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Energy Storage Systems and its role in future of Renewable Energy Demand

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Abstract
Energy demand is growing at an exponential rate, but supply is lagging behind global demand. The emphasis on global warming and climate change is taking centre stage in almost all countries. It has driven the international community to look for alternative sources of energy. Solar & Wind Energy is one such alternatives . But the Solar & Wind Energy generation being intermittent in nature, robust and reliable Energy Storage system can play a pivotal role in bridging the gap between the consistent energy demand of the utility grid and renewable energy supply. Thus, an optimum energy storage system is necessary to safeguard grid stability, meeting the demands of power and to prevent blackouts due to sudden surges in electricity demands. The large capacity storage system is still in an evolutionary stage . International organisations such as ‘The Energy Sector Management Assistance Program’ (ESMAP) in collaboration with the World Bank and with a team of fifty-plus experts have been assisting developing and emerging-market countries in addressing their energy challenges for the last 40 years. Innovations in Energy Storage Systems have been recognised as fundamentally important innovations for advancement in Energy Storage Technology. The forthcoming role of energy storage has resulted in being recognized as a significant technology for the future. Energy Storage Systems act as a disruptive technology to lead the change towards a low greenhouse gas emission society. The social constituents of Energy Storage Systems are a key segment of fully utilizing the potential of Energy Storage Systems. Energy storage and rechargeable batteries are key to harnessing the potential of renewable energy. However, there exists a risk of uncontrolled release of the energy that could result in a fire accident or an explosion whenever a large amount of energy is stored. In the coming years, the global commitment to reduce greenhouse emissions will lead to the large-scale deployment of Energy Storage Systems. This would result in continuous improvements, cost innovations & reductions by reengineering the components for Li-ion batteries and other electrochemical energy
storage technologies. This would make it economical, justifying large-scale deployment in future

Key Words: Storage Technology, Energy Storage Systems, Optimisation

1.0 Introduction

One of the major challenges faced by renewable energy sources such as Solar & Wind is that the availability of the electricity generated by Solar or Wind power is intermittent. The Solar power can be generated only during the daytime when ample sunlight radiations are available. Thus, there is an urgent need to have energy storage systems to supply electricity when it is needed. According to Hernandez RR, Armstrong A & Burny J, in order to improve the performance & efficiency of energy storage systems, there will be more focus on developing & increasing the efficiency of the components of storage technology in future (Short et al., 2017). Thus, in the coming years, these strong innovative arrangements will drive client commitment (Ala-Juusela et al., 2019a). The strict emissions norms for greenhouse emissions justify the large-scale deployment of Energy Storage Systems. Thus, there would be continuous improvements, cost innovations & reductions by reengineering the components for Li-ion batteries and other electrochemical energy storage technologies to make it economical, justifying large-scale deployment in future (De Sisternes et al., 2016a). Although the government policies favouring the development of large-scale energy storage systems would spur growth in its development, it does not establish any strict evidence of determinants between specific policies and the rate of energy storage deployment (Diezmartínez, 2021). The advancement of energy storage technology would need disruptive innovative development and breakthroughs in capacity, long-lifespan, low-cost, and high security for electrochemical energy storage (Yao et al., 2016).

Nonetheless, the advancement of energy stockpiling innovation requires the development and leap forward in the limit, long-life expectancy, minimal expense, and high security for electrochemical energy stockpiling.

2.0 Research Questions

The primary aim of this study is to understand the role of energy storage systems and its role in renewable energy via the following questions:

a. Do Refinements to the components improve the performance and efficiency of storage systems?
b. Do Robust technological solutions help drive customer engagement in adopting storage systems?

c. Are cost-effective Innovations for electrochemical energy storage technologies necessary to justify large-scale economic deployment?
d. Do specific policies influence the increase or decrease of energy storage system deployment?
e. Does energy storage technology require high safety and security measures for electrochemicals?

