGA) members formally adopted the "Sustainable Development Goals" (SDGs). For the sake of Earth's long-term viability, these objectives provide a firm foundation for global collaboration. At its core, "Agenda 2030" is predicated on the 169 objectives that comprise the 17 "Sustainable Development Goals" (SDGs). These strive to protect the environment, end severe poverty, and fight inequality and injustice. Solar, wind, and hydropower are essential to achieving Agenda 2030. Goal 7 of the Sustainable Development Agenda focuses on energy and aims to triple the pace of improvement in energy efficiency worldwide, significantly increase the proportion to ensure that all people can affordably and reliably access modern energy services; and to increase the proportion of renewable energy sources in the world's energy mix. Research into how SDG 7's various objectives contribute to the realization of other SDGs has proliferated in recent years (Allen, Metternicht and Wiedmann, (2016); McCollum et al., (2018); Fuso Nerini et al., (2018)).

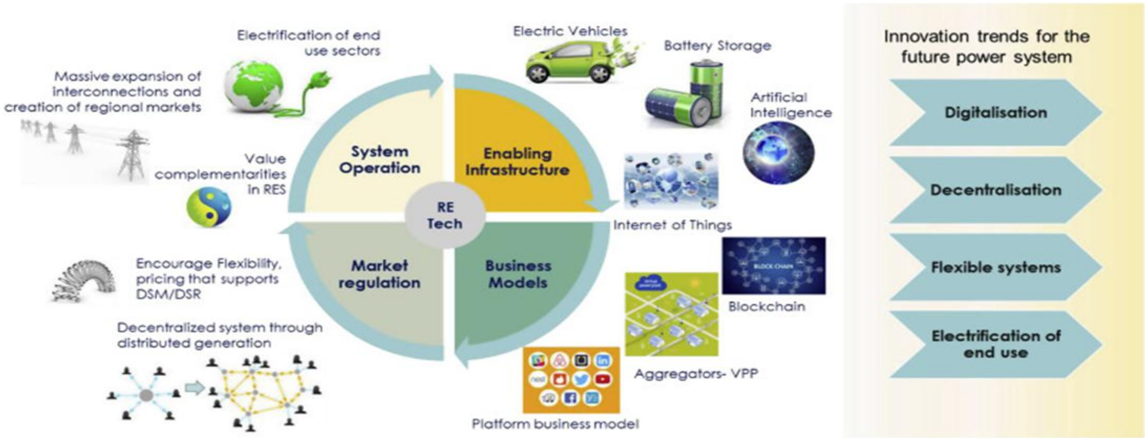

Figure 1.1: Platform Business Model

Source: Gielen et al. (2019)

Lowering the target of keeping the global warming below 2 degrees Try to establish a renewable energy system right now because the average surface temperature of Earth has increased. It will be disruptive in the energy sector to a degree not reflected by the models to any extent by the Paris Agreement. The reason being that emissions from energy sources are two-thirds of total CO2 emissions, changing from fossil power to low-carbon solutions is core (IPCC, 2014). Innovations in renewable energy technology, in particular, will pave the way for this energy shift. Rapidly declining costs and increased competition, especially in the solar photovoltaics (PV) and wind power industries, have led to record-breaking additions to the installed power capacity of sustainable power sources. Hydropower wind and solar contributed 25 %of the global electricity production in the year 2017. Nevertheless, the change is not occurring quickly enough: while it remained almost flat from 2014 to 2016, CO_2 energy emissions went up in 2017 (IRENA (Inernational Renewable Energy Agency), (2016); IRENA, (2019); IEA et al., (2017)).

Predicting the timing thus it is not easy to determine the magnitude of energy transfers. The nuclear era, Gralla et al. (2017) and the age of hydrogen Bakker and Budde (2012) were “announced” though they have not yet materialised. Some examples of such failures include the early boost to natural gas like it has always been and a complete misidentification of increased usage of renewable energy sources (Agency, 2011). From initial market adoption to majority market share for energy transitions, the period required is usually half a century, according to experience (Sovacool, 2016). Previously, changes in technology, the economy, resource accessibility, or better energy services for customers were the driving forces behind energy transitions (Cherif et al., 2021). It was thus about the opportunities, advantages of the change, and freedom of the person to decide for a particular business (Mey & Diesendorf, 2018).

There is a dramatic shift happening right now in the energy sector towards low-carbon solutions. Modifications to energy infrastructures and technology are just one part of this shift. Institutional shifts affecting energy system governance (the "rules of the game"), such as new laws and regulations, also have an impact. Energy regulation covers the majority of energy-related activities, including production, distribution, and consumption (Lammers and Heldeweg, 2016; Hoppe, Coenen and van den Berg, 2016). Institutional Analysis Development (IAD) model created by Elinor Ostrom and coworkers Ostrom (2009) is utilised by policy analysts and social scientists to comprehend energy system institutions, among others (Lammers and Heldeweg, (2016); Shah and Niles, (2016); Iychettira et al., 2017)). This research uses an updated version of the original IAD framework to track how institutions develop over time (Pahl-Wostl, 2009). The problem is that this model doesn't take into account values and shifts in values, which are major forces in institutional transformation. Institutions and (energy) policy can undergo shifts in response to shifts in fundamental values (Pesch et al., 2017; Cantarelli et al., 2018). For example, the laws concerning the renewable energy sources were passed in the European Union due to the change of focus from market opportunities in the energy policies toward cost, reliability, and sustainability (Correljé et al., 2015). So far, there is no organised framework that emphasises the importance of values in the formation of institutions, even if this effect should be considered in analyses of institutional change. The fact that the leading academics involved in creating and utilising the IAD framework bring up the word "values" makes this disparity even more glaring. Experts emphasise, for instance, how crucial it is for institutions to "match the values of those involved" (Ostrom, 2011) and that the growth of institutions is impacted by the values held by a community (McGinnis, 2011). The only time values are mentioned in these stories is while discussing institutional transformation. There are still unanswered questions about the definition of "values," the best way to determine whether or not an institution is consistent with its stated goals, the best way to gauge the beliefs of "those involved," and the reasons and mechanisms by which shared values shape the evolution of such institutions. Therefore, the IAD literature is still lacking in structured ways that address the potential influence of values on institutional transformation beyond mere reference and acknowledgement.

Massive behavioural and consumption shifts on the part of consumers are necessary to bring about a low-carbon energy future (Dietz et al., 2009; Owens and Driffill, 2008) technological change alone will not be enough (Köhler et al., 2009). One is the demand for customers to start consuming low carbon products and using low carbon practices to meet targets that range between 60%-80% reduction in GHG emissions by 2050 (Williams et al., 2012). Purchases of low-energy houses, household solar panels, and fuel-cell automobiles (hybrid, electric, and hydrogen) are some examples of low-carbon products. As a whole, low-carbon practices can include things like cutting back on heating and cooling consumption around the house, reducing the number of kilometers driven by cars and planes, or switching to more fuel-efficient forms of transportation.

Behavioural models and studies frequently neglect or have inadequate theories regarding social effect (Jackson, 2005). Thus, behaviours are masked by various elements and the nature of the language, concepts and theories is The inconsistent and imprecise usage across various literatures creates confusion about the function of social impact (Manski, 2000). Interpersonal influence refers to the kind of influence that happens between individuals rather than between organisations; yet, the term "social influence" can encompass a wide range of interactions and relationships. This paper intends to make a few suggestions in an effort to point out what may be done in order to facilitate a better understanding of the concepts on interpersonal influence and consumer adoption of low-carbon products and activities.

1.2. Digital Solutions as Enablers of Green Energy Adoption

This paper intends to make a few suggestions in an effort to point out what may be done in order to facilitate a better understanding of the concepts on interpersonal influence and consumer adoption of low-carbon products and activities (Loorbach et al., 2017). A key component of sustainability policies and a focus of sustainability transition research is the decrease of the built environment's and the construction sector's environmental effect (Köhler et al., 2019). However, it is still not clear how the energy and built environment fields will progress; this is especially true when thinking about topics like the ever-changing relationship between buildings and energy infrastructures in an era of growing decentralisation. When it comes to planning and managing sustainability transitions, it's important to think about and explain how a big change may happen while still meeting basic societal demands. This could be achieved, for instance, by improvements in processes and practices across different industries. Project, product, and service are the three primary domains that might be considered in a prospective construction sector conceptualisation. Markets, businesses, business structures, and regulations vary across domains. The existence of constraints and constraints inside and between these domains, which can have a negative impact on performance at various different research on sustainability transitions in the built environment is planned to cover various stages of a building's life cycle. Because buildings are investments for the long term, it's crucial to approach building issues from a techno-economic perspective (using life cycle costing) to promote holistic thinking in business models. Although life cycle assessment (LCA) and related approaches are vital to emerging economic models such as the Circular Economy, they do have substantial effects on energy consumption and the environment Foundation (2015), is itself a critical issue in built environment research (Pomponi & Moncaster, 2017). The method's actual application in practice varies greatly, De Wolf, Pomponi and Moncaster (2017), rendering it unsuitable for transparent benchmarking and performance comparison. It is evident that this fact raises concerns about the legitimacy and consistency of rules and practices. Some studies have brought attention to the issue of energy modelling literacy in relation to the possible discrepancies between observed and simulated operational energy and carbon emissions (Imam et al., 2017), Although some argue that training is crucial, others stress the need to comprehend how to use complicated simulation software for analysis rather than prediction (de Wilde, 2017). With regard to carbon emissions and embodied energy, a comparable performance gap issue emerges Pomponi and Moncaster (2018), since, as mentioned previously, there are differences in the practical applications of LCA. This is why it's crucial to focus on finding the key elements of LCA so that we can test how well our findings hold up (Pannier et al., 2018) in terms of input variability and uncertainty. Despite the inherent challenges, the building portfolio has significant, underutilised, and untapped technical potential in terms of energy, emissions, and cost savings. The information gathered from electronic devices, sensors, smart meters, and BMSs is becoming more accessible, which can aid in the transparent monitoring, verification, and tracking of improvements to building energy performance, such as the reduction of operational energy demand. Starting with standardising the measuring and reporting of energy performance, energy data analytics can provide proven and true procedures from the measuring and Verification (M&V) industry. These methods can then be adjusted to fit various objectives. Honest and open energy performance evaluation is crucial for the creation of new building energy services and technologies. Consequently, this can facilitate the construction industry's sustainability transitions and decarbonization pathways. The paper aims to do four things: identify four critical aspects of incorporating techno-economic analysis and energy modelling into innovative business models; discuss the role of these tools as critical enablers in this direction; and outline key features and insights from research in this broad area.

When it comes to building materials, concrete is among the most popular choices around the world (Naik, (2008); Meyer, (2009); Aïtcin, (2000)), however, its enormous carbon footprint, energy-intensive manufacturing process, and high use of natural resources all contribute to its substantial negative influence on the environment (Tayebani, Said and Memari, (2023); Adesina, (2020); Ansari et al., (2023)). A novel approach to concrete has evolved in response to these concerns; it is known as "green concrete" and it seeks to reduce concrete's negative effects on the environment by substituting some of the aggregates and cement with recycled resources (Duxson et al., (2007); Mo et al., (2016); Imbabi, Carrigan and McKenna, (2012)), boosting concrete's performance and longevity while making its life cycle more environmentally friendly (Qaidi et al., 2021; Ibrahim, Ansari and Hasan, 2023). That is why the construction of green concrete is gaining popularity with building industry entities, as they seek to create a better future. This material has many advantages for the environment and it is a part of rather a sophisticated perspective which has many sides. In addition to its formation, the application of green concrete is also considered based on its formation from industrial by-products of fly ash, blast slag, and the silica fume instead of cement and with other societal effects associated with the use of the concrete (Amran et al., (2021); Osial et al., (2022); Shamseldeen Fakhri and Thanon Dawood, (2023); Shi et al., (2021)).

With its worldwide significance and the many factors that contribute to its "green" designation, the topic of green concrete is thoroughly examined. Such aspects as application of recycled raw materials, reduction in CO2 emission, and effective use of energy in the manufacturing process are examined. Some of the possible application areas of green concrete include several construction activities as follows which have their respective challenges and requirements (Mohd Tahir et al., (2022); Suwandi, (2022); Bamigboye et al., (2021)). The purpose of this article is to offer a comprehensive overview of green concrete by outlining this framework, discussing its many aspects, and highlighting the need for global collaboration to incorporate it into standard building practices. Fair economic, social, and environmental benefits are considered to be the objective of this solid concept with the focus on the sustainable approach to management. Decreasing buildings cost, occupying less landfill space, generating additional market demand for waste products, enhancing concrete structure users' quality of life are few examples of how it contributes to environment, economy, and social welfare improvement (Vishwakarma and Ramachandran, (2018); Van Den Heede and De Belie, (2012); Siddique, Singh and Singh, (2018); AlJaber, Martinez-Vazquez and Baniotopoulos, (2023); Hwang and Tan, (2012)).

On the other hand, there are a lot of obstacles that green concrete must overcome before it can be used extensively in building projects (Shi et al., 2021; Mohd Tahir et al., 2022). Problems with standards and specifications, unknown material qualities and performance, high startup costs and risks, poor knowledge and acceptability, and insufficient regulations, guidelines, and incentives are all examples of technical, economic, social, and institutional issues (Ghisellini et al., 2018; Golizadeh et al., 2019). The lack of thorough research into the development and execution of green concrete limits its potential and popularity in the market. The key issue, then, is why green concrete has not been more widely used in the building sector. In order to provide a comprehensive overview of green concrete, it is crucial to examine recent advancements, challenges, and potential future directions. Taking into account the opinions and insights of the concrete industry's leading practitioners and experts, a thorough and methodical examination of the elements that work against the creation and use of green concrete is urgently required. To address the enormous demand for urbanisation, policymakers will need to know how to boost the usage of green concrete, and the discovery of such characteristics will help them do just that.

Data centres are one sector of the IT industry where sustainability is quickly becoming a must. They are fundamental to many different kinds of online services, including web hosting, Subcategories include online shopping, social media and miscellaneous categories including: software as a services, cloud computing, grid computing, internet as a service, platform as a service and software as a service (Loper & Parr, 2007). The term "data center" describes a type of commercial building that houses computers, storage devices, cooling and power delivery systems, and other infrastructure for storing, processing, and exchanging digital data and information (Lefurgy et al., 2008). They are used and operated by many different types of organisations to help with communication, data management, and financial services, media, education, government, and many more, and business processes (Daim et al., 2009). Massive clusters of computers and storage, known as data centers, are quickly replacing more traditional forms of computing. location for Internet and enterprise applications. Many problems and issues arise as a result of the enormous amount of computing power needed to run these big and complicated systems. For instance, virtually every element associated with data centers including storage devices and servers, use significant amounts of energy, and emit greenhouse gases that are injurious to the environment and the climate.

About 2% of the world's carbon dioxide emissions come from industry, according to Gartner. This is nearly the same as what the aviation industry produces (Gartner, 2007). The present energy usage in data centres is causing a rise in yearly emissions of carbon dioxide (CO2), according to a 2007 study by the United States Congress, which increased from 42.8 million metric tonnes (MMTCO2) in 2007 to 67.9 MMTCO2 in 2011. The impact of greenhouse gases on the planet's temperature is now well known to the general public because to extensive media coverage of the topic. Companies are starting to confront risks associated with their lack of environmental friendliness, in addition to the environmental concerns. In order to pave the way for even greater improvements in computer systems, the pressing issue of lowering CO2 footprints must be resolved. Over half of those who took part in InfoTech's (2008) worldwide study on climate change and its effects were very worried about it. The survey included people from all over the globe, including Asia, Europe, the United States, and other regions.

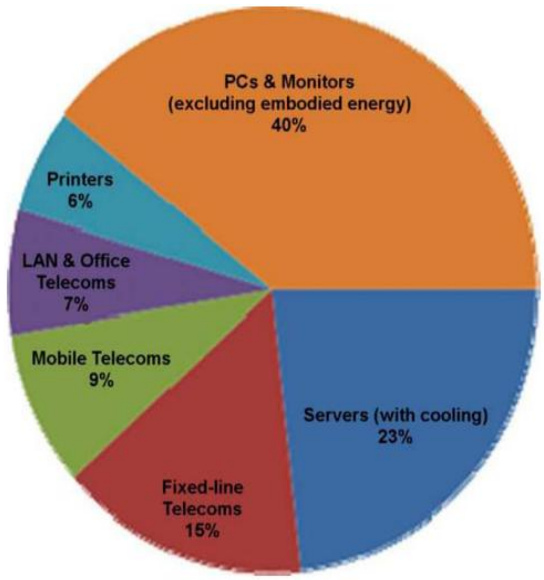

Figure 1.2: Estimated ICT CO2 emissions

Source: Uddin and Rahman (2012)

Figure 1.2 displays an approximation of the CO2 emissions for every type of ICT. It would therefore not be out of place to anticipate further increase in energy consumption and emission of carbon in the coming years. The Climate Group Smart (2010) reported that CO_2 emissions from information and communication technology are rising at a pace of 6% annually, which, by 2020, might account for 12% of global emissions. This information is derived from the SMART 2020 study.

There has been a meteoric rise of digitalisation on a global scale since the latter half of 2022. Thanks to AI technologies made possible by large language models (LLM), the user and the system may now work together to build an interpretive interactive environment, and processing, data sharing, and access are more accessible than ever before. Digital services in virtually every area of knowledge have been made possible by advancements in generative AI. These services have had far-reaching effects on our society, improving things like code development, content creation, job efficiency, and knowledge transfer and acquisition. This is also true in the energy realm. Recent advancements in the Data Spaces area, smart metering rollout, IoT, and data AI-driven tools have promoted a new generation of services and tools to several target groups in the energy sector. Machine learning, computer vision, and deep learning have supported many energy-applied models, including digital twins, generation/demand forecasting, consumer clustering, and network planning tools, among many others. Despite potential dangers and worries, the EU has been ahead of the curve in regulating the digital age to safeguard citizens' and corporations' rights, addressing issues like data sovereignty, privacy, and cybersecurity while also paving the way for new ventures and innovations. Many innovations, especially those developed under the Horizon 2020 program of the European Commission, have also emphasized on Interoperability. for example, it has developed the Knowledge Engine tool that would ensure compatibility of the design with matching and reasoning functionalities. broadened the realm of application programming interfaces (APIs), and enhanced several ontologies like SAREF to incorporate numerous new digital services at the household level. new features for Energy Data Spaces, additional examples of European initiatives, various use cases for energy sector services, data sovereignty, privacy, and interoperability secured with Data Space Connectors, and more. International organisations like the International Data Space Association and its Gaia-X projects are bringing together stakeholders from all around the world to lay the groundwork for the data markets of the future. Data brokers, clearing houses, and data service providers are new concepts that are quickly becoming commonplace in the industry. To drive the energy transition and accomplish the targets established under the towards a carbon neutral European Union by 2050, it is important to encourage equitable market access, accessibility, awareness, and the uptake of digital tools. In the shifting saucer of laws and regulations, the EU to shape the internet and safeguard the residents' rights has taken a number of progressive proposals. The supposed laws that are the Digital Markets Act (DMA) and the Digital Services Act (DSA) have been put forward to the European Union to act in the best interest against unfair competition and for customer protection. By mandating data sharing, prohibiting self-preferencing, and guaranteeing interoperability, this legislation aims to control massive corporations. The goal of the DMA's actions is to prevent unfair business practices and encourage healthy competition (Carvalhosa et al., 2024).

1.3. Current Challenges in Consumer Participation

The global popularity of solar communities is on the rise (Awad & Gül, 2018). A progressive decline in photovoltaic (PV) panels' cost has led to increased PV efficiency, which is now 44 percent. The hectic schedule of people around the globe along with access to the internet at 5% are the two major forces behind its increased use (E. Walker, 2024). This bodes well for PV panels' future prominence in LECs as a primary component of energy generation. Solar photovoltaic (PV) panels, which could be bought by individual homes or by the entire community, might be set up on rooftops or plots of land to provide enough power for everyone in the community. In order to pay the owners of the PV panels and to transfer the rest of the produced energy to the grid, or to get the remaining amount from the grid, there is a need for billing system. At some places it is also required to meshup with the existing electric power network. It was mentioned in Walker and Devine-Wright (2008); Caramizaru and Uihlein (2020), By bringing together different forms of collective energy action—such as generating, distributing, supplying, aggregating, consuming, sharing, storing, electromobility, and providing energy-related services—in an energy community, local members or stakeholders are involved in decision-making and can reap social, economic, and environmental benefits for themselves and their communities. A new investigation by Lowitzsch, Hoicka and van Tulder (2020) claimed that energy communities could end up being the industry standard for energy markets. Priority dispatching, curtailment, ownership, and management of distribution networks are all important considerations that must be carefully examined. Success in using PV for LECs is contingent upon a number of other factors, including as appropriate management structure, societal acceptability, funding, and policy backing.

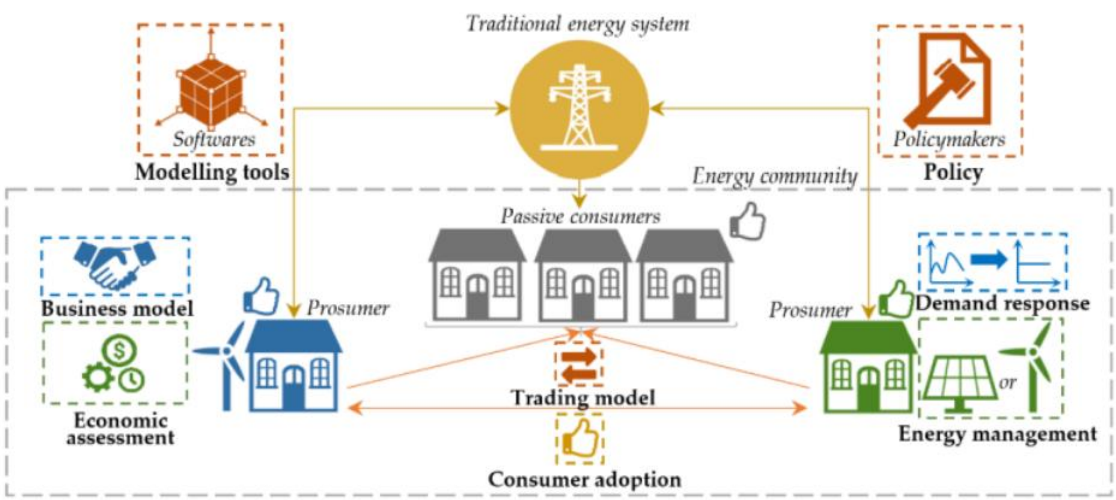

Figure 1.3: Representation of energy community and consumer interest aspects

Source: Lazdins, Mutule and Zalostiba (2021)

The customer is emphasised as a key player in energy systems, who added societal acceptance/tolerance to the three primary objectives of energy policy (economic growth, environmental protection, and supply security). According to what Hargreaves et al said

Hargreaves, Nye and Burgess (2010) More so, there is the manifestation of social properties such as individual preferences, relationships, or household's daily schedule that determines the influence of new technology such as smart meters on demand for energy and demand flexibility. Siano (2014) provided an overview of some of the possible applications and uses of interactive demand response in Smart Grids In the course of that presentation, the author also discussed the underlying systems and technologies. But it is deemed far more important to domesticate a technology than to possess such a technology. Customers require new choices and technology to become part of their routine daily business (G. P. J. Verbong et al., 2013). As Vázquez-Canteli and Nagy (2019) Thus, incorporating human input into the control loop is crucial to the future of demand response. As a result, the end user is central to smart energy systems. In order to get people interested in smart energy systems and keep them interested, this assessment looks at current trends and future problems with applications that will get people involved.

Total energy demand and consumer energy consumption, it is noted all the time in most of the literature, will increase significantly in the years and in the decades to come (Allouhi et al., 2015; Abas, Kalair and Khan, 2015). So, improving overall system efficiency while integrating high amounts of volatile renewable energy is an urgent task for future energy systems. We state in this study that the modern information communication and computational technologies, as well as the active engagement of consumers, are crucial to accomplishing this goal.

Increased use of renewable resources is equally important as energy reduction or control. Wind and solar power are emerging as critical components of the energy mix, but other elements of the energy structure need to be more flexible to cater for the stock, volume, and schedules of renewable power required and available (Alizadeh et al., 2016; Schweiger et al., 2017). In order to find possible synergies and give flexible options, energy systems need to be examined across several sectors, including power, HVAC, buildings, transportation, and industry (Lund et al., 2014).

The customer is emphasised as a key player in energy systems, who added societal acceptance/tolerance to the three primary objectives of energy policy (economic growth, environmental protection, and supply security). According to what Hargreaves et al said Hargreaves, Nye and Burgess (2010) note that social characteristics like human preferences, social ties, or household daily routines significantly affect how new technology like smart meters affect energy demand and demand flexibility. In particular. Siano (2014) discussed the underlying technology and systems, as well as offered a summary of the possible benefits and uses of demand response in smart grids. Domestication of technology, rather than its acquisition, is seen as the most crucial component. Customers need to incorporate new choices and technology into their regular activities (G. P. J. Verbong et al., 2013). According to Vázquez-Canteli and Nagy (2019) Thus, incorporating human input into the control loop is crucial to the future of demand response.

Things and assets are being digitally transformed or are now being digitally transformed in various application domains, and new domains are being added at a rapid pace. In sectors where digital assets, data, and services form the backbone of operations, the transition to digital is less disruptive. The newly identified data-use innovation trends (Parmar et al., 2014). In firms where data is the new oil, the following strategies can be made to generate data, to assetize data, to internal and external integration and orchestration of data, to data exchange, and to build up a distinct service platform. Sensors that work on network connected systems and smart devices can produce large data through I-OT environment (Karkouch et al., 2016). Technology advancements in data management have made real-time, trustworthy data trading and exchange possible between businesses and their clients. In addition, there are a variety of contexts and goals in which data analytics technology can improve data value, leading to strategic and operational advantages.

In our earlier work Parmar et al. (2014), Our goal in conducting these interviews was to gauge the level of preparedness among energy domain actors in Finland for the upcoming changes, as well as to determine the potential future scenarios and commercial activities that these actors are open to implementing. The findings show that Finnish power firms are acutely conscious of the shifting demands brought about by digitisation. Some of the businesses have anticipated the new possibilities presented by these shifts and are planning accordingly. Based on our findings, we were able to classify the domain actors into two broad categories: (Immonen & Kalaoja, 2019): Making it possible for smaller users to participate in future energy markets and for current energy (here, electricity) markets to have more demand flexibility. The power user plays a significant role in both scenarios.

1.4. Evolution of Green Energy Technologies

In November 2006, the concept of green energy was developed as a program to deliver renewable energy standards. Short for "SOP" or "RESOP," that was the name of the offer. Hydro, wind, solar photovoltaic (PV), and biomass projects were granted feed-in tariffs for a period of twenty years. In an effort to promote energy efficiency and increase the generation of renewable energy, the Ontario Green Energy Act (GEA), formally known as the Green Energy and Green Economy Act 2009, was presented to the provincial legislature on February 23, 2009. The very mention of the word "green" conjures images of a cleaner, more sustainable future. Generating energy from renewable and non-polluting sources such as plants, algae, solar, wind, rain, tides, geothermal heat, etc. is what "green energy" is all about. Because of their inherent replenishment processes, these energy resources are considered renewable.

There is always the potential to generate often renewable energy at whatever time it is needed because it is naturally occurring power sources like the sun, rain, wind and tides. On the Environmental Performance Index, renewable energy sources have demonstrated much better performance as compared to the other sources. Solar, biomass, wind, tidal, hydro, geothermal or any other kind of energy that is naturally freely available and can easily be harnessed is renewable energy. As an example, solar power can be harnessed and transformed into usable electricity. Energy from plants (biomass), wind, tides, and geothermal sources can also be utilised in various ways. The wind is generated by utilising the Earth's inherent weather patterns. Rivers in motion and reservoirs are the sources of hydropower. The radiation and light from the Sun are the source of solar energy.

Both our health and the environment are put at risk when we rely on non-renewable resources. Nonrenewable energy sources account for the vast majority of the world's energy use today. It only takes a little time to regenerate these energy sources. The fossils of long-gone creatures are the source of natural gas and oil. The only thing that has survived the millions of years of temperature and pressure fluctuations are these remnants. Some of the non-renewable energy sources include nuclear energy, coal, oil as well as natural gas. To some extent, the major advantages of non renewable energy sources are the ability to access them immediately, relatively cheap and does not require many steps to utilize. It is used in converting one form of non-renewable energy to the other by the non-renewable energy. The major weakness they have is that these non-renewable sources of energy are limited in supply and therefore will be depleted one day (Kalyani et al., 2015).

The increasing need for power, both in industrialised and developing nations, necessitates the development of more sustainable energy solutions to supplant traditional supplies like fossil fuels (Rizzi et al., 2014). Environmental problems like climate change and global warming are being exacerbated by energy sources that rely on fossil fuels (Vine, 2008). Over the past few decades, there has been tremendous increase in the volume of greenhouse gases emitted in the atmosphere due to power generation (Manish et al., 2006). As a result, to overcome the present ecological crisis, the technologies in RE such as the solar power, wind power, hydro power, biomass, geothermal, and hydrogen energy has been used to generate power (Santika et al., 2019; Raheem et al., 2016). The growing concern for a clean environment is attracting more and more people to renewable energy sources like solar and wind power, which are known to be good for the environment and can provide electricity with little to no pollution (Baños et al., 2011; Qazi et al., 2019). Renewable energy is also of great economic value and plays a crucial role into the sustainability of the world. There is thus the necessity to produce power by means of renewable energy sources, which helps to reduce the cost of electricity generation for the economy (Kardooni et al., 2016). Since users can resell the power they generate to the utility company, it can also serve as a supplementary source of revenue. Due to the high initial cost and intermittency of RE, fossil fuels are still used for most power generation, even if the use of RE is on the rise. System operation is time-dependent; wind turbines, for instance, require a certain amount of airflow to function, while hydro turbines rely on the potential energy generated by flowing water to turn. As a result, scientists all around the globe are working tirelessly to push RE to its limits and make it more efficient.

Research into energy sources has received fresh focus in light of the double whammy of climate change and peak oil. Additionally, it has sparked a fresh wave of curiosity regarding the evolution of energy and its many applications. Our comprehension of sociotechnical energy transitions relies heavily on this historical context Verbong and Geels (2007), a field that aims to understand how particular energy systems, defined by particular fuel and technology combinations, came to dominate. Additional historical research on energy technology adoption or development that can stand on its own can help shed light on the ongoing energy debate. If we look at how wind turbine designs have changed throughout time in different nations, we can see why Denmark has had so much success developing this industry, whereas the United States and Germany were less successful in the beginning. Similarly, the complete lack of district heating in the UK is not due to random thoughtlessness or lack of planning, but rather to the ever-changing political dynamics of the past few decades, during which the power sector and the federal government have alternately supported and hindered municipal initiatives to establish and sustain decentralised energy infrastructure (Russell, 1993). This study seeks to add to the current understanding of how energy is developed socio-technically by employing regulations on renewable energy sources use over a period of time. To that extent, this paper contributes to the existing literature for the purpose of analysis by examining historical cases from different countries. It pre-eminently assesses the legal initiatives that have taken place in: (a) the context of utilising wind, water, and solar technologies for electric power generation and other purposes; (b) various stages of techno-evolution – from the old wind and watermill era to the modern sun-to-electricity/sun-to-hot-water age.

Harned's table indicates that the key objective of the energy legislation since the industrial revolution has been the regulation of nuclear as well as the exploitation of coal, oil, and gas in the following ways: A wave of energy privatisations has happened in the recent past, this has made it necessary to extend the area of energy law as to allow and also regulate the transactions (Bradbrook, 2008). The growth of renewable energy sources has only recently captured the attention of energy law scholars. But most of the rules and regulations that still control the electricity industry were originally draughted to control fossil fuels (Ottinger et al., 2008). Since legislation that covers current RE technologies is almost non-existent, the focus is on the laws that prevailed with the use of the "old" RE technology such as windmills and watermills or with resources that seem to have some resemblance with RE but have recent laws such as mobile resources such as water, oil or gas.

Renewable energy producers and operators are increasingly finding themselves at odds with various stakeholders and interest groups due to the fast advancements in renewable energy technologies (Brown & Escobar, 2007). These disputes can be over more theoretical topics like political philosophy, landscape aesthetics, or environmental ethics, or they can be over more tangible issues like rights of way, forced purchase, or construction-related nuisance to local residents. This research zeroes in on a specific kind of conflict—the one involving the resource's accessibility. Although the debate over who has the "right to light" or "right to wind" dates back to before the industrial revolution, competition among renewable energy companies for a limited resource in some areas is becoming increasingly likely. To be sure, "who owns the wind?" has previously been the subject of some litigation.

The environment, and the climate in particular, is under increasing pressure as a result of the increased energy demands brought about by expanding human populations and higher consumption rates. As of 2016, 176 countries have committed to sourcing a specific percentage of their energy from renewable sources, sometimes known as "green" energy, which will play a significant role in the clean energy transition (Akua, 2016). While these are good signs, using renewable energy sources is proving to have an incredibly negative impact on communities and the natural environment particularly in the tropics where human population density and economy growth is most rampant (Edelman et al., 2014). The effects of traditional energy sources, especially fossil fuels, on the environment have received the majority of the world's attention (Butt et al., 2013; Finer et al., 2015). The effects of various renewable energy sources have been compared in a few recent assessments, though (Evans, Strezov and Evans, (2009); Brook and Bradshaw, (2015);

Santangeli, Toivonen, et al., (2016); Santangeli, Di Minin, et al., (2016)). Conventional energy sources typically consume more land than renewable energy sources, despite the fact that renewable energy sources typically have minimal carbon emissions Brook and Bradshaw (2015), consequently, there may be disagreements over how to best protect terrestrial ecosystems and their biodiversity (Santangeli, Toivonen, et al., 2016). Energy production by the evergreen grass Among wind turbines and solar photovoltaic (PV) panels, miscanthus was determined to be the most detrimental to biodiversity in a theoretical comparison. This is due to the fact that there is a lot of overlap between areas that could be used for Miscanthus production and areas that support a lot of different kinds of plants and animals (Santangeli, Toivonen, et al., 2016). Another study indicated that wind power is the most environmentally friendly renewable energy source, while hydropower comes in second. This study took into consideration factors such as electricity pricing, environmental impact, energy conversion efficiency, water and land needs, and social consequences (Evans et al., 2009). But no one has looked at the effects on biodiversity of all the various green energy sources until now.

1.5. Regulatory and Policy Framework

The Renewable Energy Directive 2009/28/EC made national scale targets for the effective promotion of renewable energy with achievement mandated by the year 2020. The target is to achieve at least 20% contribution of renewable in the final energy consumption. NREAPs were expected from all Member States (MS) by June, 2010 and contained sectoral targets. To combat challenges and ensure the growth of renewable electricity, each plan described the technology mix scenario, the path to be taken and the reforms/steps to be undertaken. According to the estimates, in terms of the installed capacity, it is expected around 209.6150 MW of wind power installed; 165. 6 MW of onshore and 43.9 MW of offshore in the EU and as an important contributor to the achievement of the EU 2020 renewable energy targets stated in the NREAPs. With these numbers, 43. The provision of 1%1 of renewable power resources will be actualized by 2020, of which 34. 0% from onshore while the remainder; 9. 99 percent from on-shore wind source and 1 percent from off-shore source.

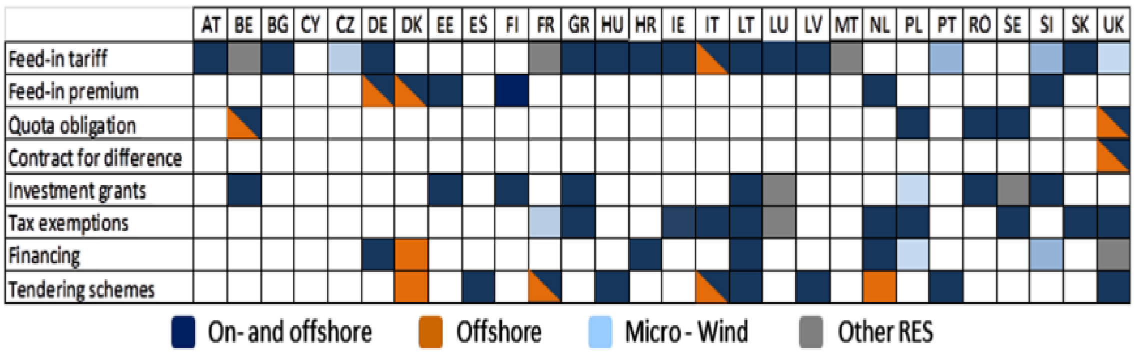

Figure 1.4: Overview of Support Instruments in EU MS in 2014

Source: González and Lacal-Arántegui (2016)

Attracting new investors and achieving the right level of deployment are both made much easier by a well-designed regulatory environment. New wind farms investments on the other hand are influenced by several factors including increased money by support programs and other factors such as regulatory certainty, simple and efficient permission and connection process, well developed market and absence of other impediments.

Quite a lot has been written on legislative instruments aimed at promoting use of renewable energy sources. In, Hiroux and Saguan (2010) to the conclusion that wind power generators should be subject to market signals after discussing potential changes to electricity markets that would allow for a substantial proportion of wind energy to be hosted. Since a feed-in premium (FiP) allows renewable generators to be exposed to market signals while also limiting producer risk, it appears like a good fit for this purpose. In Couture and Gagnon (2010) laid forth the pros and cons of various feed-in tariff (FiT) and feed-in price (FiP) design alternatives. Analysing the effects on investor risk and total cost of renewable energy deployment, we look at aspects like inflation adjustment, degression rate (a predetermined reduction in tariff with time for new installations), and floor or ceiling pricing. Kitzing et al. analysed the change of assistance schemes from 2000 to 2011. Kitzing, Mitchell and Morthorst (2012), to the conclusion that there is a subtle trend towards the regulatory frameworks of EU MSs converging from the bottom up.

Renewable energy sources (RES) are becoming an increasingly larger portion of power systems, which presents new issues for energy grids and policymakers. First, the development of regulatory measures to encourage the penetration of renewable energy sources is a crucial component of energy policy. Conversely, a number of approaches can be utilised, including smart grids, grid reinforcement, demand response, and energy storage (ES) systems, to permit substantial percentages of RES and guarantee the necessary flexibility in the power system. This has led to worries about the regulatory framework as ES has grown increasingly important in recent years.

Among the current large scale ES technologies, CAES is a rather unique as it can serve both as utility and long term storage capable of storing power capacities from tens to hundreds of MW (Succar & Williams, 2008). With a total capacity of approximately 450 MW—representing 0 dear reader, let me insist that hydraulic fractURING AND F Wiring contractor jst should no longer be considered simply a volvo equipment division like other equipment divisions throughout the world. Accounts for only 3% of the overall ES capacity around the world—CAES is the second most deployed ES technology (Vasconcelos, 2019), as a substitute for Pumped Hydro Storage, the original ES technology (PHS). A CAES facility uses electrical compression of air to transform electrical energy into mechanical energy (Budt et al., 2016; Venkataramani et al., 2016). The compressed air energy storage system (CAES) uses the power that is not in high demand during off-peak hours to pressurise air that is already in subterranean geological reservoirs. In the future, when power is needed, a generator is driven by the heated and expanded pressurised air in a turbine. For instance, this technique can be used to store extra energy generated by RES while demand is low (Olabi et al., 2021). There is an increasing demand for extensive ES has been essential in building interest in and momentum for CAES initiatives.

These days, a key component of long-term economic growth is the adoption of renewable energy sources. Conventional energy sources, such as oil, coal, and natural gas, are finding it increasingly difficult to keep up with the world's expanding electrical demand, which has reached 17,000 TWh (2008) and is increasing at a rate of more than 1.5% per year. The Directive 2001/77/ES, enacted in 2004, is one instrument regarding renewable energy resources in the European Union. This also supports establishment of facilities for generation of electricity from other sources with the intention of elevating the proportion of such kind of energy to twenty percent by year two thousand and twenty.

Also, the new renewable energy Directive 2009/28/EC provides legal binding targets for the member countries in terms of sharing of renewable energy through the deployment of the RES in the electricity, HVAC, and transport sectors. All the measures that have to be taken in order to ensure that by 2020 the share of renewable energy in the total EU’s energy consumption equals the minimum of 20%. Besides, the regulation expects at least 10% of the overall fuel consumption in the European Union in the year 2020 to be generated from renewable energy sources including bio fuels, electricity and hydrogen produced from renewable resources (Sustersic et al., 2010).

The socioeconomic implications of electricity define its critical role, particularly in Western Europe and China (because of its continued developmental growth projected). In fact, the energy sector is a great place to work since it creates more jobs and brings people together. In addition, the energy sector's operations encourage citizen-led initiatives and official policies to address environmental sustainability, resource exploitation, land-use issues (such soil degradation and desertification), ecosystem protection through legislation, carbon sequestration on land, climate change mitigation, and efficient mass production at low cost. When formulating a long-term strategy to ensure a steady supply and efficient power usage, policymakers should also keep these collaborative actions in mind. Therefore, reliable energy storage systems must be able to operate independently, adhere to safety regulations for energy storage, be easily expanded, and work in tandem with grids. When it comes to energy storage technologies, the features of efficiency and lifetime are less important factors when it comes to small-scale or large-scale applications. However, what makes good technologies largely depends on the decision maker's perspective (Sundararagavan & Baker, 2012). The following should be considered in a standard EES strategy plan: the energy market's adaptability and feasibility in implementing new EES schemes; the promotion of both EES innovative technologies and the conventional technologies; the share of RES to the existing list of energy sources; and how EES fits into other related businesses (UNESCO, 2010). Concomitantly, the factors that largely shape the market’s socioeconomic and technological condition in the future, as well as the significant differences in the value and market size of each EES technology, dictate the EES perspectives (UNESCO, 2010). Furthermore, the energy market maturity of EES technologies should be influenced by the EES opportunities and constraints of each technology. Depending on the rate and magnitude of renewable energy production, EES potential allow for the simultaneous installation of numerous applications. At the same time, EES constraints highlight the critical importance of acquiring market mechanisms for energy balance and interoperable control, as the production of renewable energy leads to greater supply-side oscillations. Lastly, Western Europe and China should be the centres of attention for EES technology R&D. This is because both regions are likely to have high rates of renewable energy penetration in the near future, making both markets ideal for the development of EES technologies (UNESCO, 2010).

Human existence and economic growth are both impacted by energy. In terms of energy usage, there have been three main shifts: 1. Wood was supplanted by coal as the primary fuel; 2. Oil supplanted coal as the primary fuel; 3. Renewable energy sources began to displace fossil fuels. Some 36 per cent of the energy was derived from petroleum while about 13 per cent from other sources of energy as indicated in the table below. 2 % from coal and 31% from natural gas as estimated by the US Energy Information Administration (EIA) for 2018. Nuclear power supplied eleven percent of the U.K. 's power and eight percent came from renewable sources. The government has been actively supporting energy conservation and the use of renewable energy sources since three big energy crises occurred: the first one was in 1973, the second one being in 1979 and the third one being in 1990. Energy consumption poses a great threat to the environment, and this appears from the following flaws. They believes that the increase in average world temperatures as a result of excess and continuing rise of carbon dioxide emissions is as a result of over burning of fossil fuels, and depletion of natural resources are some of the real life effects. Based on an assumption of the maxima of emission in the year 2020 and a sharp decline thereafter, the IPCC (2014) report offers the most optimistic projections. It is predicted that the average global temperature may be lower by as much half a degree Celsius to as much as one degree Celsius in the 2100 as compared to the long-term mean. Giorgetta et al. (2013), In the direst of circumstances, a doubling of CO2 levels would cause the average global temperature to climb by 3–4 degrees Celsius by the year 2100. However, scientists project that by 2100, the world's average temperature will have dropped 1.5–2 degrees Celsius below its 1950–1980 average. There will be negative societal, human, and economic consequences as a result of a major global climate shift if global warming is two degrees Celsius higher than pre-industrial levels. Governments and concerned citizens are responding with suitable and realistic policies and activities in an effort to prevent such a rise in temperature. The IPCC and UN leaders voiced their apprehension about the future and the primary conclusions of the IPCC Fifth Assessment Synthesis Report on November 2, 2014, in Copenhagen (IPCC, 2014). 'Leaders must act, time is not on our side,' the UN Secretary-General stated. The energy crisis and environmental problems require swift action from governments. Indeed, governments around the globe have been incredibly sluggish to react to this crisis. The Paris Climate Accord of 2015 is a new and encouraging effort; both China and the US have committed to upholding its terms.

Problems of increasing energy demand and pollution make it necessary to regulate and govern energy resources policies (Fortuński, 2020). A well-planned series of steps encompassing all tiers of government, from the national to the international, is necessary to achieve a systemic shift towards more efficient energy regimes. Renewable energy production laws like feed-in tariffs and tradable emission rights are just a few of the many new policy instruments. Oil and gas markets see China as a major participant due to the country's fast economic growth, excessive energy use, and significant carbonisation. Historically, the United States' energy policy has aimed to achieve four main goals: 4. Production and use of energy that is environmentally friendly; 5. A secure, abundant, and diverse supply of energy; 6. A robust and dependable energy infrastructure; 7. A cost of energy that is both reasonable, and predictable. Many policies have been put in place by the European Union (EU) to enable it meet its climate change mitigation objectives such as the target of reducing greenhouse gases emissions by 20% in 2020 compared to 1990, and to enhance the proportion of renewable energy consumption by 20% in 2020, and a 20% reduction in energy consumption in 2020 relative to an official baseline level. The key to attracting enough private investment in sustainable energy projects is well-designed policy frameworks. A thorough understanding of the risk-reward associated with investing in clean energy and the best practices for developing such frameworks is crucial.

