Manufacturers' Perspectives: Overcoming barriers and unlocking solutions for battery manufacturing in South Africa

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ABSTRACT

The global energy sector is transitioning towards sustainable sources. South Africa, a country heavily reliant on coal for its energy needs, faces myriad challenges compounded by persistent electricity shortages. These shortages have widespread negative economic impacts, prompting the exploration of technological solutions such as battery energy storage systems (BESS). Adoption of BESS is on the rise in South Africa. However, the country is still heavily reliant on imports for battery storage systems. This study sought to explore the barriers and solutions for the manufacture of BESS in South Africa, thus contribute to the rapid implementation of these systems in the energy sector.

A qualitative approach was employed, including collecting insights from key energy sector role players, among them, representatives of global battery cell manufacturers and local battery assembly companies. Semi-structured interviews were conducted with five participants from global electro-chemical battery manufacturers, two from BESS assembly companies operating in South Africa, and seven key local stakeholders such as policymakers, and representatives of research institutes, and a financial institution. Thematic analysis of these interviews revealed that, first, battery energy storage systems present substantial opportunities for South Africa. Second, localising battery manufacturing could enhance grid stability, renewable energy integration, job creation, and economic growth.

The study identified key barriers to local battery manufacturing. These include market, financial, technology, and policy barriers, and a lack of skills and international partnerships specific to South Africa. To address these barriers, the study suggests fostering strong partnerships between government and battery manufacturers, sound policy development and implementation, manufacturing incentives, tariff reforms, and regional demand validation. Key considerations for battery manufacturers entering new markets like South Africa include market entry challenges, cost competitiveness, intellectual property protection, infrastructure improvements, access to raw materials, and government support. The study revealed that government leadership is crucial for developing the battery manufacturing industry in South Africa. Stimulating domestic demand for electric vehicles, developing mineral refining capabilities, and fostering government-industry partnerships are recommended to capitalise on market potential and industry growth. These findings complement existing literature and highlight factors unique to the South African context, as perceived by stakeholders within the battery industry.

Key words: Battery Energy Storage Systems, battery manufacturing, barrier-solution framework, South Africa, renewable energy.

DECLARATION

I, Ravisha Shantikumar, declare that this research report is my own work except as indicated in the references and acknowledgements. It is submitted in partial fulfilment of the requirements for the degree of Master of Management in Energy Leadership at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in this or any other university.

Name: Ravisha Shantikumar Signature: Shantikumar

Signed at Blairgowrie, Johannesburg.

On the 18th day of November 2024.

DEDICATION

Research is often described as a challenging journey, one that demands perseverance and resilience. My own research journey has been both demanding and fulfilling, shaped by the support and contributions of many individuals. To all those who have played a part, whether directly or indirectly, in the preparation of this research report, I extend my deepest gratitude. This dedication is for the growing network of energy leaders in South Africa and Africa, whose commitment and passion are driving positive change in the energy sector.

ACKNOWLEDGEMENTS

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To my beloved family, who have instilled in me the core values of education, perseverance, and resilience, I owe a profound debt of gratitude. Completing this research report was made possible by your unwavering support and sacrifices. To my husband, Kumaran Shantikumar, your unwavering belief in me has been my anchor throughout this journey. To my cherished family, friends, and colleagues, your encouragement and support have been indispensable throughout the research process. Lastly, to all the research participants, your contributions have added depth and relevance to this research. I extend my heartfelt thanks to every one of you.