3.0 Research Objectives
As a solution to the above research questions, this study seeks to answer the following research objectives:
a. To understand the impact of refinements to the components to increase performance and efficiency of storage systems
b. How more robust technological solutions can increase customer engagement
c. Can continued innovation and cost declines for Li-ion batteries and other electrochemical energy storage technologies economically justify large-scale deployment in future low-carbon power systems
d. How specific policies affect the rate of energy storage deployment
e. How development of energy storage technology requiring innovation and breakthrough in capacity help increase lifespan, low-cost and high-security and safety of for electrochemical energy storage

4.0 Scope of the study
Global Warming and climate change primarily caused by the extensive use of fossil fuels have driven the international community to look for alternative sources of energy. The United Nations Climate Change Conference in Paris, France in December 2015 reached an agreement with the international community of 196 parties to limit global warming. Thus, renewable energy sources such as solar and wind power have gained considerable importance in every country's energy mix. However, renewable energy sources such as solar and wind have severe limitations as they cannot produce power consistently. Hence, technologies for energy storage are necessary to bridge the gap between the consistent energy demand of the utility grid and renewable energy supply which are variable and intermittent.

5.0 Literature Review
There is a lot of emphasis on moving towards a clean energy globally, to address the carbon emission and greenhouse gases concerns. The major challenge faced by Solar and Wind Energy is the availability of reliable Energy Storage Technology for storing electricity as both Solar & Wind Energy are intermittent. A robust Energy Storage Structure would thus provide a means of optimising energy generation and consumption. The Energy Storage Technologies help in meeting excess demands during evening peak hours by storing surplus electricity generation during a period of low demand and releasing it during a period of high demand, giving utility companies flexibility in managing & meeting demands of electricity by better load management.

Thus, Energy Storage Technology will play an increasingly dominant role. Energy Storage Technology with large storage capacities can help in the integration of different renewable energy sources, improve grid reliability, and make energy more affordable and accessible as and when required. Electrical energy storage systems enable the accumulation of energy and play an especially important role in reducing the greenhouse gasses emitted by fossil fuel power plants. By offering a new, carbon-free alternative of functional adaptability, and improving the utilization of generation assets, it clears the path of integrating divergent renewable energy sources. Yet, the future cost of energy storage technologies is uncertain, and the value that they can bring to the system depends on multiple factors.

It is expected that Solar & Wind energy will change the electricity generation composition and will replace fossil fuels by 2050 reducing greenhouse gas emissions by half of that of 2015 levels (Zhou et al., 2018). Alberto Boretti1, Stefania Castelletto, Wael Al-Kouz, and Jamal Nayfeh (2020) have opinioned that once Large Capacity Energy Storage issues are addressed and Large Capacity Energy Storage Systems are invented, large-scale Solar and Wind Power Plants will soon replace Fossil Fuel based Power Plants

Some environmentally friendly power sources, like Sun and Wind, have variable supply. The electricity generated using these variable renewable energy (VRE) sources can only generate electricity when weather conditions are right, i.e. abundant sunlight and strong breeze of wind.
To overcome this challenge, government agencies usually incorporate the development of large energy storage systems into policy agendas as an important factor for broader energy transition plans. This would see a significant increase in variable renewable energy (VRE) sources (Diezmartínez, 2021).

5.1Optimisation
The fundamental requirement of modern-day smart grids is to have an optimum energy storage system. This is necessary to safeguard grid stability, meet the demands of power and to prevent blackouts due to sudden surges in electricity demands. Thus, there is a need for substantial improvement in energy storage technologies to become techno-

commercially feasible. This can be achieved through the Investment-based optimisation method. The most important factor in energy storage systems is the discharge efficiency of the energy storage system.

At present, the Calcium Looping (CaL) process is being utilized, as a thermochemical energy storage system in concentrating solar plants. This has been widely examined in the recent past and large-scale pilot plants are now under construction. The use of a thermochemical energy storage system in concentrated solar power plants increases the availability of electricity, and by hybridizing with a photovoltaic system, it can become cost competitive. This would be the first step towards improving the modelling and optimisation of the integration of Calcium Looping (CaL) as a thermochemical energy storage system in hybrid solar power plants comprising of CSP & PV Plants. The next step for optimisation would be to define the best capacities of the main components of the power plant by exploiting synergies associated with the availability of electricity of CSP-CaL and the ability to order PV systems (Bravo et al., 2020).