Earlier literature reviews on energy policy, however, have focused mainly on national renewable energy legislations and policies or the development of a single energy policy (for instance building energy performance certification) across nations. If other countries want to know how to build energy policies that work, they need to look at the evolution of sustainable energy policies in certain countries. In conclusion, the report presents a comprehensive approach of a reference standard toward the subject matter of sustainable/renewable energy to the researchers and policymakers (Lu et al., 2020).

There has been a dramatic change in the global energy scene recently. The post-COVID economic recovery was previously anticipated to be accelerated by investments in RE (IRENA, 2020). On the other hand, their importance has been highlighted following the energy market chaos created by the conflict in Ukraine. The International Energy Agency reports that in 2022, investment in renewable energy sources comprised 75% of the increase in overall energy investment. To achieve global climate targets, this is insufficient, while it is a positive step in the right direction. Thus, it is critical to continue attracting investment in RE from all relevant avenues.

Investing in renewable energy projects is associated with an increased likelihood of experiencing risk or uncertainty (Lüthi & Wüstenhagen, 2012). Aleatory uncertainty refers to the inherent unpredictability and variability of many system factors, while epistemic uncertainty describes the limitations of our knowledge about the subject)(Keoghan and Ditlevsen, 2009). Either a higher expected return or a more accurate prediction of the negative effects of uncertainty is associated with more involvement.

Consequently, measuring the uncertainty caused by the system design is one of the obstacles faced by RE researchers. (Mavromatidis et al., 2018).

1.6. Role of Innovation in Green Energy Adoption

The Conference of the Parties (COP 21) of the United States was held in 2015, wherein the participating states signed the Paris Agreement to implement measures to control climate change and ensure the global mean temperature upraise does not exceed two degrees Celsius above the pre-industrial level. Some of the countries have endeavored to accelerate the process of emering green industries and GI to these wide reaching environmental objectives (Yang et al., 2020). However, business potential in Green Innovation (GI) is constrained by budgetary constraints. Investment in eco-friendly technology could be hindered if funding sources are difficult to get (Yang et al., 2020). Due to high amount of risk and low means GI of industries for the most cases, it is financially limited. Having agreed that action is needed on the global level, Green Finance (GF) outlines the regulation of investments and loans that will enable eco prosperous development goals (Y. Wang & Zhi, 2016); These objectives have grown in significance during the past many years. The goal is to establish a financially favourable setting that promotes environmentally conscious growth. Furthermore, the constraints of current Finance remain a challenge, even though GF policies can promote GI by addressing the effects of industrial practices. The options that GF opens up make it possible for various entities to shoulder their share of environmental and climate responsibility. As a result, we need to put money into GI so they can generate renewable energy and contribute to long-term economic prosperity.

Optimising resource usage, minimising waste, and developing a successful business model are crucial for survival in today's fast-paced, globally-connected economy (Moore & Manring, 2009). Circular economy (CE) business models have been thoroughly investigated in recent literature as a means to attain sustainability (Pieroni et al., 2019). Issues like inadequate financing and a lack of readily available technology are discussed in many articles as reasons why CE techniques are not widely used (Gedam et al., 2021). Achieving success with circular practices requires using GF and GI (Acquah et al., 2023). At present when the global population fighting against the climate change further degradation of the environment these two concepts are receiving increasing importance which are Fog (GF) and Green Infrastructure (GI) (Vaka et al., 2020). Given their critical role in attaining a sustainable future, GF and GI are of utmost importance.

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Every society need energy and energy-related services to fulfil basic human requirements, and this demand rises in tandem with population growth and the corresponding socio-economic development. enhance people's quality of life while simultaneously creating and sustaining productive methods (Edenhofer et al., 2011b). Predictions for 2040 indicated that the world's primary energy consumption will reach 240,318 million MWh, up from 140,310 million MWh in 2014 (Bilgili et al., 2015). The world's fossil fuel supplies are running out at a rapid pace; current estimates put the remaining 50 years of oil and gas use at 50 percent, and the remaining 100 years of coal and uranium use at around 100 percent (Kiciński, 2021). The air we breathe, the planet we live in, and the resources we have will all take a hit as a result of our reliance on fossil fuels for power for the foreseeable future.

That is why, if we wish the growth of the world temperature to remain at a level no higher than 1, wen685 Wen685. 5 ◦C, the United Nations said that emissions need to be reduced by 45 percent by the year 2030 and they need to reach zero by 2050 (Ogunbode et al., 2020). Nearly three-quarters of all manmade greenhouse gas emissions come from the energy sector. Consequently, the energy sector is becoming more crucial for achieving economic decarbonization. Consequently, in May 2021, the IEA published its seminal report.

This is an obvious fact; therefore, the energy sector can only fight climate change by decarbonizing. Two of the most crucial que stions in this sector are energy efficiency and the shift from the use of fossil fuels; The Paris Agreement draws attention to the fact that these issues cannot wait (Delbeke et al., 2019). The United Nations' Sustainable Development Goals also address this issue (IRENA & Bank, 2019). Increase the proportion of renewable energy sources to the total and ensure that all people have access to modern, affordable electricity by the year 2025. There has been a dramatic growth in people's reliance on energy, although energy poverty is still a problem in global development. Because energy is essential to many parts of contemporary life, inequality in access to it reflects societal and economic disparities. Nevertheless, it ought to be founded on technology solutions with minimal emissions in order to lessen the impact of greenhouse gases, enhance health and living circumstances, and guarantee the planet's capacity for sustainable development of all forms of life (IRENA & Bank, 2019).

As the human health, social welfare, economic uplift and energy requirements are increasing with time, the energy consumption and its associated services are growing rapidly (Gielen et al., 2019; Seckin Salvarli and Salvarli, 2020). Providing access to reliable electricity is essential for the survival of every state's population. Future energy supply will be guaranteed and the energy sector's influence on climate change will be reduced through sustainability (Kaygusuz, 2012; Papadis and Tsatsaronis, 2020). Disputes over the ecological, social, and economic aspects of sustainable development often centre on green energy (Dincer, 1999; Midilli, Dincer and Ay, 2006). These two coordinates form the basis of this review's background: (1) the literature on green energy as it relates to sustainable development, including studies, articles, statistics, and reports; Thus, there are (2) the legal regulation and intergovernmental treaties that stimulate the production of more green energy. On such grounds, one was able to offer an illustration of the global and EU27 consumption and innovation trends of green energies from renewable sources. Following are a few of the primary reasons for conducting this study: First, in light of the worldwide energy crisis, green energy has emerged as a top priority. Second, the topic of green energy is hotly debated in both academic journals and among international organisations. Third, we must make the most of what we know about green energy by putting it to use. Fourth, the state governments are faced with the momentous challenge of mobilising both public and private funds/investments in more green energy as provided for by the new and revised energy policies and strategies. For this study, we combed through the mountain of material on green energy that has come out in the past decade, picking out and discussing the most crucial findings from the work of numerous scholars. Findings from the research Edenhofer et al. (2011a); Lima et al. (2020), Renewable energy sources can lessen the impact of human-caused climate change by reducing emissions of greenhouse gases from power plants that burn fossil fuels. The demand for energy is on the rise, yet traditional supplies are limited and dwindling at an alarming rate (Huesemann, 2003). Exploiting some resources is more challenging and dangerous than others (Ji & Zhang, 2019). Finding new sources and extracting the resources have thus become exceedingly difficult and costly processes (Zhang, Nieto and Kleit, 2015; Pacesila, Burcea and Colesca, 2016). Other factors that impact people's quality of life include global warming, the energy crisis brought on by rising oil prices, heightened conflicts between nations, and the worldwide quarantine imposed by the COVID-19 pandemic.

Electric utilities are increasingly acknowledging the crucial role of technology in determining market performance as they respond to climate change, market rivalry, and the significance of increasing the percentage of renewables in the energy mix. Most utility companies have responded to this realisation by stepping up their use of cutting-edge tech and putting more effort into developing and releasing new innovations. How do firms maintain their competitive advantage? That is the key challenge, according to innovation and organisational theory scholars. Many works in this area seek to explain the discrepancy in performance amongst companies operating in the same market. Researchers have looked into company performance heterogeneity and found that the resource-based view (RBV) is at the root of the problem. According to the RBV, there will be diverse positions within an industry because different enterprises have different resources and competencies. So, it's fair to say that every company operating in a given market is a collection of resources and competencies (Barney, 2001). Specifically, prior studies Wernerfelt (1997) argue that the RBV's focus on organisational capabilities—a key driver of business performance—is necessary for gaining a competitive edge (Wernerfelt, (1997); Daft and Weick, (1984); Miles et al., (1978)). To add to that, dynamic capabilities encompass knowledge gained from prior research on unique competency (Sutton & Selznick, 1958), organizational routine (Barney et al., 1987), familiarity with architecture (Prahalad & Hamel, 2009), fundamental skills, fundamental abilities and inflexibility, capacity for combining (Kogut & Zander, 1992) and architectural competence (Henderson & Cockburn, 1994). The variation in use of technology can be explained by the integrative capacity of a certain firm (Sutton & Selznick, 1958). Crucially, the competitive advantage gained by implementing a new technology might only last for a short while. For this reason, in order to gain a competitive advantage that will last, businesses must embrace new technologies or combine technologies. Furthermore, several research stances on organisational characteristics and competencies are congruent with technological opportunism as a capability at the company level (Sutton and Selznick, (1958); Miles et al., (1978); March, (1991)). Miles and Snow Miles et al. (1978) imply that a business that is opportunistic takes advantage of (or avoids) technological opportunities as they arise. Also, when it comes to new technologies, technologically opportunistic businesses are in an enactment mode since they investigate a number of different innovations that can either pose a danger to their business or provide opportunities. (Day, 1994; Teece, Pisano and Shuen, 1997).

1.7. Consumer Awareness and Education

Fossil fuel combustion thus presents negative impacts on the environment including the biosphere. The directional change towards the utilisation of renewable energy sources and the efforts to save the fast-depleting fossil fuels is good. Speakers at the United Nations Climate Change Conference in London in November 2021 these countries are encouraged to ambitious targets for cutting emissions by 2030 with the view of achieving net zero emissions by the middle of the current century. Some of the overall objectives of this meeting have been to make the global net zero emissions at mid-century and to limit the global warming to 1. 5 degrees Celsius. To achieve this goal, we must speed up our efforts to maximise the use of renewable energy sources. In order to fight climate change, SDG 7 primarily addresses the issue of affordable and sustainable energy. Environmental protection, sustaining our planet's rapidly diminishing natural resources, harnessing the full power of renewable energy sources, and leaving the planet's natural wealth to the next generation are all issues that every citizen should be aware of and work to address. Advanced energy conversion technologies can be fostered through the implementation of practical research activities and adequate energy education. In order to ensure the planet's long-term viability, it is critical that we quickly raise awareness about the importance of utilising renewable energy sources. Prioritising solar energy should be a top priority. There is an infinite supply of solar energy that the sun provides, and we can make good use of it. Tapping and using solar energy for our energy demands requires an evaluation of our energy needs as well as the application of the necessary techno-economical abilities. If we want to make energy sustainable and increase energy awareness, we must educate the public about solar power (Ciriminna et al., 2016; Ott, Broman and Blum, 2018). Countless species have gone extinct due to unchecked human activity. To preserve Earth as a habitable world for future generations, we must act now, before it is too late. Consequently, all developmental operations prioritise sustainability. This review essay places him in the perspective of current developments in solar energy teaching and research.

One in twelve dollars of the nation's energy comes from homes. An essential tool for controlling power consumption, electricity pricing Borenstein (2005) on top of making sure power utilities get enough money (Hledik, 2014), particularly with the rise of distributed renewable power sources and improved energy efficiency (such as solar panels installed on rooftops)(Rubin, 2015). Because of this trend of penetration, utilities are facing enormous difficulties in recovering their high initial capital expenditure costs (Hledik, 2014). U.S. Energy Information Administration (EIA) data shows that residential sector energy sales and revenues have been relatively flat over the last many years. Commercial and industrial sectors have already embraced demand charges, while residential sectors have yet to follow suit (Rubin, 2015). Homeowners have always been able to recoup fixed expenses through volumetric energy pricing. The regularity with which utilities have introduced demand charges, however, has been on the rise recently. For instance, in 2015, electric providers put demand charges on distributed generation in 21 separate cases across 13 different states. Utilities urging price hikes on solar users say they aren't paying their fair share for grid access. This is due to the fact that these solar users limit their maximum demand to 65% of solar production (McLaren et al., 2015), The solar installation maintains the greatest peak. Utilities see a drop in income due to the same load and lower overall electricity, with no change to the initial investment (Domigall et al., 2013).

Existing research has concentrated on how customers feel about and what they like in terms of electricity pricing. Consumers' demographic traits influence their opinions towards power pricing, according to existing studies. Take Wang et al. as an example. Wang, Zhang and Zhang (2012) find that middle-class Chinese citizens are more opposed to a tiered power pricing system than low- and high-income Chinese citizens. Determine that various tariffs are more or less acceptable depending on demographic factors. More dynamic tariffs are often well-received by consumers with higher levels of education. Also, look into how demographics and risk mitigation measures (such money-back guarantees) affect electricity cost and how customers might react. Hobman et al. (2016) look into how customers react to low prices and the mental processes that play a role in this. While these studies do a fantastic job of illuminating consumers' perceptions of pricing schemes and the elements that influence their attitudes, they fail to account for energy-related behaviours as impactful factors. Also, dynamic power price is the main topic of these research projects. Renewable energy and other utility services have been the subject of numerous studies on customer preference and willingness to pay (Soon and Ahmad, 2015; Sundt and Rehdanz, 2015). But there is a dearth of research that zeroes in on how customers feel about renewable energy and efficiency levies.

With the rise of worldwide concerns like climate change Chen et al. (2016), Research on the effects of energy restrictions and environmental repercussions on human existence is growing more relevant by the day. These problems can be made easier with the support of sustainable development. Growing energy use, however, poses a threat to sustainability, and renewable electricity sources, in particular, are essential to achieving environmental sustainability. As a result of this, regulators & lawmakers are working on putting measures that would increase the use of Renewable Energy Sources. For instance, there is the global renewable energy policy multi-stakeholder network that seeks to promote usage of renewable energy sources through information sharing, policy making and acceleration of the world's move to renewable power. Collective and individual goals of European nations under several policy regimes are as follows: Specifically for the first commitment period which is 2008 to 2012 and for the second commitment period that is from 2013 to 2020, the thirty-four member states of European Economic Area (EEA) that are parties to the Kyoto Protocol are legally bound to cap their emission of GHG and to reduce their total emission. Achieving these goals mostly involves decreasing energy usage, increasing efficiency in energy use, and utilising renewable energy sources more. Aside from renewable energy policies at the national and regional levels, raising public knowledge about energy consumption and its effects and origins is crucial.

1.8. Research Problem

As of the current developments, over 191 countries have ratified the Kyoto Protocol concerning the tackling of the emissions of greenhouse gases in an attempt to mitigate the impacts of the biosphere pollution resulting from the use of fossil energy and reduction of forest cover. Since the Fukushima nuclear reactor catastrophe in Japan in March 2011 and the German government's formal statement in May 2011 that it will be shutting down all of its nuclear reactors by 2022, this tendency has been accelerated.

Although RE technology is rapidly advancing, it has been reluctant to catch on with the general public. Some governments have implemented pricing plans to provide consumers the option to purchase green electricity for a little charge. To compel power supply firms to boost their generation of electricity from RE sources, certain governments have also implemented regulatory schemes known as Renewable Portfolio Standards (RPS). Since RPS successfully promote consumer-owned distributed generation, these programs have had some degree of success (Carley, 2009), albeit not enough to have a significant impact on the market (Hain et al., 2005). According to Rowlands, Parker and Scott (2002), the public believes that these programs are merely symbolic and are being implemented to improve utilities' image as environmentally friendly. Some conventional rural utilities have been slow to adjust to the new rules in the interim (Tierney, 2011).

1.9. Purpose of the Research

Utilities are driving energy transition projects aiming at carbon-free generation and encouraging consumers to support green energy initiatives. The net zero commitment is gaining traction throughout the world. It is crucial for the utilities to have a socioeconomic viewpoint and a multifaceted strategy that involves a wide range of stakeholders, including investors, customers, rivals, and governmental and regulatory agencies, in order to achieve the ambitious objectives. Customers' active involvement can help utilities develop cutting-edge plans to lessen their carbon footprint. The utilities must put their attention on innovative business strategies to include customers in accomplishing the decarbonization and sustainability goals. However, there aren't many choices available on the market for involving customers.

The primary objective of this research is to enable readers to comprehend why it is very crucial to enhance end consumer participation in net zero targets globally. The other aim of this study is to identify the issues and bottlenecks faced at different stakeholder levels to enable digital or information technology solutions for green energy adoption. Any new business model's viability in this situation will largely depend on the legislative framework and how successfully customers and utilities can coordinate their efforts. The desired results of this study would be to identify the key importance of end consumer green energy digital products which could accelerate in achieving overall net zero targets and proposing art of possible digital business model that can uplift the adoption.

1.10. Significance of the Study

I believe the Significance of this study lies in the potential to change the current dynamics between energy utilities and end consumers with regards to the adoption of sustainable power sources and the push for zero carbon emission. As climate change is still one of the most pressing problems of the century, the use of technologies that promote sustainable energy systems is essential now than ever before. The shift of focus in the study towards digital tools to support consumers is a significant strategic innovation in terms of enhancing the pace of energy sustainability through use of technology and consumers. Being aware of the position of the end consumer in the green energy environment this work underlines the shift from the passive energy use to active engagement. This shift brings more knowledge to the consumers in terms of the energy they are consuming, the energy they are spending in green energy and the effort they are putting into reducing carbon emissions.

Besides consumer literacy, the research also fills the existing technological and regulatory gaps that today prevent consumers from engaging in green energy as much as possible. In this regard, the study aims at including these barriers to help narrow the gap between energy providers, policymakers, and consumers to enable them to design appropriate digital tools and policies for implementing collaboration. Closely related to each other, these gaps need to be bridged in order to develop sustainable business models for the future that can open up new value propositions for consumers as well as energy companies. Integrated energy business models for decarbonization also allows energy providers to develop new sources of income and customer loyalty while inspiring other industries to follow suit.

However, this study may greatly contribute to the achievement of the net-zero goals worldwide. Thus, the study points out ways to promote digital solutions that can reach consumers at the scale level and increase the demand for green energy and significantly contribute to the climate goals on the national and international levels. Thus, the enhancement of consumers' engagement can contribute to the minimization of the overall carbon intensity of nations; therefore, the findings of this research are valuable for policymakers, investors, and representatives of the energy sector. In addition to energy industry, the study unveils more socioeconomic and environmental gains that may be obtained in the event of high consumers' engagement in green energy projects. Through digitization, customer access to green energy can be enhanced, the cost of energy can be lowered, public awareness on sustainability can be enhanced and in turn; the effects of climate change to the global communities can be minimized.

CHAPTER II:

LITERATURE REVIEW AND RESEARCH GAP

2.1. Theoretical Framework

Theory of Planned Behavior (TPB)

Ahmed et al. (2020) Changes to renewable energy sources are crucial if we are to meet the public's demand for measures to curb emissions of carbon and mitigate the effects of climate change. Consumption of green energy, as a distinct category, is seeing slower rates of market diffusion than any other green product, despite rising ecological consciousness and expressed desires for green adoption. Consumers' green energy decision behaviour is influenced by psychological aspects, which has to be studied in order to encourage more green energy choices. This study aimed to apply the theory of planned behaviour to the question of what factors, if any, impact consumers' GEB (green energy buying behaviour). The goal was to identify the main components that influence GEB and rank them in importance. With the TPB as its theoretical lynchpin, the study sheds light on the conceptual aspects of green energy consumption and proposes a number of research hypotheses that could be tested in the context of future studies in industrialised nations like Australia. Benefiting GEBs, this study ensures their environmentally sustainable development and encourages people to engage in green behaviour related to GEBs. Finally, we address the theoretical and practical ramifications as well as the potential avenues for further research.

Ghali-Zinoubi (2022) Researchers and politicians are under increasing pressure to alleviate sustainability challenges and ensure environmental health for generations to come in the face of mounting evidence of fast urbanisation and fast consumption growth. Given the global interest in environmental degradation and the dearth of research on developing countries in the existing literature, this study set out to fill that gap by using a developing country (Tunisia) as a case study to identify potential factors that influence environmentally conscious consumer behaviour. Consumers are supposed to act in an eco-conscious way when they have environmental concerns, a positive view of their own effectiveness as consumers, and a desire to do their part to protect the planet. A conceptual framework was established to enhance comprehension of these relationships. A development from TPB, this paradigm served as an expansion of that theory. We also checked for potential moderators of these associations by looking at cultural traits. Significant incentives for environmentally conscious consumer activity include issues related to environment, perceived consumer efficacy, and a desire to be nice to the environment, according to quantitative data examined using the "Structural Equation Modelling (SEM)" method from an online survey. Environmentally conscious consumer behaviour and its determinants are greatly enhanced by the cultural component of collectivism. Also, long-term orientation's moderating effect is good, but it's not strong enough. This study stands out among the few that use TPB to investigate eco-conscious purchasing habits and the factors that influence them directly, bypassing the role of intention as a mediator. Assessing the moderating effect of cultural elements is another way it expands the TPB. The study's findings provide useful managerial advice for marketers looking to foster positive attitudes towards environmental issues and put into action plans that will have a positive impact on both people and the planet. Managers can better encourage eco-friendly actions in other nations if they have a firm grasp of the moderating effect of culture.

Spangenberg & Lorek (2019) Sufficiency, especially robust sustainable consumption, is becoming more and more apparent as a necessary complement to eco-efficiency measures for protecting environmental sustainability. Two distinct theoretical frameworks that shed light on consumer behaviour and how to shape it are theory of planned behaviour (TPB) and social practice theory (SPT). The paper provides a concise overview of the difficulties, addresses the relevance of the ideas, and suggests potential solutions. As a heuristic sufficiency policy tool, they present the Prism of Sustainable Consumption. To support it, they propose a method that integrates findings from both theoretical frameworks, with insights from political economy. Find out what the affordability criteria are for each dimension's change so you can make better policy intervention recommendations. It is necessary to address multiple aspects of affordability at once, they say, and the sufficient policy space prism could be helpful for organising planned actions. They also say that successful interventions are possible to undertake.

Mohd Noor et al. (2023) aims at identifying which factors affect the adoption of green building in Malaysia. The study found a substantial association between the intention to use green building technology and five selected determinants: cost; attitude; information, knowledge and awareness; management and government; technology and training. Government and management were the next closely followed by the most important factors. The expected result of this study is the prediction of motivation towards the adoption of green buildings based on set standards.

Technological Acceptance Models for Green Energy Solutions

X. Zhang & Chang (2023) Environmental preservation and renewable energy sources have recently sparked intense debate in response to the alarming rate of global warming. As part of their plans to achieve net-zero carbon emissions, several nations have identified low-carbon transport as a top priority. Taiwan has the uppermost concentration of motorbikes in Asia, making it a highly sustainable and advantageous means of transportation from a global viewpoint when it comes to energy saving, carbon reduction, sharing economies, and environmental preservation. Using the technological acceptance paradigm, this research explores the behavioural intentions of Generation Z in Taiwan with regard to the usage of electric motorcycles. Environmental considerations, value arguments, and policy initiatives are all part of the model. To find the correlation between the variables, 391 surveys were analysed with partial least squares structural equation modelling (PLS-SEM). Positive consumer attitudes, value propositions, and government legislation all influence the likelihood that consumers will actually use electric motorcycles, according to the study. The utility and usability of the automobiles, however, have little bearing on how customers feel about them. Lastly, consumers' concerns about the environment do not affect their attitudes towards these vehicles. Academic reference and the motorbike industry will both benefit from and be affected by the aforementioned results.

Bouaguel & Alsulimani (2022) The Saudi Arabian government has made great strides in recent years towards using renewable energy, which is both clean and sustainable. Domestic solar energy was one of the big projects in Saudi Arabia's 2030 plan to preserve nature reserves, with sustainability at its core. Solar photovoltaic systems installed on private dwellings are encouraged and sanctioned by the Saudi government, which has taken multiple steps in this direction. But there have been very few applications despite these efforts to make solar energy accessible to households. Consequently, it is critical to investigate the several elements that impact Saudi public opinion on the adoption or rejection of emerging solar technology. Think about the Technology Acceptance Model if you need a guide to assist you get on board with new tech. The model analyses attitudes and intentions towards adopting new technologies along two dimensions: “Perceived Usefulness” and “Perceived Ease of Use”. The authors of this work expand upon the “Technology Acceptance Model (TAM)” by including three additional constructs: environmental consciousness, the relative benefits of solar photovoltaic systems, and their associated costs. Intentions of 492 men and women were analysed to determine these characteristics. Information was gathered by means of online questionnaires. According to the results, every component of the Technology Acceptance Model has a substantial effect on how people feel about using solar power at home. Based on these findings, the Saudi government should prioritise raising environmental consciousness, reevaluating the price of solar photovoltaic systems, and highlighting the benefits of these systems for home usage.

Tan et al. (2019) The commercialisation of cutting-edge green technology is essential for making manufacturing processes more environmentally friendly. However, a major obstacle to the commercialisation of innovative technology is the inherent risk in funding their development. With the use of mathematical models, decision-makers can better manage the consequences of techno-economic risk and allocate funds optimally. For independently functioning technologies, there is the time-tested Technology Readiness Level (TRL) scale, and for networks of interconnected technologies, there is the more modern System Readiness Level (SRL) scale. Even though these technological maturity scales are primarily made for passively evaluating current tech, they can be utilised in optimisation models to help with innovation planning.

- **Diffusion of Innovations Theory**

The Study Mani & Dhingra (2012) reviewed the literature in the area of consumer behavior within the diffusion of innovations domain to identify what is required to create market demand for renewable energy sources. The Study compared the conditions in the Renewable Energy sector to the launch of mobile phones and the internet in India and mentions that regulatory issues, which were a serious problem for the newcomers to the Indian market, as well as high entry costs are the two primary challenges. The study also concluded that adaptation and planning plays a vital role since the regulatory environment is constantly under transformation, thus presenting opportunities as well as challenges to

RE producers. Although a vast amount of data has been documented on governmental incentives for RE adoption, little has been done to provide management methods to help Renewable Energy suppliers to upscale their operations.

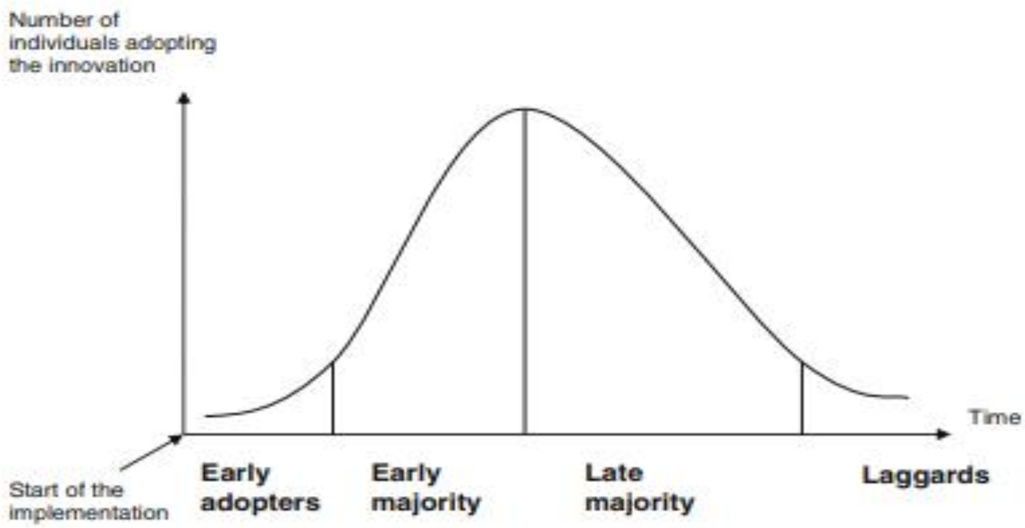

Figure 2.1: Diffusion of Innovation Theory

Source: Vedel et al. (2013)

Based on the Context of Diffusion of Innovation theory, a study has been conducted by Nygrén et al. (2015) whose purpose is to is to understand how the forerunners advance the utilization of renewable energy innovations in Finland through interviews and surveys. Current systems of energy production are coherent with path dependency, as there are high entry barriers to any new alternatives due to interest groups and huge costs of production. The higher costs of the traditional sources of energy and enhanced regulation measures may create the demand for renewable energy products and services, in which the state's pursuit of a powerful policy of stimulation of innovations is necessary. The level of new energy technology acceptance depends on the perceived benefits and ease of implementing these technologies, compatibility with the current practices and values, and, finally, the sophistication of the innovation. Renewable energy technologies cannot be adopted unless there are driven individuals and societal institutions such as communication networks and information. These results affirm that, while the psychological factors motivating behavioral change are crucial to adopting sustainable energy practices, they must also consider structural factors to succeed.

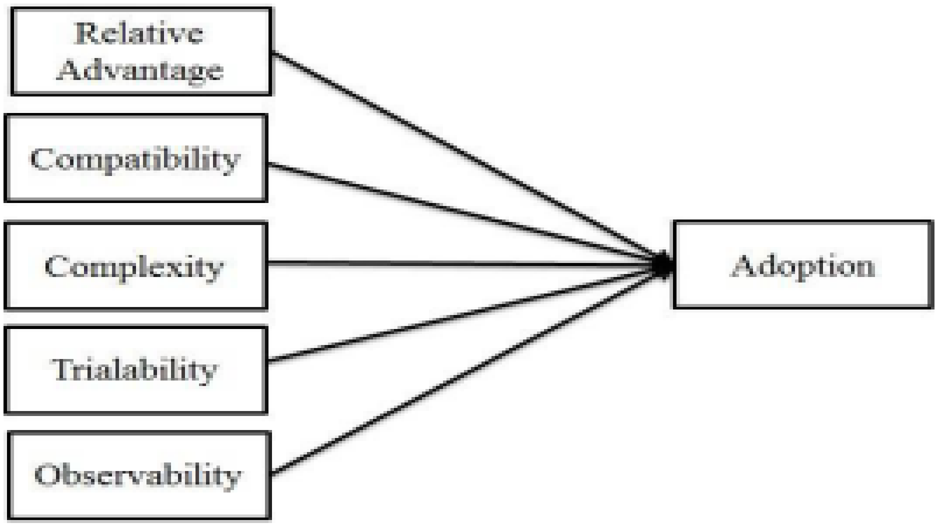

Figure 2.2: Roger's Diffusion of Innovation Theory

Source: Turan et al. (2015)

The purpose of the research Hyysalo et al. (2017) is to understand the process of creation and dissemination of consumer innovations in sustainable energy technologies (S-RETs). It emphasizes the importance of consumers or, as it is called, prosumers who are not only users of new technologies but also create them and then implement them into social groups on the internet. The findings show that 8. 2 percent of consumer innovations are passed on from one consumer to another via word of mouth and 2. 7% through commercial channels. As for "Innovative peer diffusion", additional and/or other adjustments were made among peers for a fairly large percentage of projects (34. 1%). While prosumers are making some rather feeble efforts to spread their solutions, these efforts indicate possible directions for the expansion of platforms that can help spread prosumer solutions.

2.2. Theories of Consumer Behavior in Sustainable Practices

B. Wang & Udall (2023) People are starting to pay more attention to sustainable development as the severe climate problem gets worse. Still, sustainable consumer behavior (SCB) isn't widely used, despite being a key driver of sustainable development. We set out to discover a novel strategy to support sustainable consumer behaviors in this study. Three crucial aspects of SCB—moral identity, altruistic values, and promotion—have not yet been integrated into a single model based on identity theory, research on environmental values, and marketing practice. The Research focussed on the connection between moral identity, SCB and altruistic aims and see if promotion alters this link. We collected this information using a social media poll that made use of the same validated scale. To begin, the outcomes demonstrate that "Group identity" and "Moral Self" enhance SCB. Second, those who prioritize helping others are more likely to have a strong sense of moral self and group identity. Third, "Moral self" and "Group-identity" completely mediate the connection b/w "SCB and altruistic values". Lastly, the relationship between SCB and promotion is unaffected by it. Lastly, this study shows policymakers how to foster SCB through the use of identities and values, which is a valuable tool.

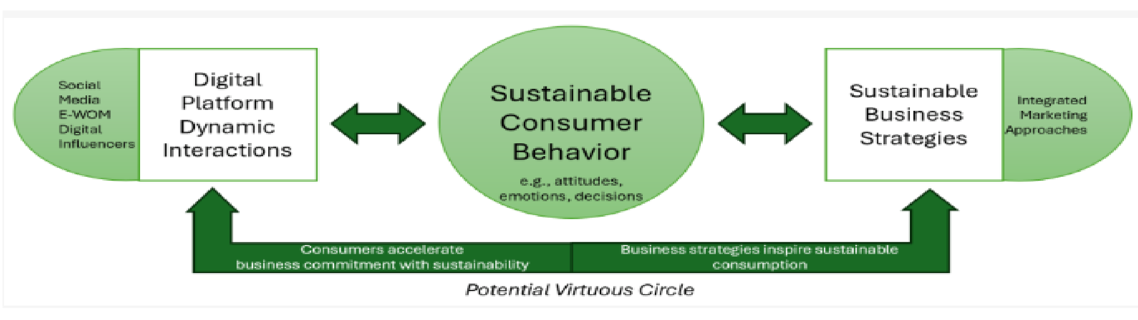

Figure 2.3: Interlink between Digital Platform, Sustainable Consumer Behavior, and Business Strategies

Source: Qalati (2024)

Elhoushy & Jang (2023) Both the success of sustainable companies and the reduction of environmental problems depend on consumers maintaining sustainable behaviors. Nonetheless, the adoption-continuance link has received less attention than the motivation-adoption link thus far. This study uses a systematic literature evaluation to investigate the connection between sustainability adoption and continuation. In particular, this study reviews and integrates the findings of eighty-seven studies to provide a synthesis of the current understanding of the sustainable customer journey after adoption. In this review, we found three main things. The article begins by contrasting the motivational and early adoption phases with the continuity stage, which is defined by several unique and "changing" features. What follows is an examination of the three primary components of the continuance stage—behavioral patterns of (dis)continuation, spillover, advocacy, and habit building—as well as the cognitive views and affective effects that follow adoption. Finally, the study provides a theoretical framework for discussing relationships and presents the idea of sustainable consumer behavior continuity. Finally, this review points out where our understanding is lacking, suggests areas for future study, and discusses theoretical and practical implications.

Gallo et al. (2023) In order to gain and keep a competitive edge, more and more companies are realising the importance of incorporating circularity and sustainability into their business models. This is because more and more people in power, in the business world, and in civil society are thinking about sustainability and Customer Engagement. In order to mitigate the environmental impact of corporations, consumers must take personal responsibility for their own actions and choices. An increasingly pressing issue on a worldwide scale, "sustainable consumption" will connect human actions to the fate of our planet. The environment is heavily impacted by people's careless actions in their daily lives, which threatens the very existence of our species. A small fraction of the population is actually committed to sustainable practices and is eager to hold the motive of “Saving the Planet” as a result, despite the fact that concerns related to sustainability and the circular economy have captivated consumers and given them an air of environmental consciousness. A subpopulation of eco-conscious customers, according to this study's hypotheses, is especially interested in making ecologically responsible food product purchases. Our work significantly expands previous knowledge by utilising a technique that can increase the trustworthiness of a consumer dataset used over an extended period of time to investigate consumer behaviour. One of the most popular methods, cluster analysis, can be used to choose a subset of customers whose beliefs about sustainability and the environment impact their propensity to purchase environmentally friendly food items. According to the findings, there are four distinct groups of customers. One group is very concerned about sustainability and environmental issues; another group is completely unconcerned; and the last group pays very little attention to sustainability but is quite active in environmental causes. The research demonstrates that there are obvious scientific, administrative, and policy implications of paying attention to environmental sustainability, which can raise consumer awareness.

Krefeld-Schwalb (2023) As the impacts of climate change become more apparent, 2022 stands out as one of the warmest years on record. There is broad agreement among scientists that people's actions contribute to greenhouse gas emissions; as a result, policymakers are turning to behavioural interventions to get people to change their ways. Interventions aimed at boosting sustainable behaviour frequently fail because changing behaviour is so challenging. Most "one-size-fits-all" strategies that give every customer the same interventions ignore the fact that people's reasons for being sustainable vary and that they react differently to various interventions. In order to help policymakers tailor behavioural interventions to individual needs, this research aims to build a deep machine learning strategy. They use data from both controlled laboratory settings and a large-scale field experiment to develop a strategy for intervention targeting that takes into consideration people's receptivity to treatments, their reasons for and against engaging in sustainable behaviours, and the ways in which these behaviours interact with one another. Our theoretical understanding of heterogeneous treatment effects is advanced towards sustainability thanks to this project's insights, and policymakers now have practical advice on how to drive behavioural change more successfully.

Corsini et al. (2019) There has been a recent uptick in calls for consumer studies to incorporate practice theories into sustainability research with the assumption that doing so will help scholars better understand consuming in its societal context. Consequently, there has been very little research looking back at how social practice theories have been used to this area, despite the fact that their use is growing at an exponential rate. A bibliometric examination of practice theory applications in consumer sustainability research is carried out. Our findings reveal a chronological progression of research trends: from 2009 to 2012, the field was dominated by "consumer identity." From 2012 to 2014, it was "business and governance." From 2013 to 2014, it was "sustainable consumption and production." From 2014 to 2015, it was "urban living and policy." Finally, from 2015 until the present, it was "household energy." They anticipate that smart city studies, the sharing and circular economy, and related domains will find many future uses for practice theories. For the fields of sustainability and consumer studies, they shed light on how social practice theory has been applied and where it is headed in the future.

Jaeger-Erben & Offenberger (2014) Choices made by consumers or appropriation of products are typically boiled down to sustainable consumption. By limiting our attention to specific actions, we miss the bigger picture of consuming and the role that individuals play in maintaining social order. When we look at consumption through the lens of social practices, however, we can see the iceberg at its base and the imbedded socio-cultural and socio-technical contexts in which our everyday consuming patterns exist. To illustrate how social constructions of parenting practice's pre-structure changes in household consumption patterns, qualitative research on life course transitions to motherhood is used as an example. In its last section, the report advocates for a shift in policy towards sustainable consumption that is more reflective, collaborative, and experimental.

2.3. Digital Transformation in Energy Sector

Haouel & Nemeslaki (2024) Increased hydrocarbon recovery, corporate ecosystem safety, and operational reliability are three ways in which digital technology can help the oil and gas industry. This research looks at the digital transformation trends in the oil and gas supply chain and the projects undertaken by Equinor, a petroleum refining corporation based in Norway. The primary goal is to investigate the oil and gas industry's current digital strategy and potential areas for digitalisation. These results lend credence to the idea that the biggest names in the business should keep pouring money into their collaborative ecosystem, which consists of partnerships with suppliers and startups and a shared platform for easy data sharing that can boost their economic standing. Similar to what Equinor did, they should prioritise developing a digital strategy roadmap. Equally crucial is the maintenance of investments in R&D and the recruitment of competent specialists to encourage technological advancement and widespread use. In order to safeguard the organisation from future cyberattacks or other hazards, it is crucial to enhance employees' digital abilities and cultivate a digital culture company-wide. Globally, market dynamics and energy network management will be transformed by the successful adoption of digital solutions.

Nazari & Musilek (2023) Changes in technology have brought about substantial shifts in the production, transmission, and consumption of energy, a phenomena known as digital transformation, which has emerged as a major force in the energy sector. Benefits like as increased efficiency, decreased costs, and an improved consumer experience are just a few of the ways in which digital transformation is changing the energy industry. This paper summarises the digital transformation impact on the energy industry, drawing attention to significant developments and new technology that are changing the landscape of this field. To set the stage for a thorough comprehension of digital transformation, the research first defines the term, describes its breadth, and then explains two conceptual frameworks. The study continues by looking at the positive aspects of digital transformation, its effects, and the factors that can help or hinder it. In order to determine the value of each source and draw any qualitative conclusions, they were all carefully read and evaluated. Cybersecurity, data privacy, and the loss of jobs are just a few of the issues that this study recognises as being associated with digital transformation.

Liu & Song (2023) The energy sector is seeing new growth potential as a result of the digital economy, and the role of digitisation in this sector's shift to a low-carbon, eco-friendly model is gaining increasing attention. The purpose of this research is to use panel data from 55 Chinese energy firms to determine how digital transformation has affected workplace green innovation. A dynamic capabilities lens will be used to view the data. The authors carry out this empirical investigation using a double-fixed-effects regression model. This article uses heterogeneity analysis to look at the role dynamic capability plays as a mediator between digital transformation in the energy sector and green innovation in businesses. Data shows a favourable correlation between energy businesses' degrees of digital transformation and green innovation. By increasing their dynamic potential, energy organisations could enhance their digital transformation capabilities and hence their ability for green innovation, according to the mechanism test. Digital transformation of energy businesses significantly boosts green innovation at state-owned organisations, but has no discernible impact at non-state-owned ones, according to heterogeneity research. With this study's findings as a guide, we can help businesses become more environmentally conscious, speed up the energy sector's transition to renewable energy, and ensure their long-term viability.

Galkovskaya & Volos (2022) Since digitalisation of the energy industry is the most crucial route of power transformation, this study set out to accomplish the SDGs by concentrating on this area. A few examples of these aims are encouraging responsible consumption and production and lessening the effects of climate change. With energy production prices falling, the authors calculated how economically efficient it would be to use digital instruments. Methods for calculating energy costs both before and after digital technology deployment, as well as a new approach for calculating digital technology costs according to technological readiness level, were used in the review. The research shows that there are several advantages to digitalising energy power, including facilitating the transition to low-carbon electricity and contributing to the world's sustainable development goals. Academics investigating the efficacy of economic digitalisation can benefit from the results since they are relevant to all countries and energy production methods. Future research should aim to develop an analytical notation that shows how various factors contribute to the cost of digital technology. These factors include the availability of labour and capital, the rate of technological development in industries and national resources, the volume and speed of distribution, and the overall level of technological development.

Giraldo et al. (2021) The United Nations has set seventeen Sustainable Development Goals (SDGs), one of which is to ensure that all people have access to modern, cheap, reliable, and ecologically friendly energy. To achieve this goal, the energy industry must undergo digital transformations and transitions, and a wide range of stakeholders must act swiftly to pave the way for more adaptable power systems. This study details a case study that discusses AES Colombia's commercial digital transformation strategy, which involved building a new platform with specialised apps that make use of Industry 4.0 technologies. We begin with a description of the Chivor hydropower project. Owned and operated by AES Colombia, this 1000 MW powerplant supplies 6 percent of Colombia's electricity needs. What follows is a comprehensive analysis of the Colombian market, covering its energy matrix, trading and dispatch systems, and forthcoming developments. Then, the procedure that was used to undergo the digital transformation with the use of contemporary instruments is detailed. Designed as an all-encompassing framework, the project includes commercial information systems, platforms to enable research and consultation by various users, and applications for managing hydrological, operational, and market information. The development of this groundbreaking initiative in the Latin American setting aims to lessen potential hazards and make a future-proof contribution to the energy supply.

Daneeva et al. (2020) In discussing the energy revolution, the authors bring up the subject of digitisation among the leading oil and gas suppliers. To help oil and gas companies transition to a low-carbon economy, the paper suggests measures that they should adopt. The change from oil and gas to energy is central to the company's strategy. As the primary contributor to atmospheric CO_2, hydrocarbons now constitute the backbone of the world's energy balance. Questions on how to decarbonise the oil and gas sector, for instance, in order to lower CO2 emissions, are gaining traction. In order to facilitate the proper replacement of "dirty" business processes with "clean" ones, digital transformation firms will utilise digital technology for data collecting, process monitoring, and management. This ecosystem will be built by these companies. Those at the head of the oil and gas industry's massive corporations are the focus of this research. The research aims to shed light on how oil and gas firms may leverage corporate digitalisation technology to facilitate their energy transformation. Using energy transition paradigm and company digitalisation plans as examples, the study lays out the key themes. The authors investigate the drivers behind O&G firms' energy transitions, examine the opportunities for digital transformation in the oil and gas industry, and examine the mechanism of energy transitions using the case of the biggest international oil and gas corporations.

Dang & Vartiainen (2020) Business models that have been effective in the past are being challenged by the rapid pace of digitalisation and technological change. This is the driving force behind the rise of digital transformation strategies (DTSs), which are business plans that incorporate digital technology. It is unclear how exactly a traditional company's organisational structure, culture, and procedures may undergo such a radical transformation when a DTS is implemented, in contrast to digitally-founded businesses. Consequently, this study delves into the process of adopting a DTS at a multinational energy firm situated in Finland and how such modifications were implemented. The research method is an interpretive case study that makes use of multiple data sources. Throughout the three stages of a DTS implementation, they note important features and patterns that change, adding to the study. Specifically, this process follows a broad pattern of continual incremental change; nevertheless, there are distinct characteristics, models, and orientations for each phase.