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BESCIPPPP	Battery Energy Storage Capacity Independent Power Producer Procurement Programme
BESS	Battery Energy Storage System
BMS	Battery Management System
BTM	Behind the Meter
BVC	Battery value chain
DMRE:	Department of Mineral Resources and Energy
EV	Electric Vehicles
FTM	Front of the Meter
GDP	Gross Domestic Product
GW	Gigawatt
GWh	Gigawatt hours
IEA	International Energy Agency
IISD	International Institute for Sustainable Development
IPP	Independent Power Producer
IPR	Intellectual Property Rights
IRP	Integrated Resource Plan
LFP	Lithium Iron Phosphate
LI-ION	Lithium-ion batteries
MW	Megawatt
MWh	Megawatt hour
NCA	Nickel Cobalt Aluminium
NMC	Nickel Manganese Cobalt
RMIPPPP	Risk Mitigation Independent Power Producer Procurement Programme
SA	South Africa
SAREM	South African Renewable Energy Master Plan
USA	United States of America

CHAPTER 1. INTRODUCTION

1.1. Purpose of the study

This qualitative study investigates the barriers and solutions for battery manufacturing in South Africa. The study used purposive sampling to obtain perspectives from both key local and international role-players in identifying key challenges and informing the solutions proposed for localisation of battery manufacturing systems in South Africa.

1.2. Context of the study

The global energy landscape is undergoing a significant transition due to the growing emphasis on sustainability and the need to address climate change. Key global shifts include increased utilisation of renewable energy sources, accelerated adoption of electric vehicles, energy efficiency improvements, and increased investment in energy storage technologies (International Energy Agency, 2023). South Africa, being heavily reliant on fossil fuels such as coal for its energy generation systems, is particularly affected by the global energy transition which is impacting job creation, energy affordability, and economic development (Bischof-Niemz & Creamer, 2018a).

Amid this energy transition, South Africa is confronted by a persistent power crisis and slow economic growth. The country frequently experiences power cuts, referred to as ‘load-shedding’, which is, interruption of supply to manage a state in which there is insufficient electricity available to meet the demand. As shown in Figure 1, power shortages first occurred in 2008, then intensified from 2014 to date. Figure 1 shows that the highest intensity of load shedding in the country occurred in 2022 and 2023. For example, in 2022, 11 759 Gigawatt hours (GWh) of load shedding was recorded (International Energy Agency, 2023; International Institute for Sustainable Development, 2023). Power supply shortages in 2022 resulted in a loss of five percentage points in the Gross Domestic Product (GDP) of the country, corresponding with the highest recorded intensity of load shedding at the time (PricewaterhouseCoopers, 2023). This shows the negative impact of energy shortages on the socio-economic development of the country.

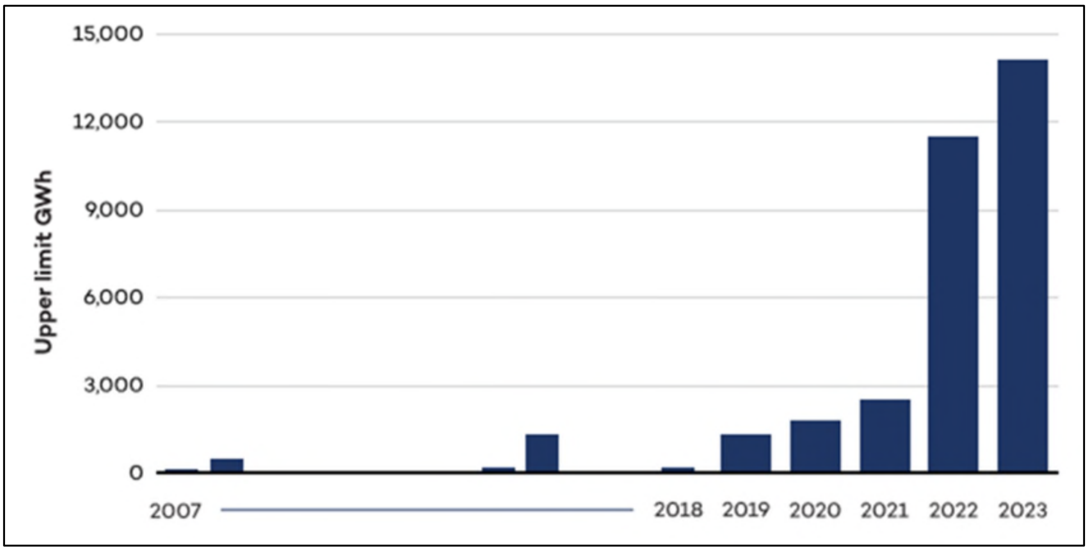

Figure 1: Load shedding in South Africa between 2007 and 2023

Source: International Institute for Sustainable Development (2023)