The Electricity storage can play a vital role in smoothing fluctuations caused by generation from renewable energy sources. In order to locate prospective sites for battery storage applications, an experimental approach is applied. This technique will be further developed as FlexiGIS, an open-source GIS-based platform for modelling energy systems and flexibility options in urban areas. FlexiGIS stands for Flexibilisation in Geographic Information Systems. It would provide the background for future studies on other storage technologies and flexibilisation portfolios like electrical vehicles and heat pumps (Alhamwi et al., 2019).

Daniel L. Rodrigues, Xianming Ye, Xiaohua Xia, Bing Zhu, (2020) are of the opinion that the Battery Energy Storage System (BESS) model is a better financially viable model than the Energy Storage Partnership (ESP) model. However, ESP opens the doors for individuals who produce as well as consume power. Such individuals can participate in a Peer-to-Peer energy sharing model thus reducing overall energy costs without a BESS.

5.2 Technological Solutions

The pumped hydropower is the simplest and most commonly used technology for energy storage. With the new technological advancements, nowadays, PV solar power plants and wind power plants are utilizing Battery Energy Storage Systems (BESS). Similarly, nowadays concentrated solar power plants use Calcium Looping (CaL) as a means to store energy.

Monetary and technical expectations for the renewable energy and storage technologies are global in nature. Therefore, the expectations and assumptions vary widely for different regions and also for various countries within the regions (Barbosa et al., 2017). The organisations such as 'The Energy Sector Management Assistance Program' (ESMAP) in collaboration with the World Bank and with a team of fifty-plus experts have been assisting developing and emerging-market countries in addressing their energy challenges for the last 40 years. It puts emphasis on bottom-up change, commencing the establishment of government policies, regulatory frameworks, and operational procedures.

Availability of finances for developing even simple technologies is not readily available thus leading to lengthy deliveries and difficulties in operations and maintenance. Also changing government policies and regulations deter the fast deployment of storage technologies. Therefore to roll out a successful storage technology, a high level of public acceptance is necessary. Hence strong technological solutions and consumer commitment are necessary for the quick deployment of robust storage technology. ESMAP is also granting soft loans and technical knowledge to underdeveloped countries in deploying energy storage and is addressing key knowledge gaps through an international Energy Storage Partnership (ESP) (Ala-Juusela et al., 2019b).

While numerous energy storage solutions exist, the existing solutions are so diverse and dissimilar in terms of specifications and features that it is extremely difficult to select any one technology for all energy storage applications. There are promising technologies such as Liquid Air Energy Storage (LAES), Advance Energy Storage (AES) Batteries, Gravity Power Module (GPM) & Advanced Rail Energy Storage (ARES) Technologies. These technologies have potential for large-scale application once they are fully developed (Aneke & Wang, 2016). Similarly, a hybrid energy storage system (HESS) consisting of two or more ESSs can help overcome the challenges posed by a single Energy Storage System. HESS can accommodate the Micro Grids operation meeting the power requirements of power stability and the fluctuating energy demands under uncertain power demand conditions. The main arrangement of HESS is to integrate limited energy and power resources to cope with the requirements (Hajiaghasi et al., 2019). The area of focus for future research would be towards enhancements of components to increase their performance and efficiency.

5.3 Innovation

Innovations in Energy Storage Systems have been recognised as fundamentally important innovations for advancement in Energy Storage Technology. The forthcoming role of energy storage has resulted in being recognized as a significant technology for the future. Nevertheless, the swift developments in the group of energy storage technologies are facing challenges under the existing government rules as these technologies have to compete with conventional electrical generation systems for providing electricity system services. And this is probably going to block the development of energy storage systems, notwithstanding, to eliminate the recognised barriers, a market structure is required which would