Table 2.1: Comparative analysis of Case studies Related to Digital Transformation

Case Study/Authors	**Digital Transformation Focus**	**Key Outcomes**	**Challenges**

Haouel and Nemeslaki (2024)	Hydrocarbon recovery, corporate ecosystem safety, operational reliability	Improved economic standing through partnerships, data sharing, and R&D investment	Cybersecurity risks, need to develop company-wide digital culture
Nazari and Musilek (2023)	Production, transmission, and consumption of energy	Enhanced efficiency, cost reduction, improved consumer experience	Cybersecurity, data privacy, job losses
Liu and Song (2023)	Digital transformation and green innovation in energy firms	Positive correlation between digital transformation and green innovation, especially in state-owned companies	Limited impact on non-state-owned firms
Galkovskaya and Volos (2022)	Economic efficiency in energy production through digitalisation	Contribution to SDGs, transition to low-carbon electricity, reduced energy production costs	Need for advanced cost-calculation methods
Giraldo et al. (2021)	Digital transformation in hydropower (AES Colombia)	Development of Industry 4.0 platform for hydropower, improved adaptability and information management	Managing market and operational risks

Daneeva et al. (2020)	Transition from oil and gas to energy through decarbonisation	Improved data collection, process monitoring, and management to aid energy transition	Decarbonisation challenges in replacing hydrocarbons
Dang and Vartiainen (2020)	Adoption of digital transformation strategy (DTS) in a Finnish energy firm	Incremental organisational change, improved business models, and adaptation to digitalisation	Difficulties in transforming traditional business structures

2.4. Digital Solutions for Green Energy Adoption

Overview of Digital Tools and Platforms

Minuto et al. (2022) Achieving carbon neutrality is the energy policy goal of the European Union, according to the historic "Clean Energy for all Europeans" law package. The idea of making the individual the focal point of the energy transition was a fresh perspective. One approach is to give him more freedom to make his own decisions, and another is to get him involved in the movement to lower energy consumption and fund the construction of new distributed RES power plants. The approach was made possible through the regulatory framework of Renewable Energy Communities, which was established by the Renewable Energy Directive Recast (RED II). In particular, RECs promote community engagement by reducing the Not In My Backyard (NIMBY) effect on RES, increasing energy demand flexibility, and decreasing consumption. As part of their energy transition strategies and national laws, all member states are implementing the RED II directive. Countries who were early adopters of this framework, such as Italy, have begun testing it out and creating prototypes. Citizens' desire and will to engage in REC initiatives necessitate supporting technologies that guide them through all three stages of project development: "design," "creation," and "operation." In this paper, we classify the digital resources needed to build REC projects into three groups: commercial, EU-founded, and freeware. At each step of a REC project's rollout, they assessed the services offered using 30 distinct tools.

Jakub Zawieska et al. (2022) For the purpose of facilitating social involvement in climate change mitigation procedures, this study examines the possibilities of digital tools like gamification-based apps or digital currencies to encourage pro-environmental behaviours. In light of this, the overarching goal of this research is to lay the groundwork for an environmentally friendly digital tool that will assist cities in building resilience through the promotion of bottom-up activities and educational interventions aimed at getting residents involved. A literature research on SLR, an evaluation of current solutions' merits and shortcomings, and qualitative workshops with relevant parties were the four stages that made up the study's methodology. The current understanding of pro-environmental nudging, as well as the lessons gained from previous solutions, formed the conceptual framework for the suggested solution. In addition to strengthening communities, the created theoretical framework can boost local economics. Since it is co-created with citizens from the start, it has the ability to establish communities that can work together to make cities more resilient to climate change. In order to shape climate change understanding and attitudes towards active engagement, the idea outlined in this paper can be a helpful answer for cities.

Sivarajah et al. (2015) An important initial step in promoting energy-saving practices that lead to efficiency is making consumers more aware of how much energy they use. Despite information technology's reputation for having negative impacts on the environment, green information systems are gaining acceptance as a remedy for numerous environmental issues. Although there has been some academic interest in Green ICT, there is a dearth of literature on how to use social media and other forms of ICT in an energy efficiency context to educate consumers and get them more involved in solving environmental problems. Consequently, this study's overarching goal is to investigate how individuals may make better use of social media and other available platforms to have meaningful conversations on energy efficiency and to raise awareness and get involved in these topics. A state-of-the-art review of energy awareness, consumer engagement methods, and, most crucially, social media's role in promoting energy efficiency is presented in this study. This study aims to shed light on the use of information and communication technologies (ICTs) to raise energy consumers' consciousness and encourage their participation in energy saving initiatives by drawing on findings from a desk-based normative review.

2.5. Smart Grids and Energy Management Systems

Olatunde et al. (2024) In recent years, smart grids have been more important tools in the fight for sustainable and efficient energy use. Highlighting important discoveries, obstacles, and future prospects, this paper offers a thorough examination of how smart grids affect energy efficiency. Electricity generation, distribution, and consumption may all be optimised with the help of smart grids, which use cutting-edge sensing, communication, and control technology. Smart grids allow utilities and consumers to communicate in two ways, which increases grid dependability, decreases energy losses, and makes it easier to incorporate RE sources. The substantial effect of smart grids on energy efficiency is one of the main conclusions drawn from this analysis. The ability to monitor and adjust energy usage in real-time is what makes smart grids so effective in reducing consumption, according to studies. This lessens the electrical sector's total carbon footprint and helps consumers lower their electricity prices. High initial prices, problems with interoperability, and worries about data privacy are only a few of the obstacles to the widespread use of smart grids. The broad use of smart grid technology depends on resolving these issues. As we look ahead, smart grids have a lot of potential to increase energy efficiency even more. The integration of the Internet of Things (IoT), algorithms for artificial intelligence (AI), and the management of distributed energy resources (DERs) are all emerging themes that will likely drive additional innovation in smart grid technologies. To sum up, smart grids are revolutionising energy efficiency and providing enormous advantages to consumers, utilities, and the planet. To fully utilise smart grids, however, issues like cost and interoperability must be resolved. Electricity sector efficiency and sustainability can be further improved if players embrace new trends and technology.

Nitasha Khan , Zeeshan Shahid , Muhammad Mansoor Alam , Aznida Abu Bakar Sajak , 4 M. S. Mazliham , Talha Ahmed Khan (2022) Power technology and distribution system stability are threatened by the incorporation of highly variable dispersed generating. The main cause, though, is that there can be an imbalance between electrical supply and demand. Problems like voltage drops/rises and, in the worst case scenario, power outages can arise when there is an overabundance or shortage of electricity during energy production or consumption. Efficiently balancing supply and demand and decreasing peak load during unexpected hours are two goals of energy management systems. - ANo matter the state of the power grid, an energy management system can keep loads supplied economically and safely by distributing or trading energy among the many energy supplies at its disposal. The structure, purpose, benefits, and problems of the energy control system are investigated in this study by looking closely at all the people who have a stake in it. Demand response, demand management, and energy quality management are just a few of the programs that are examined in this evaluation of the power management system. It provides a thorough breakdown of how these applications function. It summarises the smart grid's features, functionalities, and related approaches while also pointing out research gaps, challenges, and issues. Furthermore, this study's authors examine the energy management system, a crucial new technology, and measure various uncertainty approaches. They also perform a literature assessment on smart grid enabling technologies. The authors also included the thorough evaluation of researchers' work and smart grid energy management system contributions in this study. It also accomplishes a number of limits while comparing and evaluating the main optimisation methodologies used by energy management structures to accomplish their impressive goals. It would be an excellent service to the academic community and new researchers alike to compile this thorough evaluation.

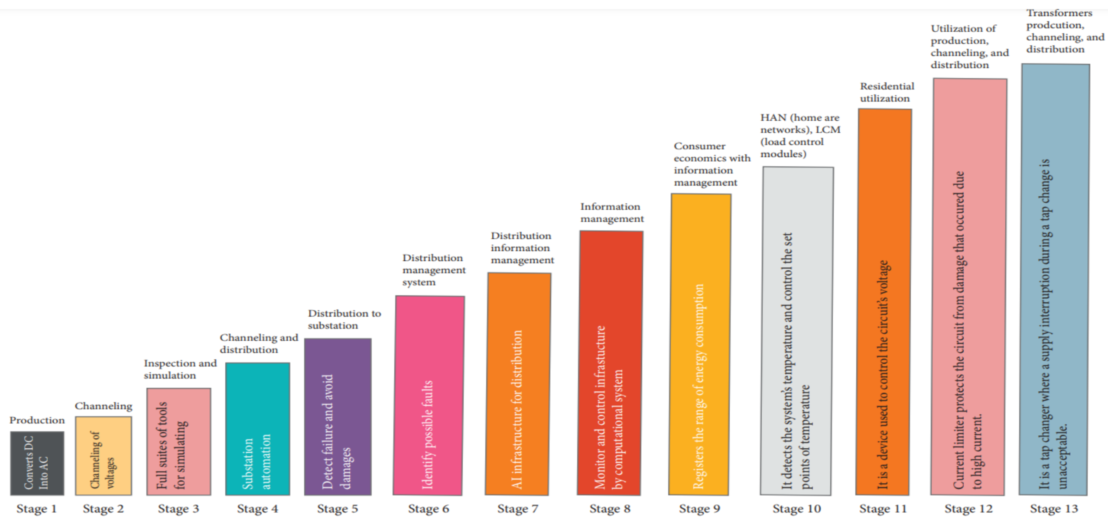

Figure 2.4: Smart Grid Main Technologies

Table 2.2: Smart grid elements

Elements of smart grid	Explanation
Generation	Generation consists of system devices, control systems, programs, and stations which are the actors who generate the electricity in bulky quantities that can also be stored for later distribution.
Transmission	In transmission, the generated power is transferred from stations to distribution centres.
Distribution	In distribution, the generated, transmitted, and stored power interconnects with the consumer.
Customer	Customers are the end users who consume the power and can also be categorized into domestic and commercial consumers.

Meliani et al. (2021) Solar panels, wind turbines, electric vehicles, and energy storage devices are examples of decentralised, highly variable generation sources that pose a threat to the reliability of power grids and distribution systems. However, a difference between the supply and demand for power can be the primary reason. Critical difficulties, such as a decrease or increase in voltage and, in extreme cases, power outages, can be caused by an excess or shortage in the production or use of electricity. Energy management systems are a great tool for reducing peak load during unanticipated periods and balancing supply and demand. In addition to facilitating the sharing and exchange of energy among the many energy resources at its disposal, the energy management system can reliably and efficiently deliver loads at an economical cost, regardless of the environmental factors affecting the power grid's functioning. Through an exhaustive examination of the various stakeholders and players, this study explains the design, goals, pros, and cons of the energy control system. This review covers all the bases when it comes to the power management device's several features, such as Energy Quality Management, Demand Response, and Demand Management. It also summarises and quantifies the many methods of uncertainty. On top of that, it helps with a lot of things while comparing and contrasting the primary optimisation techniques used to accomplish the outstanding goals of energy management systems.

Zafar et al. (2020) In order to maximise energy usage and distributed renewable energy generation while keeping consumers comfortable, home energy management systems (HEMSs) assist with electrical demand control. Energy cost, weather, load profiles, and customer satisfaction are just a few of the many factors that HEMSs take into account when operating. By lowering power usage in both business and residential smart grids, they are becoming more and more important in the fight against energy waste. With an eye towards key ideas, setups, and enabling technologies, this study provides a thorough literature evaluation of HEMS. Also included in this summary are the most popular communication methods for demand response applications and current trends in HEMS computing. This survey provides a synopsis of the state of HEMS solutions and technology as it stands right now and where it's headed in the future.

Bayram & Ustun (2017) The globe's fast expanding energy demands have made it an urgent matter to find ways to reduce the generation and operation costs of power systems while simultaneously reducing hydrocarbon emissions. Beyond that, developing countries lack the financial means to build conventional power grids, leaving a quarter of the world's population without access to electricity. While these issues are real, behind-the-meter (BTM) energy systems let consumers meet their energy demands through distributed generation and storage, which is more cost-effective. This study aims to fill that need by providing an exhaustive analysis of BTM EMSs. The first step of the research is to categorise the electrical loads according to their size, priority, and physical characteristics. The next step is to organise the research on BTM energy management systems into three distinct layers: technological, economic, and societal. On one level, we have power system studies, which include distributed generation and storage technologies; on the other, we have economic incentives, scheduling methodologies, and optimisation tools to affect energy use. On the other side, the social layer presents new research on how to reduce energy usage without new technology by utilising the social sciences. The standards and technology that facilitate communication, sensing, and monitoring are also outlined in this study. Finally, a case study is given to show how the system is put into action.

Miceli (2013) Energy management ideas and the emergence of the smart grid are outlined in the paper. Energy management should be considered a critical innovation in load supplying that allows for a stronger penetration of renewable energy usage at the building and municipal level, performs energy savings, and reduces CO2 emissions. Presented here are the motivating causes for improving the present electricity distribution, and the advantages of smart grids are emphasised. Taking into account the entire electric value chain, the study presents a detailed analysis of energy management, detailing the steps taken for demand-side management and distributed on-site control. Here, we offer a home simulator and a grid simulator and examine the results in three distinct situations to confirm the efficacy of control actions for energy management. The study also reports the results of an assessment of environmental advantages and conducts a cost-benefit analysis of the energy management system. The findings demonstrated that conventional control measures do not result in a financially viable system for the end user. The utilisation of energy management systems coupled with renewable energy sources is the sole means to achieve financially rewarding energy savings during on-site production. The presentation concludes with a history of smart grids, touching on their possible advantages and technical challenges. After outlining active grids, microgrids, and virtual utilities, the paper concludes with some last thoughts on possible future situations.

2.6. Impact of Digital Marketing and Social Media in Promoting Green Energy

Czarnecka et al. (2022) Companies operating in the energy sector (ESCs) have increasingly relied on social media to reach out to customers in recent years. Consumers today not only seek out information, but also generate it independently and share it with others online. When it comes to electronic word-of-mouth (eWOM) communication, energy firms have two main responsibilities. The first is to be active on social media so that consumers can learn more about them. The second is to intentionally mould their image to meet customer expectations. Measuring client satisfaction or engaging in one-way communication is insufficient in today's market. Consumers and businesses alike are increasingly interested in products with a "green product" or "green company" reputation, according to market trends. When asked whether they are destructive to the environment, very few businesses admit it. Almost every business claims to be good corporate citizens. Particularly concerning to the buyer is the product's impact on the natural world. Which means businesses aren't bridging the gap in their expertise. Customers' views on your company's commitment to environmental responsibility can be gauged alongside the promoted satisfaction indicators. In other words, environmental responsibility must accompany social responsibility research and results. Accordingly, the study's overarching goal is to reveal how social media users' pro-environmental attitudes and actions influence consumers' impressions of the green energy business model, as well as whether or not consumers' degree of social media engagement influences this perspective. Also, the study finds that ESC perception is affected by social media-related elements.

Zatwarnicka-Madura et al. (2022) As a buying power and trend-setting generation, Generation Z is becoming an increasingly important player in the market. This is the generation that finds a wealth of knowledge, ideas, and inspiration in the posts made on social media, and they devote a great deal of time to these platforms. Because its representatives are wary of conventional advertising messaging, influencer marketing is the most effective strategy for reaching them. Ecology and environmental issues also affect them deeply. So, looking at green energy from the point of view of Poland's Generation Z, this study set out to determine the feasibility of using influencer marketing. Using a quota system, 533 adults (ranging in age from 18 to 26) were surveyed between April and June of 2022 using the Computer-Assisted Web Interviewing (CAWI) research methodology. Structure indices (percentages) and correlation measures that were statistically significant were utilised in the analysis. It was proven by the results that Generation Z loves social media and that young consumers are very involved in following influencers' activities. While over 50% of persons who took the survey saw value in influencers advocating for green energy, the great majority said that their own decision to become green was based on what others thought, and that influencers had no bearing on their final decision.

Richard (2021) Startups need to communicate often, clearly, and thoughtfully to succeed in today's digital world where CSR and sustainability are major concerns for both customers and enterprises. I learnt a lot about how to persuade businesses and customers that environmental preservation should be a top priority for all eco-friendly enterprises via my internship at Clearloop and my research into effective social media marketing of such concerns. Businesses who don't care about their environmental footprint aren't going to make it in this century. By forming partnerships with businesses to manage solar energy investment and construction, Clearloop attracts customers to those businesses while freeing itself to focus on renewable energy infrastructure design and development. As a consequence, businesses are able to brag about their dedication to environmental preservation through carbon offsetting, thanks to initiatives that have been successful (the first of which was in Jackson, TN).

Aimiuwu (2017) Despite the fact that climate change and global warming have emerged as serious threats to human survival, few studies have examined the role of information systems in preserving the environment, and many people are unaware of the potential of social media in this fight. How can we use social media to get more people to use green technology, which will reduce the cost of environmental sustainability? That was the point of this particular case study's qualitative analysis. The integrated sustainability framework provided the theoretical underpinnings for the research, which concluded that in order to ensure environmental sustainability, businesses should integrate green practices into their operations, encourage green culture among their clientele, maintain a culture of innovation, and expand their green market share. For this study, we used LinkedIn to reach out to twelve green energy experts in the United States. In order to analyse the data, Stake used their data analysis technique in conjunction with member checks. Structured telephone interviews were used for data collection. Increasing green technology use through social media centred on three main ideas: reaching a wider audience, educating people, and raising awareness. Cleaner, cheaper, and more lucrative were major themes when discussing the advantages of green technology surpassing its costs. According to this research, millions of individuals can be reached through social media with information about how to live a greener lifestyle that helps the environment, people, and businesses. In the battle against climate change and global warming, the results of this study may encourage individuals to utilise social media to advocate for the usage of eco-friendly technology.

In his Studies Tenhunen (2016) says that, As the Internet and digitization grow at a fast pace social media is becoming a vital factor for businesses today. But still, most companies do not have a well-considered digital marketing plan and do not realize the possibilities of social media. Regular and fully functional social media pages affect the SEO and are important channels in presenting oneself or the facility. One of the most effective means of using social media for business development is participation in discussions through the creation of new topics or joining ready topics as an administrator. The intended goal of a company's social media account is to capture leads and traffic the account's users to the company's website. While designing a mobile marketing plan, there is a need to pay more attention to the efficiency of social networking sites that the company needs to leverage depending on the Company and industry strategies. A component of this is to survey or otherwise gather information about how potential issues exist in professional SM and lay out plans for the platforms where the company's employees are present or interested in being present. The use of content marketing and social media marketing is often widely used as a part of a strong digital marketing mix. It includes the evaluation of readily available resources, identification of the intended market, and formulation of a mission statement that will shape the strategy. One of the key components of this approach is the audit of the current state of social media accounts for the company as well as the competitors, choosing the appropriate platforms, and creating proper plans for further activity. Content marketing is at the center of this process as the process of coming up with valuable and timely content continuously is one of the most difficult tasks in digital marketing. To counter this, a content plan is needed to help with post organization as well as schedule them. Discussions on the social web can be coupled with the sharing of pertinent content in aspects of the relevant discussion groups and the synchronization of the posts to industry-related events, can further increase the reach of the companies' social media undertakings. The ideal future course of action should entail the use of specific social media platforms including LinkedIn, Facebook and Twitter, specific company-related tags, and organizational editorial calendar. Integration with other functional groups can enhance the social media strategy by decentralizing the management tasks and promoting a variety of contributions to the information promotion process.

2.7. Role of Blockchain Technology in Green Energy

Renewable energy is energy that comes from natural materials that can be replaced in a matter of few years for instance; solar, wind, rain and heat from the interior of the earth (Naveen Kumar & Vigneshwaran, 2023). It is deemed to be less damaging to the environment than the conventional fossil fuels (Solarin et al., 2021). Green house gases can be reduced and air can be made fit for breathing by using renewable energy which is sufficient for the needs of the world (Shahsavari & Akbari, 2018).

The shift towards the utilization of renewable energy sources has been hampered though due to a number of concerns and issues. Another problem is that renewable energy is unpredictable, and therefore supply and demand for energy can be unpredictable (Sovacool, 2009). These considerations are no longer of much concern today due to the existent energy storage instruments such as batteries and pumped hydro storage (Guezgouz et al., 2019).

There is however one major problem, which is the fact that renewable energy technology is still relatively expensive compared to conventional fossil fuels. As for this problem, government subsidies and incentives, as well as the technological progress that has made the costs lower (Abdmouleh et al., 2015), have solved it.

These solutions have not normalized or contracted the complexities that are inherently contained in the utilization of renewable energy sources. One of them is that, there is no well-defined centre where the implementation and production of the renewable energy are being closely supervised (Di Silvestre et al., 2020). This has led to fraud as well as the issue of double-trialing of renewable energy credits. To these questions, one possible solution has emerged in the form of blockchain technology, which offers an effective means of tracking and authenticating the use of renewable energy production and consumption (Baashar et al., 2021).

Distributed ledger technology or commonly referred to as the blockchain eliminates the need for middlemen through offering trustless and transparent transactions. It may revolutionize the renewable energy industry by offering a reliable method of monitoring and certifying generation and consumption of green power. Thus, more people might trust the renewable energy markets (Gawusu et al., 2022). It is now possible to have smart grids that rely on distributed energy resources such as wind and solar power thanks to blockchain. Through its platforms, DERs can sell the excess energy in the energy trading market with ease and certainty. Lowered transaction costs and settlement time is realized through the use of smart contracts on buy/sell energy agreements (Zahraoui et al., 2023). Through the use of blockchain technology to record and track energy data, the sector gets enhanced transparency in the trading of gas and energy commodities and a decrease in the chances of exploitation (Downes & Reed, 2020).

From the literature, it is possible to get a perception of what is currently prevailing and the issues arising from the integration of blockchain technology with renewable energy systems. Unlike Nepal et al. (2022) that centered on the applicational and transactional concerns of smart RE solutions (Henninger & Mashatan, 2022) "Examined each of the three technological layers of the grid infrastructures and defined the vision for the future state of using blockchain." Barceló et al. (2023) discussed the issue of regulatory development and how the issue of risk management is addressed concerning the deployment of the blockchain technology on the other hand, (Gawusu et al., 2022) discussed the importance of integrating blockchain in renewable energy sector. In the bibliometric analysis of (Cui et al., 2023), Some of the research gaps in blockchain for RE applications, technology and policy were identified as well as the future trend in energy Internet, management, systems and trading were found.

2.8. Application of Blockchain Technology in The Energy Sector

Several cases can be seen in the energy industry where it can leverage the adoption of blockchain technology in its process and business process. The following is a synopsis of the relevant literature that outlines possible uses and parts of business models that could be impacted

- **Billing:** Consumers and distributed generators can achieve automated billing through blockchains, smart contracts, and smart metering. It might be of interest for utility companies that are in the process of implementing energy micropayments, pay as you go or payment solutions for prepaid meters.
- **Sales and marketing:** Customers' energy consumption patterns, their preferences or level of green consciousness may influence the sales strategies. When combined

with blockchains, AI methods, including machine learning (ML), it is possible to identify usage patterns of energy by consumers and proceed to offer tailored, premium energy products.

- **Trading and markets:** Trading in commodities, management of risks and management of the wholesale markets could be disrupted by distributed trading platforms, based on blockchain technologies. At the present, only the activity that uses the block chain system is within the active stage and soon the block chain will be used in the trading of green certificates.
- **Automation:** Blockchain technology has the potential of improving the control of microgrid and decentralised energy system. An increase in proportion of energy generated and consumed in addition to consumption of the excess energy that is sold back to the grid or through distributed platforms or localised P2P energy trading may have impacts on different revenues and tariffs.
- **Smart grid applications and data transfer:** Smart technologies that can be connected through blockchain includes smart devices, data communication and data storage. They are smart meters, wireless sensors, assessment of networks and installations, management and control equipment, smart home energy managing devices and building monitoring systems. Blockchain, as a result, standards the data, and this is where smart grid applications can gain from Blockchain technology. further, in addition to its role in ensuring secure data transmission (Burger et al., 2016).
- **Grid management:** Several areas including the asset management, flexibility services and decentralised network administration could be improved by the use of blockchain technology. Blockchain may enable the idea of integrated flexibility trading platforms.

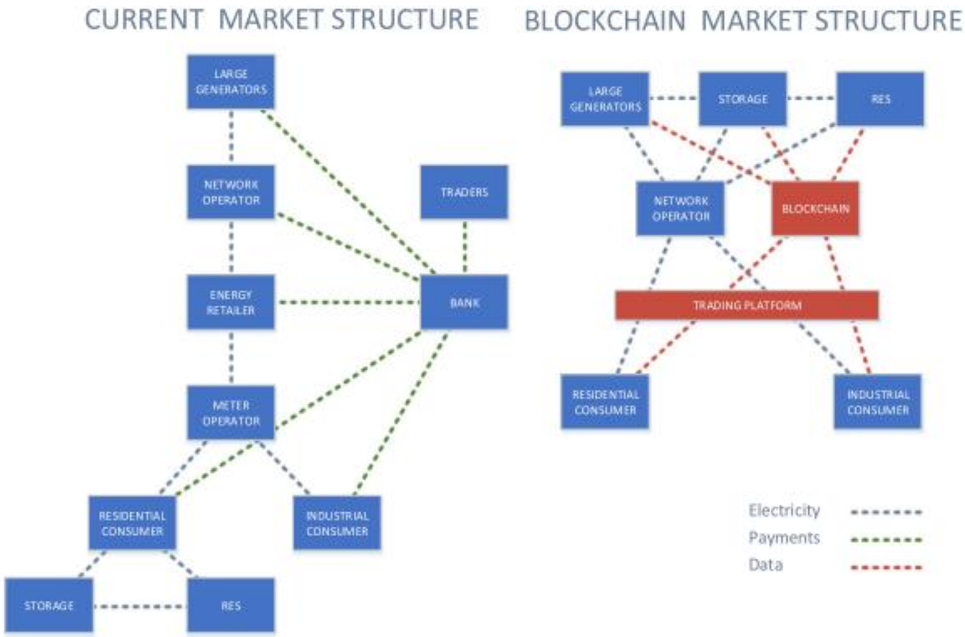

Figure 2.5: Current and Blockchain market structure

Source: Andoni (2018)

Different publications have pinpointed the possibilities of using blockchain for the wholesale energy trading, and some consulting papers even suggest that blockchain can entirely transform the energy market as we know it today. However, there are many great challenges and technical issues that have to be addressed in order to make this vision possible. Firstly, as compared to the traditional electronic payment systems, especially the those that are based on proof-of-work consensus algorithms, the number of transactions which can be cleared using blockchains is often many orders of magnitude less. In fact, clearing thousands of transactions per second, banking's electronic payment systems dwarf Bitcoin network—the world's largest blockchain-enabled cryptocurrency—in terms of processing capabilities as the latter can clear tens of thousands of transactions at best. One might think that an answer to this could be PoS and Byzantine fault tolerance systems such as Tendermint or Ethereum. But achieving these solutions is quite a burden and needs to be designed and done very systematically.

In addition, we expect that the emergence of a new, rapidly evolving environment for the energy market will be challenging. Thus, as only a part of the energy industry has been identified to be highly sensitive to blockchain technology up to this point, for instance, imbalance settlement, the majority of the active blockchain projects have focused on this area to date (Andoni et al., 2019).

2.9. Use of Blockchain in Electric Vehicles (EVS)

When it comes to electric vehicles, several methods of battery swapping do not require waiting for a long time to charge such as the battery swapping with charging stations. The technique may make the deal fair if the case is applied. It is affordable because battery type and degree of discharge will determine the transaction's equity. However, if data is stored on a central server, and trading fairness is to be attained, the task becomes more complicated as a standard centralised system of management would be used. Thus, Kim, Kang and Hong (2017) introduced a decentralised blockchain system-based battery swap technique. Here, the blockchain holds data concerning the batteries; payment is also done through smart contracts together with the price differential. If this is done, most of the unfairness issues that are rife in the transaction process will be eliminated. It should also be noted that, there is continuous rise of electronic vehicle in the Electronic Vehicle Market, which can be depicted in the figure below:

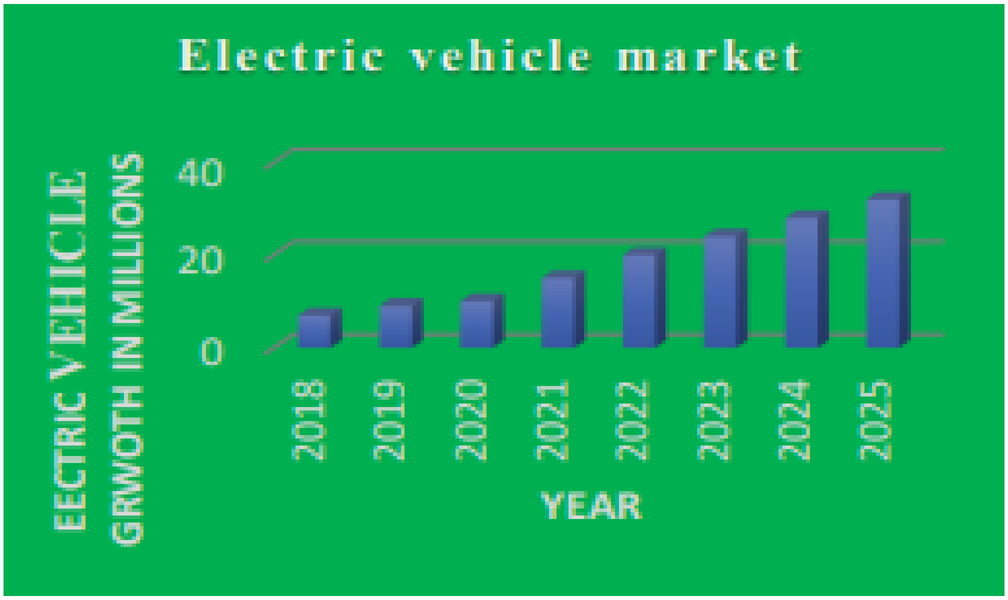

Figure 2.6: Electric vehicle market

Source: Subramanian and Thampy (2021)

As for battery switching and to mitigate the trust issues between EV owners and swapping stations, Hua et al. (2018) suggested an objective method which involved the use of the blockchain platform. The network proposed below, containing all the battery operating data, will attend to nonexistent issues with regard to the battery's health, performance decline, and depreciation. Knirsch, Unterweger and Engel (2018) described an electric vehicle charging ecosystem based on blockchain. An accountable, self-service, and secure web site. Electric vehicles estimate the demand charges and then give the charging station quotes. Charging stations are among the electric vehicle attributes that can be selected by consumers based on the costs and geography. In this process, the use of blockchain technology can be used in order to increase the level of trust in trading and make it more transparent. However, it can be concluded that privacy is kept safe since the locations of each EV are not exposed. There are four steps to completing a transaction: include the research, the bidding, the evaluation and billing phases. For reasons such as these, EVs can choose and charge at the most appropriate stations without leaking any information: First, nothing is posted because everyone operates under a pseudonym on the blockchain. The second metric is the geographical position of the user's demand message in the space of regions. Besides, the method enables the delivery of power to the target areas without compromising on the exposure of the data and location. Moreover, other users will not be able to identify which transaction was made or how much it was since most transaction operations do not need blockchain (Baashar et al., 2021).

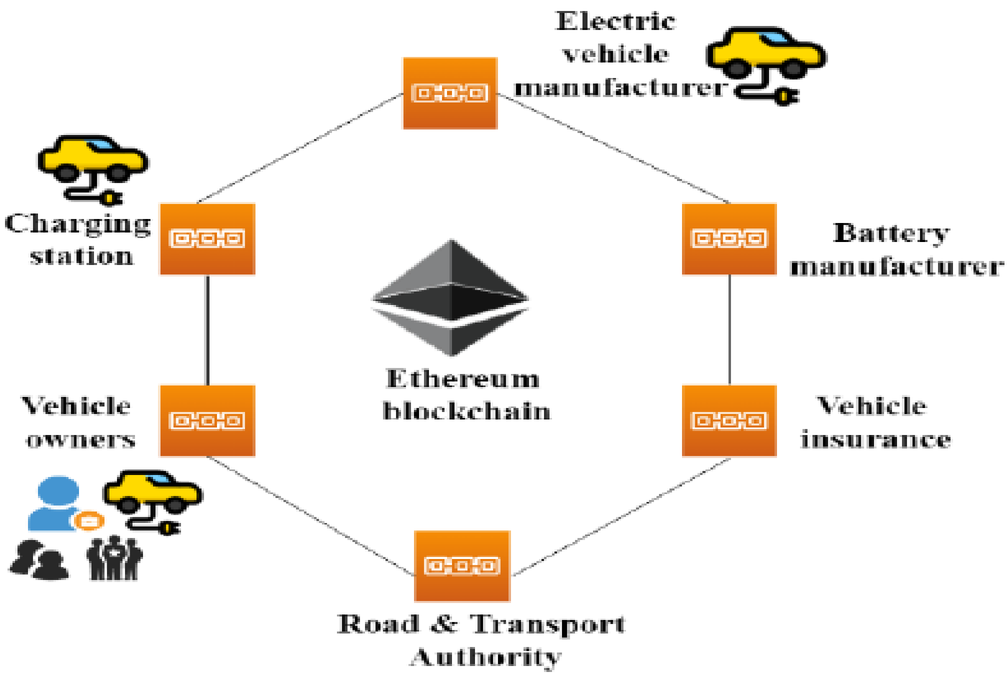

Figure 2.7: Blockchain-Based Electric Vehicle Supply Chain

Source: Subramanian and Thampy (2021)

2.10. Use of Blockchain in The Charging of Electric Vehicles (EVS)

The Ethereum blockchain client (Parity) on a Raspberry Pi (RPi) to bring blockchain integration on-premises for a completely safe trust has been set up in a study conducted by (Okwuibe et al., 2020). Installed on every CP, the R-Pi acts as a node in the blockchain, as shown in Figure below. Elasticity offers and the smart charging algorithm's

Python code are hosted in the cloud. Code for the SC's Application Binary Interface (ABI) is inserted into the Python script so that it may communicate with the blockchain network after it is produced and uploaded to the network. This Python script uses the SC ABI to communicate with the blockchain network every fifteen minutes. In order to determine the next available time slot for flexible offers, we now receive the charging requests (E,T) from EV consumers. Hash encryption is used to keep the computed results for approved requests on the blockchain. Using the cloud, the CPO's backend communicates with the database and the Python script in tandem with the blockchain node that is connected to it for redundancy and direct communication. The EV user receives a token as compensation for the given flexibility once the charging process is complete and the blockchain node deployed on the CPO's node confirms that the offer was accepted. To put it another way, this is how electric vehicle owners get compensated for the time and energy variability they provide.

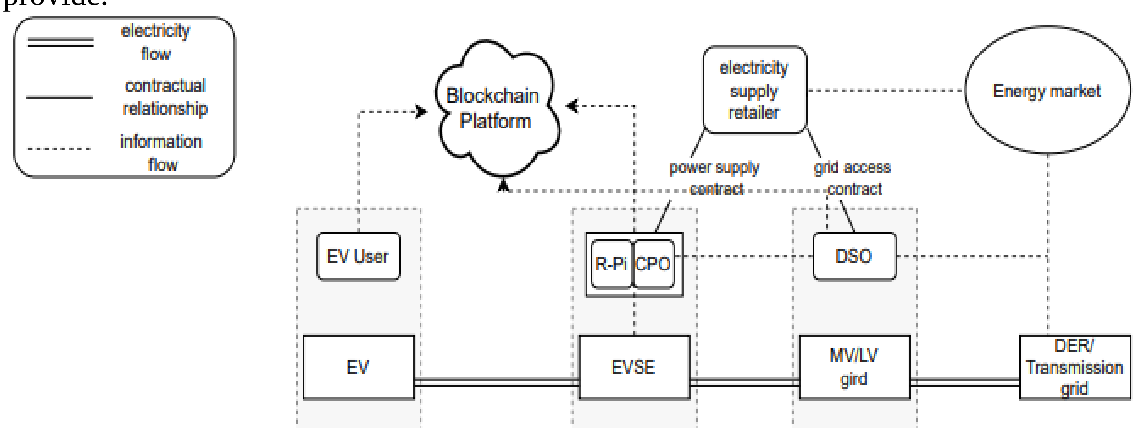

Figure 2.8: Blockchain-Based Electric Vehicle Supply Chain

Source: Subramanian and Thampy (2021)

2.11. Consumer Participation in Green Energy Initiatives

Factors Influencing Consumer Participation in Green Energy

Deo & Abhnil Prasad (2024) The Green Perceived Value (GPV) framework, which includes functional, emotional, conditional, and social aspects, is used to analyse the factors impacting green energy consumer behaviour in Australia. It takes this stance to analyse how Australian consumers feel about renewable energy. The information was supplied by 380 individuals who utilised Amazon Mechanical Turk to finish the survey. This research reports positive sentiments towards renewable energy sources by use of factor analysis and structural equation modelling. Many people have a favourable impression of it because of its high quality, practical uses, and favourable impact on the environment. According to these results, in order to get people to switch to green energy, marketers need to stress the practical and ecological advantages of the technology. Findings from the study stress the need of highlighting the environmental and financial advantages of green energy in targeted educational efforts directed at younger generations through digital media. It also suggests encouraging community involvement and using social and emotional value marketing to make green energy solutions more appealing. Adding to the ongoing discussion over renewable energy in Australia, this study calls for measures that benefit all demographics by making green energy more accessible and affordable. More research into the GPV dimensions, including prospective buyers from diverse cultural backgrounds, is urgently needed. It provides a thorough framework to back policies that are in line with sustainability goals and aim to increase the usage of green energy.

Polcyn et al. (2022) In recent years, both rich and developing nations have made ending the energy problem and reducing inequality their top concerns. Also, as a consequence of the COVID-19 pandemic's impact on economic recovery, natural gas shortage, and subsequent increases in energy prices, energy imbalance has grown even more noticeable. In order to confirm that growing renewable energy consumption is associated with a growth in national GDP, this study sets out to do just that. Between the years 2000 and 2018, this research looks at how different European countries' usage of renewable energy sources changed. World Bank Open Data and OECD Stat provide the yearly data utilised for panel regression analysis. Panel unit root test, Pearson correlation, fixed- and random-effects models, generalised method of moments (GMM), Hausman, and robustness testing were among the estimated approaches used in this empirical investigation. The findings of the Hausman test indicate that panel balanced data is beneficial for the fixed-effects regression model. For the whole sample, we found a positive and statistically significant connection between GDP per capita, CO_2 emissions per capita, and the proportion of renewable energy use overall using generalised linear modelling (GMM) and fixed-effects regression. There is a negative relationship between the usage of renewable energy and the total labour force, gross capital formation, and production-based CO_2 intensity. This study's findings could be useful for policymakers looking to boost the renewable energy sector and the economy in the long run.

Wall et al. (2021) Finding out what makes Thai consumers switch to renewable energy sources was the driving force behind this research. The research used an expanded version of TPB, which includes three extra variables. A survey of customers in five big Thai cities provided the main data used in this quantitative research. The data was analysed using structural equation modelling (SEM). This study found that consumers' perceptions of their own efficacy, their care for the environment, their familiarity with renewable energy sources, and their ideas of the advantages of these sources all significantly and positively affect their desire to use these sources. Researchers found that customers' perceptions of risk and trust had a favourable but non-significant effect on adoption, while the cost of renewable energy had no effect. Research in Thailand has shown that stakeholders may boost renewable energy adoption by focussing on four key areas: self-efficacy, environmental consciousness, knowledge of renewable energy sources, and benefits perceptions.

Masrahi et al. (2021) Despite the fact that home energy consumption in the US is heavily influenced by consumers' demographics, behaviours, and physical attributes, research has shown that public acceptability is crucial for the immediate and future use of renewable energy. Taking into account demographics, socioeconomic status, and behavioural traits, this study sought to identify the elements influencing residential consumers' adoption of RE sources in the United States. The researchers in this work set out to test the assumption that consumers' "willingness to pay" could be a useful predictor of their propensity to purchase renewable energy sources. The participating states provided 25% of the nation's renewable energy. The findings revealed that consumers' propensities to utilise renewable energy are significantly affected by the average household income in the residential sector. The findings also match the expectations of the TPB structural equation model. Here, consumers' intentions to utilise renewable energy were significantly impacted by the subjective norm and the willingness to pay construct, but consumers' views towards the activity were unaffected. The paper also includes a detailed discussion of its limitations and recommendations for future research.

Venugopal & Shukla (2019) In order to encourage the adoption of energy-efficient technology, utility companies offer a variety of financial incentives to buy, rent, or lease energy solutions. Customers' preparedness to pay a premium for renewable energy is influenced by their ethical commitments to sustainability. This research uses structural equation modelling and data gathered from 140 Canadian residential energy users to investigate the hypothesis that customers' moral disengagement with environmental issues affects their readiness to pay more for renewable energy. In addition, the impact of moral disengagement on willingness to pay is amplified when consumers perceive a higher degree of control when assessing energy options. The socio-economic elements that promote ethical involvement with renewable energy sources are also shed light on by these results. The results back up the arguments in favour of moral self-regulation and add to the body of data supporting it. In light of these findings, energy providers may want to consider developing specialised business models to encourage the purchase and usage of energy-saving appliances. Likewise, policymakers might use the results as a roadmap for understanding the mental and emotional aspects that influence consumers' ethical involvement in environmental issues.

Sangroya & Nayak (2017) The potential of green energy to lessen environmental harm has piqued the interest of researchers around the world. Government laws alone will not bring about universal adoption of green energy; consumers must also be eager to utilise green energy if they want to make a positive impact on the environment. Improving the perceived value of green energy to consumers may foster this willingness. To achieve this goal, though, we must first determine how much value customers now attach to green energy. To gauge current levels of consumer perception, this study creates a multi-dimensional green perceived value scale. Green perceived value is seen by the scale as a complex second-order entity with multiple dimensions, including social value, emotional value, conditional value, and functional worth. The novelty of the current investigation is enhanced by the fact that no prior effort of this kind has been made. One possible use of the scale is to gauge how people feel about renewable energy. Strategies to encourage consumers to freely adopt green energy could be informed by such information. According to the research, consumers are influenced by a variety of factors when making decisions on green energy, including financial, emotional, and social factors. Policymakers might then create pro-green energy campaigns and public education materials that encourage people to embrace green energy on their own will, rather than relying on financial incentives. Additional research into the scale's examined dimensions in relation to other consumer behaviour components is possible.

Rolando Madriz-Vargas (2015) The United Nations Sustainable Energy for All (SE4All) program anticipates that minigrids will be crucial in guaranteeing access to energy for all. However, community integration is lacking, users have unrealistic expectations, and local maintenance capacities are low, among other technological, organisational, social, and financial hurdles to their effective implementation. There is hope that CREMs, or community renewable energy minigrids, may improve outcomes compared to minigrids with different ownership and operation structures by increasing community engagement and so mitigating some of these challenges. Other significant socioeconomic benefits and better rural livelihoods are also projected to be offered by CREMs. Nevertheless, the literature reports a variety of difficulties encountered by current CREMs. Some of the specific obstacles include the following: the necessity for substantial communication; risks associated with technology choice; disputes regarding the governance of benefits; and, frequently, a lack of local organisational and technical competencies. We don't yet know what kinds of community skills or implementation methods will be needed to overcome these obstacles. A sustained and effective CREM may necessitate unique consideration and participation from practitioners, funders, and community activists; this study will offer a survey of current experiences by investigating the elements that impact CREM effectiveness.

2.12. Behavioral Economics and Consumer Decision-Making in Energy Consumption

Blasch et al. (2021) Substantial welfare losses may result from the home sector's unrealised energy savings potential. The lack of adoption of energy-efficient durable products has been the subject of numerous research examining behavioural biases, but the impact of poor energy-specific knowledge and financial literacy has received less attention. An integrated notion of "energy-related financial literacy" is proposed in this study. This term encompasses both the knowledge and abilities necessary to analyse energy cost information. Utilising information derived from a comprehensive household survey conducted in three European nations, they delve into the factors that influence various literacy assessments. Of paramount importance, they offer concrete proof of the correlation between a lack of understanding and ability to execute an intertemporal optimisation and the utilisation of energy-saving light bulbs. Our research lends credence to the idea that financial education programs and resources tailored to energy needs can encourage more people to buy long-lasting products that use less energy.

Reisch & Zhao (2017) Behavioural economics studies have demonstrated that people's judgements and decisions are very context dependent and subject to systemic biases and heuristics. This challenges the long-held belief in neoclassical economics that humans are essentially utilitarian beings who never deviate from their "real" preferences and always seek to maximise their own utility. Research in consumer behaviour and consumer policy has been impacted by the shift in focus from behavioural economics to neoclassical economics, which is briefly covered in this article. Specifically, we go over the ways in which some fundamental principles—like mental accounting, the sunkcost effect, the status quo bias, and the endowment effect—influence consumers' choices. We also discuss how various biases and heuristics impact consumers' decision-making, such as the anchoring effect, simplicity rules, and heuristics involving salience. These principles have practical implications for consumer policy that can be easily put into practice. They aim to encourage healthier eating, more sustainable consumption, better financial decisions, and product choice, and they make a significant contribution to the field of consumer behaviour research.