The South African context prompts enquiry into the structure and issues confronting the electricity sector. The country's electricity supply system has heavily relied on a monopolistic model dominated by Eskom, a state-owned power utility. Currently, Eskom owns approximately 80% of the total power generation fleet, from which it produces and distributes power mainly from coal-fired power plant generation systems. The performance of the ageing coal fleet is, however, declining thus contributing significantly to electricity shortages (International Institute for Sustainable Development, 2023). For example, in 2022, the average peak electricity demand in South Africa was 34.6 GW, while the coal power stations' maximum peak electricity output was 23 GW (International Institute for Sustainable Development, 2023), demonstrating the existing imbalances in electricity demand and supply in the country. The technical and financial challenges experienced by Eskom prompted the state to allow the private sector to invest in electricity generation infrastructure and renewable energy, beginning in 2011. As the country has opted to diversify its electricity supply systems, including through the introduction of private sector-driven renewable energy, it is expected that all viable solutions and technologies to manage the electricity supply crisis will be considered (Eskom, 2023). One such technological solution is battery energy storage systems (BESS). The role of batteries in the global clean energy transition is growing, thus in the context of this research, battery technology presents itself as a potential technological solution for South Africa (Metzger, Mendonça, Silva, & Damásio, 2023).

1.3. Research problem

South Africa's electricity supply problems exacerbate key socio-economic challenges, in part by stifling the potential of key sectors such as manufacturing. The potential for local manufacturing to stimulate economic development is a subject of debate amongst researchers, academics, and policymakers. Proponents argue that manufacturing can create jobs, enhance industrial capacity, and promote economic resilience (Kaplinsky & Morris, 2016; Rodrik, 2006; Unite Nations Trade and Development, 2012). At the same time, there is recognition that the policy environment is critical for realisation of these benefits, with critics warning that ill-advised local manufacturing policies could lead to inefficiencies and reduced competitiveness (Eichengreen & Gupta, 2012; Fine & Rustomjee, 1996). In South Africa, the draft South African Renewable Energy Masterplan (SAREM), initiated in 2022, aims to promote renewable energy and battery storage deployment, as well as battery manufacturing and mineral beneficiation of Lithium-ion (Li-ion) batteries (DMRE, 2023b).

The high potential for wind and solar renewable energy technologies to avert local energy supply problems has long been touted in the South African energy sector. However, grid constraints hinder rapid deployment of new renewable energy plants. Utility-scale BESS have been identified as possible initiatives that could mitigate these constraints and enhance grid capacity (Eskom, 2022). Broughton and van der Walt (2022); Fourie (2018), have argued that the technical capability of BESS to store and release electricity into the grid on demand has the potential to accelerate the adoption of intermittent renewable energy sources in South Africa.

Furthermore, market demand for batteries is growing locally and globally, presenting an industrial development opportunity for South Africa. In the first half of 2023, for example, South Africa spent R20 billion on imports of Li-ion cells and batteries from global markets (Kuhudzai, 2023). Government has initiated measures to adopt grid-scale BESS in the country. A request for proposal was launched in March 2023, where the government initiated the first-ever procurement process for 513MW of utility-scale battery storage from Independent Power Producers (IPPs) which is expected to provide grid support services for renewable energy projects (International Institute for Sustainable Development, 2023). A second and third round of request for proposals are underway in 2024 in which the government aims to procure 1200MW of utility-scale stationary BESS projects in South Africa (DMRE, 2023a). The objective of the procurement through these requests for proposals is to secure storage capacity and grid ancillary services from BESS.