value the flexibility offered by storage systems looking at it as complementing rather than competing with network and generation assets.
Therefore, Electrical Energy Storage Systems can play a significant role in reducing carbon footprints in the energy sector. This is possible through continuous innovations and cost reductions in battery energy storage systems especially for Li-ion batteries. The new Li-Ion batteries and other similar electrochemical storage devices can offer a new, carbon-free source of operational flexibility, improving the utilization of generation assets, and accelerating the integration of variable renewable energy sources. And therefore it is essential to make continuous improvements to improve efficiency and reduce the costs thus justifying their large-scale deployments to be economically viable (De Sisternes et al., 2016b).
At present 56% of the energy storage system is used mainly for small, distributed generation and microgrid systems. And in these systems, 89% of the total storage technology used is lithium-ion batteries and lead acid batteries. Therefore, there is a huge scope for developing large-capacity Li-ion battery storage technologies for large-scale deployment in the main grid. The researchers are focusing on developing large-capacity Li-ion batteries at an economically viable cost including energy storage simulation and operation optimization in multiple applications.
The main objective of these innovations is to improve energy density, cycle life, safety, and scalability while lowering the prices. Lithium-ion batteries have achieved importance due to their high energy density and fast charging capabilities (Yao et al., 2016).
There is a need to have a combined techno-economic approach for Energy Storage Systems in the marketplace of electricity generation. This would include assumptions about, both, interest rates that play an important role in differentiating between EES technologies, and modelling specifications upon the entrant EES technologies selected. The upcoming costs of energy storage systems are uncertain, particularly for emerging technologies like batteries. Innovations in BESS are taking shape such as Solid-state batteries, replacing the liquid electrolyte with a solid counterpart. These technologies are quite promising in terms of safety and performance. Similarly, the Redox flow batteries, with their separated power and energy capacity, are gaining interest for their scalability and long cycle life. A successful innovation that reduces technology costs requires the deployment of technologies to strengthen knowledge. It is essential that the innovation drive is successful so the energy storage systems would be able to compete with other generations in the electrical energy segment (Kyriakopoulos & Arabatzis, 2016).

5.4 Social Contributions

It has been observed that social constituents of Energy Storage Systems are a key segment of fully utilizing the potential of Energy Storage Systems. Energy Storage Systems act as a disruptive technology to lead the change towards a low greenhouse gas emission society. With more and more Distributed Systems and Microgrids coming up as an alternative to traditional centralized fossil-based power plants for meeting energy demands, decentralised renewable energy models are being developed as a feasible and reliable alternative. In this set-up, Energy Storage Systems are supporting technologies which eventually boost the stability and operational flexibility of power in the short-term allowing the local communities to visualize their energy independence in the medium term.
Hao Yu, Yi-Ming Wei, Bao-Jun Tang, Zhifu Mi, and Su-Yan Pan, (2016) have opinioned that in comparison with traditional centralized fossil-based power plants, whether the renewable energy technologies have an investment advantage needs to be explored. The future energy mix may change with the availability of new efficient Energy Storage Systems. For this to happen a few aspects are to be taken into account such as successful and economical allocation of investments. The future strategies should be more creative, and the monetary assumptions are to be promoted to combine with management decision-making techniques (Yu et al., 2016).
There are some diverse opinions. According to Jácome Polit D., Maldonado D., Dávalos D. (2016), “Solar might not always be a green source of energy”. There is an urgent need to evaluate the represented carbon in PV systems. The loss of efficiency over a period of the lifetime of the PV systems needs to be considered. Then only the final carbon payback time can be estimated, and it could be even more than that of which has been originally estimated. There is an important effort made to change the energy generation mix, in order to reduce emissions from electricity generation, India must work to prioritise energy savings and energy efficiency (Polit et al., 2016).
An overwhelmingly referred to theoretical framework proposes three aspects of social acknowledgement: markets, socio-political and local communities. There is a need to examine the paradigm and ethical considerations of a country-level centralized infrastructure. This would influence the decision-makers thought processes about the potential technological paths for Energy Storage Systems. This would possibly lead to recommendations of policies for large-scale deployments of Energy Storage Systems over medium and small technology arrangements (Devine-Wright et al., 2017).