Hobman et al. (2016) Reforming energy rates is a challenging subject that many countries throughout the world are presently confronting, including the Australian electrical market. There is growing consensus that residential users should be moved towards more "cost-reflective" pricing. This approach aims to convey a "price signal" that more precisely reflects the actual costs of generation and delivery, thereby encouraging less usage during peak periods. These plans charge customers more for power used at peak demand times, as opposed to the more traditional "flatrate" tariffs, where prices remain constant regardless of demand or time of day. Results from pilot projects suggest that cost-reflective tariffs have the potential to lower peak demand, but usually only for a tiny subset of consumers, leaving little to no effect on demand across the board. The authors of this study draw on the fields of behavioural economics and psychology to determine the best ways to design, portray, and implement cost-reflective pricing in order to increase its adoption and optimal usage by a wider demographic and to facilitate "appropriate" demand response. The authors provide actionable advice for businesses to increase the likelihood of cost-reflective pricing significantly reducing peak demand at the population level. These methods account for the psychological and cognitive biases that have a significant impact on people's decision-making and actions. Everyone wins: consumers, businesses, networks, and authorities.

Schubert & Stadelmann (2015) Improving energy efficiency, lowering energy demand growth rates, and cutting carbon dioxide emissions are all necessary for sustainable development. A large portion of the overall energy demand and carbon dioxide emissions in many nations come from residential energy consumption. Durables that use energy are crucial in this situation. In an effort to reduce their environmental impact, individual families should prioritise the purchase and usage of durable goods that are designed to be energy efficient. Since the more energy-efficient products have a positive net present value

(NPV) due to reduced overall expenses over their lifetime, it might be economically optimum to buy them. The "energy-efficiency gap" occurs when individual households' spending habits diverge from the most efficient use of resources. This study seeks to understand why there is still a disparity between the energy-efficient products that would be best from an economic perspective, but which people avoid buying, and the less energy-efficient things that people do own or purchase, even though they have higher total expenses. Inadequate knowledge, lack of focus, or inaction are some of the factors that appear to discourage private households from buying energy-efficient goods with favourable NPVs. Their research will demonstrate that private families face many obstacles that prevent them from making the most economically efficient decisions. They will also provide solutions to these problems. Along with offering some additional policy suggestions that could aid in adequately reducing household energy demand and CO_2 emissions, they will demonstrate how well-designed energy labels could aid in overcoming the information-related causes of inefficiently low investments in energy efficiency.

Frederiks et al. (2015) Researchers, practitioners, and politicians now face the formidable problem and exciting possibility of household energy saving. Amid rising public worries about greenhouse gas emissions and climate change, consumers are increasingly becoming more conscious of the importance of sustainable energy practices. People still don't do much to improve energy efficiency and conservation, even if they know enough about the topic and say they want to. There is frequently a significant difference between what people say they know and what they really do; the famous "knowledge-action gap" and "value-action gap" are only two examples. Household energy use is also not mainly influenced by monetary incentives and the logical pursuit of material goals. The goal of using incentives and punishments to encourage more sustainable habits is admirable, but people often have surprising and unintended reactions to these strategies.

What gives? Why are fundamental principles and material interests not good predictors of family energy usage and conservation? They provide light on the main cognitive biases and motivating factors that may explain why energy-related behaviour does not always match up with customers' personal values or monetary goals by utilising essential insights from behavioural economics and psychology. Gaining insight into these mental processes can help us anticipate and prepare for community and household reactions to public policy initiatives, while also guiding the development of more efficient and broadly applicable behavioural interventions to promote the use of renewable and sustainable energy sources.

Lavrijssen (2014) Energy users, according to European lawmakers, play a crucial role in helping the EU accomplish its energy policy goals. Promoting competition, guaranteeing cheap energy prices and supply security, and contributing to the environmental and climate goals of Europe are all part of this. Despite lawmakers' high hopes for energy users, studies of their actions reveal that they are only partially (if at all) competitive drivers in reality. There is evidence that energy users aren't doing much to cut down on carbon dioxide (CO2) emissions and aren't taking use of possibilities to save energy that are already available to them. Examining the implications of behavioural economics for legislators' presumptions about energy customers' roles and for the regulation and structuring of the energy industry, this study draws conclusions. It goes on to look at how these findings could change the way energy supervisory agencies implement the European energy regulations. This reflection will centre on the energy sector's regulatory landscape and the potential and constraints of utilising behavioural economics' insights.

2.13. Technological Challenges in Implementing Digital Solutions for Green Energy Adoption

Abusohyon et al. (2021) Companies can better adapt to changes in technological development and achieve better results by digitalising their business processes with the help of Digital Twins. Maximising the usage of digital twins requires acknowledging the impact of the creative phase, as a foundational component of the technology, on the efficiency of the other parts and the end product. The focus of this research is the fact that there isn't a single set of guidelines for starting the creative phase of digital twins. We used a qualitative empirical approach and interviewed digital twin industry experts to learn about the phase, its visible and invisible components, the entities involved, potential problems, and successful solutions so that we could build the right framework. In order to incorporate improvements internally, the suggested framework's structural feature constantly gets the system ready for updates. All businesses interested in digitising their physical assets can use this study's findings as a guide, and those working with digital twins can utilise them to enhance the interactions between their systems.

Lichtenthaler (2020) Digitalisation, AI, and related innovations are at the forefront of most companies' agendas since they are essential to strategic transformation. The strategy creation phase of digital transformation is now over for many companies, and they are moving on to the execution phase. A lot of companies have a hard time in this area because they focus too much on technological problems and not enough on market-related ones. This conceptual research lays out crucial components of effective digital transformation, following the innovation-based approach and a theoretical framework of technological push and market pull impacts. This exemplifies the current standard of care at most companies and draws attention to the shortcomings of these methods. Several implementation approaches are provided to address these restrictions. Therefore, this study adds to the literature on AI and digital transformation and on managing strategy renewal in the face of technological change.

The article Söderholm (2020) highlights factors that cause difficulty in achieving sustainable technological change with the hope of educating the policymakers and the public on the different socio-technical systems in this process. Focusing on the external factors, the paper reveals the difficulty of handling the environment issues related to the diffuse emissions in transportation and agriculture sectors. These emissions, despite being small when regarded individually, can create massive environmental issues, for which global collaboration and creative policymaking are needed. It also stresses the importance of radical transformation in five sectors to support sustainability improvements. However, there is risk aversion among firms, and existing technology tends to limit the adoption of radical innovation. When sustainability is implemented into business practices, there is a problem with policy, in order for there to be greater process change and respond to the vagueness of green capitalism. It examines equitable distribution of green transitions, pointing out that green policy adjustments may be regressive. This requires balance in the measures being taken to make the transition legitimate and acceptable in the society.

From a review of literatures and expert elicitations, Clifton et al. (2023) find three main cross-cutting challenges to the digitalisation of wind energy. We argue that these barriers can only be addressed by level strategy and we label them as "grand challenges" in the digitalisation of wind energy; This we substantiate by comparison with other networked industries as well as previous as well ongoing attempts at facilitating digitalisation. First, they are developing FAIR data frameworks, secondly, linking people and data for innovation, and thirdly, promoting organisation collaboration and competition. The grand challenges in the digitalisation of wind energy are therefore a combination of technical, cultural and business factors that are going to require a multi stakeholder approach involving business, academia and government. Addressing them is the start of a continuous process that will establish wind energy as a core component of the world's clean power future.

According to Baidya et al. (2021), the problem is that one can encounter certain difficulties when it comes to obtaining energy in an efficient manner, which in turn slows down the digitalization process. Handling big grid data is challenging, more so due to the growing amount of data produced by smart grids. These are the concerns as to data fusion and congestion. Decentralization of data analysis requires cases where data can be processed and analyzed without a central power, which is important for efficient energy control. Smart grid is an area of concern when IoT is integrated into them, the issue of security comes into play in terms of consumer data privacy and transaction authenticity. Challenges such as gap in data, inadequate quality of the data collected, and the presence of corrupted data affect the smart grids' performance greatly. Tackling climate change and carbon has remained a big challenge in developing a green energy system. Currently, one of the biggest concerns when it comes to consumer energy data is privacy, without which the use of digital energy systems will not garner consumer trust.

2.14. Consumer Trust and Privacy Concerns in Digital Platforms

Opportunities for Enhanced Consumer Engagement through Digital Innovation

Czarnecka et al. (2022) seeks to signify its intention to show whether the level of consumer engagement in social media determines the perception of green energy business model as well as the attitude and the pro-environmental behaviour of the users of the social media. What this study established was that respondents consider social media to be a credible source of information that has an impact on their buying decisions. This explains why eWOM plays a crucial role in influencing the consumers' behavior towards green energy products. It is also evident that users' pro-environmental attitudes are related to their perception of energy companies (ESCs). However, the level of interaction of these companies on social media does not have a great impact on the consumer's perception; this shows a great communication policy/strategy disconnect. The study underlines that energy companies need to shift from an informational model of communication and start a two-ways conversation with consumers. This shift is important in gaining the confidence of the masses for the green energy business. The present study concludes that environmental friendliness increases with age, education level, income and even occupation. From these demographics, ESCs can use this to help them in marketing to these groups. The results suggest that it is critical for businesses to develop new sustainable solutions that can help them respond to the current pandemic obstacles and customer demands for greener products.

The research Moreno-Munoz et al. (2016) therefore seeks to understand the potential that mobile social media has for improving customer relations in smart grids. It underscores the importance of approaches that foster engagement of citizens as concerned stakeholders and, more importantly, as 'prosumers' of electricity. ICT is highly effective for enhancing efficiency of energy and decreasing energy intensity and it is a significant factor for achieving energy efficiency. Understanding can be gleaned from successful brands to improve the digital customer journey and the utility evolves from a simple energy seller to a seller of energy services. Engagement strategies require flexibility to cope with changing consumer behavior and address complementary delivery channels such as, mobile apps. Utilities should instill the active management of electric consumption in the customers which can enhance the quality of energy supplied and fed into the grid. The paper also argues that, for smart grids to achieve their full potential and deliver long-term customer value and engagement, a new market model has to be developed. With the adoption of mobile social media technologies, there are prospects that the utility can improve on the customer relations and in the process increase their satisfaction thus improving the overall energy value network.

The purpose of the research GONÇALVES (2022) is to explore customers' experiences of smart energy services, with attention to value co-creation practice patterns and customer interaction patterns. This paper aims at outlining a conceptual framework for designing the strategies to improve the customer engagement in this regard. The study defines a number of perceptual response variables to do with customer experience of smart services, including specific to smart services and relationship to smart services. That is because value cocreation and customer engagement depend on the roles customers take and their relation with other actors in the smart energy service environment. The study also shows that self-interest-based incentives are not suitable for long-term customer engagement with energy services, therefore implying the need for policies that would embrace customer value co-creation and engagement behaviour. The findings are useful to policymakers in their understanding of the need to develop financial models that are compelling and sustainable for customer patronage of smart energy services. By examining the energy and service interface, the study also calls for more studies to combine value creation and engagement theory. From this it implies that ESCOs should shift more towards integrated service orchestration for improvement on customers' side.

The study Ullah et al. (2018) seeks to develop a concept that would help in explaining the role of automation and connectivity in EVs to deliver a positive customer experience. This paper considers the case of low customer adoption of EVs by focusing on the use of ICT characteristics to enhance the relationship between EVs and their users. The study finds out that smart automation and connectivity features in EVs offer a major boost in customer experience, thus enhancing customer interaction. It explains that brand value and customer involvement as mediating variables in the link between customer experience and engagement. According to the research study, there is a need for EV manufactures to incorporate ICT elements into EVs to make them more attractive and customer friendly hence increasing the chances of their use. The study calls for empirical testing of the proposed conceptual model and suggests that more research is required to determine other attributes that are likely to pull the customers. It also points out that analysis of big data sourced from these technologies to determine customer preferences can improve the implementation of features in EVs to the benefit of the driver.

The purpose of the study Prasad et al. (2020)is to set a framework of gamification strategy that will help in increasing engagement of the citizens in energy saving. It also presents the game strategies, mechanics, motivation, and rules that are required for the development of an application of gamification. Namely, the framework points to the significance of motivation as the underlying aspect in gaming and thus, it is argued, links to psychological needs can cause more effective gamification. The suggested application of gamification is a level-based game and its participants can get money for the tasks accomplished, which will enhance the motivation rates. The framework is not only specific to sustainability issue but can be applied to other sustainability issues like waste management and water conservation. While adding fun elements into traditional ideas of energy saving initiatives, the framework supports sustainable development and encourages people to take a closer look at energy saving programs. This application will create considerable user data that can be used to enhance the gamification experience and do it in an iterative manner.

The research Rodrigues et al. (2020) was focused on investigating the level of users' participation in the community energy schemes in the framework of the Sustainable Community Energy Networks (SCENe) project at Trent Basin, Nottingham. It centered on trying to uncover how various forms of engagement can impact behavior and level of participation in energy related issues. The primary reasons that were instrumental in the decision to adopt BP were mostly to do with self-advantages like lowering electricity bills, self-generation of power, and reducing their environmental impact. Initial questionnaires showed that financial motives as saving money were the biggest reason for taking part in the programmes were identified, whereas, later questionnaires in the frame of the workshops revealed the incentives such as rewarding for low electricity consumption and re-investing in sustainable activities. An interconnection of different engagement technologies, such as online forums and community centres, meaningfully boosted participation and energy concerns. The study recommends that an understanding of the characteristics of communities can improve energy utilisation and participation in similar projects. The approach proposed in this paper could also be extended in future work to study the dynamic behaviors of end users in the context of community energy schemes to yield better insights into engagement and energy management. This type of research brings important findings about the centrality of user participation to the effectiveness of community energies, and the necessity of the development of more effective strategies to engage users.

2.15. Policy and Regulatory Support for Digital Solutions in Green Energy Adoption

Qiaoya Zhang, Qing Li, Jingwen Yao (2024) Promoting innovation in green technology, the digital economy achieves a win-win situation by both increasing energy efficiency and advancing the digital economy. As a theoretical and practical framework, the digital economy offers valuable direction for China's green sustainable development and dual-carbon objectives, particularly in the areas of energy efficiency improvement and green innovation in enterprises. The effects of the digital economy on environmentally conscious innovation and energy efficiency upgrades to businesses are investigated in this research. Using panel data and a double-difference model, this study examines the impact of China's national-level big data comprehensive pilot zone policy on polluting listed firms from 2010 to 2022. Furthermore, a threshold model is built and evaluated using data from China's tech industry spanning 30 cities and provinces from 2010 to 2022. The results demonstrate that digital economy positively affects green innovation efficiency in enterprises, but via a nonlinear "U" threshold effect. It is necessary to conduct diverse countermeasures based on regional differences because the regulatory impacts of an active government and an effective market on this process vary at different phases of development. The digital economy plays a key role in fostering environmentally friendly innovation in smart city construction. With a "N"-shaped characteristic, the study indicated that the digital economy—and particularly industrial digitization—plays a key role in encouraging energy efficiency, according to data from 284 cities at the prefecture level.

Aboalsamh et al. (2023) Faster and more efficient services for customers and lower costs for banks are only two ways in which fintech has changed the conventional financial environment. The ever-expanding capabilities of technology are expected to fuel significant growth in the financial technology business in the years to come. This will result in expanded access to financial services and a higher level of financial inclusion on a global scale. What effect does green Fintech have on smart city sustainability and customer behaviour? That was the primary research topic. Among the goals of this research was to determine how green fintech regulations and activities influence consumer behaviour in the Middle East by analysing consumer perceptions of the impact of green fintech on sustainability. This qualitative study used a convenience sample of eight people to interview about the issue and a subset of six primary sources to compile and analyse data. Online interviews were videotaped and subsequently transcribed for data analysis. According to the findings, green fintech helps the environment by luring businesses towards renewable energy investments, which allow them to borrow money at cheaper interest rates. Green fintech also aims to increase access to capital for small firms and startups by making it easier for them to invest in environmentally friendly technology. But the current regulatory framework was a major roadblock to green fintech's broad acceptance. More businesses would adopt sustainable practices, according to the report, if the benefits of green fintech solutions were well publicized.

Arvanitis et al. (2016) already-existing literature on policy-induced adoption of technology in multiple ways. To begin, propose a different survey format for gauging the policy climate surrounding energy. Thirdly, they estimate the policy impacts for both the intensity and propensity of adoption at the same time, and secondly, they compare the policy effects worldwide. Data from a cross-section of Austrian, German, and Swiss businesses shows that national policies encourage technology adoption but do nothing to address intensity, a problem that will need to be addressed in future policy formulations. One of the most influential elements in the tendency to embrace green energy technology is voluntary agreements or demand-related considerations. Austrian subsidies are more successful than German taxes, whereas Swiss demand-related variables are relatively more effective, all taking into account the present institutional structure in the analysed nations.

Costantini & Crespi (2013) To lessen the impact of unintended consequences associated with economic activity, several developed nations have enacted environmental policy measures. Different policy actions have different impacts on the economy because different regulatory mechanisms are used for different purposes. When considering the trajectory of technology, it becomes much more difficult to foretell the impact on innovation. The energy sector was chosen as a case study due to the intricate network of interconnected social, economic, and technological elements that can exacerbate policy disputes. The study's overarching goal is to demonstrate how a patchwork of incoherent energy regulations may impede the spread of green energy technology and how weak coordination amongst various energy-related public policies might exacerbate this problem. The OECD nations have embraced a gravity equation model that takes into account the two-way flow of technology exports for renewable energy generation and consumption as well as energy efficiency solutions. Different public support metrics for the energy industry have been having different impacts on energy technology competitiveness on a global scale, according to our main findings.

Coelho et al. (2024) A new technology called a digital twin (DT) can make sustainability a reality. Nevertheless, the factors that will determine the level of acceptance of digital twins, particularly in homes, are still unknown. This study aims to address a knowledge vacuum by developing a theoretical framework for understanding the factors that influence family adoption of digital twins and how it relates to overall health. This research adheres to the principles of mixed-methods methodology. The model is created using a qualitative approach, drawing from results in the literature as well as important insights gained from interviews with experts and potential customers. After that, 149 people filled out a survey to verify the model's accuracy. The findings indicate that a variety of elements pertaining to knowledge, society, the environment, and practicality can impact the desire to utilise digital twins as a green energy solution, and hence, one's sense of happiness.

2.16. Application of Block Chain Technology in Green Energy

The objective of the study Wu & Tran (2018) is to discuss the concept and history of blockchain and its possible use cases in the Energy Internet. It aims to offer a brief on how Blockchain can help in solving some of the issues in energy industry most notably, in the area of efficiency, openness and credibility. It also points out that blockchain technology is suitable for the Energy Internet and that blockchain can assist in dealing with challenges of DER and enhancing transaction activities. The Use of this technology has been shown such as the P2P electricity trading and the formation of the decentralized electricity infrastructure. The paper also covers the issues arising from the integration of blockchain technology in the Energy Internet including high energy demands and the question of regulation. In summary, the research highlights the opportunity of blockchain for the change of energetic systems while at the same time pointing out the need for the further examination of the current challenges.

The study Juszczyk & Shahzad (2022) will focus on the application of the blockchain technology and its implementation in renewable energy market. It reviews what is known about the technology currently, its benefits, and challenges to adoption particularly among the experts. This research also identifies the level of knowledge of these professionals regarding the blockchain technology as moderate. Although the majority have heard about it, they lack detailed information on how it works in their area of specialization especially with cryptocurrencies. The identified benefits of blockchain in the analysis include; increased transaction throughput and better trust. But it also reveals numerous issues that might hinder the adoption of blockchain, such as the regulatory hurdles and a lack of proven applications.

The Study Thukral (2021) seeks to identify how blockchain technology can be used to enable P2P energy trading with an emphasis on how prosumers can be able to sell electricity to their neighbors. This is the reason why blockchain is so vital in the case of introducing more renewable energy sources to the general public. The study has revealed that blockchain technology is relatively new but has attracted a lot of attention from the different sectors, which suggest that the technology has a promising future in the energy sector.

The purpose of the study Baashar et al. (2021) was to identify the existing body of knowledge on the blockchain technologies and their usage in the energy industry. Thus, the Result showed that blockchain can improve privacy and data accuracy in the energy sector and mitigate numerous issues associated with customer data processing. The study also revealed that the decentralized trading algorithm can decrease the individual cost by up to 77% and the total cost by 24% proving the cost saving potential of blockchain in energy transactions. The possibilities of the application of the blockchain in the energy sector are enormous, including peer-to-peer energy trading and usage, electric cars, and distributed storage.

The research objectives of the study Gawusu et al. (2022) are to analyse the adoption of blockchain technology in the renewable energy (RE) sector. It aims to know how blockchain can solve problems in energy sector and participate in sustainable development. As stated above, it has been observed that the integration of blockchain in renewable energy has attracted the attention of people and organizations from 2017. Trading in electricity has been decentralised because players can transact at the peer- to-peer level without the use of intermediaries, thus making the process more efficient and less costly. The research thus shows that though there are benefits that can be derived from blockchain, the take up of blockchain in the RE sector is still low as compared to other sectors. This means that there is a scope for further enhancement and research that can explore the full potential of the concept.

The potential advantages and consequences of applying blockchain in the context of energy efficiency are further elaborated in a study Khatoon et al. (2019) using two case studies as potential use cases of blockchain—(i) the United Kingdom Energy Company Obligation scheme and (ii) the Italian White Certificate Scheme. For instance, research has shown that Blockchain technology is waiting at the doorsteps to revolutionise almost every economy and market including the energy market. Largest energy players around the globe have already begun investigating multiple applications of blockchain technology in wholesale energy markets, distributed energy trading, green energy financing, supply chain management, and renewable assets etc. ICTs have only begun disrupting the energy sector in recent years and now blockchain technology offers another way to make the energy system smarter, more efficient, more transparent, and more secure in the long term.

2.17. Future Trends and Research Directions

Emerging Technologies in Green Energy and Consumer Participation

Lucas et al. (2021) In response to the critical need to hasten the shift to a competitive low-carbon economy, governments worldwide have set ambitious, long-term goals for renewable energy and energy efficiency. Because these technologies are modular and renewable energies are inherently distributed, there are opportunities for consumer empowerment through involvement. However, more needs to be done to raise worldwide awareness and implement legislation that empower citizens to have an active role in the energy system. This includes buying renewable energy, investing in clean energy, and producing clean energy themselves. To build a conceptual framework for comprehending the significance of shifting public opinions, this study draws on scholarly literature and research interviews. Following this, it explores the factors that influence acceptance, including common misunderstandings, effective communication strategies, public awareness campaigns, and possible approaches to increase popular backing for renewable energy. There are still many misunderstandings and inadequate and fruitless efforts to educate the public and spread the word, according to research interviews conducted at a technical workshop on the social acceptance of renewable energy in Abu Dhabi in October 2013. Despite this, more and more citizens are getting involved. Sustainable energy communication and awareness campaigns can be created based on the main findings to increase participation in the energy transition, public knowledge and acceptance of renewable power, and other related topics.

Schweiger et al. (2020) Improving overall system efficiency while designing and operating systems that incorporate substantial proportions of renewable energy is an urgent problem for future energy systems. The importance of buildings cannot be emphasised enough, since they are responsible for around 32% of the total global final energy use. Recent empirical research, theoretical analyses, and economic and social studies have all pointed to the importance of customer engagement and integration in smart energy systems. For ambitious climate goals to be achieved, it is imperative that solutions and business models include and integrate the following elements: the customer, society, the physical environment, virtual reality, and economic circumstances. But there is a dearth of comprehensive discussions covering all these aspects. The study delves deeply into the data and computational methodologies needed, the psychological aspects of customer participation, and the essential phases and challenges that arise throughout the creation and implementation of user centric business models. They also hope to find problems that require fixing and areas that could use more study in the future.

Soeiro & Ferreira Dias (2020) In order to achieve its crucial energy and climate policy objectives, the European Union is now developing and implementing a new energy system. This system will prioritise renewable energy sources. People may get more involved in community-based projects as a result of the energy transition. Together, these groups participate in the energy market by creating RE or by forming local networks based on cooperative efforts. Energy community development varies throughout member states. Additionally, it is observed that their development varies between European countries. Gathering information about citizen energy initiatives, their key characteristics, and the reasons people want to be a part of them is the goal of this study, which will be accomplished through the use of a survey. For these kinds of communities to flourish, citizen involvement is essential. Worries about the effects of climate change and the environment appear to be the primary drivers of membership in these groups. Furthermore, they point out that building trust is crucial for the success of any renewable energy initiative in these communities.

2.18. Future Research Opportunities in Digital Solutions for Green Energy

Ahmad et al. (2021) There is a turning point in the energy industry. Changes in our energy supply, trading patterns, and consumption habits might be precipitated by advancements in digital technology. The strength of the new digitalisation paradigm is derived from artificial intelligence. Intelligent software that enhances decision-making and operations will oversee the autonomous control of power consumption, the power grid, and the integration of renewable sources. Using AI is crucial to the success of this endeavour. This research mainly focusses on applying AI technologies to the energy business. Readers and researchers can benefit from this study's realistic baseline by comparing it to their own AI initiatives, goals, new state-of-the-art applications, problems, and worldwide regulating tasks. We mainly discussed three areas: (i) how AI helps with solar and hydrogen power generation; (ii) how AI helps with supply and demand regulation; and (iii) how AI is involved with the latest technological advancements. This study aimed to examine the ways in which artificial intelligence techniques surpass conventional models in several domains, including controllability, computational efficiency, energy efficiency optimisation, cyberattack prevention, smart grid, Internet of Things (IoT), robotics, and predictive maintenance control. In the energy market of the future, big data, AI, and the creation of a model for machine learning will all play significant roles. Based on our research, AI is quickly emerging as a game-changer in the energy sector, helping businesses thrive in a dynamic and data-driven market where competition is fierce. Consequently, utilities, power system operators, independent power producers, and the energy sector as a whole may need to give artificial intelligence (AI) technology a higher priority if they want to maintain their competitive edge. Addressing the difficulties of new rivals, creative firm strategies, and a more proactive approach to customers requires informed and adaptable regulatory involvement, all while guaranteeing customer safety, privacy, and information security. Data analysis, AI, and IT have come a long way, allowing for the digital energy market to govern new services and goods at breakneck speeds.

Soeiro & Ferreira Dias (2020) The next generation of the electrical grid, also known as future grid, will enable smart integration of various power sources, energy storage, transmission, distribution, and demand management. The shift to a greener energy system and a less carbon-intensive economy cannot be achieved without renewable energy. The widespread use and unpredictability of renewable energy sources pose serious threats to the reliability of the electricity grid. Incorporating smart grid technology is a worldwide imperative and a potential game-changer. Many other fields are touched upon and included here, such as: energy, communications, computation, generation, transmission, distribution, operations, markets, and service providers. Developed and developing nations alike are seeing the rise of smart grids as a means to a more stable and trustworthy power grid. In the long run, a regulatory framework, policies, and standards will be necessary for the successful adoption of smart grids. We kindly requested unique submissions for this special issue covering a wide range of subjects, such as renewable power and clean energy technologies, smart grid architectures and cyber and physical security, management of renewable energy sources, electric vehicle systems for smart grids, distributed generation and storage, agent-based smart grid simulation, decision support approaches for smart grids, modelling and simulation of electricity markets for renewable source integration, intelligent approaches for smart grid management, and multi-agent applications for smart grids.

Bibri (2020) Modern thinkers point to ecological urbanism as a potential solution to the problem of how to build a civilisation that doesn't rely on fossil fuels. As the most ecologically responsible form of sustainable urbanism, the eco-city is a policy priority on a global and regional scale. One of the main arguments in favour of eco-city ideas and solutions is that they will reduce the strain on energy resources and, by extension, the environment. In addition, it has been suggested that the eco-city should do more to promote environmental sustainability by utilising current ICT, particularly in the field of sustainable energy systems. This study delves into the practice and rationale of eco-cities in urban planning and development, with a focus on the integration of data-driven smart technologies at the district level and sustainable energy systems. The researchers opted for a descriptive case study methodology to better understand this urban phenomenon. The empirical basis for this study was produced by a combination of secondary data, scientific literature, and documents pertaining to urban planning and development. An up-to-date review of ecological urbanism's theoretical underpinnings, practical applications, research obstacles, and data-driven smart technology developments is the first section of this study. This will establish the rationale for this investigation and provide a theoretical framework. According to the research, the Eco-city District of Stockholm Royal Seaport manages to accomplish sustainable development's environmental objectives by utilising data-driven smart technology and green energy to decrease energy consumption and pollution. Energy management, sustainable waste management, large-scale smart grid systems, bio-fueled combined heat power systems, passive solar homes, and other renewable resource conservation and demand reduction measures are all part of this. Scholars now have a better grasp of the smart ecocity phenomena thanks to this study, which sheds light on the synergistic potential of using data-driven technological solutions in tandem with sustainable energy methods to promote environmental sustainability.

Alotaibi et al. (2020) An innovative bidirectional automation system, the smart grid has the potential to revolutionise the energy business by bringing about a new age of networked, intelligent, responsive, and cooperative management of electricity generation, transmission, and distribution. The many smart grid applications and technologies have the potential to improve energy efficiency through intelligent energy curtailment, distributed renewable generation, energy storage, and effective integration of demand response. There has been a lot of work on the smart grid concept over the last 20 years, and this study summarises it all. This study aims to give an application-focused survey by independently and comprehensively investigating each and every area and sub-category. The study's preface explains what smart grids are and how they work. The offered work provides a thorough and comprehensive overview of the current state of smart grid energy data management, pricing mechanisms for a modernised power system, and the smart grid's main components. The study lists all the new developments in network dependability recently. However, data integrity becomes an even more pressing issue due to smart cities' need on sophisticated communication infrastructure. As a result, the research includes a subsection that focusses on cybersecurity's problems and current solutions. Finally, the review underlines the new advancements in the pricing mechanisms.

Scharl & Praktiknjo (2019) Keeping Germany's electricity grid stable is becoming more difficult as the country moves towards intermittent energy output from RES. However, the essential endeavour to regulate the system is hindered by the increasing quantity of RES. Many people believe that the best way to deal with this increasing complexity is to implement digital or smart energy systems. As a sector that uses a lot of energy, manufacturing is right now going through a digital transformation, often known as the fourth industrial revolution, which is kind of convenient. Using Germany as an example, this research delves into the present status of expert discourse regarding the function of a digitalised sector as a possible facilitator of the energy transition. To achieve this goal, they conducted semi-structured interviews with energy academics and industry managers to collect qualitative data. As far as the experts' predictions for the future of the industry are concerned, there are three main points: (1) making the energy system more transparent; (2) making demand flexibility possible; and (3) making energy efficiency improvements. Addressing internal impediments and investigating industry's unwillingness to engage with the energy system to commence a transition are the foci of this research.

2.19. Research Gap

Through an extensive literature review, a clear gap was identified in the existing research regarding the comprehensive evaluation of energy management systems across multiple dimensions—technological, economic, social, environmental, and institutional—within industrial and emergency backup contexts. While prior studies have addressed energy efficiency and cost-reduction strategies, they often focus on isolated aspects without integrating these factors into a unified framework that considers their broader operational, environmental, and societal impacts.

Additionally, the literature reveals a lack of research on the practical integration of energy management systems with emergency backup infrastructure, particularly concerning aspects such as cost reduction, system resilience, and environmental sustainability. Previous studies have predominantly focused on theoretical models or case-specific investigations, which fail to capture the real-world complexities and challenges associated with these systems.

Furthermore, while technology's role in energy management has been widely discussed, the literature often overlooks the interplay between technological advancements, organizational practices, and regulatory frameworks. This gap highlights the need for more research to understand how industry standards and institutional support influence the successful adoption and integration of energy management solutions across diverse sectors.

This study addresses these gaps by offering a comprehensive, multi-dimensional analysis of energy management systems, exploring their effectiveness, challenges, and alignment with industry standards, while also examining their long-term impacts on operational efficiency, cost-effectiveness, and environmental sustainability.

CHAPTER III:

TECHNOLOGY AND CONCEPTUAL FRAMEWORK

3.1. Power Bank on Cloud Framework (PBoC)

Typically Power Bank on Cloud (PBoC) concept refers to the use of grid-connected consumers in combination with renewable energy sources to allow for efficient storage, trading, and sharing of energy through cloud technology. This concept seeks to engage the end consumer in the choice to go green on energy usage through a decentralized cloud-based consumer-controlled platform. PBoC uses IoT, cloud computing, and blockchain technology to enable P2P energy trading, energy storage, and decentralized energy management. It means consumers can store the extra green energy produced in their homes, such as solar energy produced by solar panels, in the cloud and sell it to other consumers or put it into a common energy reservoir for the benefit of all. Not only does it provide energy facilities to the mass population, but it also improves the effectiveness of energy distribution networks by encouraging the use of green energy. The heart of PBoC is the utilization of blockchain technology, which brings transparency, decentralization, and security into the energy transactional process, as well as optimizes its performance relying on the principles of trust and accountability.

Many academics from all around the world have committed their past few years to studying and using energy blockchain. It's noteworthy to note that there is no evidence of a widespread adoption of a blockchain-based energy management system in the actual energy market, considering any geography.

The primary cause, which is represented in the following three factors, is that the current blockchain-based energy management mode cannot adapt to the DES with high renewable energy penetration.

1. The energy blockchain technology that is now in use primarily ensures the atomicity of asset interaction through the deployment of electronic cryptocurrencies (Wang et al., 2020). The conventional blockchain architecture cannot be immediately used to complicated energy management situations due to the fact that DES comprises enormous computation workloads including frequency, voltage, and power
2. Financial transactions and currency circulation are intended uses for the common blockchain consensus processes (Albayati, Kim and Rho, 2020). In contrast to a financial trading platform, energy management must take into account power balance, the use of renewable energy, the reduction of carbon emissions, and other factors. Energy blockchains require the establishment of a consensus mechanism that is in line with the properties of energy interaction.
3. As renewable energy sources become more prevalent, energy management mode needs a second-level reaction to deal with the volatility of power generation (Albayati, Kim and Rho, 2020). The current blockchain encryption algorithms prioritize data security and seldom consider operational effectiveness. However, the network latency could have an impact on how reliable the system is and how much renewable energy is used.

The net zero pledge is already dominating across the globe and utilities are leading the energy transition initiatives aimed towards carbon free generation and motivate customers to contribute towards green energy initiatives. To meet the ambitious targets, it is important for the utilities to have a socio-economic perspective and a multidimensional approach involving a wide array of stakeholders - investors, consumers, competitors, and government/regulatory bodies (Dmytriyev et al., 2021). Blockchain as the technology have a great potential to integrate all the key stakeholder in the overall ecosystem (Kitsantas &

Chytis, 2022). Having said that, active participation of consumers can support the utilities in implementing innovative strategies to reduce the carbon footprint. It is imperative for the utilities to focus on new business models to engage end consumers in achieving the decarbonization & sustainability targets. However, we are not left with many options in the market to have direct involvement of end consumers, not just merely a source of revenue generation, but also as a direct participant in the overall progress. In a nutshell there is no proper mechanism or platform that encourages the end-consumer participation towards renewable energy adoption and purchase. It is also important to note that at present there is lack of transparency also which can really indicate that consumer is consuming power generated through a renewable energy source (Ang et al., 2022). To cater these challenges faced by utilities and to increase consumer participation we hereby propose a blockchain based model naming "Power Bank on Cloud".

Application of Blockchain Technology

A major reason for adopting blockchain technology as the cornerstone of the Power Bank on Cloud (PBoC) system is that blockchain can establish an efficient, safe, and shareable energy trading platform. Again, the concept of blockchain works well with the needs of green energy systems since it creates trust and traceability in energy production, storage, and distribution. The following factors indicate that blockchain is the most appropriate technology for PBoC;

1. **Decentralization**

Another advantage of blockchain is that it is a distributed technology. In conventional energy supply, the stakeholders involved in the management, production, and distribution of energy are large utility companies or grid operators. This centralization of decision-making results in poor productivity as well as poor accountability. Blockchain provides a distributed database in which the consumers, producers, or any other involved parties have ownership of the network and can access information. This will guarantee the consumer flexibility to decide on how his energy is consumed or even transacted without the intervention of brokers between him and the producers of energy. In addition, decentralization reduces a single opportunity for system disruption hence increasing the stability of the energy market (Singh et al., 2021).

2. **Transparency**

In a system as complex as PBoC, with distributed management of energy resources, it is essential to establish trust between participants. Blockchain guarantees that every record of a transaction within energy production, storage, and distribution is recognized and accessible by each of the parties in the network. For example, with the help of blockchain, it is possible to identify the source of energy, and thus the consumer can judge for himself whether he consumes electricity generated from solar panels or wind turbines. Such traceability goes a long way in building confidence among users and hence inducing them to participate more in green energy-related activities. Moreover, the fact that all activities are transparent can encourage even more consumers to engage in sustainable energy activities, which will help expand the use of green energy (Park & Park, 2017).

3. **Security**

Blockchain utilizes various cryptographic techniques to protect the transaction and thus offers the best protection for data. Each transaction is a block in the chain and each block is secure and cannot be tampered with or hacked easily. These necessitate high levels of security that customer and operational data, and indeed data involved in energy consumption, pricing, and trading should not be vulnerable to hacking among other vices. In the PBoC system, all the data related to energy usage, storage, and trading can be stored on the blockchain, and no third party can change information in the blockchain without authorization. It also builds confidence among the participants because blockchain is unchangeable and ensures the authenticity of the energy records and the whole system (Sharma et al., 2020).

4. **Traceability and Accountability**

Another factor where Blockchain's feature of providing traceability comes into play is in the adoption of green energy. With a focus on sustainability, a need to know the source of energy that is being used also arises. Blockchain makes it possible to have a record of energy that consumers can track from the time it is generated to the time it gets consumed the energy consumed has to be green energy. However, blockchain promotes accountability as every participant working within the network leaves an imprint of their actions and or transactions. Such a level of traceability is useful in compliance with green energy standards as well as legal requirements enabling better management of renewable energy (Do, 2021).

5. **Peer-to-Peer Energy Trading**

However, the use of blockchain technology in the PBoC system has another advantage – P2P energy trading. Blockchain makes it possible for consumers to engage in P2P transactions, without necessarily involving intermediaries like utility companies. This direct trading mechanism cuts the cost of a transaction and gives customer power as to how they are going to manage their energy. For example, in a PBoC system, people who have their solar panels at home can exchange power with their fellow residents who require it. This has a more flexible and decentralized energy market that has the effect of promoting stewardship of energy and making renewable energy more attainable (Thukral, 2021)

6. **Encouraging Consumer Participation**

The features such as transparency, security, and P2P inherent in the blockchain present considerable drivers for consumers to engage in green energy marketplaces. Blockchain enfranchises users by providing them with the ability to control their energy data and participate in the energy market. When it comes to people's choice for the blockchain-based decentralized system, the security and trust in this platform are claimed to be the requirements for consumers shifting to renewable energy sources. Blockchain technology makes it possible for consumers to confidently handle and trade energy in an environment that is safe and reliable all in a way that promotes sustainability. This promotes the use of green energy in the system and increases the efficiency of the PBoC system all around (Kaynak et al., 2020).

When it comes to developing the PBoC system, the selection of the right blockchain platform has to be made, given that it supports the goals set for the spread of green energy. Several blockchain platforms can support PBoC and the selection of the platform marginally affects the efficiency of the system and the level of demand among users.

- **Ethereum:** Ethereum is one of the largest blockchain platforms that specializes in smart contracts that are crucial for automation in a trustless world. Smart contracts automate the relations between energy producers and customers with the actual functioning of the contract coded to enable transactions between the two without the help of third parties. Ethereum offers Flexibility. Because of the number of people that adopted Ethereum and developers, the platform is quite versatile enabling developers to create numerous dApps concerning energy management. Smart contracts within Ethereum can be utilized in the management of energy generation from tracking production to trade without supervision from other entities. Ethereum has a problem of scalability that has been made worse by the high fees required for each transaction (gas fees). However, such upgrades as Ethereum 2.0 will look at solving some of these problems through the implementation of a more efficient proof of stake protocol (Kushwaha et al., 2022).

- **Hyperledger:** Hyperledger is, therefore, an open-source blockchain solution built for the business world. While Ethereum is an open Blockchain for anyone to join, Hyperledger is a private Blockchain since only approved members are allowed to use the Blockchain. This makes Hyperledger best suited for energy companies and their regulators, as such parties would need privacy and control of who should be accessing their systems. The benefits of Hyperledger to PBoC include; Data privacy. Thus, for utility companies or grid operators privacy is always an issue of paramount importance. Hyperledger guarantees access control of sensitive data meant to be accessed by select organizations only. The Hyperledger system fits well within other enterprise solutions and can be easily integrated into existing energy management systems. Hyperledger is a permissioned blockchain that enables the acceptance of high throughputs of many transactions, making it ideal for large-scale energy systems (Firdayati, 2021).
- **IOTA:** The last one is called IOTA which is a specific kind of blockchain created for the Internet of Things market. It operates on a new concept known as Tangle, instead of blockchain like other cryptocurrencies which results in a greater capacity with little or no cost. As it has been earlier established, PBoC relies on IoT devices to monitor energy consumption and generation; thus, the following benefits accrue to it from the adoption of IOTA. IOTA also does not have a transaction fee, which would make it good for micro-payments, such as small amounts of energy generated by consumers or producers being sold. IOTA is highly scalable and very energy friendly and this is in line with PBoC green energy especially knowing that other blockchains consume a lot of electrical energy in mining. IOTA is best suited for IoT devices because it reformed to work

with IoT devices, such as smart energy meters and other devices required for recording and controlling energy usage (Alshaikhli et al., 2022).

The concept

The suggested model in this paper takes into account blockchain technology smart contract and investigates the role of renewable energy resources as prosumers and their implication on data sharing when considering distributed energy transactions. We proposed Ethereum smart contract based renewable energy transaction structure between consumers, prosumers, EV retailors, utilities distributors and renewable energy generators. It offers the data flow that makes energy transfer between generators and consumers possible through smart contracts. Additionally, a safe renewable energy market system based on smart contracts is suggested.

There are two distinct nodes in this whole network, renewable generators (who produces electricity from various sources of energy) and End consumer (Who just use energy at home or to uses it to recharge his/her electric vehicle). All data on energy usage will be tracked through blockchain based smart contracts unique hash function (Pierro, 2017). Transactions involving renewable energy are examined through the platform in the forms of virtually created Power Bank.

As shown in the flow diagram Figure 3.1 the utilities will be virtually creating power banks with specific power quantity, price, and time limitations on to the platform. Power bank referred here is nothing but a blockchain based smart contract build upon any of the available technologies like Ethereum, Hyperledger fabric (S. Wang et al., 2018) Solana, Polka dot (Ghiassi-Farrokhfal et al., 2021) etc. These smart contracts, as already discussed in above sections, would be having unique hash key associated with it. Due to which it can be backtracked to its origin and also have the capability to record all the transaction nodes during its journey.

The total quantity, which would be in terms of Kwh, of these listed power banks would be in accordance with the total quantity of the Power Purchase Agreements (PPA's) (Ghiassi-Farrokhfal et al., 2021) that the utility retailers/distributors purchased already or planning to purchase from various renewable generators.

Under bilateral power purchase agreements, a buyer (firm) agrees to pay a seller (renewable energy producer) a predetermined amount for the buyer's future power output. PPAs offer price certainty for future green energy delivery, which makes them financially appealing to sellers. In fact, production unpredictability in PPAs increases worse when businesses raise their sustainability standards, which has deterred many businesses from taking part in PPAs (Ghiassi-Farrokhfal et al., 2021). These contracts are being signed between retailors/distributors mentioning quantum of power to be supplied, negotiated price, duration of supply, point of supply, penalties for non-compliance and all other terms & conditions.