5.5 High Security

Energy storage and rechargeable batteries are key to harnessing the potential of renewable energy. The energy so stored can be in any form such as stored in conventional forms of liquids or gases or batteries. And in this direction, lithium-ion batteries are already accelerating the integration of renewable energy supplies to the grid. However, there exists a risk of uncontrolled release of the energy that could result in a fire accident or an explosion whenever a large amount of energy is stored. As happens with all the emerging technologies, this field is undergoing rapid change, and some trends and dangers are beginning to surface. One risk is fires caused by thermal runaways causing significant losses in the industry and a tragic loss of life in some cases

The energy security is positively impacted by all energy storage technologies and there is also a positive correlation between energy storage technologies and energy security. Energy security evaluation is thus a significant part of assessing energy storage systems choices. The energy storage systems being selected need to be checked out cautiously at the effects of the peaked energy capacity innovation on the energy safeguards for the system. Thermal energy storage (TES) systems that can store heat or cold which can be used later are one of the safest in energy security assessment followed by Gas or Liquid Storage Batteries and so on. The use of energy storage has to be based on techno-economic requirements, which in turn present recommendations to decision-makers regarding the system's energy security (Azzuni & Breyer, 2018).

Some key concerns the industry needs to consider while selecting which BESS would be the right Energy Storage System for integration with Renewable Energy Systems has to include

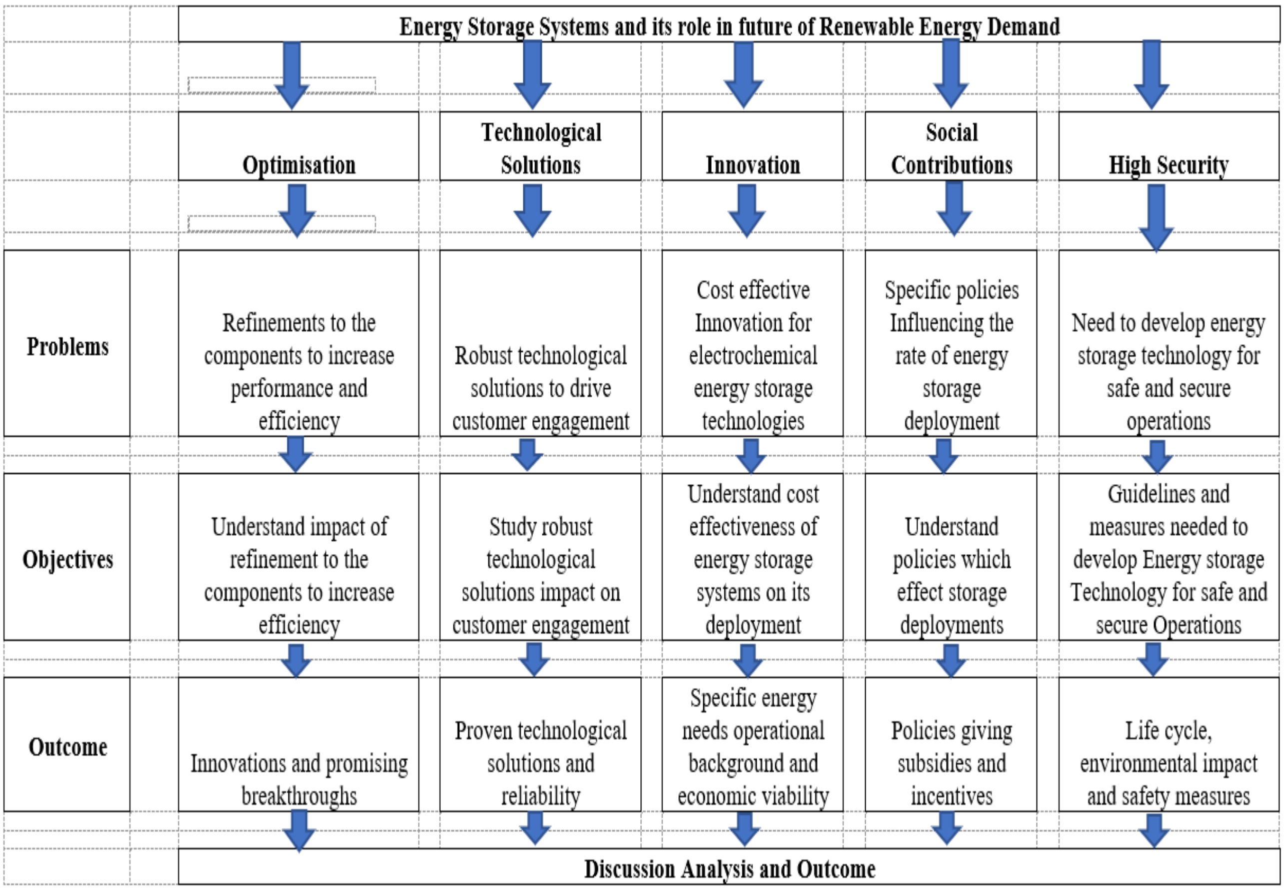
- Raw Materials
- Fire and Explosion Risks
- Environmental Pollution and Health Hazards (Heuberger et al., 2017).