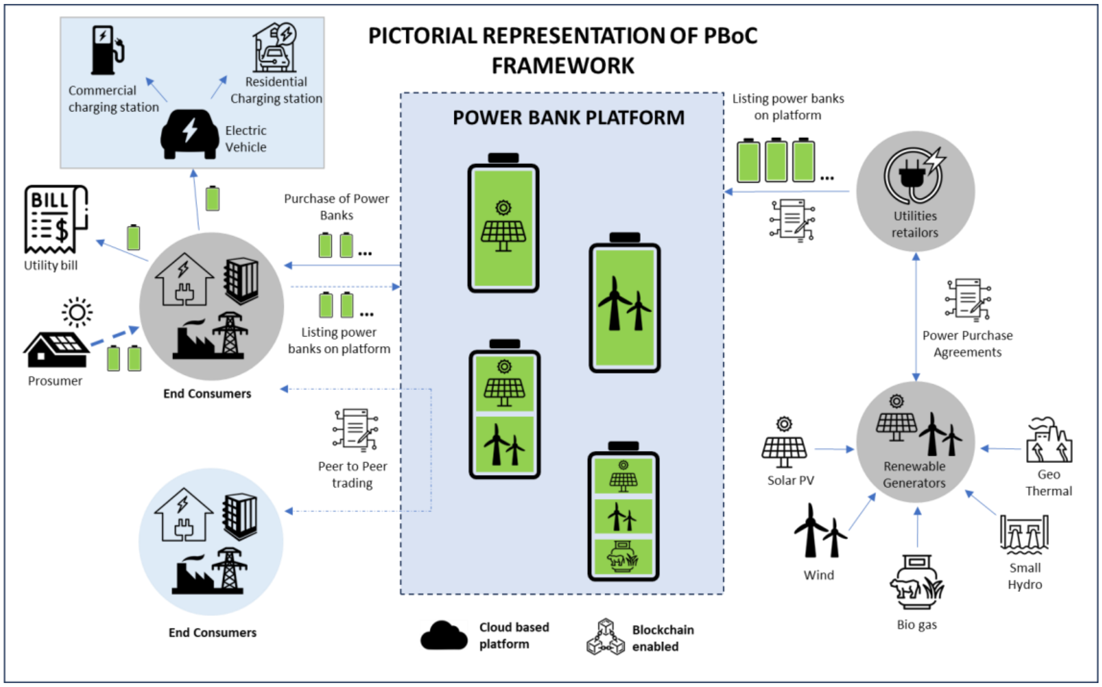

Figure 3.1: Power bank platform

The utilities basically get into those PPAs based on their power demand and then segregate the power into small quantum known as **‘Power Banks’** and list them on to the platform. These power banks can be of different Kwh quantities, different renewable energy proportion, time range and different price points based on the purchase price of PPA’s they purchased from the generators. The end-consumer, as one of the direct participants to the platform, can purchase these listed power banks as per their renewable energy requirements. Whenever the consumer purchases these power banks, a smart contract gets generated mentioning all the required details and gets deposited into consumer’s account. Each of these contracts will be having associated unique hash key, which would be the function of blockchain smart contract. As stated earlier, these contracts would be having specified purchase price, quantity, source of energy and expiry date associated with it.

End consumers then can utilize these purchased power banks whenever they charge their EV vehicle either at home or at any public charging point. The consumed energy is then being adjusted from the already purchased power bank quantities in their respective accounts. The unique hash key associated with each power bank provides it a unique identify and is used for the account settlements. Apart from recharging their batteries, power banks can also be utilised to compensate their monthly utility residential bills.

In case of contracts reaching near to the expiry dates, end consumer can sell back these power banks, having unused quantity of energy, back to the platform, altering the price point. In this way, end consumer is also acting like a seller in this system. Even it also enables the scenario for prosumers, which can create their own power banks, specifying the details and can sell them on to the platform. Therefore, as an end consumer, they would have options to purchase the power banks which are listed by Utilities retailors/distributors, hosted by prosumers and power banks which are listed by other consumers having un-used energy.

All the transactions happening through the platform would be blockchain based smart contracts, having unique transaction Hash key, due to which it could be backtrack to its original source.

3.2. TESEI Framework

The TESEI (Technology, Economic, Social, Environmental, Institutional) framework is the best model through which the feasibility of Power Bank on Cloud (PBoC) to support green energy adoption can be assessed. Every element of this framework reflects an analysis of essential factors, which makes it possible for PBoC to be technologically ready as well as encompass environmental, societal, and economic goals in their solution.

From a **Technology** point of view, the success of PBoC depends on how well it is ensured that the blockchain is compatible with renewable energy systems. While blockchain applies to performing secure and transparent transactions it is crucial to extend its capabilities to work with other infrastructures such as smart grid and IoT. Smart grids provide an intelligent way of managing energy and on the other hand, IoT gadgets help in tracking energy production, consumption, and storage in real-time. For PBoC to be technologically viable, PBoC must be able to show how blockchain can complement these technologies to improve the efficiency and robustness of the system.

The cost and financial aspect of the implementation of PBoC is captured under the Economic dimension. Intermediary costs may be eliminated because Blockchain can enable P2P energy trading thereby probably lowering the operational costs of energy producers and consumers. A more elaborate cost-benefit analysis should consider the decrease in transaction costs and other permanent financial motivations for participants. For example, for consumers, direct trading may lead to lower energy prices for consumers, while producers may mention lower overheads. Moreover, PBoC opens opportunities for decentralized energy markets that could give the consumer the necessary control, and new business models and financial incentives for the renewable energy sector.

Socially, the **social** component of the TESEI framework addresses the potential of PBoC to democratize access to green energy. By removing centralized control and enabling consumers to participate as prosumers, the system can foster greater social equity in energy distribution. This decentralized model allows individuals and communities, especially those in underserved regions, to generate, store, and trade their own energy. PBoC could thus lead to more inclusive energy markets, reducing disparities in energy access and empowering consumers to take active roles in the renewable energy transition. In doing so, it encourages social participation and ownership, which are critical for the long-term sustainability of green energy systems.

From the **Environment** point of view, PBoC must have the capability to encourage the use of renewable energy and minimize carbon emissions. Blockchain makes it possible for companies to accurately identify the energy sources used and guarantee that the energy used is renewable. Furthermore, PBoC's decentralization could mean that the management of energy resources will be more efficient and there would be little waste in energy storage. Therefore, by enhancing the circulation and use of REs, PBoC can help fight climate change since the use of conventional energy systems produces high emission rates.

Last, the **Institutional** aspect covers the legal and policy environment for the large-scale implementation of PBoC. Government and other international organizations must ensure that an enabling environment is created that will see blockchain technology adopted within the energy sector. Policies aimed at data security, and consumer protection together with standardization of the market should be in place to manage how the technology will function optimally in the economy. Furthermore, it is crucial to consider international cooperation because today's energy markets are highly integrated, and intergovernmental policies can contribute to the synchronization of the world's energy transition objectives with those of the PBoC (Ahl et al., 2022).

Accessing PBoC by Applying TESEI Framework

The analysis based on the TESEI (Technology, Economic, Social, Environmental, Institutional) framework will help to evaluate the prospects of the proposed Power Bank on Cloud (PBoC) solution for the green energy transition. All the dimensions of the framework point to factors imperative for a successful PBoC implementation.

- **Technology**

The technological component of the TESEI framework assesses the compatibility of the blockchain technology adopted in PBoC with renewable energy systems. Smart contracts based on blockchain are pivotal for P2P energy trading due to decentralization and transparency while maintaining security and the ability to trace all transactions and their details. But one must consider its integration with the smart grid systems and IoT appliances that track the generation and use of energy in real time, in real life. When adopting blockchain with these technologies, it has to be done in a way that PBoC functions well to ensure the right renewable energy is distributed and traded.

- **Economic**

The economic argument of PBoC is that it may revolutionize energy markets by simplifying cost analysis. P2P energy trading backed by a blockchain reduces the number of intermediary parties that facilitate transactions, which means that the cost of power is more affordable than before. A more careful cost-benefit analysis would evaluate how such an implementation can lead to long-run economic benefits for producers and consumers and can be a profitable proposition for PBoC. Through direct transactions between producers and consumers, the system can also encourage the consumers to engage in the green energy economy through schemes of dynamic pricing besides encouraging efficiency in the use of green energy.

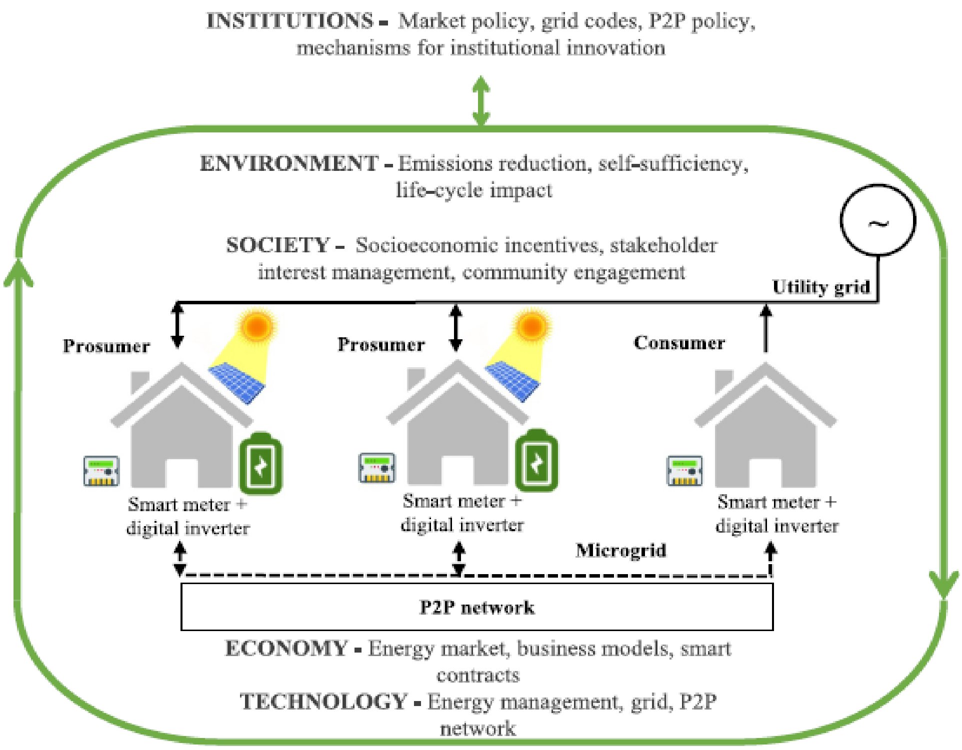

Figure 3.2: Application of TESEI Framework in PBoC

Source: Ahl et al. (2019)

- **Social**

On the social level, PBoC can have a positive impact on energy access and fairness. The decoupling of the system may expand the availability of green energy, especially to people in remote or hard-to-reach areas that may be served by expensive or inefficient energy grids. By making the consumers become both producers and consumers, PBoC encourages consumers to engage more in the energy markets. This increased engagement of consumers may help to increase the fairer distribution of energy resources among different societies and also make them inclusive of the green energy transition.

- **Environmental**

The environmental dimension is concerned with PBoC's efficiency on the issue of climate change and its promotion of a sustainable energy system. In the field of energy distribution, the usage of renewable sources and the efficient storage of energy through smart contracts will greatly decrease the amount of carbon emissions tied to energy production. Since blockchain tracks the sources of energy, green energy is always used in transactions to help fight climate change. Further, it reduces wastage and promotes sustainable use of energy storage systems in its distribution to the public through PBoC.

- **Institutional**

The institutional dimension focuses on the legal and political environment and the policies that are needed for the implementation of PBoC. Governments, energy regulators, and international bodies set the standards, participate in the promotion of blockchain solutions in green energy markets, and make necessary legislative adjustments to follow the environmental and energy legislation. The use of blockchain in energy systems would require a favorable legal framework, which would allow the application of blockchain in energy systems securely, efficiently, and at large scale. Institutions also need to coordinate to guarantee that other bodies of the Chinese government, together with PBoC, are in harmony with the global transition to cleaner energy and adhere to data protection and user rights.

In conclusion, the TESEI framework presents a holistic analysis tool that enables the assessment of the potential of PBoC in achieving sustainable, efficient, and equitable green energy systems. All the dimensions of the framework respond to pertinent issues and possibilities for each of the aspects, it is guaranteed that the system is not only technically possible but also sustainable from economic, social, ecological and institutional perspectives (Ahl et al., 2020)

3.3. Methodology

This section presents the research methodology employed in assessing the feasibility of the PBoC system for different sectors, including the residential, EV charging parking lots, commercial buildings, the industrial sector, and emergency backup. The research will use a mixed-method approach to evaluate each sector's four dimensions of the TESEI model. The surveys will be conducted with the respondents, and the interview will be held with the respondents. The survey data will be analyzed by the Statistical Package for Social Science (SPSS) to get a quantitative understanding, and the interview data will be analyzed by the content analysis method to get the qualitative understanding. The survey part will include five questions designed for each of the variables described in the TESEI framework. This approach will ensure that each of the five perspectives of applicability; technology, economics, social and environmental, and institutional, is considered in the analysis of PBoC (Tanner, 2018).

Survey Process

The study included a survey of 200 respondents which is based on the TESEI framework. The major segments are as follows:

- **PBoC @ Residentials**

For the residential users, five survey questions will be developed and refined for each of the TESEI dimensions. These questions will assess the technological viability of incorporating PBoC into smart homes, the economic advantages of applying PBoC in terms of cost, the societal advantage in terms of consumer engagement, and energy decentralization, the environmental advantages such as a decrease in carbon footprint, and the institutional challenges or policies that are required to facilitate PBoC adoption in this sector.

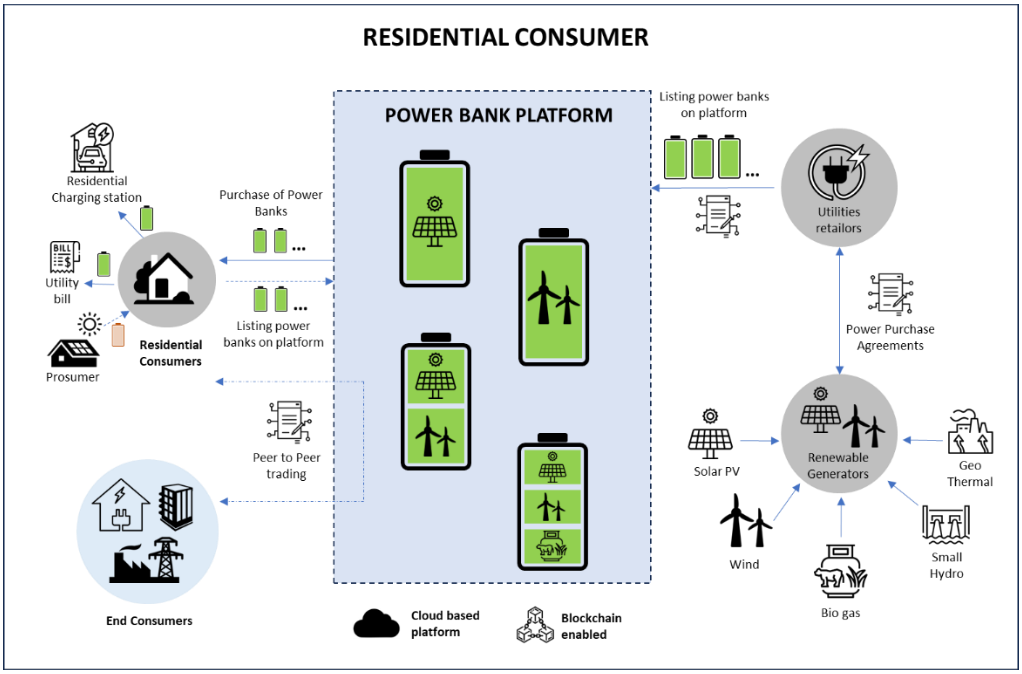

Figure 3.3: Residential consunsumer role in PBoC

- **PBoC @ EV Charging Parking Lots**

The second variable will seek to find out how PBoC can enable infrastructure for EV charging. Five survey questions will be developed to capture the following aspects: how the blockchain technology can be incorporated into the EV charging systems; the cost advantage this model will provide to the user and operator; the consequent increase in social acceptance of EVs; the environmental benefits such as encouraging the adoption of sustainable transportation; and the appropriate institutional arrangements needed to encourage the adoption of this integration.

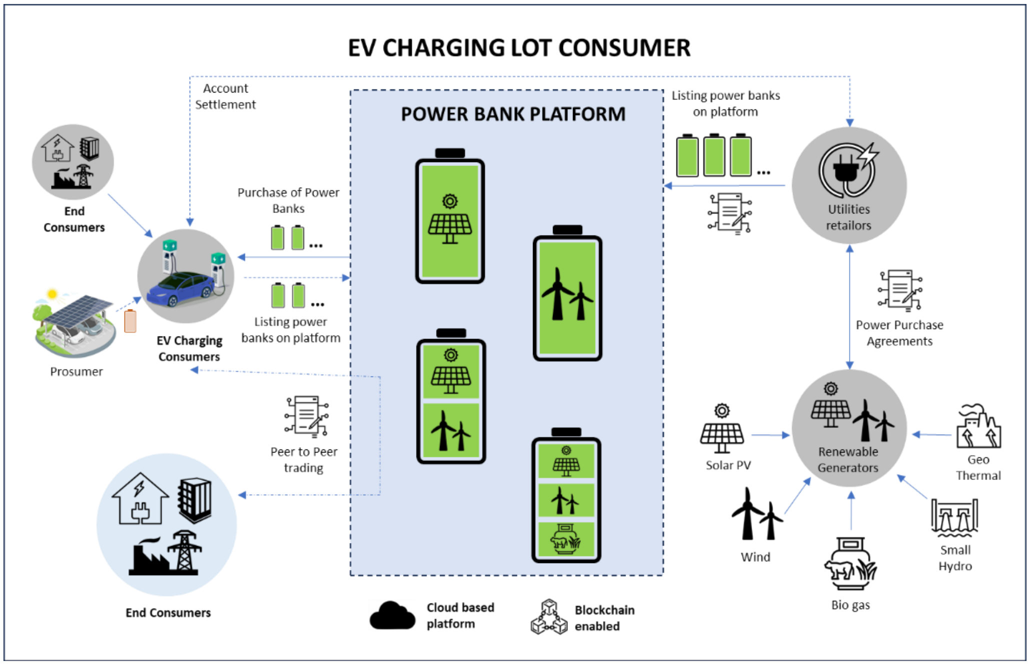

Figure 3.4: EV Charging Lot role in PBoC

- **PBoC @ Commercial (Malls/Offices)**

In cases of commercial buildings such as malls and offices, the research will assess the possibility of PBoC to improve energy control. Five survey questions will be There will be five: the technological readiness of PBoC for commercial energy management, its financial effectiveness in reducing energy costs, the commercial implications for consumers and other stakeholders, the environmental impact of the system on energy usage and emission, and the requirements for regulation to create PBoC infrastructure for commercial usage.

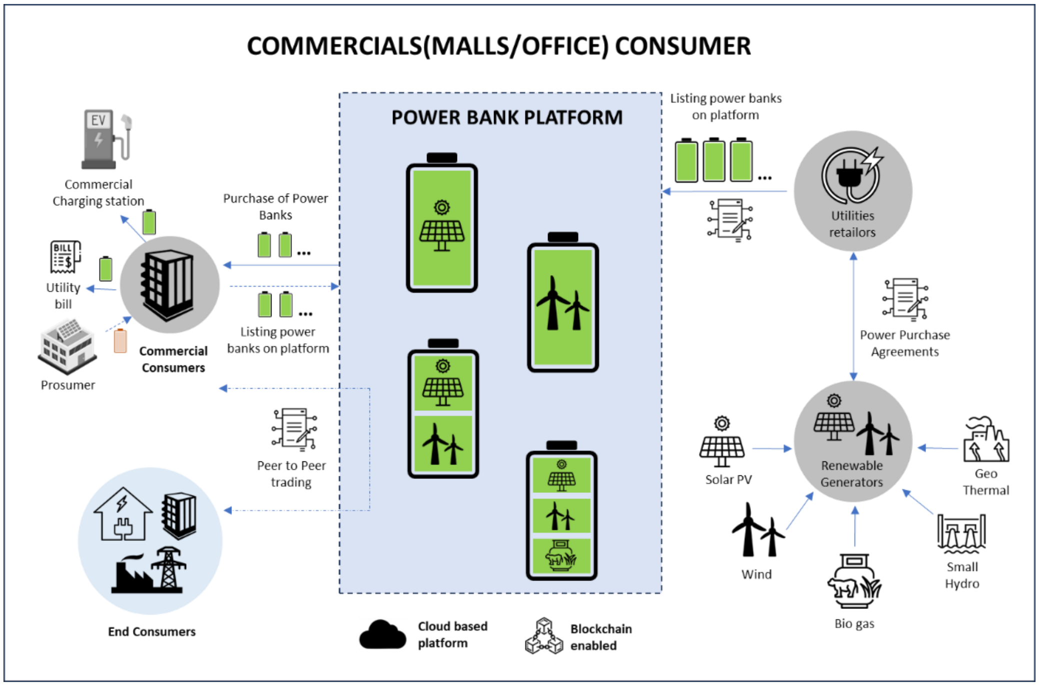

Figure 3.5: Commercial consunsumer role in PBoC

- **PBoC @ Industrial**

The industrial sector offers prospects and challenges to PBoC, which are discussed below. The five survey questions are: (1) How can PBoC technology enhance energy management in an industrial environment? (2) What are the economic returns to be had from implementing PBoC in terms of energy efficiency? (3) What is the social side of the story, in terms of the changes that PBoC will bring to energy practices in the industry? (4) What is the environmental aspect of the story, in terms?

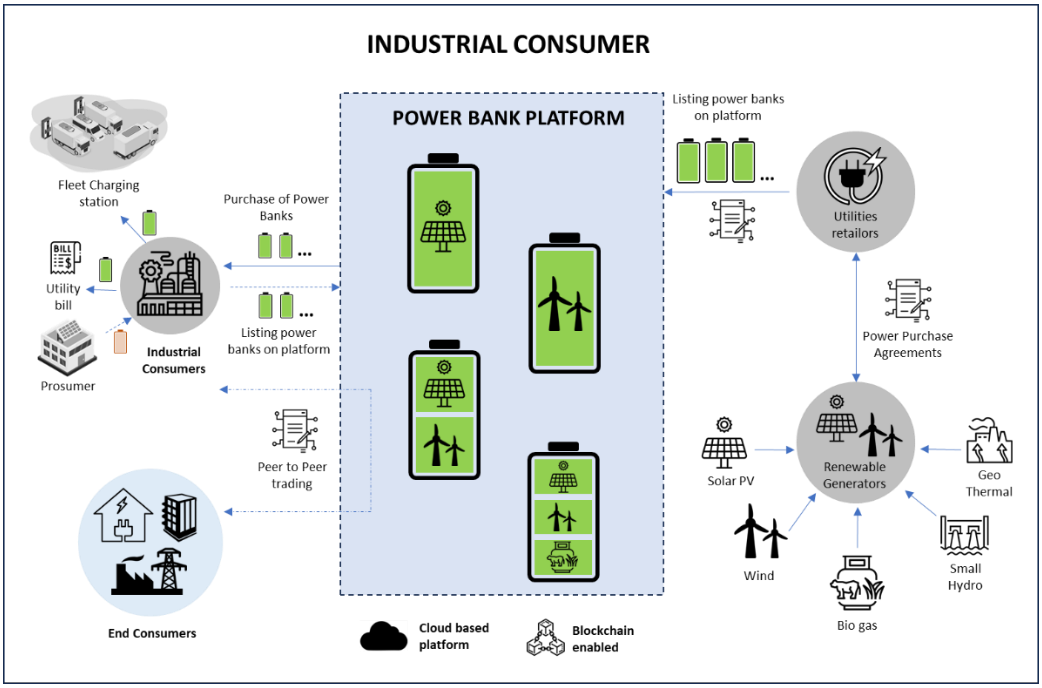

Figure 3.6: Industrial consunsumer role in PBoC

- **PBoC @ Emergency Backup Systems**

The requirement for emergency backup systems is one of the most common use cases of PBoC, especially in areas of society. Five survey questions are as follows: The surveys will include five questions to evaluate technological reliability, economic benefits for the institutions that may require backup systems using blockchain, social importance for providing energy security, environmental benefits for utilizing renewable energy sources in backup systems, and the institutional requirements for this use case.

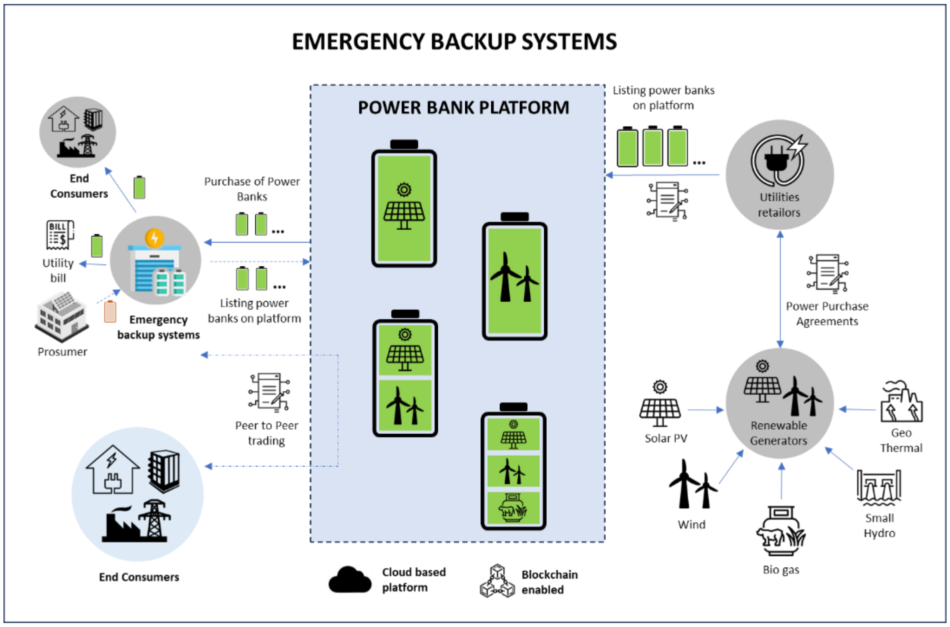

Figure 3.7: Emergency backup role in PBoC

Interview Process

Interviewing in this study will involve conducting 10 face-to-face interviews that would be used to capture qualitative data on the feasibility and possibly take up of the PBoC system across the different sectors. Some of the types of participants to be involved include; residential consumers, managers of EV stations, commercial consumers, industrial consumers, and backup power consumers. Before conducting any interviews, participants will be briefed about PBoC, its narrative, and the idea behind the app. The interview questions will be tailored to assess participants' views on how PBoC could apply in their respective sectors, based on the five dimensions of the TESEI framework: technology, economics, social consequences, environmental aspects, and institutions.

Interviews will be semi-structured to provide the participants with the opportunity to vent their opinions while at the same time ensuring that data is collected across the subjects of focus. For example, participants will be required to respond to questions like how they think blockchain incorporates it with the current energy systems, the economic feasibility of decentralized energy distribution, sharing, and usage, and social issues regarding user engagement and accessibility to embracing green energy. Further questions will be concerned with the effect on the environment of using PBoC to encourage the use of renewable power and what part governments and regulators play in supporting or discouraging the use of PBoC. This qualitative approach will assist in capturing stakeholders' perceptions and hence offer broader perspectives of the practical implications, and potential benefits as well as, the peculiarity of each sector regarding PBoC adoption (Roberts, 2020).

Data Analysis

Data collected through the surveys and interviews will be subjected to a two-pronged approach for analysis: quantitative and qualitative. The gathered survey data will be analyzed using Statistical Package for the Social Sciences (SPSS) which is a Statistical software package. SPSS will be utilized to determine the viability of the PBoC system within different sectors based on the analysis of the data and the establishment of patterns and relationships (Rahman & Muktadir, 2021). In pursuing this purpose, the study wants to estimate the possible value additions of PBoC in terms of cost-cutting, productivity enhancement, and eco-friendliness. Descriptive statistics and inferential techniques will be used to analyze the extent to which each of the TESEI dimensions: technology enabler, economic incentive, social attributes, environmental advantage, and institutional support, influence the viability and scope of the PBoC adoption in the surveyed sectors (Dong, 2023).

Similarly, interview data will be analyzed using content analysis, which is a quantitative technique applied to analyze textual data to obtain of themes, patterns, and valuable insights. All the interviews will be taped, and the responses will be analyzed with the help of the TESEI framework. The content analysis will contribute clearer insights into the participants' perception of the PBoC policy, and capture real-life issues, challenges, and prospects in the practical implementation that may not be fully reflected by the survey results. For instance, while using content analysis, there could be issues to do with regulations in the institutional dimension or more social issues regarding future consumer acceptance. This qualitative analysis will enrich the present quantitative study and offer an overall conceivable of how PBoC can facilitate the diffusion of sustainable energy in multiple sectors and what aspects require improvement or additional support. This way, the feasibility and impact of PBoC will be analyzed quantitatively using the results from SPSS, and qualitatively using content analysis from the identified sources (Aspers & Corte, 2021).

CHAPTER IV:

RESULTS AND DISCUSSION

4.1. Reliability

Table 4.1: Reliability Statistics

Cronbach's Alpha	N of Items
.973	25

The above Table 4.1 Cronbach's Alpha of 0.973 for 25 items indicates great internal consistency and dependability. It may indicate item redundancy.

4.2. Results

4.2.1. Demographic Details of Respondents

Table 4.2: Description of Demographic Details of Respondents

		Frequency	**Percent**
What is your Gender?	Man	126	63
	Woman	64	32
	Non-Binary	4	2
	Prefer Not to Say	6	3
What is your age?	18-24 Years	1	0.5
	25-34 Years	61	30.5
	35-44 Years	85	42.5
	45-54 Years	37	18.5
	55-64 Years	12	6
	65 Years and Over	4	2
What is your highest level of education completed?	High School Graduate	3	1.5
	Bachelor's Degree	34	17
	Master's Degree	146	73

	Doctoral Degree	17	8.5
What is your current employment status?	Employed Full-Time	162	81
	Employed Part-Time	10	5
	Self-Employed	17	8.5
	Unemployed	6	3
	Retired	3	1.5
	Student	1	0.5
	Other	1	0.5
Where do you currently reside?	Urban Area	160	80
	Sub-Urban Area	25	12.5
	Rural Area	15	7.5
What type of residence do you live in?	Single-Family Home	77	38.5
	Apartment/Condominium	86	43
	Townhouse	28	14
	Mobile Home	3	1.5
	Other	6	3
Do you currently use any renewable energy solutions in your home?	Yes	70	35
	No	130	65
How interested are you in adopting new green energy technologies or solutions?	Not at all Interested	1	0.5
	Slightly Interested	15	7.5
	Moderately Interested	51	25.5
	Very Interested	59	29.5
	Extremely Interested	74	37

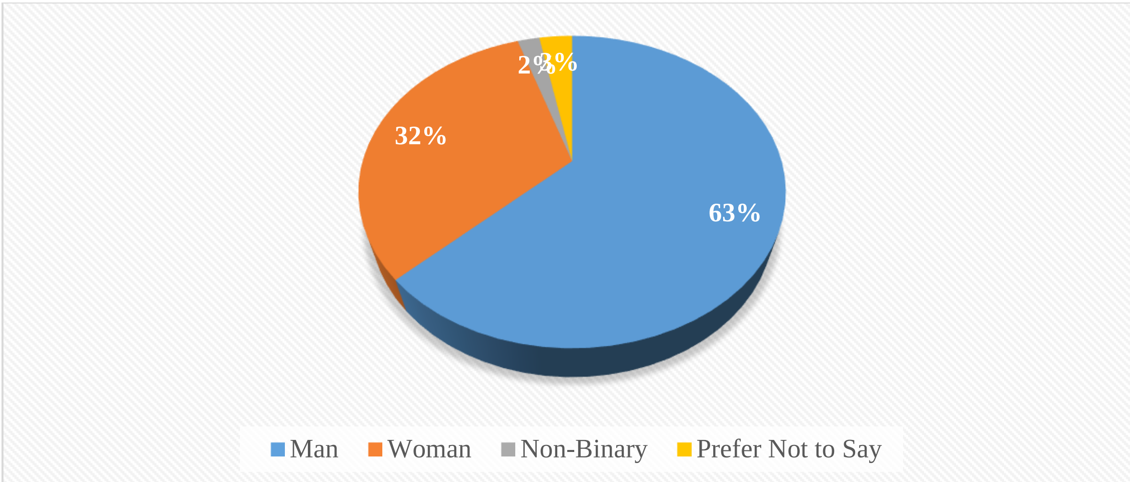

Figure 4.1: Gender

Figure 4.1 demonstrates that males (63%), followed by women (32%), constitute the majority of responders. Some were non-binary (2%) or decided not to reveal their gender (3%).

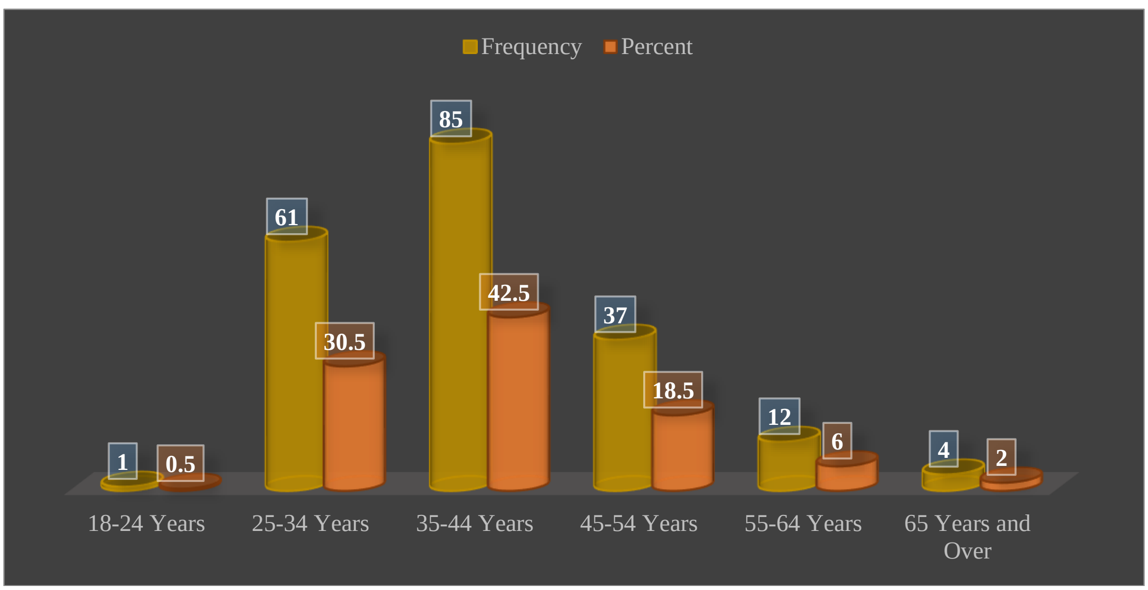

Figure 4.2: Age

Figure 4.2 shows that the majority of respondents are 35–44 years old (42.5%), followed by 25–34 (30.5%) and 45–54 (18.5%). Smaller proportions include 55-64 (6%), 65+ (2%), and 18-24 (0.5%). This implies a typically middle-aged sample.

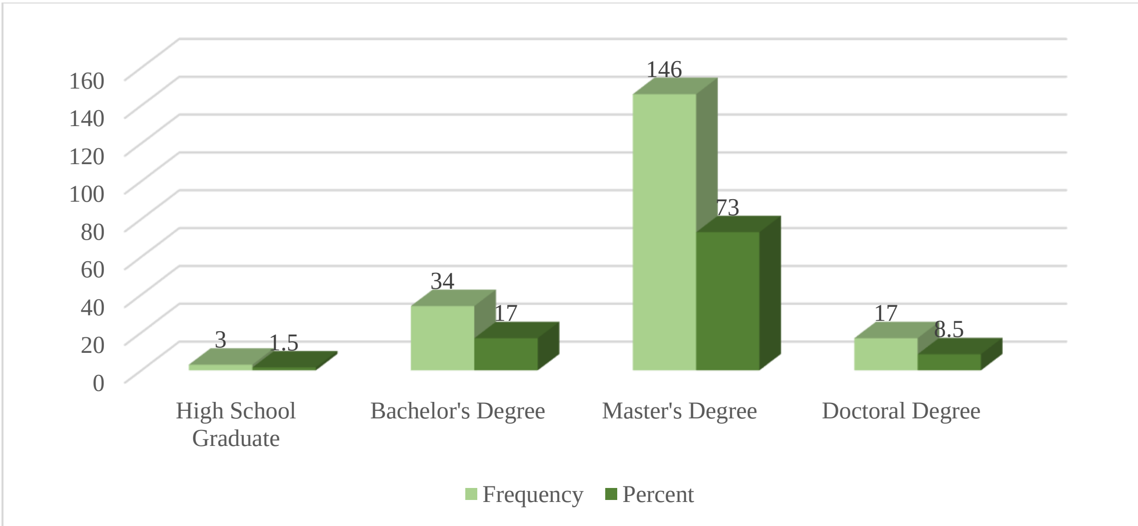

Figure 4.3: Highest Level of Education

Figure 4.3 illustrates respondents' education levels. The majority (73%) have a master's degree, followed by Bachelor's (17%) and Doctoral (8.5%). High school grads make up 1.5% of the sample, showing high education.

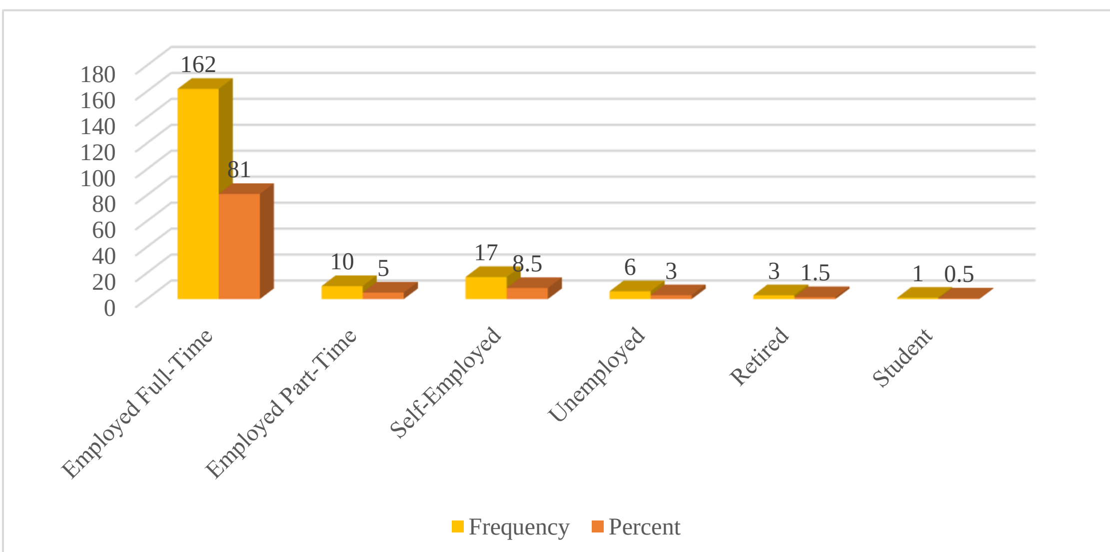

Figure 4.4: Current Employment Status

Figure 4.4 indicates the respondents' work status. Full-time workers make up 81%, while part-time workers make up 5%, and unemployed people make up 3%. 0.5-1.5% of the sample includes retirees, students, and "other" respondents, indicating a mostly full-time workforce.

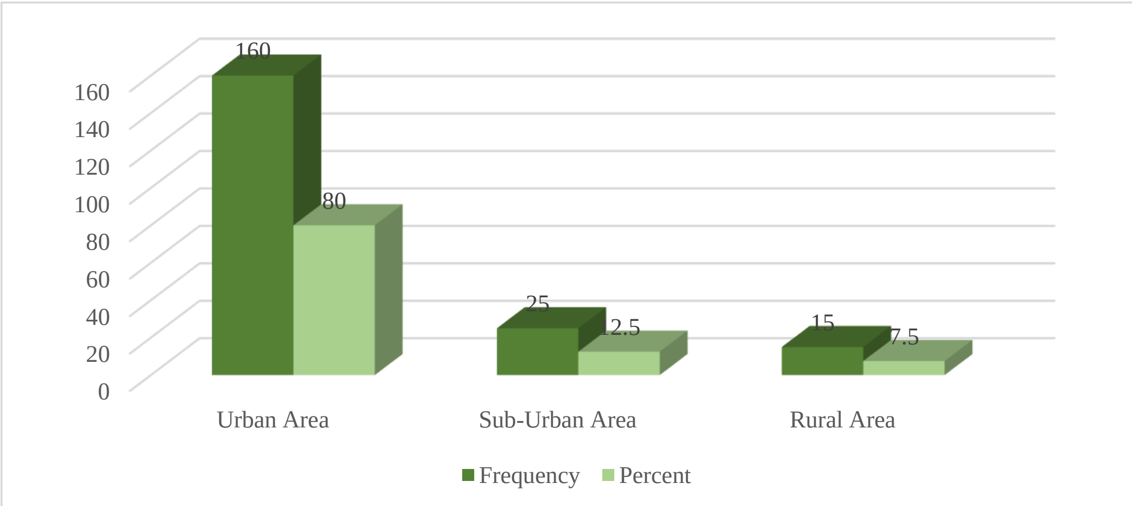

Figure 4.5: Currently Reside

Figure 4.5 demonstrates that 80% of respondents live in cities, 12.5% in suburbs, and 7.5% in rural regions. Thus, the sample seems urban.

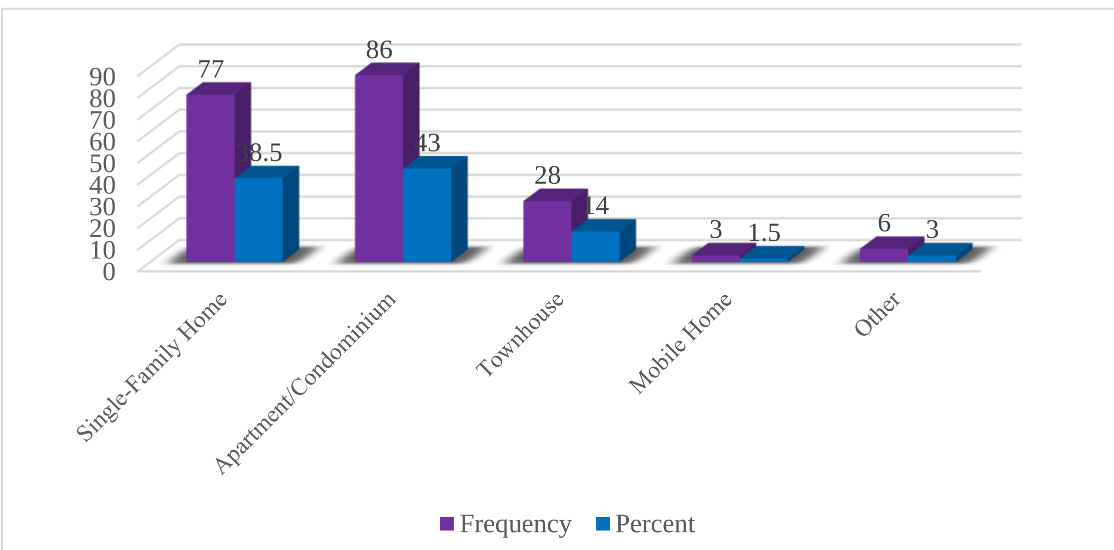

Figure 4.6: Residence Do You Live In

Figure 4.6 indicates that over half of respondents live in flats or condos (43%), followed by single-family homes (38.5%) and townhouses (14%). Some live-in mobile homes

(1.5%) or other housing (3%). Apartment-style housing is preferred in this diversified living arrangement.

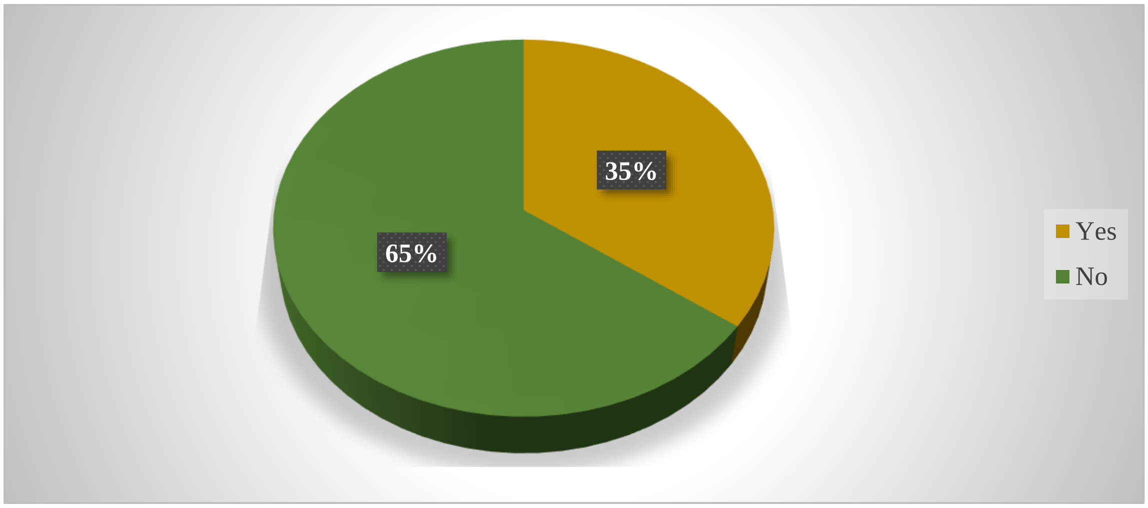

Figure 4.7: Do you currently use any renewable energy solutions in your home?

Figure 4.7 shows that 35% of respondents utilise renewable energy in their houses, whereas 65% do not. This suggests poor renewable energy uptake in the sample.

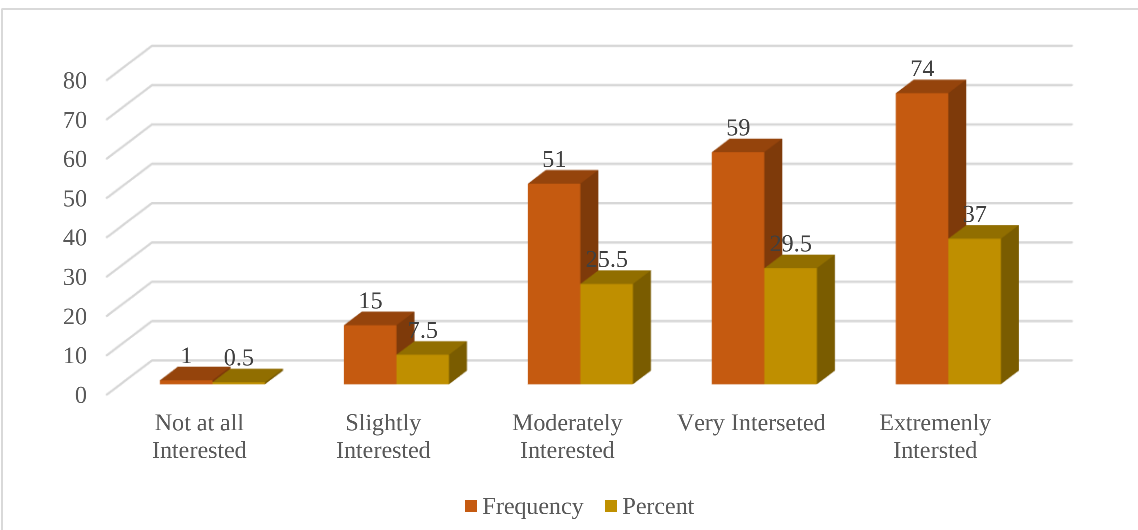

Figure 4.8: How interested are you in adopting new green energy technologies or solutions

Figure 4.8 reveals that 37% of respondents are highly interested in new green energy technologies, 29.5% are pretty interested, 25.5% are somewhat interested, 7.5% are slightly interested, and 0.5% are not interested. This suggests widespread support for green energy.

4.2.2. Residentials

Table 4.3: PBoC @ Residentials

Category	Question		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Test Statistic	Sig.
Technological	PBoC offers real-time monitoring of energy consumption in my home.	Frequency	4	4	48	75	69	118.050[a]	.000
		Percent	2	2	24	37.5	34.5		
Economic	PBoC offers good value for the cost of installation and maintenance in my home.	Frequency	2	3	70	69	56	120.250[a]	.000
		Percent	1	1.5	35	34.5	28		
Social	PBoC increases my social standing as an eco-friendly consumer.	Frequency	1	1	48	90	60	150.150[a]	.000
		Percent	0.5	0.5	24	45	30		

Environmental	I feel that using PBoC reduces my household's carbon footprint.	Frequency	1	3	39	95	62	160.000[a]	.000
		Percent	0.5	1.5	19.5	47.5	31		
Institutional	There is sufficient customer support available for PBoC users in residential areas.	Frequency	5	15	65	71	44	86.300[a]	.000
		Percent	2.5	7.5	32.5	35.5	22		

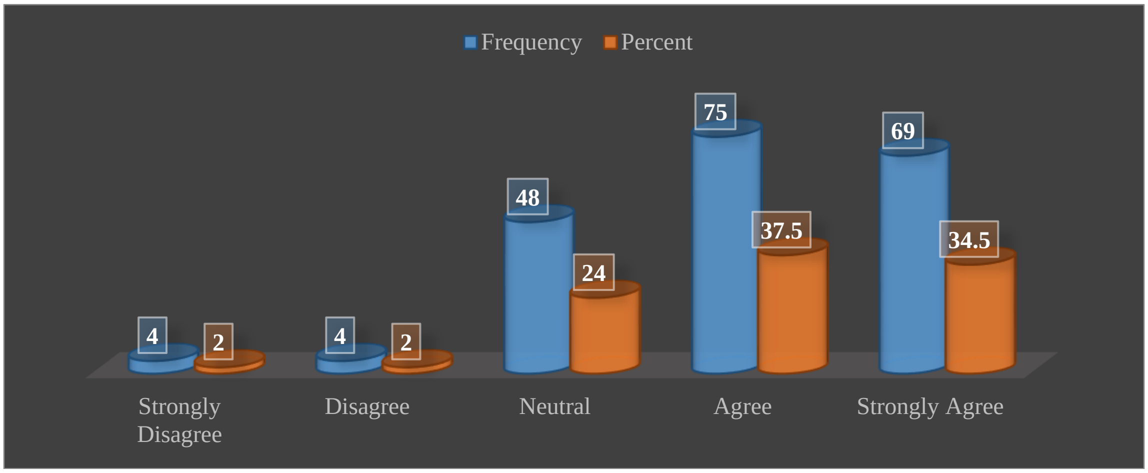

Figure 4.9: PBoC offers real-time monitoring of energy consumption in my home.

The above figure 4.9 shows that most respondents agree (37.5%) or strongly agree (34.5%) that PBoC offers real-time monitoring of energy consumption in their homes. A smaller percentage are neutral (24%), while very few disagree (2%) or strongly disagree (2%) and the test statistic of 118.050. This suggests that the majority perceive PBoC as an effective tool for monitoring energy usage.

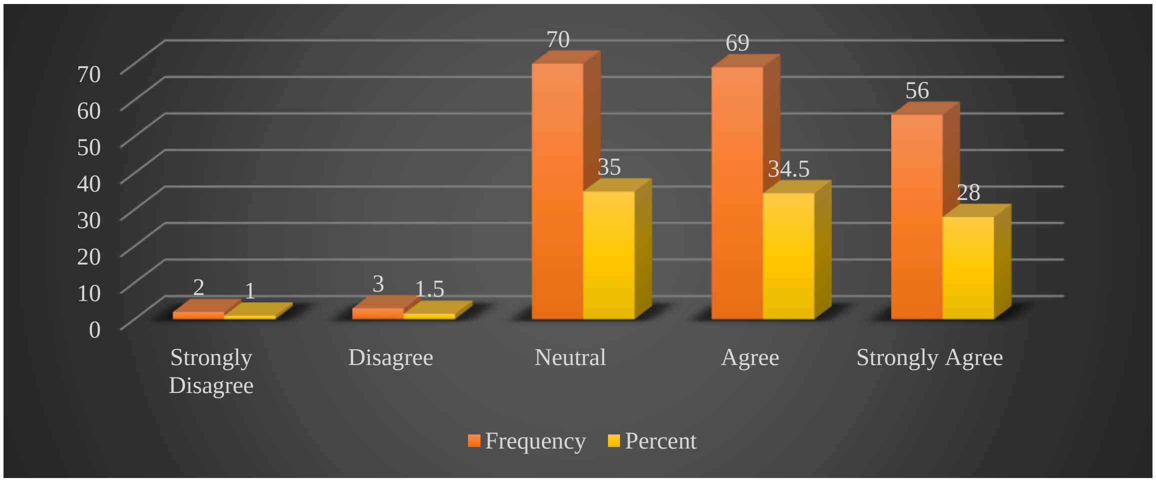

Figure 4.10: PBoC offers good value for the cost of installation and maintenance in my home.

In Figure 4.10, 34.5% of respondents agree or strongly agree that PBoC is worth the installation and maintenance expense. The majority (35%) are impartial, whereas the minority (1.5%) or strongly disagree (1%) are unsure, 120.250a test statistic While many see PBoC as economically useful, many remain unsure.

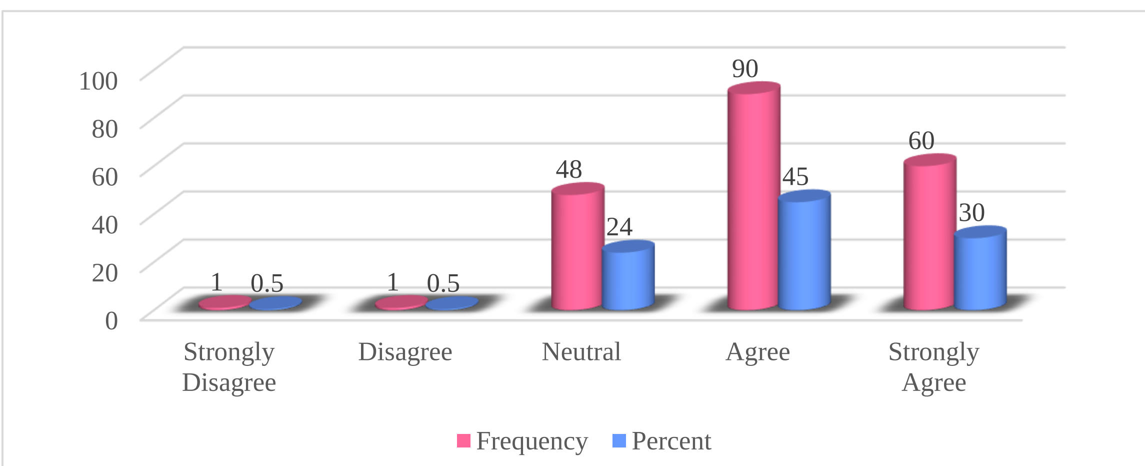

Figure 4.11: PBoC increases my social standing as an eco-friendly consumer

According to Figure 4.11 above, the majority of respondents approve (45%) or strongly concur (30%) that PBoC improves their reputation as environmentally conscious customers. Just 1% (combined) oppose or strongly disapprove, while a lesser percentage is indifferent (24%).

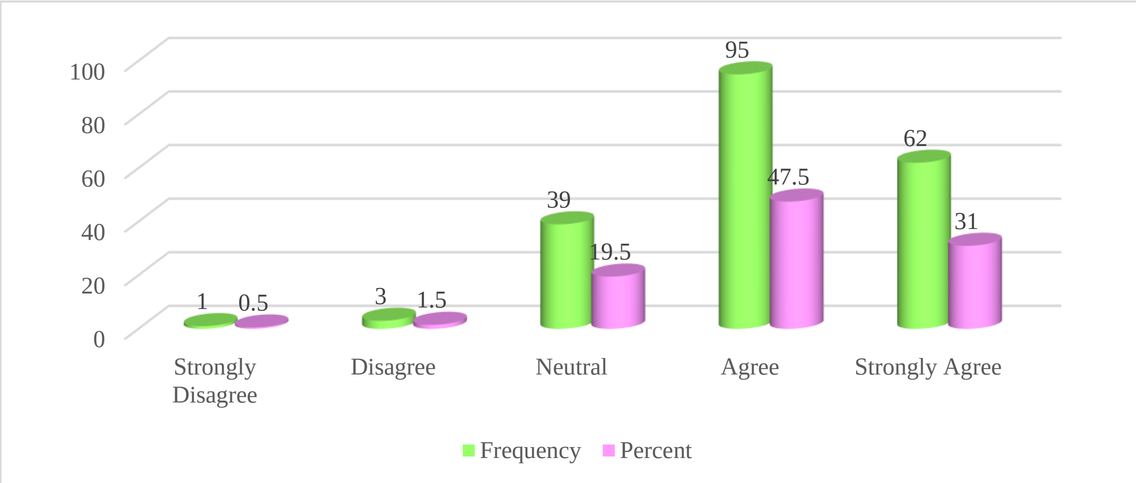

Figure 4.12: I feel that using PBoC reduces my household's carbon footprint.

Figure 4.12 shows that (47.5%) or (31%), most respondents believe that PBoC decreases their household's carbon footprint. A smaller portion is moderate (19.5%), and very few disagree (1.5%) or firmly disagree (0.5%). The test value of 160.000 (with statistical significance) shows that respondents agree that PBoC reduces household carbon emissions.

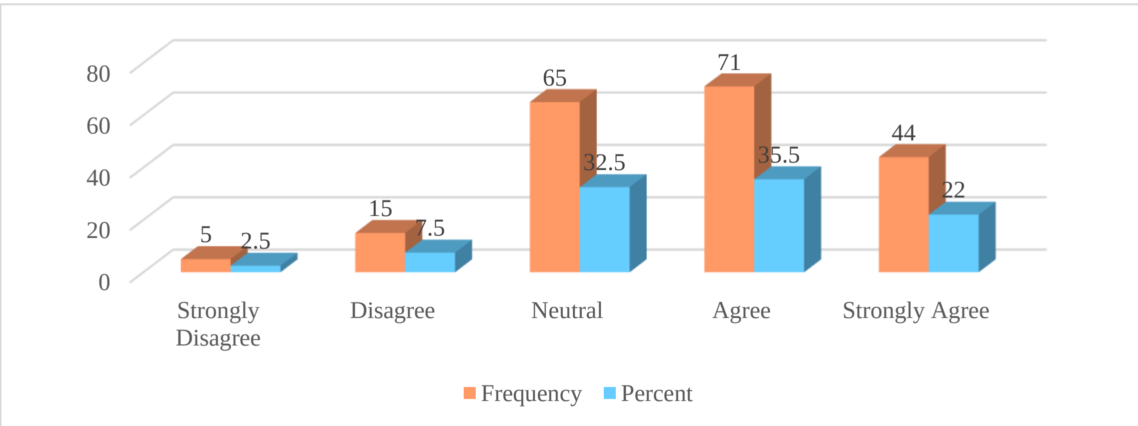

Figure 4.13: There is sufficient customer support available for PBoC users in residential areas.

Figure 4.13 reveals that most respondents (35.5%) or entirely concur (22%), that residential PBoC customers get adequate customer service. Most are indifferent (32.5%), while a few reject (7.5%) or completely disapprove (2.5%). There is diversity in user views of customer assistance availability, but the test statistic of 86.300 with a p-value of.000 suggests universal awareness.

Table 4.4: Residential

	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5	Participant 6	Participant 7	Participant 8	Participant 9	Participant 10
Smart Home Integration	4	3	4	4	2	4	7	4	8	4
Energy Management	4	2	1	4	6	4	4	4	4	4
Privacy Concerns	3	3	3	3	3	3	3	3	3	9

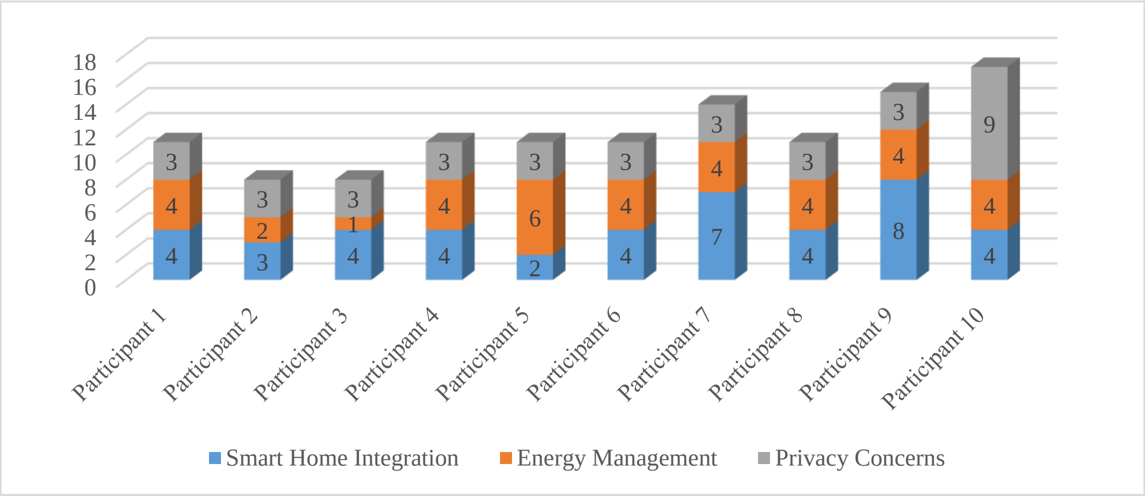

Figure 4.14: Residential

The interview data captures the frequency with which ten participants—Participant 1, Participant 2, Participant 3, Participant 4, Participant 5, Participant 6, Participant 7, Participant 8, Participant 9, and Participant 10—mentioned three key aspects of residential applications: Smart Home Integration, Energy Management, Privacy Challenges Smart

Home Integration, Energy Management, and Privacy Issues. In terms of Smart Home Integration, the frequency of mentioning this aspect was fluctuating, though Participant 7 mentioned this aspect seven times while Participant 9 talked about this aspect eight times which shows lots of interest or concern towards technological integration existing in the houses while Participant 5 mentioned this aspect lowest i.e two times. Concerning Energy Management, most participants observed it four times moderately and consistently, excluding Participant 2, who observed it twice and Participant 3, who observed it only once, and Participant 5, who focused significantly more on it (6). Privacy Concerns were raised three times by most participants which shows that though it was not emphasized but was being recognized, the only person who raised it nine times was Participant 10 who has either strong focus or concern over it. These findings also indicate those measures and emphases have shifted, showing how the participants' concerns and foci are concentrations and not just differences in residential energy solutions.

4.2.3. EV Charging Parking Lots

Table 4.5: PBoC @ EV Charging Parking Lots

Category	Question		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Test Statistic	Sig.
Technological	PBoC ensures fast and efficient charging for electric vehicles at parking lots.	Frequency	1	5	36	99	59	165.100[a]	.000
		Percent	0.5	2.5	18	49.5	29.5		
Economic	PBoC reduces the cost of energy for	Frequency	2	6	46	88	58	131.600[a]	.000

	EV charging stations.	Percent	1	3	23	44	29		
Social	PBoC encourages more EV drivers to use charging stations in my area.	Frequency	2	5	54	85	54	127.150[a]	.000
		Percent	1	2.5	27	42.5	27		
Environmental	PBoC makes EV charging more sustainable in the long run.	Frequency	2	2	49	81	66	133.150[a]	.000
		Percent	1	1	24.5	40.5	33		
Institutional	The regulations governing PBoC in EV charging stations are clear and supportive.	Frequency	6	12	63	68	51	84.350[a]	.000
		Percent	3	6	31.5	34	25.5		

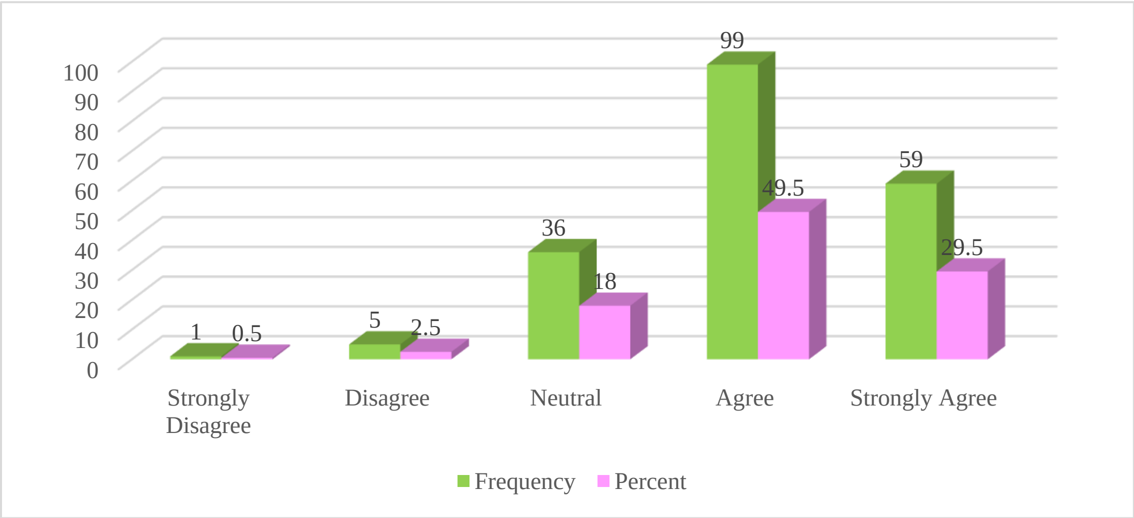

Figure 4.15: PBoC ensures fast and efficient charging for electric vehicles at parking lots.

Figure 4.15 demonstrates a significant favourable assessment of the PBoC's capacity to charge electric cars quickly and efficiently at parking lots. This statement was agreed with by 79% of respondents (49.5%) or strongly agreed (29.5%), indicating great trust in its performance. Only 3% of participants disagreed (2.5% disagreed and 0.5% strongly disagreed), while 18% were indifferent. These replies are statistically significant, with a test statistic of 165.100 and a p-value of.000 indicating satisfaction with PBoC parking lot charge efficiency.

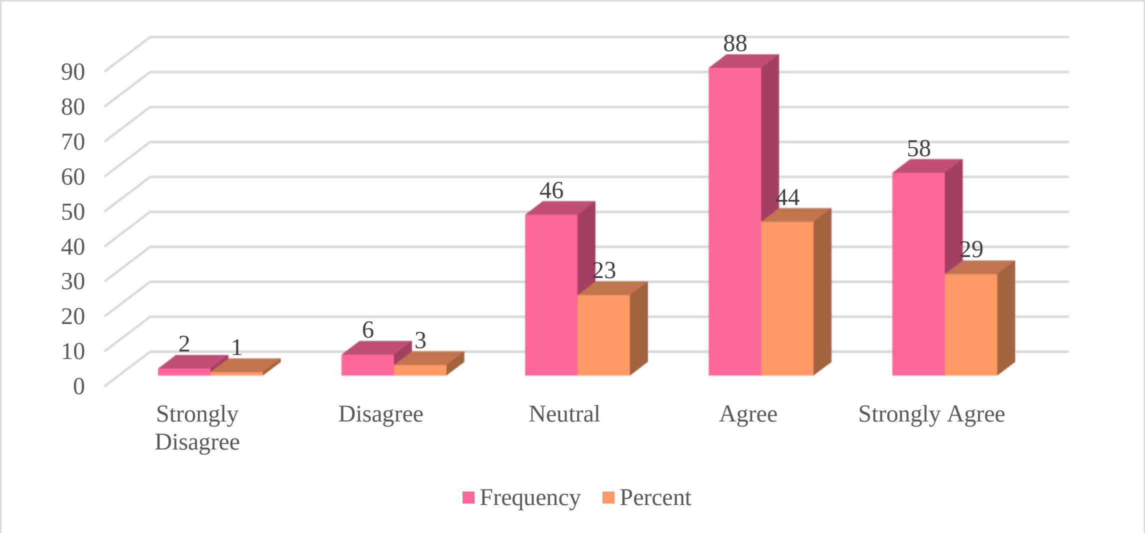

Figure 4.16: PBoC reduces the cost of energy for EV charging stations.

The PBoC's economic effect on EV charging station energy prices is mainly favourable, as shown in Figure 4.16. Overall, 73% agreed, with 44% and 29% highly agreeing. 23% were unfavourable, showing ambivalence or a lack of a strong view. Only 4% disagreed or strongly disagreed. The test statistic of 131.600 with a p-value =.000 suggests that these data are statistically significant, supporting PBoC's influence on EV charging station energy prices.

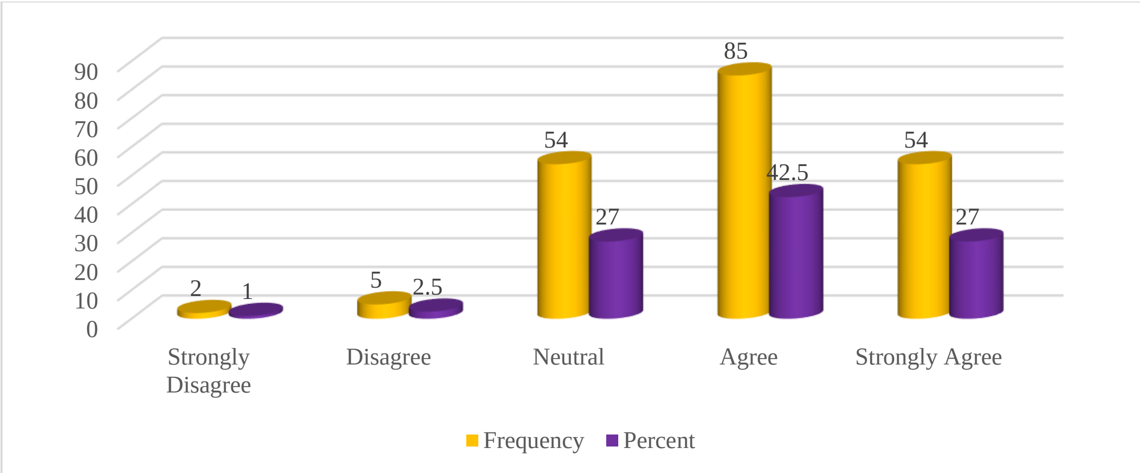

Figure 4.17: PBoC encourages more EV drivers to use charging stations in my area.

Figure 4.17 illustrates that the PBoC is largely seen as successful in encouraging EV drivers to use local charging stations. 69.5% of respondents expressed positive feelings, either agreeing (42.5%) or firmly concurring (27%). Some 27% were neutral, suggesting uncertain or disinterested replies. A mere 3.5% concurred. The test statistic of 127.150 with a p-value of.000 supports the idea that PBoC increases EV charging station utilisation in the examined locations.

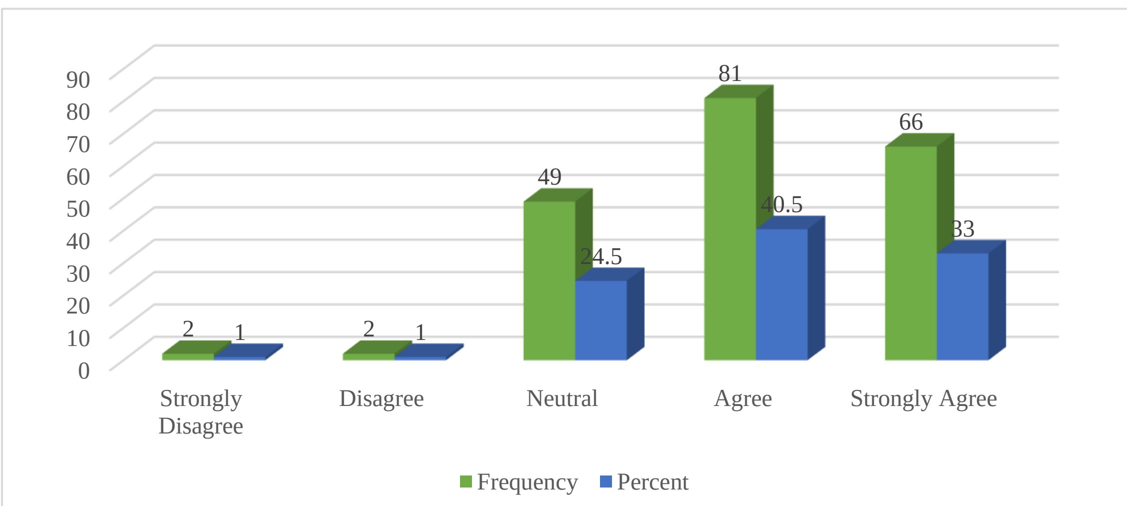

Figure 4.18: PBoC makes EV charging more sustainable in the long run.

Figure 4.18 shows a significant favourable impression of the PBoC's environmental advantages, notably in long-term EV charging sustainability. The majority of respondents, 73.5%, concurred (40.5%) or firmly concurred (33%), supporting its sustainability effect. About 24.5% were impartial, indicating indecision. Only 2% disagreed, as the test statistic of 133.150 with a p-value of.000 suggests that respondents think PBoC lowers EV charging station energy costs.

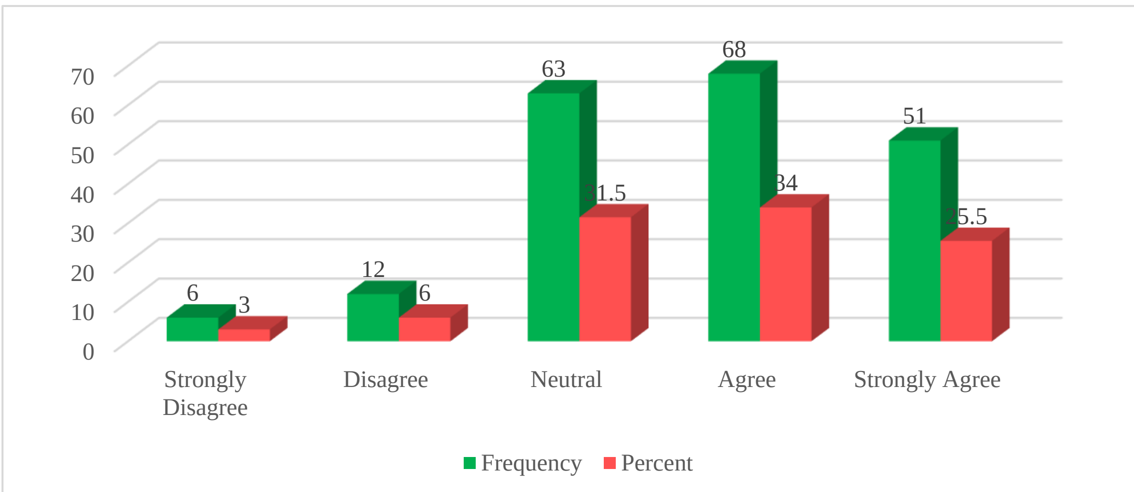

Figure 4.19: The regulations governing PBoC in EV charging stations are clear and supportive.

As seen in Figure 4.19, the PBoC is seen as helping to support EV charging. The majority of responders, 73.5%, approved (40.5%) or completely agreed (33%), indicating trust in its environmental advantages. In contrast, 24.5% of individuals were indifferent, indicating indecision. Few, 2%, objected or strongly objected, the test statistic of 84.350 with a p-value of.000 suggests that respondents believe PBoC regulations in EV charging stations are clear and provide adequate support.

Table 4.6: EV Charging Parking Lots

	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5	Participant 6	Participant 7	Participant 8	Participant 9	Participant 10
Infrastructure Development	3	5	5	4	5	8	5	1	4	5

User Experience	4	3	5	5	1	5	5	5	5	9
Scalability and Reliability	2	5	6	5	5	5	2	5	7	5

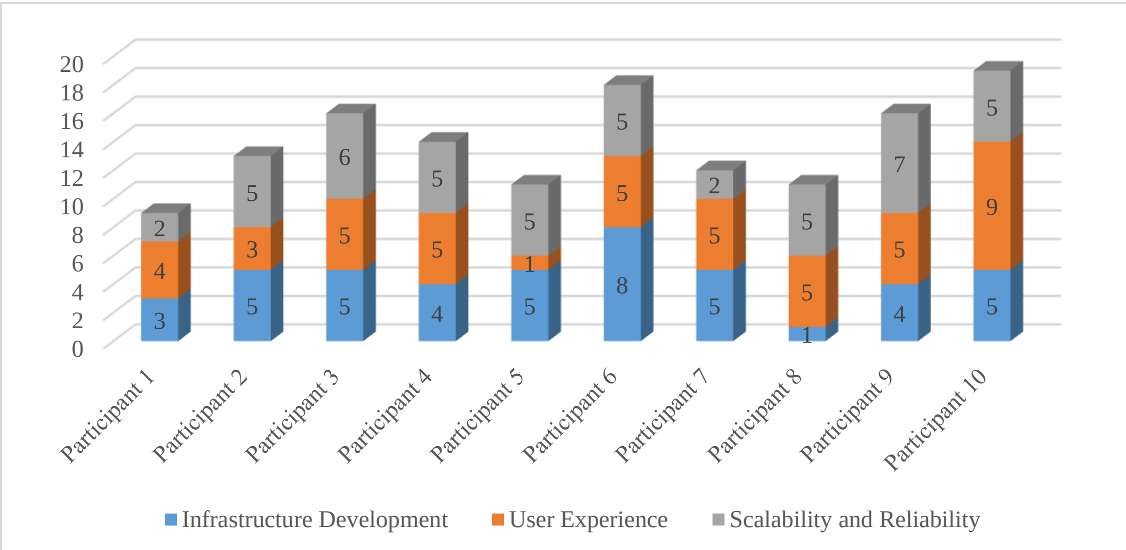

Figure 4.20: EV Charging Parking Lots

The interview data analyzes the frequency with which ten participants—Participant 1, Participant 2, Participant 3, Participant 4, Participant 5, Participant 6, Participant 7, Participant 8, Participant 9, and Participant 10—referred to three critical aspects of EV Charging Parking Lots: Among the significant technical benefits of Adopting and Embracing the New Paradigm for the Datacenter, three of them provide strategic importance: Infrastructure Development, User Experience, and Scalability and Reliability. In the case of "Infrastructure Development", nine participants mentioned it with an f-rec of five which is quite an emphasis, although Participant 6 (8) seems to place a particular emphasis on the need for infrastructure. When using the term, it was mentioned least by Participant 8 (1), indicating perhaps lower priority when addressing the project. The category “User Experience” emerged to be evenly distributed among participants as majority had between 4 and 5 mentions while Kushagra priced it low with only 1 mention and Participant 10 putting high price to it with 9 mentions which shows that user experience is of paramount importance to Sujit. In “Scalability and Reliability”, therefore, there were minor variations with all giving an average of five and thus a steady focus on the aspect while Participant 3 (6) and Participant 9 (7) paid more attention to it in relation to dependability of systems they were implementing/describing and Participant 1 (2) and Participant 7 (2) a less focused on the aspect. Altogether, the data points to the range of varying concern levels throughout the participants, along with important individual variations, suggesting dissimilar priorities regarding the charging for EV infrastructure and management.

4.2.4. Commercials (malls/offices)

Table 4.7: PBoC @ Commercials (malls/offices)

Category	Question		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Test Statistic	Sig.
Technological	PBoC integrates effectively with commercial energy management systems	Frequency	2	1	49	89	59	145.200[a]	.000
		Percent	1	0.5	24.5	44.5	29.5		
Economic	PBoC reduces energy costs for	Frequency	3	5	51	87	54	128.000[a]	.000

	commercial properties.	Percent	1.5	2.5	25.5	43.5	27		
Social	The PBoC system supports the commercial sector's sustainability goals	Frequency	3	4	50	86	57	129.250[a]	.000
		Percent	1.5	2	25	43	28.5		
Environmental	PBoC helps commercial properties reduce their carbon footprint effectively	Frequency	4	3	46	88	59	134.150[a]	.000
		Percent	2	1.5	23	44	29.5		
Institutional	The implementation of PBoC in commercial settings is well supported by relevant policies.	Frequency	4	5	71	70	50	112.050[a]	.000
		Percent	2	2.5	35.5	35	25		

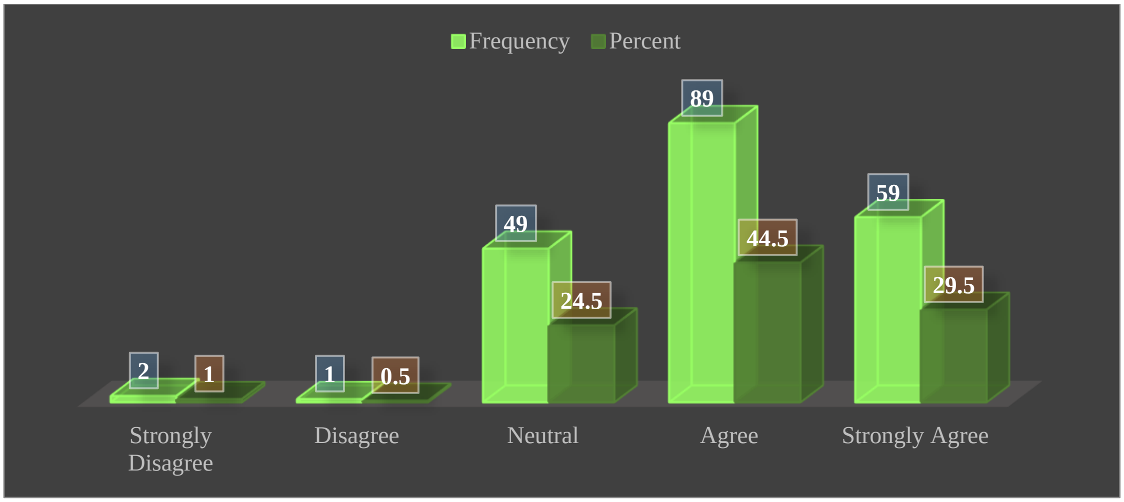

Figure 4.21: PBoC integrates effectively with commercial energy management systems

According to Figure 4.21, most respondents feel the PBoC (assumed to be a particular energy management system) interfaces well with commercial systems. This statement was supported by 74% of participants (44.5%) or highly (29.5%). The remaining 24.5% were ambivalent about the integration's efficacy. A small minority (1.5% of respondents) expressed disagreement or strong disagreement, with a high-test statistic (145.200, $p < .000$) showing significant agreement.

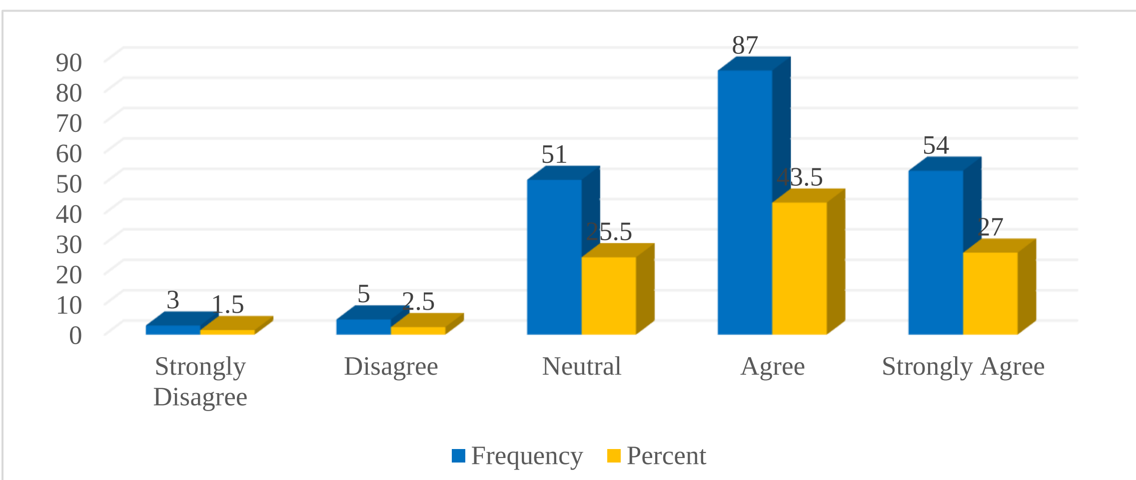

Figure 4.22: PBoC reduces energy costs for commercial properties.

Figure 4.22 shows that the PBoC is largely believed to lower business energy prices. 70.5% of respondents concurred (43.5%) or completely concurred (27%) with this statement, indicating considerable positivity. About 25.5% were unfavourable meaning they were undecided. Only 2.5% and 1.5% disapproved totalling 4%. A substantial test value (128.000, p <.000) indicates high agreement.

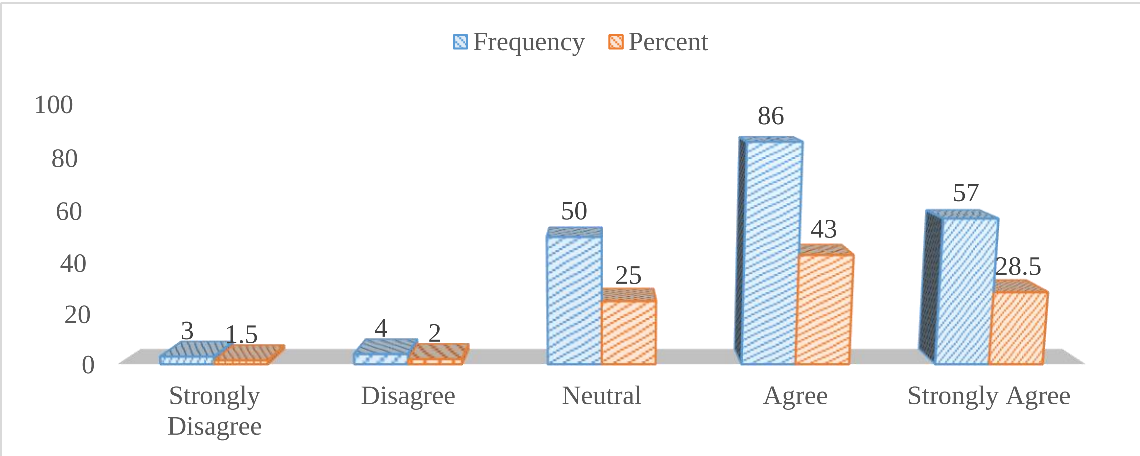

Figure 4.23: The PBoC system supports the commercial sector's sustainability goals

Figure 4.23 shows a good view of the PBoC system's involvement in commercial sustainability. Overall, 71.5% of respondents accepted (43%) or fully concurred (28.5%), suggesting sustainable alignment. Some 25% of individuals were neutral, indicating ambiguity or lack of view. A mere 3.5% disliked or highly objected. A significant test statistic (129.250, p <.000) supports this assertion.

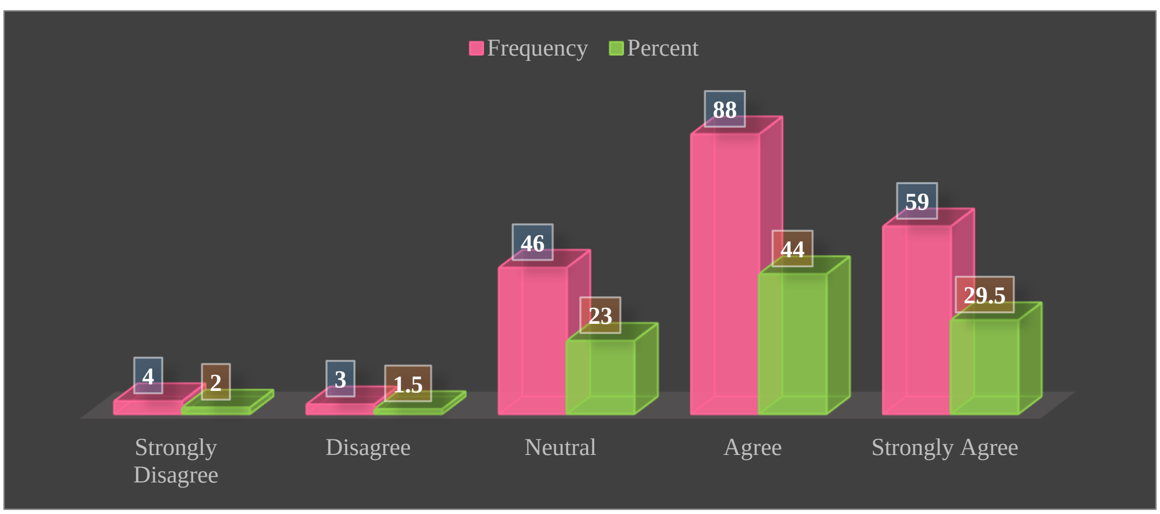

Figure 4.24: PBoC helps commercial properties reduce their carbon footprint effectively

Figure 4.24 shows that the PBoC helps commercial buildings minimise their carbon footprint. The majority, 73.5%, accepted (44%) or fully concurred (29.5%) with the statement, supporting its environmental effect. About 23% were impartial, indicating uncertainty or disinterest. With a test statistic of 134.150 and a p-value of less than 0.000, only 3.5% objected or firmly disagreed, showing little dissent.

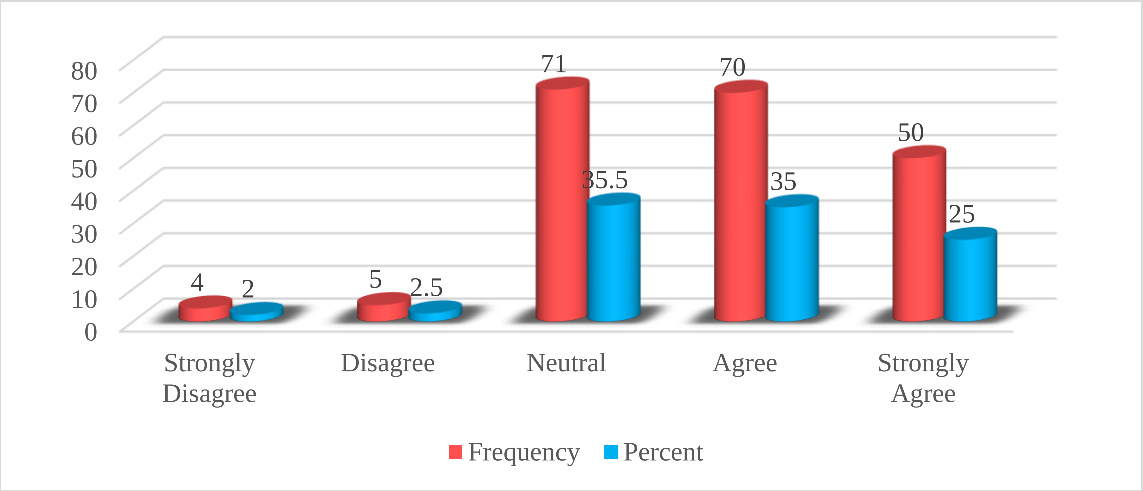

Figure 4.25: The implementation of PBoC in commercial settings is well supported by relevant policies.

Figure 4.25 illustrates varied institutional support for PBoC deployment in commercial contexts. The numbers for "112.050a" and ".000" may relate to other breakdowns or data points. While 60% of respondents agreed (35%) or strongly agreed (25%) that key policies help implementation, 35.5% were indifferent, suggesting ambiguity or lack of a strong view. Most participants saw institutional backing, although policy support and transparency might be improved. A tiny minority, 5.5%, disagreed (2.5%) or strongly disagreed (2%).