6.0 Research Methodology

The research data came from a variety of secondary data sources. The majority of the data was gathered by searching relevant indexed journals, industry reports, and reference books online. The existing core variables that were discovered through a thorough literature review are described in detail in the research methodology. A straightforward direct connection between five central factors — Optimisation, Technological Solutions, Innovation, Social Contributions and High Security and their role in future of Renewable Energy Demand — is situated in the examination model.

7.0 Research Framework

From the literature review, a proposed research framework is developed as shown below.



7.1 Discussion, analysis and outcome

7.1.1 Optimisation – Analysis of solutions and outcome

In the recent past , the addition of Renewable Energy Sources in the Power grid have multiplied many fold. With the smart grids using the digital technology to match demand and supply on real time basis , having an optimum energy storage system has become the fundamental requirement of modern-day smart grids. This is necessary to safeguard grid stability, meet the demands of power and to prevent blackouts due to sudden surges in electricity demands. Thus, there is a need for substantial improvement in energy storage technologies to become techno-commercially feasible. This can be achieved through the Investment-based optimisation method. The most important factor in energy storage systems is the discharge efficiency of the energy storage system.

According to Daniel L. Rodrigues, Xianming Ye, Xiaohua Xia, Bing Zhu, (2020) the Battery Energy Storage System (BESS) model is a better financially viable model than the Energy Storage Partnership (ESP) model. However, ESP opens the doors for individuals who produce as well as consume power enabling individuals to participate in a Peer-to-Peer energy sharing model thus reducing overall energy costs without a BESS.

7.1.2 Technological Solutions – Analysis of solutions and outcomes

The recent study in energy storage deployment has concluded that energy storage deployment has the potential to rise significantly to at least five times current capacity by 2050. This storage will likely play a crucial role in determining the most cost-effective grid mix in the future. The technical and financial expectations for the renewable energy and storage technologies are global in nature. Therefore, the expectations and assumptions vary widely for different regions and also for various countries within the regions (Barbosa et al., 2017).

There are global organisations such as 'The Energy Sector Management Assistance Program' (ESMAP) which in collaboration with the World Bank and with a team of fifty-plus experts have been assisting developing and emerging-market countries in addressing their energy challenges for the last 40 years. It puts emphasis on bottom-up change, commencing the establishment of government policies, regulatory frameworks, and operational procedures.

7.1.3 Innovation – Analysis of solutions and outcomes

For the ongoing effort internationally to reduce carbon footprints, and for transition to a more environmentally friendly energy system, the innovations in energy storage are essential. The full potential of renewable energy sources can be utilised by increasing the capacity and efficiency of energy storage.

It is recognised that innovations in Energy Storage Systems is fundamentally important for advancement in Energy Storage Technology. The forthcoming role of energy storage has resulted in being recognized as a significant technology for the future. However, under the existing government rules however, the swift developments in the group of energy storage technologies are facing challenges to compete with conventional electrical generation systems for providing electricity system services. And this is probably going to block the development of energy storage systems. To eliminate the recognised barriers, a market structure is required which would value the flexibility offered by storage systems looking at it as complementing rather than competing with existing network and generation assets.

7.1.4 Social Contributions – Analysis of solutions and outcomes

Energy Storage Systems play a crucial role in fostering social cohesion and community engagement while also encouraging the sustainable and effective use of energy resources. Utilizing a variety of technologies, including electro-mechanical, chemical, thermal, and electrochemical (batteries), energy storage systems gives remote areas flexibility and opportunities. The development of stationary energy storage has been made possible by the cost-competitiveness of battery technologies.