Table 4.8: Commercials (Malls/offices)

	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5	Participant 6	Participant 7	Participant 8	Participant 9	Participant 10

Energy Optimization	2	1	5	9	5	5	2	6	5	1
Blockchain for Transparency	4	5	5	5	1	5	5	7	5	6
Smart Grid Integration	4	3	6	5	5	4	5	6	9	6

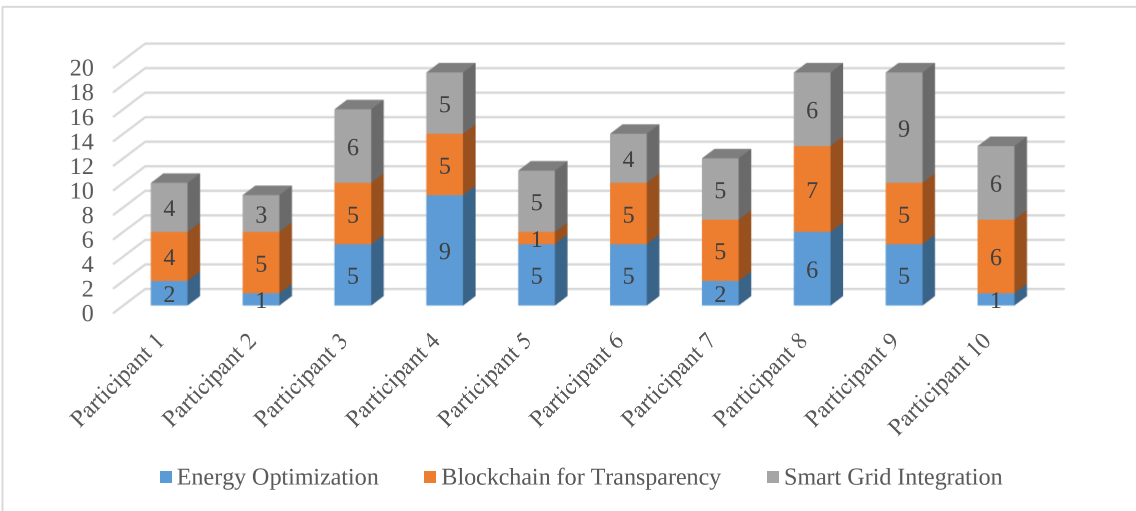

Figure 4.26: Commercials (Malls/offices)

The interview data explores how ten participants—Participant 1, Participant 2, Participant 3, Participant 4, Participant 5, Participant 6, Participant 7, Participant 8, Participant 9, and Participant 10—referred to three critical aspects of commercial energy management in malls and offices: Energy Optimization, Blockchain for Transparency, and the integration of Smart Grid. For "Energy Optimization" the student who used it most was Participant 4 (9), which puts a lot of importance on energy saving scenarios in commercial environments. On the other hand, Participant 2 (1) and Participant 10 (1) made the least references indicating that it was a less of a concern to them. While most others spoke about it five times that included Participant 3, Participant 5, Participant 6 and Participant 9 it can be regarded as of moderate business acumen. Regarding “Blockchain for Transparency” interest was moderate with five mentions on average for the majority of participants, which indicates the constant trend towards transparency using blockchain. Participant 8 with 7 cited it more while Participant 10 with 6 cited it more as well while Participant 5 with only a single citation suggested that he had a low priority for it. In terms of “Smart Grid Integration”, the number of mentions were more volatile, more so for those whose work lean towards the commercial energy system as reflected in Participant 9 9. Others include Participant 8-6, Participant 3-6, Participant 10-6 who placed relatively higher emphasis as well. Participant 2 in his article (3) and Participant 1 in his article (4) used it sparingly, therefore implying that the writers have little enthusiasm for the subject. The results highlight a lack of intensity on behalf of participants in comparison to other tasks and demonstrate that a custom strategy is required to address these priorities for commercial energy management.

4.2.5. Industries (Manufacturing, MSME etc.)

Table 4.9: PBoC @ Industrial

Category	Question		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Test Statistic	Sig.
Technological	PBoC is compatible with industrial energy systems and equipment	Frequency	3	5	58	81	53	119.200[a]	.000
		Percent	1.5	2.5	29	40.5	26.5		
Economic	PBoC helps in optimizing energy	Frequency	4	7	58	75	56	104.750[a]	.000
		Percent	2	3.5	29	37.5	28		

	costs across various industrial operations.								
Social	Employees benefit from improved energy management practices introduced by PBoC	Frequency	2	6	65	71	56	111.050[a]	.000
		Percent	1	3	32.5	35.5	28		
Environmental	PBoC contributes to reducing the environmental impact of industrial activities.	Frequency	3	4	56	79	58	119.150[a]	.000
		Percent	1.5	2	28	39.5	29		
Institutional	PBoC adheres to industry standards and best practices for energy management.	Frequency	2	4	62	75	57	118.450[a]	.000
		Percent	1	2	31	37.5	28.5		

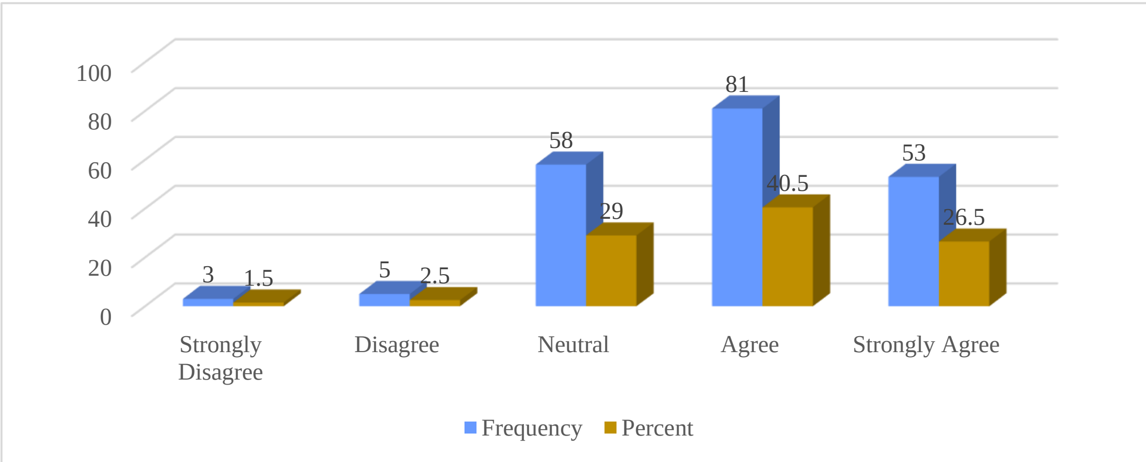

Figure 4.27: PBoC is compatible with industrial energy systems and equipment

Figure 4.27 demonstrates that most respondents think the PBoC works well with industrial energy systems and equipment. Overall, 67% approved (40.5%) or fully concurred (26.5%) with this statement, demonstrating compatibility. Approximately 29% of participants were impartial indicating ambiguity or lack of view. 4% disapproved (2.5%) or severely opposed (1.5%), PBoC's compatibility with industrial energy systems and equipment is supported by the test statistic (119.200) and significance level (0.000).

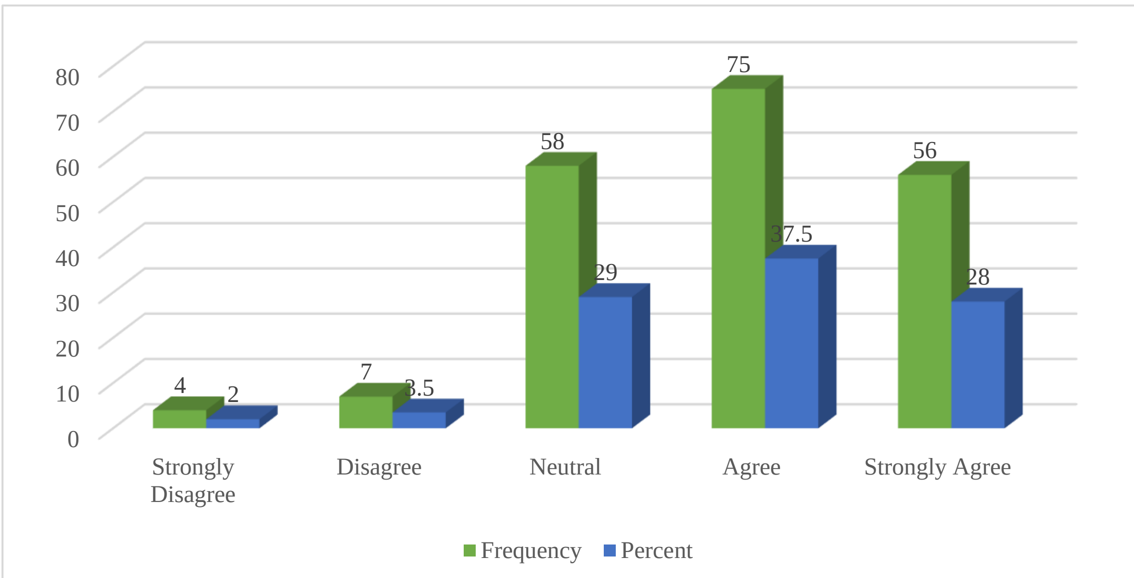

Figure 4.28: PBoC helps in optimizing energy costs across various industrial operations.

As seen in Figure 4.25, many respondents feel the PBoC optimises industrial energy costs. 66.5% agreed (37.5%) or strongly agreed (28%) with this statement, indicating a good economic effect. Neutral responders made up 29%, suggesting ambiguity or disinterest. Most perceive the cost-saving advantages, while 5.5% disagreed (3.5%) or strongly disagreed (2%), The test statistic (104.750) and significance level (0.000) indicate that the results are statistically significant.

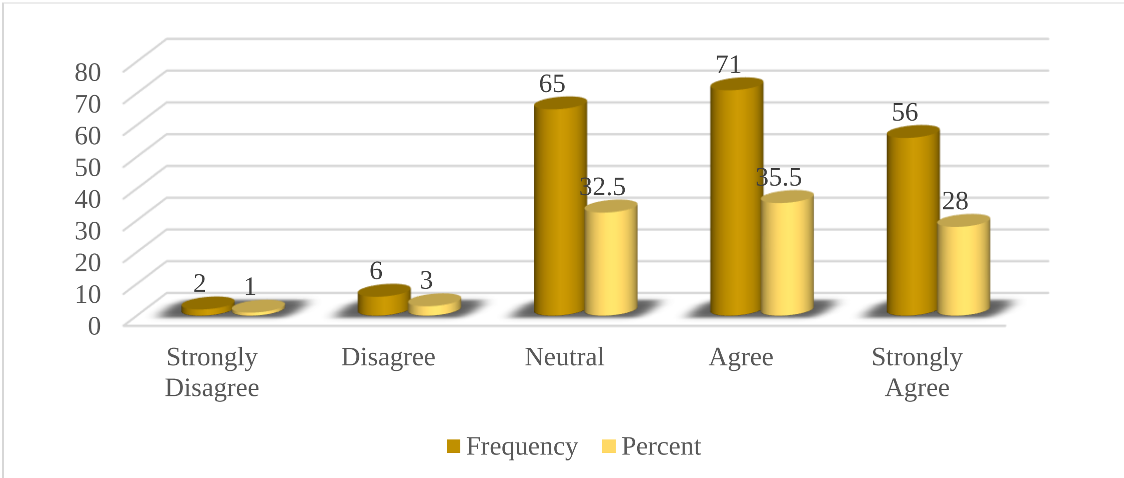

Figure 4.29: Employees benefit from improved energy management practices introduced by PBoC.

Figure 4.29 illustrates that most respondents think the PBoC's energy management policies benefit workers. A combined 64.5% agreement (35.5%) or firmly concurred (28%) with the statement, indicating a favourable influence on workers. Yet 32.5% were neutral, indicating doubt or lack of conviction. Though a few remain dubious, the majority perceive positives. Only 4% disliked (3%) or totally disagreed (1%). This data is statistically significant (111.050) and supports organisations' favourable views of PBoC's energy management effect.

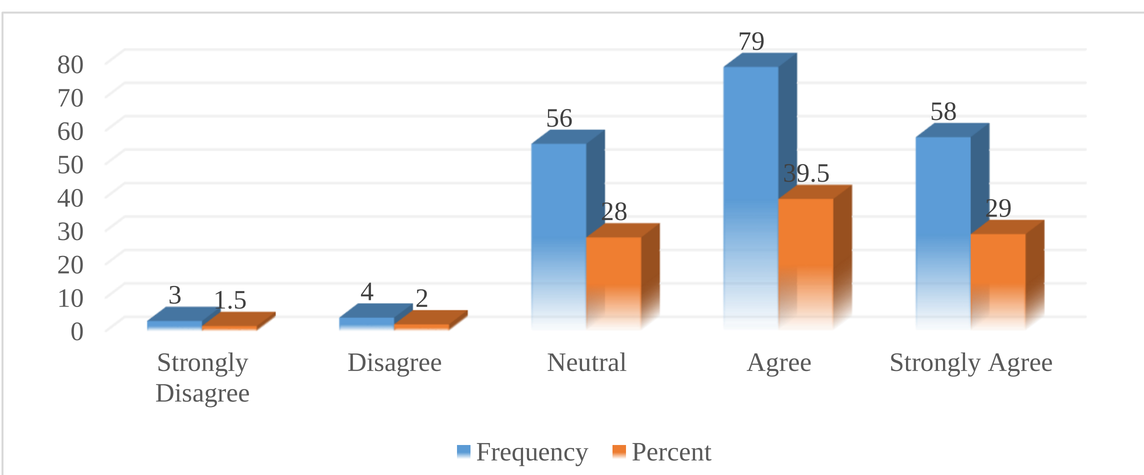

Figure 4.30: PBoC contributes to reducing the environmental impact of industrial activities.

The preceding Figure 4.30 reveals that most respondents feel the PBoC reduces industrial environmental effects. 68.5% accepted (39.5%) or enthusiastically concurred (29%) with the statement, indicating significant environmental support. Although 28% were unbiased, they were hesitant or unsure. While most respondents recognise its environmental benefits, 3.5% rejected it (2%) or argued against it (1.5%). Results are statistically significant according to the test statistic (119.150) and significance level (0.000).

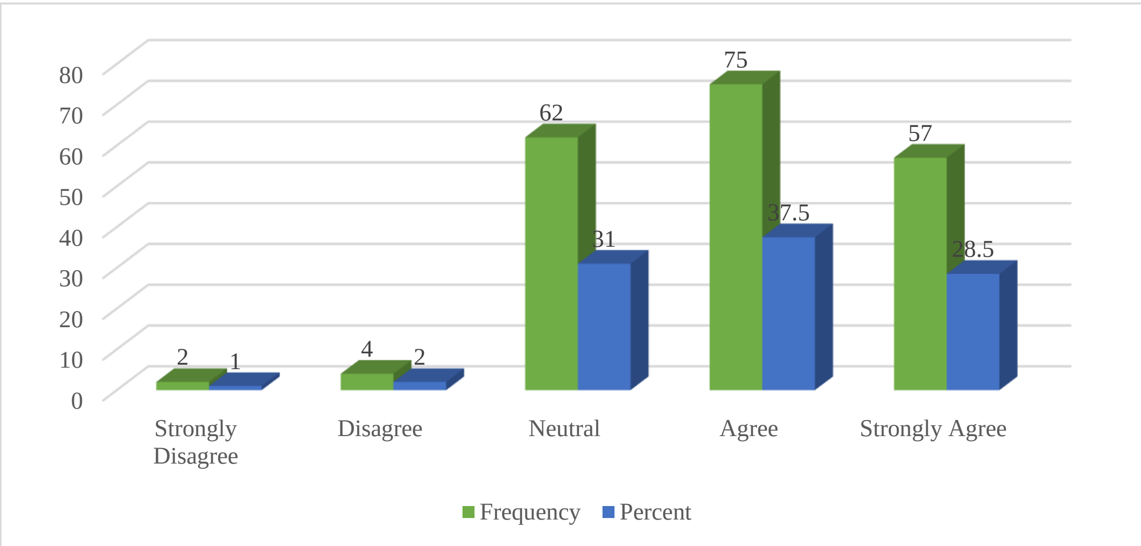

Figure 4.31: PBoC adheres to industry standards and best practices for energy management.

In Figure 4.31, most respondents think the PBoC follows energy management industry standards and best practices. 66% who agreed (37.5%) or strongly agreed (28.5%) showed strong trust in its industry norm compliance. Neutral individuals made up 31%, indicating indecision. Although most respondents believe the PBoC meets industry standards, 3% disagreed (2%) or strongly disagreed (1%). A test statistic of 118.450 and a significance level of 0.000 indicate statistical significance.

Table 4.10: Industries (Manufacturing, MSME etc.)

	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5	Participant 6	Participant 7	Participant 8	Participant 9	Participant 10

Renewable Energy Integration	5	1	8	5	6	7	6	1	6	5
Operational Efficiency	3	6	6	3	6	2	6	6	6	7
Cost Reduction	5	6	6	5	6	7	3	6	4	7

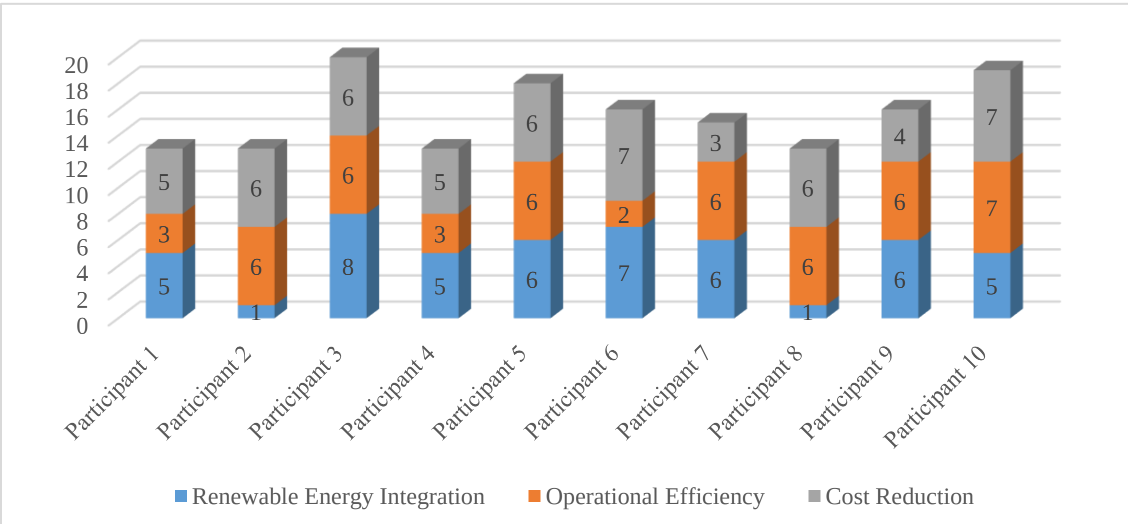

Figure 4.32: Industries (Manufacturing, MSME, etc.)

The interview data examines the frequency with which ten participants—Participant 1, Participant 2, Participant 3, Participant 4, Participant 5, Participant 6, Participant 7, Participant 8, Participant 9, and Participant 10—referred to three key aspects of energy management in industrial contexts: Renewable energy, the development of an efficient operational strategy, and implementation that lower expenditures. Among all the aspects covered in the case, "Renewable Energy Integration" was mentioned most by Participant 3 (8) with the author citing a particular focus on the integration of renewable energy sources in industries. From this, it is clear that Participant 6 clicked 7 times while the participants such as Participant 5, Participant 7, and Participant 9 also posted 6 images each. On the other hand, Participant 2 (1) and Participant 8 (1) mentioned it rarely indicating that it is of lower importance or not a focal area of integration of renewables. In as much as "Operational Efficiency", the participants were equally as consistent, those as Participant 2, Participant 3, Participant 5, Participant 7, Participant 8, and Participant 9 made mention of it six times implying their concerted importance of operations. They all used it but to different extents, mostly pointing to higher efficiency, Participant 10 used it seven times, and Participant 1 and Participant 6 used the word three and two times respectively. For "Cost Reduction", Participant 10 (7) & Participant 6 (7) considered it indispensable to Industrial Energy Management. Participant 3 and Participant 2 followed the topic closely each presenting six cases of usage; Participant 7 mentioned it three times and Participant 9 four, so, perhaps, it may be significant, but not the priority, for him. All in all, there sought-after heterogeneity in corporate motives and concerns as to renewable power, facility efficacy, and cost minimization so that these results underlined the necessity for client-tailored solutions for the specific necessities of industrial energy consumers.

4.2.6. Emergency Backup Systems

Table 4.11: PBoC @ Emergency backup systems

Category	Question		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Test Statistic	Sig.
Technological	PBoC integrates effectively with emergency backup power systems	Frequency	2	2	53	80	63	129.650[a]	.000
		Percent	1	1	26.5	40	31.5		

Economic	The use of PBoC in emergency backup systems reduces operational costs related to power out	Frequency	1	7	56	78	58	115.850[a]	.000
		Percent	0.5	3.5	28	39	29		
Social	PBoC has enhanced the preparedness for energy emergencies	Frequency	2	8	60	79	51	112.750[a]	.000
		Percent	1	4	30	39.5	25.5		
Environmental	The environmental benefits of using PBoC in emergency systems are effectively communicated	Frequency	1	10	60	78	51	109.650[a]	.000
		Percent	0.5	5	30	39	25.5		
Institutional	The support for integrating PBoC into emergency backup systems is adequate	Frequency	3	7	66	72	52	107.550[a]	.000
		Percent	1.5	3.5	33	36	26		

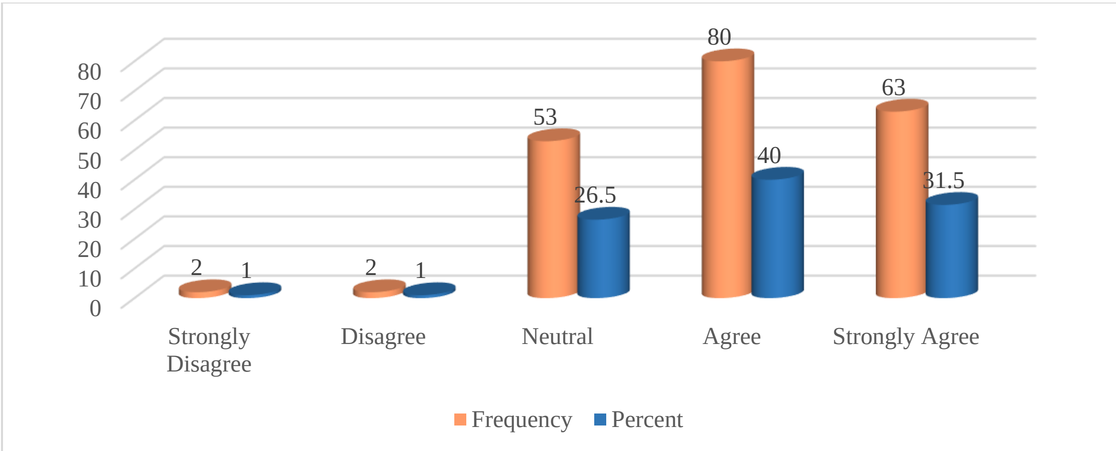

Figure 4.33: PBoC integrates effectively with emergency backup power systems

Figure 4.33 indicates most responders think the PBoC works well with emergency backup power solutions. Its compatibility was highly viewed by 71.5%, who concurred (40%) or firmly agreed (31.5%). Neutrality 26.5% of responders indicated doubt or lack of opinion. Only 2% opposed (1%) or completely disagreed (1%), showing that most respondents think it works. The test statistic (129.650) and significance level (0.000) suggest statistical significance, supporting PBoC's connection with emergency backup power systems.

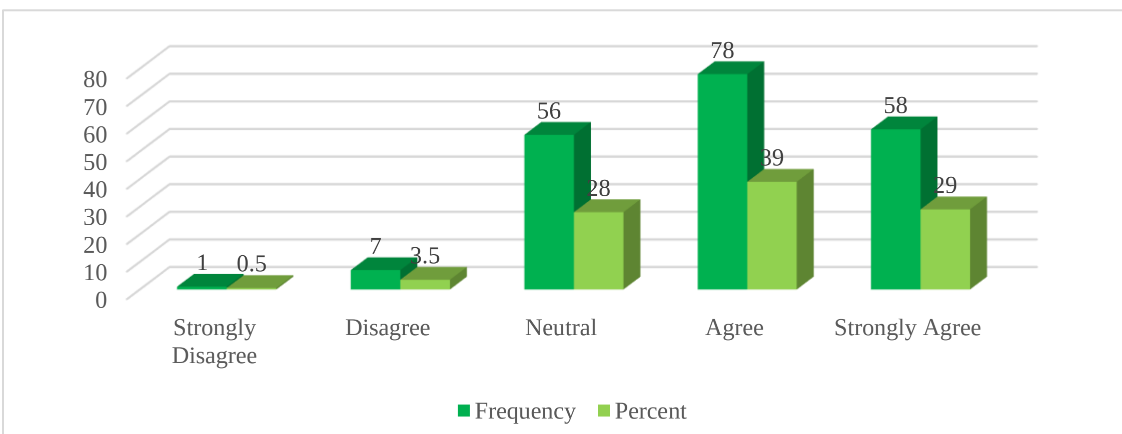

Figure 4.34: The use of PBoC in emergency backup systems reduces operational costs related to power outages.

Figure 4.34 shows that most responders think PBoC in emergency backup systems reduces power loss operating expenses. A total of 68% agreed (39%) or strongly agreed (29%) with the statement, supporting its economic advantages. About 28% of participants were neutral, indicating indecision. Some 4% disagreed (3.5%) or severely disagreed (0.5%). The test statistic (115.850) and significance level (0.000) show significant findings.

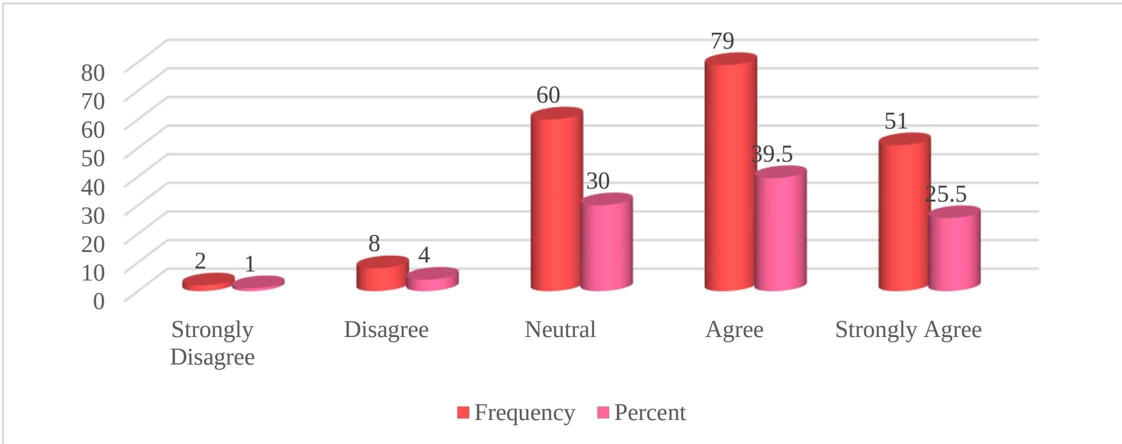

Figure 4.35: PBoC has enhanced the preparedness for energy emergencies.

As shown in Figure 4.35, most respondents feel the PBoC has improved energy emergency readiness. 65% concurred (39.5%) or firmly agreed (25.5%), indicating a good assessment of its influence on disaster preparation. Nearly 30% were neutral, indicating indecision. Most view the PBoC as boosting preparation, whereas 5% opposed (4%) or strongly opposed (1%). The testing statistic (112.750) and significance level (0.000) suggest these results are significant.

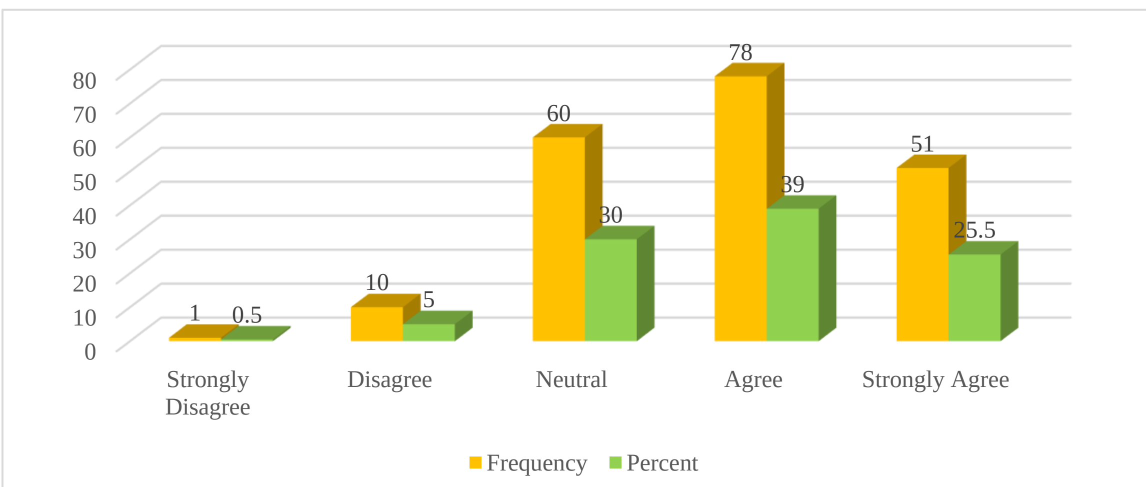

Figure 4.36: The environmental benefits of using PBoC in emergency systems are effectively communicated.

Figure 4.36 shows that most respondents think PBoC in emergency systems are well explained about their environmental advantages. 64.5 percent agreed (39%) or entirely concurred (25.5%) with the statement, showing that these advantages are communicated successfully. Nearly 30% were neutral, indicating ambiguity or lack of view. Some 5.5% opposed (5%) or severely disputed (0.5%); significant test statistics (109.650a, p <.000) indicate substantial agreement, but a few believe they are not adequately articulated.

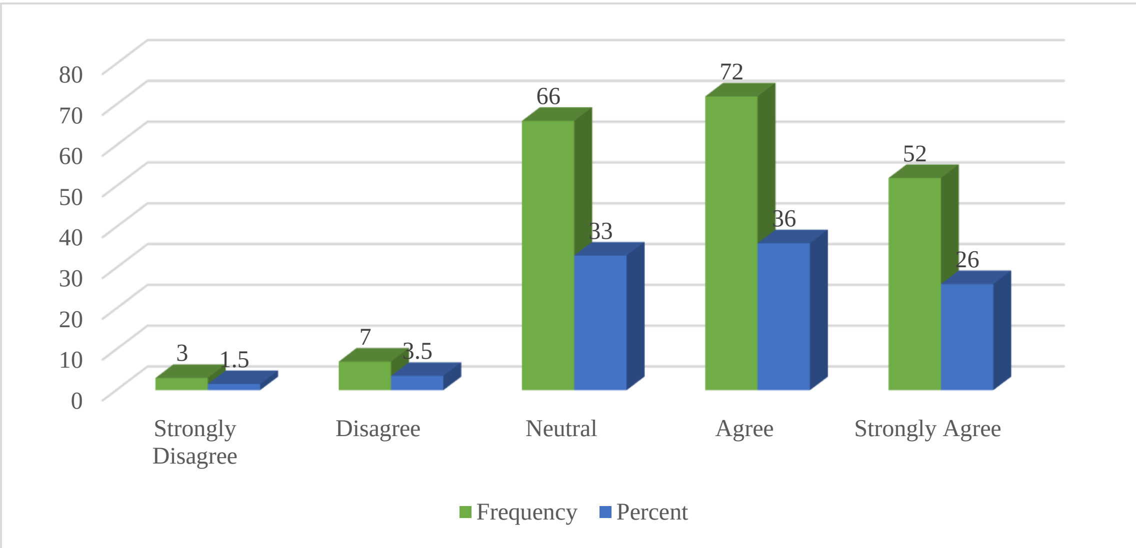

Figure 4.37: The support for integrating PBoC into emergency backup systems is adequate.

Figure 4.37 shows that most responders favour PBoC integration into emergency backup systems. 62% concurred (36%) or firmly agreed (26%), indicating a favourable view of support. About 33% of replies were neutral, indicating indecision. Some, 5%, disapproved (3.5%) or disagreed strongly (1.5%), showing that although most see the assistance as satisfactory, the test statistic (107.550a, p <.000) indicates good agreement.

Table 4.12: Emergency Backup systems

	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5	Participant 6	Participant 7	Participant 8	Participant 9	Participant 10

System Resilience	3	5	4	4	5	8	5	5	5	4
Real-Time Monitoring	2	4	4	3	5	6	2	5	3	5
Cost Efficiency	3	4	1	4	5	6	5	1	5	9

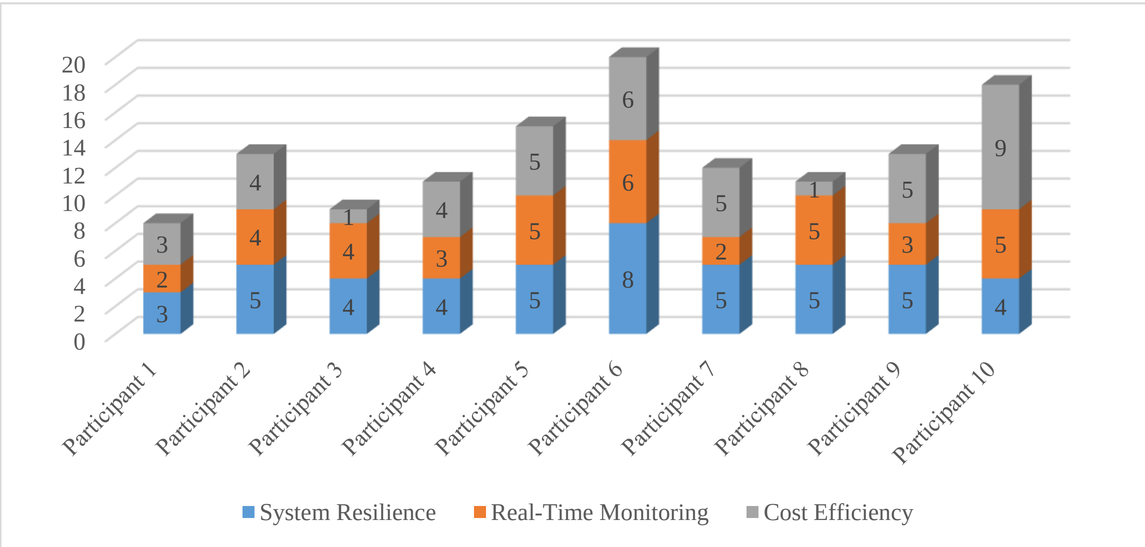

Figure 4.38: Emergency Backup systems

The interview data explores the frequency with which ten participants—Participant 1, Participant 2, Participant 3, Participant 4, Participant 5, Participant 6, Participant 7, Participant 8, Participant 9, and Participant 10—referred to three critical aspects of Emergency Backup Systems: In addition to System Resilience, Real-Time Monitoring and optimization for costs. The frequency for "System Resilience" is nearly equal and most of the participants like Participant 2, Participant 5, Participant 7, Participant 8, and Participant 9 used 5 times and it measures the ability of systems to address disruptions. Most often it was mentioned by Participant 6 (8) who feels that system durability is of paramount importance now, while Participant 1 mentioned it the least (3), which might indicate that this aspect could be not of primary concern for him. Regarding the "Real-Time Monitoring" factor, some mentions differed as most participants used it, speaking about it from three to five times, thus attributing moderate significance. Among the participants, more specifically Participant 6 (6) and Participant 8 (5), reflected more about the system's ability to monitor the performance of other systems in relation to this criterion, although with less emphasis, Participant 1 (2) and Participant 7 (2) mentioned it. For "Cost Efficiency", responses varied with Participant 10 (9) who deemed it as most important to him. The primary listed first- and second-tier suppliers by spend include Participant 6 (6) and others including Participant 5, Participant 7, and Participant 9 (5 each), who all tended to place high strategic importance on cost factors. Participant 3 cited it the least of all the students, possibly meaning that to him, the cost of services is not of much importance 1 Among those who cited it rarely, Participant 3 =1 and Participant 8 =1. The priorities demonstrated by participants also differ, with some targeting stability and affordability while others center more on control, implying that more approaches are required to address the designing and management of the emergency backup systems.

4.3. Discussion

4.3.1. PBoC @ Residentials

The study of the end consumer's response to the adoption of Power Bank on Cloud (PBoC) in residential areas provided insights into different factors that dictate the versatility of digital platforms for energy management solutions.

Technological Dimension

From the technological perspective, much emphasis goes to the large appreciation of the valuable service that PBoC can provide whereby its key service involves monitoring energy use in our homes in real-time. In this regard, the vast majority of the respondents supported the statement that through PBoC it is possible to monitor the energy consumption conveniently, which draws attention to the further technological optimization of households. Real-time helps consumers to track their consumption patterns and be in a position to rectify instances whereby they have consumed more energy than necessary. Continued focus on connecting smart home systems also strengthens the understanding of the need for advanced technology to improve energy management in homes. Indeed, there were some subjects, like Participant 5, who paid less attention to the technologies. However, the global trend is upbeat to implement digital tools that will give them supreme authority over the usage of energy resources. But at the same time, it shows that there can be issues that make the integration of the smart home solution into existing home infrastructure difficult, which has to be solved for the widespread of smart homes.

Economic Dimension

Evaluating the perceived value of PBoC in the economic dimension, especially the participants' expectations of the cost of installation and maintenance, yields the following responses. In terms of the perceived benefits, most of the respondents confirmed that the PBoC provide good usability for cost. Still, there are substantial levels of fluctuations in the rate of the concerned opinion, and as such, price sensitivity, therefore, remains a major factor affecting the adoption of PBoC. Some respondents may consider the initial cost as well high to the quantity of money that may need to be saved, following the format of budgeting among households. In that analysis of cost and the perceived benefits, consumers' willingness to use such technologies is dependent on the pricing influencing strategies and potential incentives that should be made in order to unveil PBoC as a more believable choice. In addition, there is an implication here with respect to subsidizing consumers, which, in fact, may lead to better access to green technologies in the market.

Social Dimension

The social dimension shows that the respondents have a high level of perception that adopting PBoC improves consumer status through being environmentally conscious. This suggests that there is ever increasing social drive behind the incorporation of sustainable technologies, and consumers' awareness to behave responsibly and reduce negative impacts towards the environment is improving. Some of the respondents perceive the adoption of green technologies, including PBoC, as a mechanism of showing corporate social responsibility and the need to change perceptions held by their immediate society. To this end, this social incentive is very pivotal in propelling adoption since people feel the need to be part of a social trend or a bigger movement towards the adoption of sustainable practices. Since there is an increasing trend in global awareness of the environment, people are willing to spend on products that are financially profitable while at the same time improving the environmental profile of a person.

Environmental Dimension

The environmental is viewed as emphasizing a proper concern on the part of the participants for the environmental issues. A large majority of respondents also said that the use of PBoC helps in the reduction of the carbon footprint within their households. As this response shows, stress on the potential of energy management technologies to solve climate issues is growing; many participants noted the existence of environmental problems. The high emphasis placed on environmental gains indicates that end consumers are encouraged by the potential to lessen their carbon footprint and help to attain sustainable development objectives. This dimension is especially valuable while considering the initiatives launched for the use of renewable energy sources all around the world, as the consumer readiness to become involved in the programs pushing for green energy solutions stems from consumers' sense of embracing their responsibility for the environmental problems and their intention to contribute to environmental improvement. As such, the environmental aspects of PBoC have a lot of synergy with the general concept of moving away from carbon and to cleaner sources of energy.

Institutional Dimension

The institutional dimension targets the perceived adequateness of the customer support that currently exists for PBoC users in residential areas. Thus, although most respondents reported that support was available and accessible the overall consensus was that the support mechanisms might be more effective. This disparity in perception means that end consumers may feel they lack a clear understanding of the amount of help they will get, particularly when issues come up, whether related to technical problems or installation and maintenance. This indicates that maintaining proper customer support should remain a priority to ensure that more customers would be willing to try the new technologies. Lack of development in certain PBoC technologies still exists; hence, trying to put much effort into developing a strong institutional framework that would ease the provision of proper support can act as a proper solution to the barrier. This comprises not only warranty service but also information delivery to the consumers about the technology, customer support with system problems, and customer objections about the functionality of the technology. One will find consumers more willing to adopt such a system to their homes because of effective support to the adoption process hence being helpful in boosting participation in green energy solutions.

4.3.2. PBoC @ EV Charging parking lots

The survey results concerning the integration of PBoC for EV charging parking lots give a perfect insight into aspects affecting its integration.

Technological Dimension

The technological dimension reveals a highly positive attitude toward PBoC’s capacity to facilitate charging services for electric vehicles (EVs) in parking lots. Through the analysis of the multiple-choice questions, most of the participants confirmed the assertion to the effect that PBoC enhance charging speed and efficiency, which is vital in enhancing electric vehicle uptake. The availability of convenient charging stations is urgently necessary as this problem is one of the main concerns of consumers who consider switching to electric cars. Also, participants' discussions on infrastructure development assert that there must be adequate charging infrastructure. The focus on infrastructure development is justified by the notion that PBoC is an infrastructure that needs to have a reliable and efficient technological basis for this offering to be convenient to use as EV adoption grows.

Economic Dimension

As indicated in the economic dimension of the survey, PBoC's most appreciated aspect is to decrease the cost of energy required for EV charging stations. This is important because one of the reasons that impeded broadband penetration is the high cost of infrastructure specifically the energy to charge EVs. Cost savings through efficiency from PBoC can translate into cheaper and affordable running costs for charging stations; hence, more investors are attracted to the EV charging business. However, it is essential to understand that, though most participants within the sample agree, the level of consensus differs, setting the need for well-explained and easily understandable economic models in making charging services for EVs using PBoC.

Social Dimension

In the social dimension, PBoC is expected to motivate even more EV owners to make use of charging stations in the region. This corresponds to identifying the social contribution made by improving access to safe and cheap charging stations to promote the use of electric automobiles. The fact that the utilization of more EVs may help to improve the overall infrastructure in many local communities argues for how PBoC may help foster sustainable mobility. However, the data also reveals that this social benefit is reported with variation by the participant, which suggests that the impact of PBoC on a certain social behaviour may be sensitive to certain context factors, mainly the levels of public awareness and involvement in sustainable transport.

Environmental Dimension

The environmental dimension is very much in favor of the idea that through the intervention of PBoC, the charging of electric vehicles is more sustainable in the long term. A considerable number of the respondents approved the statement that the integration of PBoC into the EV charging stations contributes to the minimization of the environmentally negative effects of the stations. This can partly be explained by the growing appreciation of the potential input of EVs to environmental concerns, including reductions in emissions as well as reliance on fossil products. The future scalability of EV charging systems, especially when connected with renewable power sources, can greatly reduce global carbon emissions. Such awareness by participants/customers embraces the perception of other indices such as the PBoC environmental benefits, indicating that technological change can positively drive green energy solutions and decrease participants' carbon footprints.

Institutional Dimension

On the institutional level, there is an attitude towards the regulations concerning PBoC in EV charging stations as not entirely clear and rather non-supportive. Although most of the participants agreed with the current set of regulations, a certain share of them believe that regulations should be even more comprehensive and helpful in PBoC large-scale adoption. The requirements for policies are important to demand creation for EV CS since unclear or limiting policies may hinder the deployment of the CS network. This means that for technologies like PBoC, there is a need to write extensive policies to guide their implementation to cover the market as they advance in their development, and the need to complement the advancement of green technologies with standards for their effectiveness and safe implementation.

4.3.3. PBoC @ Commercials (Malls/Offices)

The survey results on the use of PBoC in commercial buildings, including malls and offices, open up several keys to technological, economic, social, environmental, and institutional aspects of energy management.

Technological Dimension

In the technological dimension, it is observed that PBoC works well with commercial energy management systems. The opinions of participants show that PBoC integration with existing energy management systems has a positive impact on the overall functioning of commercial buildings. With this integration it is possible to monitor and control the usage of energy at the required time period in large commercial buildings such as malls and offices. they observed that the uneven optimism towards energy optimization indicates that power is a concern that most representatives recognize, although to varying degrees, i.e. Participant 2 and Participant 10 are less emphatic about energy optimization, which might point towards different levels of concern or awareness at the workplace. Smart Grid Integration also drew divergent levels of attentiveness: while Participant 3, Participant 9, and Participant 8 paid more heed, the rest of the participants focused on it in a regular manner, as SG is closer to the commercial energy systems that the participants are a part of. The findings suggest that the perceived benefits of the technological integration of PBoC are overwhelmingly positive, barring the question of whether its potential has not yet been fully realized for specific energy management requirements of commercial buildings.