Decentralised renewable energy models are being developed as a feasible and reliable alternative to traditional centralized fossil-based power plants for meeting energy demands. This could be possible with Distributed Systems and Microgrids coming up as an alternative to traditional grid-based systems. In this set-up, Energy Storage Systems are supporting technologies which eventually boost the stability and operational flexibility of power in the short-term allowing the local communities to visualize their energy independence in the medium term.

7.1.5 High Security – Analysis of solutions and outcomes

Energy security is what is going on in which the framework can work ideally and reasonably, liberated from dangers. The discussion of various components of the energy system is one aspect of the energy security consideration. Here the storage is a crucial component of the Renewable Energy System.

Energy capacity and battery-powered systems are critical to tackling the capability of environmentally friendly power. The energy that is stored in this way can take any form, such as being stored in batteries, conventional liquid, gas, or other forms. Additionally, lithium-ion batteries are already speeding up the grid-integration of renewable energy sources in this direction. However, whenever a large amount of energy is stored, there is a risk of uncontrolled energy release, which could cause an explosion or fire. This field is undergoing rapid change, as are all emerging technologies, and some trends

and dangers are beginning to emerge. Thermal runaways pose a risk by starting fires, which can result in devastating industry losses and even fatalities.
Some key concerns the industry needs to consider while selecting which BESS would be the right Energy Storage System for integration with Renewable Energy Systems has to include

- Raw Materials
- Fire and Explosion Risks

Environmental Pollution and Health Hazards (Heuberger et al., 2017).

8.0 Research Implications

The findings of the study are supported by secondary research data and are based on qualitative research into energy storage systems. The research framework that was created from it plays a crucial role in identifying energy storage systems for renewable energy in the future. It also includes a variety of solutions for adapting energy storage systems suitable to renewable energy sources in the future. The public's perception of energy storage systems and their potential integration with other renewable energy sources are also highlighted in the study.
Policymakers and other stakeholders should benefit from the research's findings in moving away from fossil fuel-based energy sources. As a result, this study emphasises the significance of creating large-scale energy storage systems that can be integrated with renewable energy sources.

9.0 Limitations and Scope for Future Research

The secondary data used in the literature review may not be accurate because they were collected over a long period of time. Additionally, the research's accuracy is primarily dependent on the accuracy of the collected data, which may be biased.
There is a lot to learn about the subject because there are a lot of unexplored avenues, such as the development of larger and better energy storage systems, political dynamics, public perception, and so on. Because secondary data are highly guarded and highly confidential, future research can use primary data. Because of this, free access to the information is difficult.
Even though very little research has been done in this area, this indicates the importance of energy storage systems and their role in the future demand for renewable energy.

10.0 Conclusion

This research study has analysed relevant papers and has validated it using secondary data. Given the interpretation from existing literature, this article presents the research framework suggesting the role of energy storage systems and its integration with future renewable energy demand.
Hernandez RR, Armstrong A & Burny J, have opinioned that in order to improve the performance & efficiency of energy storage systems, there will be more focus on developing & increasing the efficiency of the components of storage technology in future (Short et al., 2017). Thus, in the coming years, these strong innovative arrangements will drive client commitment (Ala-Juusela et al., 2019a).
The global commitment to reduce greenhouse emissions will lead to the large-scale deployment of Energy Storage Systems resulting in continuous improvements, cost innovations & reductions by reengineering the components for Li-ion batteries and other electrochemical energy storage technologies. This would make it economical, justifying large-scale deployment in future (De Sisternes et al., 2016a).
Although the government policies favouring the development of large-scale energy storage systems would spur growth in its development, it does not establish any strict evidence of determinants between specific policies and the rate of energy storage deployment (Diezmartínez, 2021). The advancement of energy storage technology would need disruptive innovative development and breakthroughs in capacity, long-lifespan, low-cost, and high security for electrochemical energy storage (Yao et al., 2016).
Therefore, the findings help to interpret the factors found in the literature review.

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