Economic Dimension

In the economic dimension, PBoC is expected to lower energy expenditure in commercial buildings. The data further show that most of the participants concur that it is possible to reduce energy costs through the application of PBoC in commercial environments, a value add for which many organizations are searching. Training can help overcome high operational costs common among commercial properties with the key benefit likely to be the optimization of energy consumption capabilities. The smaller response from some of the participants, such as Participant 2 and Participant 10, indicates that the economic factors may be subservient to other factors, such as technological or environmental factors, depending on the type of business the company is undertaking the developments. Nonetheless, to a great extent, this research supports the idea that adopting PBoC can be economically viable for cutting down the energy costs of commercial properties.

Social Dimension

The social dimension shows that PBoC provides support in achieving the sustainability goals of commercial businesses. It is quite revealing that a good number of participants believe that it is possible to make use of the system in fulfilling corporate sustainability goals that are gaining popularity among organizations intending to enhance their public image, besides aligning themselves with corporate sustainability goals. The emergence of sustainable goals and objectives in the field of business means that PBoC can become a heuristic tool to support commercial real estate to achieve sustainable goals. Nevertheless, similar to other dimensions, the level of emphasis applied to this aspect is lower for some participants, meaning that environmentally sustainable development may not always be a leader’s ultimate priority in a commercial sense.

Environmental Dimension

As for the environmental dimension, PBoC is only viewed as an instrument that enables commercial properties to successfully manage their resource-saving efforts. Such an agreement of the views on this aspect confirms the increasing understanding of the potential of energy management systems such as PBoC for environmental applications. Through reasonable control of energy utilization and supporting the utilization of renewable energy, PBoC can greatly avoid the amount of carbon emissions from commercial energy usage. Although participants were largely in agreement concerning the environmental value of PBoC, the low scores given to energy optimisation and smart grid integration indicate that the environmental aspect of PBoC could be seen as a minor advantage in the overall strategy of metering.

Institutional Dimension

In the institutional dimension, the survey suggests that PBoC has policies that support the use of the technique in the commercial environment. Most of the participants confirmed that current policies allow the implementation of PBoC; however, a few still noticed some potential. Additional and more articulated and favourable policies in this sense could contribute to a further increase of the use of PBoC in commercial buildings as companies and industries are more uneasy about adopting new technologies when there is the risk that they could be deemed non-compliant and thus no rebates or incentives will be available. This response implies that, although the institutional environment is relatively supportive, there is still a combination of inadequate regulation to support a much broader application of energy management solutions such as PBoC.

4.3.4. PBoC @ Industrial

The identified survey results for PBoC in the industrial context in relation to industrial applications demonstrate the need for energy management and its optimisations within different sectors of industrial processing, Technology compatibility, Economic optimisation, Social-psychological dimensions, impact on the environment and conforming to standards.

Technological Dimension

The technological dimension shows that PBoC is perceived as mostly aligned with industrial energy systems and equipment. All participants agreed that some form of PBoC implementation could be feasible in existing industrial contexts for enhancing energy monitoring and management. However, the emphasis made on Renewable Energy Integration indicates that, although some participants were more concerned with how to incorporate renewable energy sources in the industrial energy system, other participants seemed less interested. This has ascertained the idea that the role of renewable energy in industrial applications is perceived differently in different sectors, some with emphasis on the sustainability of energy while some with another aspect of energy. Also, the Operational Efficiency shows the technological contribution of PBoC in optimising energy consumption in industrial processes since some of the participants appreciated it for improving the system's performance and energy use efficiency while eliminating wastage.

Economic Dimension

In the economic dimension, PBoC is perceived to be useful in enhancing energy efficiency in numerous operations within industries. In general, participants concur that depreciating PBoC can save industrial firms the cost of energy by efficiently using it. Among the various priorities identified, Cost Reduction was the most highlighted option, especially in industrial energy management as described by Participant 10 and Participant 6. The opportunities to cut costs are considered one of the main advantages of using such technologies as it goes a long way to defining the profitability of industries. This probably explains why PBoC is considered a major reason why industries should adopt such technologies. Nevertheless, that very discrepancy in the importance attributed to cost reduction indicates some industrial sectors' participants may not consider it to be paramount but could have other factors, such as operational effectiveness or sustainability, as a priority above cost concerns.

Social Dimension

The social benefit emphasizes that PBoC can enhance the energy management experience in the industrial sector. Overall, participants evaluated the possibility for enhancement of energy management as a positive aspect that positively affects employees, working conditions and awareness of energy use. Energy saving also aids an organisation in achieving a positive organisational culture where sustainable use of resources forms part of the organizational culture. The different degrees of frequency tell us that while most participants are aware of something like a social advantage, some may value some technological/economic aspect more than using PBoC to enhance the well-being of the employees.

Environmental Dimension

On the environmental aspect, attention is paid to the participation of PBoC in decreasing the pollution load of industrial initiatives. It was further argued by many of the participants that applying PBoC will certainly go a long way in reducing greenhouse gas emissions and environmental impacts because of efficient energy utilization and renewable energy integration. The increased call for Renewable Energy Integration by several participants, especially Participant 3 and Participant 6, implies that there is greater awareness of the best practices in managing industrial operations. However, the slightly reduced emphasis on this aspect by some participants suggests that environmentalism might not always be a priority when managing energy in all industrial settings.

Institutional Dimension

There is consensus among the participants regarding the institutional quality dimension where it is understood that PBoC complies with industry benchmarks in energy management. This is important for the reason that PBoC adoption must be within the standards provided by the regulatory bodies as well as needs of the industry. Standard is used to guarantee that industrial energy systems are optimized and are within the legal requirements of the country and international agencies. The Cost Reduction and Operational Efficiency is already strengthened in this area and in line with institutional guidelines to improve competitiveness and compliance with environmental and energy efficiency norms.

4.3.5. PBoC @ Emergency backup systems

The perceived value of PBoC in emergency backup systems is found in this study by surveying users' various aspects of integration, cost, readiness, and environmental enablers, which have critical roles in guaranteeing dependable and efficient backup power systems in case of energy blackout.

Technological Dimension

On the effectiveness of PBoC integration with emergency backup systems technological dimension hard and fast that majorities of the participants confirm PBoC operates under conditions of successful integration with backup power infrastructure. This is important because validating that backup systems can perfectly integrate with other energy management tools such as PBoC can improve their resilience in the event of a disaster. System Resilience drew attention from many participants and would be aspiring for disruption tall tales and experienced by Participant 6 with eight references highlighting the need for systems to failtal with disruptions. Among all the participants, Participant 1 referred to it the least – 3 times, so, it may mean that this issue is not a top priority for him, maybe because he concentrates more on other aspects, for instance, costs saving or its constant monitoring.

Economic Dimension

The participants' evaluation carried out from an economy's viewpoint shows that the majority of participants are confident that through the assistance of PBoC the operations costs especially from power failure in cases of backup can be considerably brought down. Another important finding was the Cost Efficiency as a rated priority for many participants: SE Participant 10 said (nine mentions) that cost efficiency was crucial when implementing an emergency backup system. This is supported by others such as Participant 6, Participant 5, Participant 7, and Participant 9 each of whom mentioned five times that cost control in emergency backup systems is paramount. Nonetheless, Participant 3 and Participant 8 used it the least to mention it, which means they may not pay much attention to the aspect of the costs regarding the construction of emergency backup.

Social Dimension

The social dimension shows that PBoC is perceived as an instrument that increases the readiness to address emergencies in energy, where the majority provided consent on the improved capability of the systems to power failure. Overall participants agree with the statement regarding integration of PBoC provides better readiness to an organisation in case of disruptions of energy. This could particularly be important to identify critical infrastructure where energy security is of top most priority. The centrality of online assessment and system reliability with regard to these functions highlights the ongoing need for supervision and management during crises and the need to confirm that backups are operational and meeting requirements.

Environmental Dimension

Another interesting result was identified from the second question which related to the perceived benefits of using PBoC in emergency backup systems; a considerable number of participants noted that PBoC has a positive coefficient regarding the impact on the environment. The application of PBoC into emergency systems might help decrease emissions and wastage of energy in emergency situations if associated with renewable energy. Concerning this benefit, the majority of the participants agreed, though some of them stated that environmental features are regarded as the second order compared to operational and cost factors.

Institutional Dimension

The institutional factor recommends it to incorporate PBoC into emergency backup systems; however, there is limited strength in support from this domain. Some participants – such as Participant 6 and Participant 7 – perceived that sufficient support is available in order to achieve such integration, although others perceived that more might have to be done to harmonize the programs with relevant industry practices as well as the regulations. About institutional support, Surendran and Participant 6 stressed its need for successful deployment while the rest were equally split in their views whether they are aware of some particular policy framework for emergency energy systems and not.

CHAPTER V:
CONCLUSIONSAND RECOMMENDATIONS

5.1. Conclusions

This study underscores the pivotal role of end-consumer participation in achieving global net-zero targets and fostering the adoption of green energy solutions. The transition to a carbon-neutral future necessitates a multifaceted approach involving policymakers, utilities, investors, and consumers. The integration of digital technologies and innovative business models can bridge the gap between renewable energy supply and consumer demand, empowering individuals to actively contribute to decarbonization efforts. By exploring optimal energy mixes and proposing a digital framework like the "Power Bank on Cloud" (PBoC) platform, this research highlights the potential of technology to create secure, efficient, and collaborative renewable energy trading ecosystems. Such platforms not only enable consumer engagement but also enhance grid stability, optimize energy trading, and promote sustainable innovation diffusion.

As shown from the analysis focused on the residential users, the results show that the PBoC platform has a positive reception, and interest from the users continues to grow. A majority of the respondents confirm that PBoC efficiently monitors energy consumption in real time, boosts peoples' perception as environmentally conscious consumers and decreases household carbon emissions, given by statistically significant test values listed in the categories. The economic aspect also has a bipedal reaction as the majority of the users consider PBoC to be financially efficient while other users are indifferent to that aspect. Extended availability of the customer support service is also recognized, yet it indicates that there are the studied resources' users with different levels of satisfaction. Moreover, it is also evident from the study that there is a huge demand for integrating smart home technology solutions along with energy management solutions, which also shows technological compatibility with user needs and requirements. Privacy issues are also identifiable as a concern, although this term is less frequently used. The results presented in this paper support PBoC's ability to encourage the use of green energy in residential homes while also showing that more improvements could be made in areas like customer support and privacy to make sure consumers are accepting the technology and that it will be effective in the long run.

The study of the extent of PBoC implementation in EV charging parking lots indicates that there are positive attitudes in all the explored dimensions. From the responses obtained from the respondents, the platform is perceived as a technology which is efficient in an economic sense as well as being an environmentally friendly one, as the majority of respondents confirmed its ability to increase the charging speed, thereby making use of less energy, which in turn would cut on costs. Furthermore, PBoC is expected to support a higher utilization of the charging stations by boosting the demand for new EVs post-subsidy. The regulatory environment is understood as an adequate factor with indicators, including regulations clarity and support, which are regarded as promising for improvement but mostly sufficient.

The PBoC system also showcases the possibilities of a good interface with commercial energy management systems in malls and offices and how it could significantly address energy cost, sustainability, and carbon footprint issues. Its deployment is highly beneficial to sustainability goals and institutional policies by bringing avenues of improving energy consumption levels and meeting environmental objectives. Concerning the interview data points of interest there is Energy, Blockchain for transparency, and integration into the smart grid. Originally, energy was found to be an essential enabler, and in the blockchain case, transparency is identified as the key facilitator. The present study revealed that integrating a smart grid has possibilities for enhancing energy management. Combined, these aspects highlight the role of PBoC as a strategic organisation for enhancing commercial energy management practice especially due to flexibility in meeting the organisation's operations.

The identified PBoC system has strong benefits in the context of optimizing industrial energy management for reducing costs and environmental impacts and improving efficiency. The integration of PBoC with industrial energy systems is considered efficient by most of them due to its potential to minimize energy costs and enhance the exercise of various energy management principles. In the same way, it also encourages sustainability in industries by providing solutions to cut the bad effects towards the environment and to maintain compliance with some norms and standards. These components as the use of renewable energy sources, operating efficiency, and cost-effectiveness within industrial energy management are fundamental success factors. They emphasize such factors with different priorities according to the needs required for different industries; this shows the need for customized solutions. The research findings indicate that PBoC is perceived as an effective instrument in the industrial segment to address environmental and economic concerns in line with standards and guidelines.

By expanding systematic reliability, cost-effective operations, and preparation for power loss, the PBoC system is essential for improving existing emergency backup systems. On the question regarding how well PBoC complements backup power solutions, the majority of the respondents understood that backup power costs are brought down during power shortages. The system also enhances energy emergency preparedness, meaning that it is useful in case of an energy crisis. The awareness of PBoC environmental gains is fairly good despite some mediocrity experienced in advocacy. Moreover, sufficient institutional support in integrating PBoC into backup emergency solutions is also viewed as sufficient to enhance the implementation. This proves that overall backup concerns present distinct aspects on system availability, real time monitoring and cost. Consequently, these findings of this study supports a call for a solution to cover a specific need within an emergency backup system while only compromising the reliability, cost and efficiency in energy recall during emergency power outages.

5.2. Recommendations

Based on the findings from the study, several recommendations can be made for improving the implementation and integration of the PBoC system in various sectors:

- As for advice, it is recommended that the PBoC system integrate more with the existing energy management systems of the commercial and industrial industries. This would ensure its efficiency and raised system effectiveness all round as a whole.
- At the same time, much emphasis must be placed on the fact that PBoC's potential cost-effectiveness will be especially high in industries where energy costs are critical. The adoption rates may increase when focused efforts are made within the different markets to demonstrate how PBoC effectively 'balances' the energy prices.
- This means for it to be implemented more easier in the future the acceptance structure both institutional and policy should be improved. This will ensure that firms and sectors are encouraged differently to adopt measures that help to conserve energy.
- There is a suggestion for further improvement of the environmental management of PBoC, involving the need to expand the focus on environmental aspect of industries which is important when it comes to environmental concerns. There is availability of better and more efficient means to spread awareness and enhance reception of such systems.

- In system and economic outcome, improved overall efficacy and band-width of Take up of the system will be obtained from designing PBoC solutions better to the specifics and challenges of various Sectors, category for instance, Emergency backup powering or industrial energy usage.
- Training support for personnel involved in the roll out and management of PBoC systems for staff members and other stakeholders should be supported. It will ensure that a knowledgeable team will enhance the use of the technology with the optimization of possible advantages.
- Improving PBoC's real-time monitoring capacity would enhance energy systems' control and prevent management at an earlier stage. This can upstream hidden opportunities to find areas of inefficiency, which should be particularly valuable in the case of using backup generators in a medical facility.

5.3. Scope of Further Research

While this study provides valuable insights into the integration of PBoC in various sectors, several areas warrant further investigation:

- Therefore, for enhancing both efficiency and sustainability of industrial systems and future works, studying further advanced approaches for incorporating the PBoC with other industrial systems are required, For instance, the effective integration of PBoC with smart grid and other renewable energy sources.
- The future works could investigate how PBoC assists in enhancing energy saving in different industrial industries. Knowledge about the effectiveness of the technologies in various applications may help design respective solutions to fit the needs of various industries.

- The completion of more user-oriented PBoC systems that may deliver individual energy management solutions depending on the specific requirements of an organization and their operational challenges should be studied.
- To include how the PBoC technologies can be used to enhance the preparedness for energy emergencies in high risk areas, it will be useful to target the high risk sectors including the health sector, data centres and the manufacturing industries as they will consider how resilience of emergency back up power can be enhanced.

Another area deserving research is on formulation of sound policies and policies to govern the integration of PBoC into different industries in order to conform to industry standards and encourage innovation.

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APPENDIX A:

INTERVIEW TRANSCRIPT

	Participant 1	**Participant 2**	**Participant 3**	**Participant 4**	**Participant 5**	**Participant 6**	**Participant 7**	**Participant 8**	**Participant 9**	**Participant 10**	**Total**
Residential											
Smart Home Integration	4	3	4	4	2	4	7	4	8	4	44
Energy Management	4	2	1	4	6	4	4	4	4	4	37
Privacy Concerns	3	3	3	3	3	3	3	3	3	9	36
EV Charging Parking Lots											
Infrastructure Devel	3	5	5	4	5	8	5	1	4	5	45

opment											
User Experience	4	3	5	5	1	5	5	5	5	9	47
Scalability and Reliability	2	5	6	5	5	5	2	5	7	5	47
Commercials (Malls/Offices)											
Energy Optimization	2	1	5	9	5	5	2	6	5	1	41
Blockchain for Transparency	4	5	5	5	1	5	5	7	5	6	48
Smart Grid	4	3	6	5	5	4	5	6	9	6	53

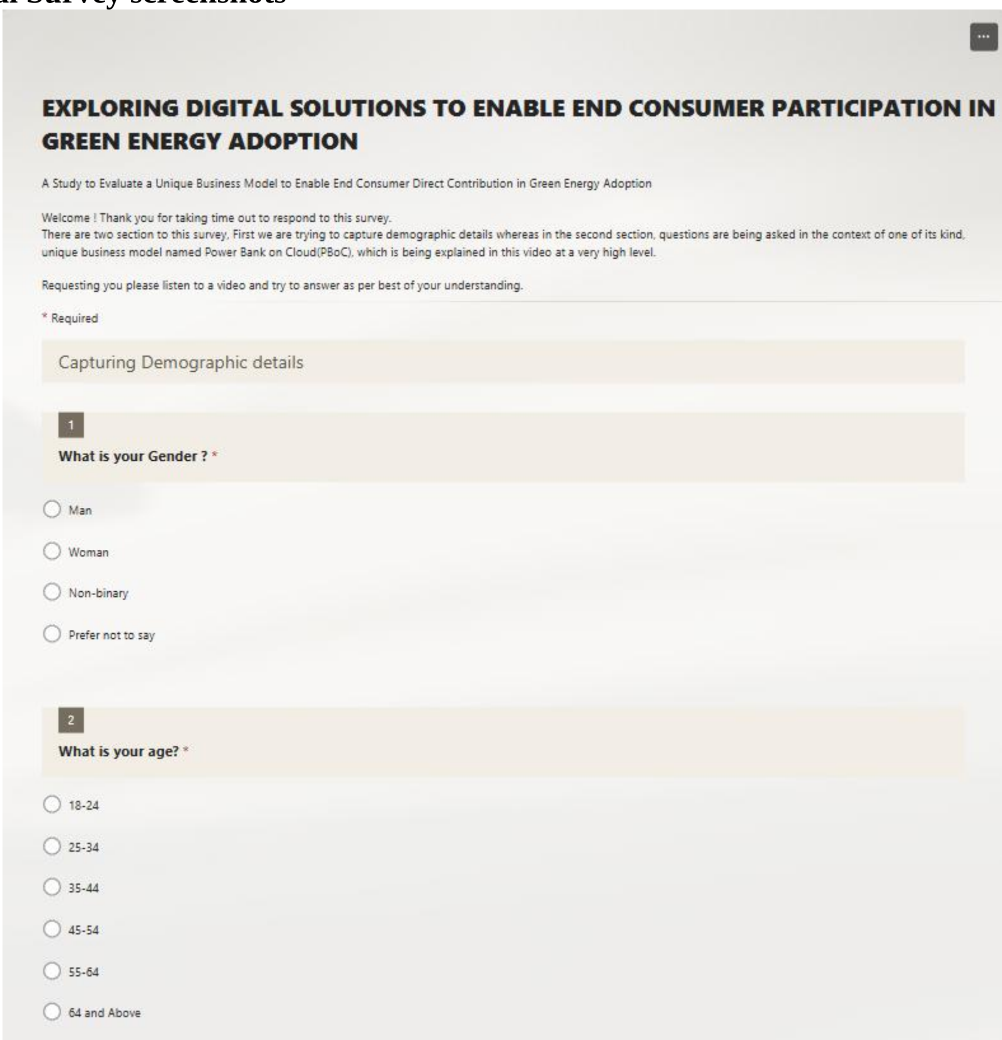
Integration											
Industries (Manufacturing, MSME etc.)											
Renewable Energy Integration	5	1	8	5	6	7	6	1	6	5	50
Operational Efficiency	3	6	6	3	6	2	6	6	6	7	51
Cost Reduction	5	6	6	5	6	7	3	6	4	7	55
Emergency Backup Systems											
System Resilience	3	5	4	4	5	8	5	5	5	4	48
Real-Time Monitoring	2	4	4	3	5	6	2	5	3	5	39

Cost Efficiency	3	4	1	4	5	6	5	1	5	9	43

APPENDIX B:

SURVEY TRASNSCRIPT

Actual Survey screenshots



EXPLORING DIGITAL SOLUTIONS TO ENABLE END CONSUMER PARTICIPATION IN GREEN ENERGY ADOPTION

A Study to Evaluate a Unique Business Model to Enable End Consumer Direct Contribution in Green Energy Adoption

Welcome ! Thank you for taking time out to respond to this survey.
There are two section to this survey, First we are trying to capture demographic details whereas in the second section, questions are being asked in the context of one of its kind, unique business model named Power Bank on Cloud(PBoC), which is being explained in this video at a very high level.

Requesting you please listen to a video and try to answer as per best of your understanding.

* Required

Capturing Demographic details

1

What is your Gender ? *

- Man
- Woman
- Non-binary
- Prefer not to say

2

What is your age? *

- 18-24
- 25-34
- 35-44
- 45-54
- 55-64
- 64 and Above

3

What is your highest level of education completed? *

- ◯ Less than High School
- ◯ High School Graduate
- ◯ Bachelor's Degree
- ◯ Master's Degree
- ◯ Doctoral Degree

4

What is your current employment status? *

- ◯ Employed Full time
- ◯ Employed part-time
- ◯ Self-employed
- ◯ Unemployed
- ◯ Retired
- ◯ Student
- ◯ Others

5

Where do you currently reside? *

- ◯ Urban area
- ◯ Suburban area
- ◯ Rural area

6

What type of residence do you live in? *

- ◯ Single-family home
- ◯ Apartment/Condominium
- ◯ Townhouse
- ◯ Mobile Home
- ◯ Others

7

Do you currently use any renewable energy solutions in your home? *

- ◯ Yes
- ◯ No

8

How interested are you in adopting new green energy technologies or solutions? *

- ◯ Not at all interested
- ◯ Slightly interested
- ◯ Moderately interested
- ◯ Very interested
- ◯ Extremely interested

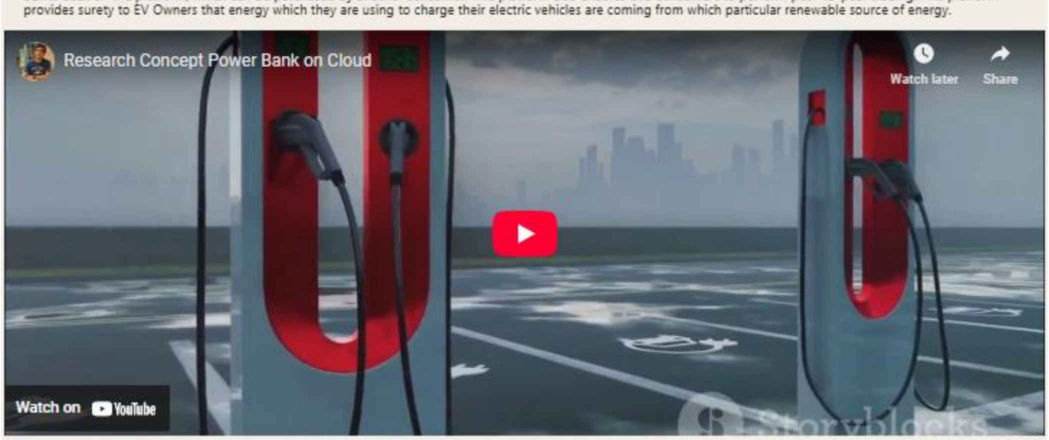
Next

Never give out your password. Report abuse

High Level overview of Unique Concept named as Power Bank on Cloud (PBoC)

Feel free to watch below video again for better understanding and kindly respond to the following questions as per the best of your understanding
Feel free to reach out author for any questions or querries

Brief detail:-
Introducing the Power Bank on Cloud platform, which enables various stakeholders to interact for the purchase and sale of renewable energy through virtually created power banks enabled by smart contracts. It will be a virtual trading platform where energy will be traded as a commodity where the renewable generator, utility/retailer, and end consumer can participate in the in the buying and selling of renewable energy in the form of power banks.
A power purchase agreement would be initiated between renewable generators and utilities, leveraging which utilities will create power banks of desired quantity and list them on the platform for the purchase and trading. End-consumers and EV owners can purchase these power banks as per their utilization and resell unused power banks back on the platform, which can be purchased by another consumer. This platform also enables end consumers to perform peer-to-peer trading. This platform provides surety to EV Owners that energy which they are using to charge their electric vehicles are coming from which particular renewable source of energy.



You Tube Video Link- https://youtu.be/x7qdX31oi6g

9

Answer below question, as per your understanding about the concept PBoC for **Residentials consumers** *

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Technological -PBoC offers real-time monitoring of energy consumption in my home.	○	○	○	○	○
Economic-PBoC offers good value for the cost of installation and maintenance in my home.	○	○	○	○	○
Social- PBoC increases my social standing as an eco-friendly consumer	○	○	○	○	○
Environmental- I feel that using PBoC reduces my household's carbon footprint.	○	○	○	○	○
Institutional- There is sufficient customer support available for PBoC users in residential areas	○	○	○	○	○

10

Answer below question, as per your understanding about the concept PBoC for **EV Charging parking lots** *

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Technological -PBoC ensures fast and efficient charging for electric vehicles at parking lots	○	○	○	○	○
Economic-PBoC reduces the cost of energy for EV charging stations.	○	○	○	○	○
Social-PBoC encourages more EV drivers to use charging stations in my area.	○	○	○	○	○
Environmental- PBoC makes EV charging more sustainable in the long run.	○	○	○	○	○
Institutional-The regulations governing PBoC in EV charging stations are clear and supportive	○	○	○	○	○

11

Answer below question, as per your understanding about the concept PBoC for **Commercials (malls/offices)** *

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Technological -PBoC integrates effectively with commercial energy management systems	○	○	○	○	○
Economic-PBoC reduces energy costs for commercial properties.	○	○	○	○	○
Social-The PBoC system supports the commercial sector's sustainability goals	○	○	○	○	○
Environmental-PBoC helps commercial properties reduce their carbon footprint effectively	○	○	○	○	○
Institutional-The implementation of PBoC in commercial settings is well supported by relevant policies	○	○	○	○	○

12

Answer below question, as per your understanding about the concept PBoC for **Industrial consumers** *

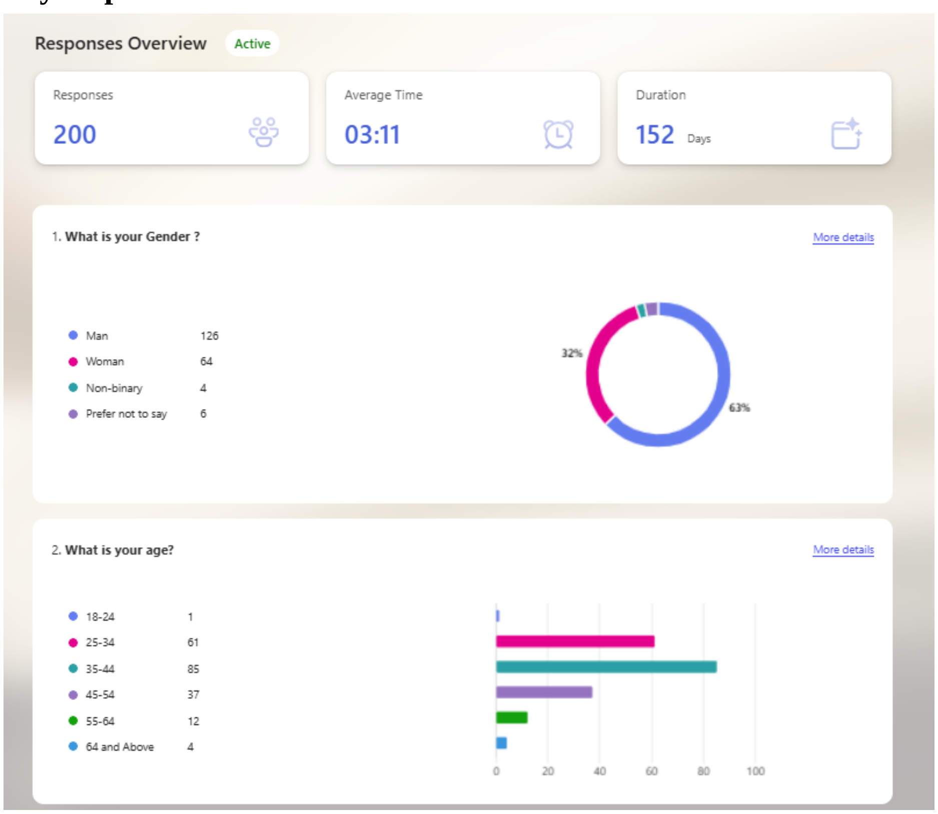
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Technological -PBoC is compatible with industrial energy systems and equipment	○	○	○	○	○
Economic-PBoC helps in optimizing energy costs across various industrial operations.	○	○	○	○	○
Social-Employees benefit from improved energy management practices introduced by PBoC	○	○	○	○	○
Environmental-PBoC contributes to reducing the environmental impact of industrial activities.	○	○	○	○	○
Institutional-PBoC adheres to industry standards and best practices for energy management.	○	○	○	○	○

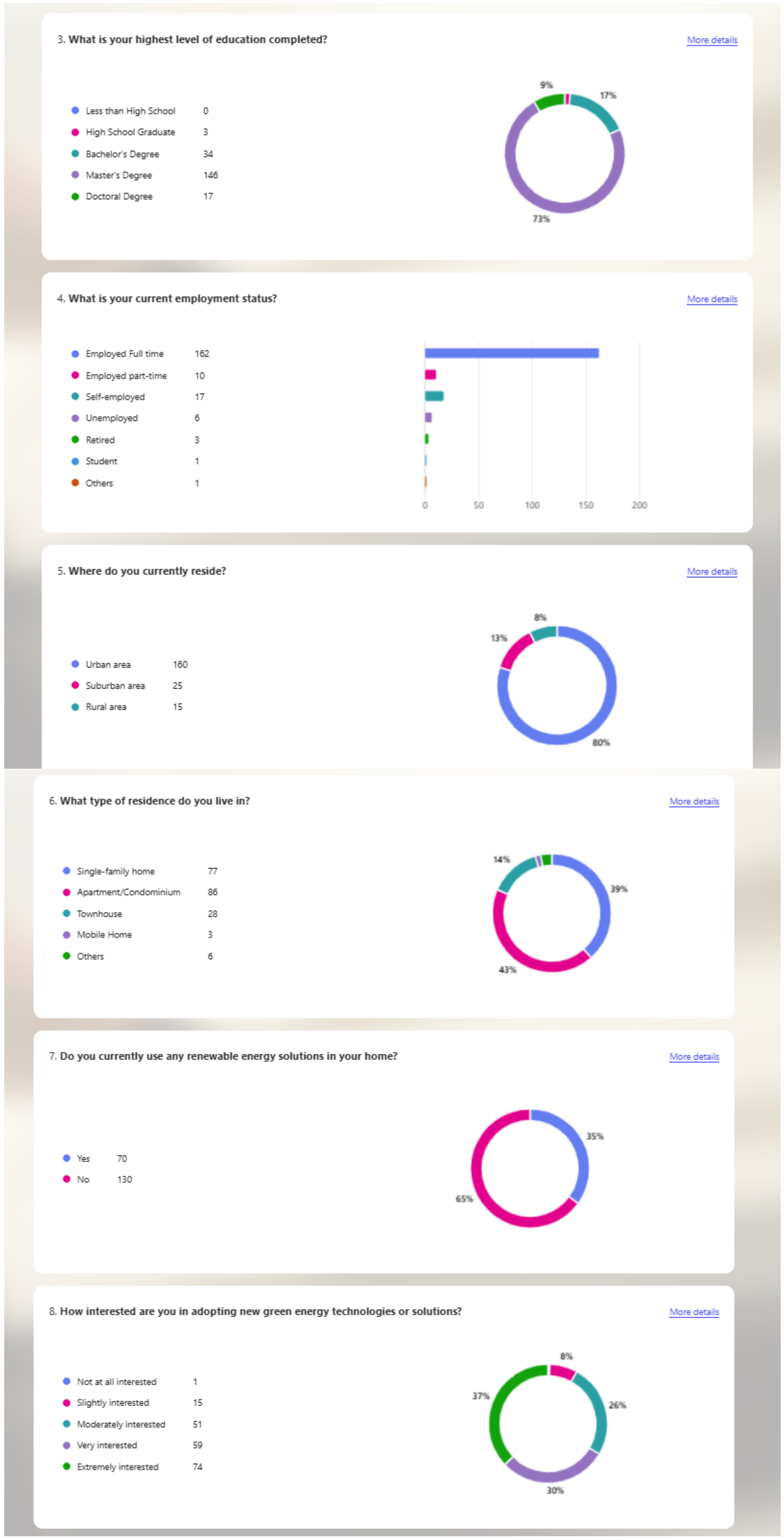
13

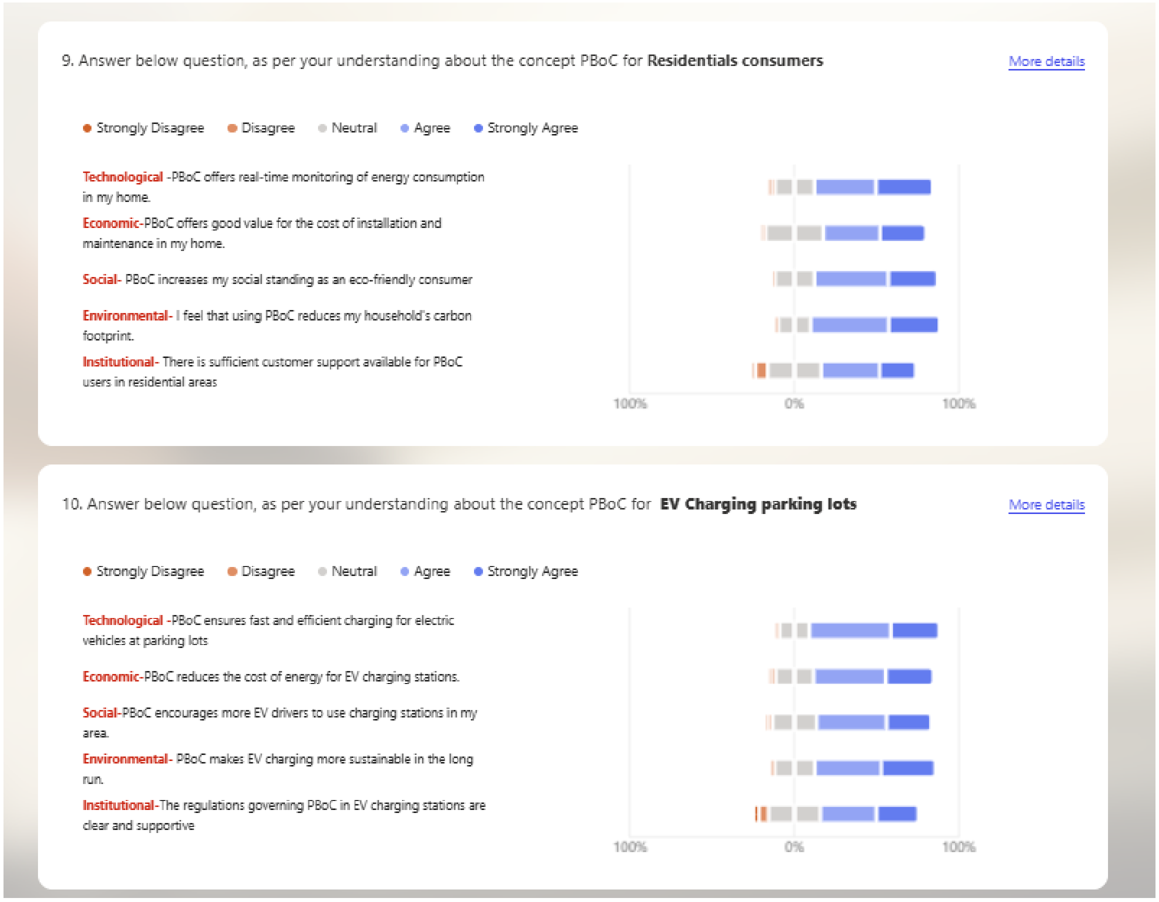
Answer below question, as per your understanding about the concept PBoC for **Emergency backup systems** *

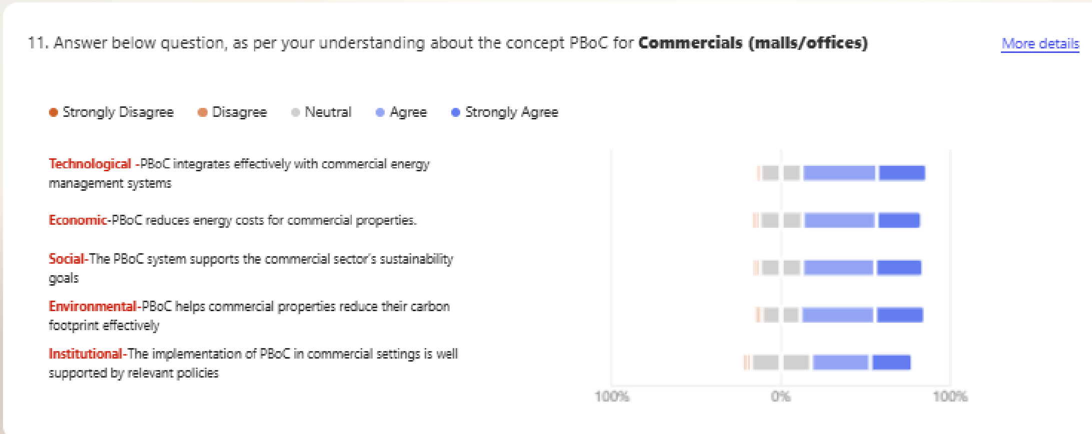
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Technological -PBoC integrates effectively with emergency backup power systems	○	○	○	○	○
Economic-The use of PBoC in emergency backup systems reduces operational costs related to power outages.	○	○	○	○	○
Social-PBoC has enhanced the preparedness for energy emergencies.	○	○	○	○	○
Environmental- The environmental benefits of using PBoC in emergency systems are effectively communicated	○	○	○	○	○
Institutional-The support for integrating PBoC into emergency backup systems is adequate	○	○	○	○	○

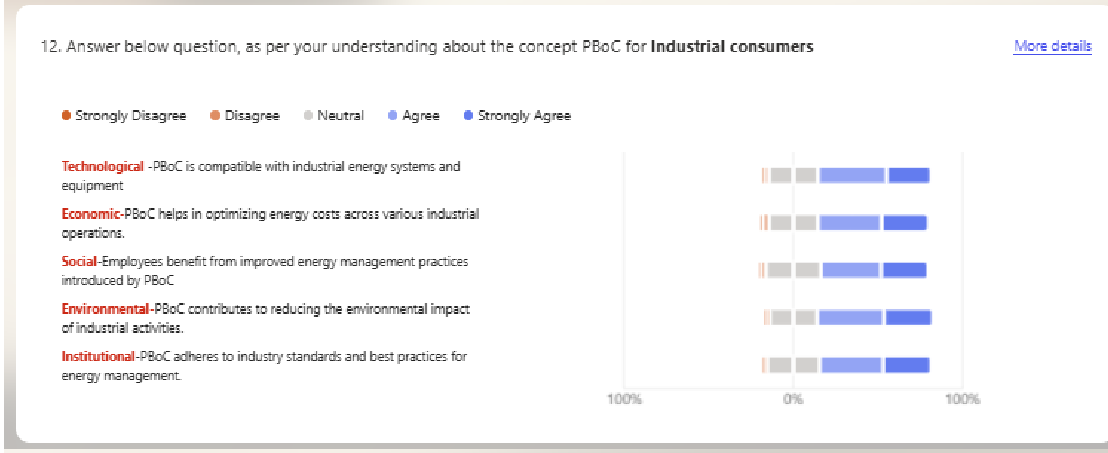
Survey response overview

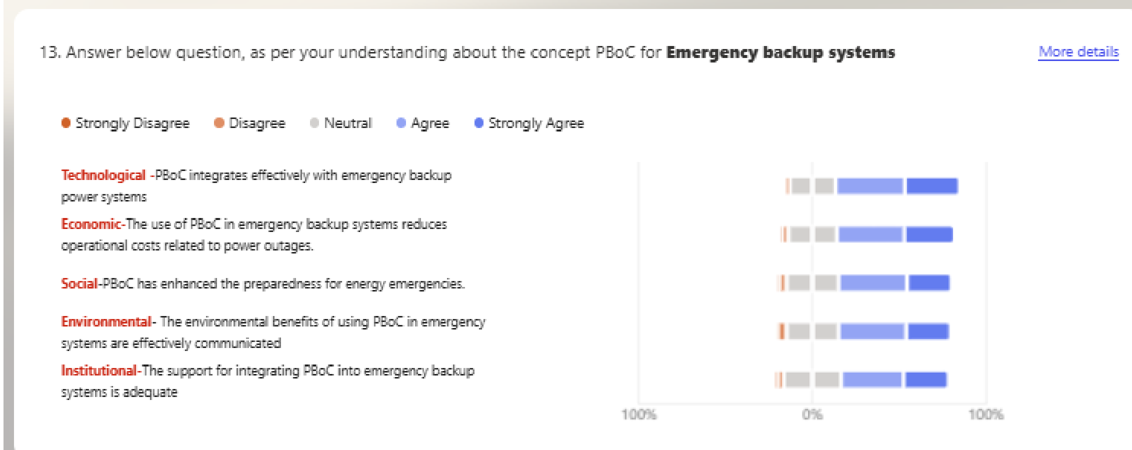



3. What is your highest level of education completed?
More details
Less than High School 0
High School Graduate 3
Bachelor's Degree 34
Master's Degree 146
Doctoral Degree 17
9%
17%
73%
4. What is your current employment status?
More details
Employed Full time 162
Employed part-time 10
Self-employed 17
Unemployed 6
Retired 3
Student 1
Others 1
0
50
100
150
200
5. Where do you currently reside?
More details
Urban area 160
Suburban area 25
Rural area 15
8%
13%
80%
6. What type of residence do you live in?
More details
Single-family home 77
Apartment/Condominium 86
Townhouse 28
Mobile Home 3
Others 6
14%
39%
43%
7. Do you currently use any renewable energy solutions in your home?
More details
Yes 70
No 130
35%
65%
8. How interested are you in adopting new green energy technologies or solutions?
More details
Not at all interested 1
Slightly interested 15
Moderately interested 51
Very interested 59
Extremely interested 74
8%
37%
26%
30%


9. Answer below question, as per your understanding about the concept PBoC for Residentials consumers
More details
Strongly Disagree
Disagree
Neutral
Agree
Strongly Agree
Technological -PBoC offers real-time monitoring of energy consumption in my home.
Economic-PBoC offers good value for the cost of installation and maintenance in my home.
Social- PBoC increases my social standing as an eco-friendly consumer
Environmental- I feel that using PBoC reduces my household's carbon footprint.
Institutional- There is sufficient customer support available for PBoC users in residential areas
100%
0%
100%
10. Answer below question, as per your understanding about the concept PBoC for EV Charging parking lots
More details
Strongly Disagree
Disagree
Neutral
Agree
Strongly Agree
Technological -PBoC ensures fast and efficient charging for electric vehicles at parking lots
Economic-PBoC reduces the cost of energy for EV charging stations.
Social-PBoC encourages more EV drivers to use charging stations in my area.
Environmental- PBoC makes EV charging more sustainable in the long run.
Institutional-The regulations governing PBoC in EV charging stations are clear and supportive
100%
0%
100%


11. Answer below question, as per your understanding about the concept PBoC for **Commercials (malls/offices)**
More details
Strongly Disagree
Disagree
Neutral
Agree
Strongly Agree
Technological -PBoC integrates effectively with commercial energy management systems
Economic-PBoC reduces energy costs for commercial properties.
Social-The PBoC system supports the commercial sector's sustainability goals
Environmental-PBoC helps commercial properties reduce their carbon footprint effectively
Institutional-The implementation of PBoC in commercial settings is well supported by relevant policies
100%
0%
100%


12. Answer below question, as per your understanding about the concept PBoC for **Industrial consumers**
More details
Strongly Disagree
Disagree
Neutral
Agree
Strongly Agree
Technological -PBoC is compatible with industrial energy systems and equipment
Economic-PBoC helps in optimizing energy costs across various industrial operations.
Social-Employees benefit from improved energy management practices introduced by PBoC
Environmental-PBoC contributes to reducing the environmental impact of industrial activities.
Institutional-PBoC adheres to industry standards and best practices for energy management.
100%
0%
100%


13. Answer below question, as per your understanding about the concept PBoC for **Emergency backup systems**
More details
Strongly Disagree
Disagree
Neutral
Agree
Strongly Agree
Technological -PBoC integrates effectively with emergency backup power systems
Economic-The use of PBoC in emergency backup systems reduces operational costs related to power outages.
Social-PBoC has enhanced the preparedness for energy emergencies.
Environmental- The environmental benefits of using PBoC in emergency systems are effectively communicated
Institutional-The support for integrating PBoC into emergency backup systems is adequate
100%
0%
100%