Despite global advancements in BESS technology, South Africa and other developing countries lag in adoption or participation in the global battery value chain due to inadequate policies, limited expertise, and institutional challenges (Akin, 2020; Customised Energy Solutions, 2023; de Sisternes, Worley, Mueller, & Jenkin, 2019; Retna Kumar & Shrimali, 2021a, 2021b). While electro-chemical batteries hold potential for local deployment, South Africa lacks a cohesive policy framework to support this industry (Van Der Walt, 2017; Customised Energy Solutions, 2023). International partnerships and financial resources are also limited, further retarding the energy transition (Tyler & Hochstetler, 2021). Given the plans to increase adoption of BESS in the country, the question whether batteries could be manufactured locally gains prominence, and is therefore the focus of this study which aims to explore the barriers and solutions to battery manufacturing in South Africa. Research into the barriers and solutions for local battery manufacturing is critical in exploring the viability of localising battery manufacturing in South Africa, and how this could support the country's just energy transition, as well as unlock broader economic benefits.

1.4. Research objectives

Within the global discourse on the emergence of intermittent renewable energy technologies are strong views that such technologies should be coupled with BESS to fully realise their value in the electricity sector. However, in many developing countries such as South Africa, it is argued that various barriers hinder the manufacturing and implementation of BESS, making the energy transition process a challenging one. This study considers the observation that challenges with deployment of BESS are delaying the effective implementation of renewable energy in South Africa's and seeks to assess the existing barriers in the adoption and manufacturing of BESS in the country. The objectives of the study are, therefore, to:

1. Determine the benefits South Africa would derive from adopting more battery energy storage.
2. Identify the barriers and solutions for South Africa to participate in the global battery energy storage value chain.
3. Explore the key factors that battery manufacturers consider when entering a new battery energy storage market such as South Africa.

1.5. Significance of the study

de Sisternes et al. (2019), Govindarajalu et al. (2021), Retna Kumar and Shrimali (2021a), and Customised Energy Solutions (2023) have identified the need for further research into how developing countries can take advantage of the opportunity to adopt and manufacture BESS technology. There is a growing body of research exploring the challenges and opportunities of implementing BESS in South Africa (Van Der Walt, 2017; Fourie, 2018; Kebede et al., 2022). However, there is limited in-depth research into the enabling factors for the growth of the battery manufacturing industry in South Africa.

South Africa is endowed with minerals such as vanadium, nickel, manganese, and cobalt that are used as raw materials to produce BESS. South Africa has leading share of up to 40% of global vanadium and manganese (Customised Energy Solutions, 2023). A study highlighted that if in the short-term South Africa increases mining of available reserves of battery minerals such as manganese and vanadium, and commences with battery pack assembly for stationary and mobile applications, the country could contribute R18.8 billion to GDP and create 25,500 jobs per year, which is significant (Customised Energy Solutions, 2023). Having an in-depth understanding of barriers and solutions to localisation of battery manufacturing could help ensure that there is relevant planning and implementation in the BESS space, thus fast-tracking the just energy transition and implementation of renewable energy programmes. This justifies the need for better understanding of current challenges experienced by local manufacturers.

1.6. Delimitations of the study

I. The study is focused geographically on South Africa while most battery energy storage research is focussed on the global north and in developed countries.
II. The electrical energy considered to be stored in the battery device is from any energy source including coal, gas, wind, solar, and hydropower.
III. Electrochemical battery storage technologies such as Li-ion and vanadium redox flow batteries are considered in the study.
IV. This research focussed downstream of the battery value chain, which pertains to battery cell production and battery assembly.

1.7. Definition of terms

Term	Meaning	References
Barrier-solutions framework	The barrier-solution framework hypothesis suggests that a battery storage business model must address three main types of barriers. These encompass barriers related to demand, project economics, and market	(Retna Kumar & Shrimali, 2021a)

Term	Meaning	References
	mechanisms or administrative constraints.	
Battery energy storage	The storage of energy in batteries for later use.	(Van Der Walt, 2017)
Battery assembly	Battery pack assembly involves packing and arranging multiple battery cells, in a casing or unit, including the cooling system and battery management system (BMS).	(Customised Energy Solutions, 2023)
Battery Energy Storage System (BESS)	A BESS comprises multiple battery cells, the battery management system, cooling system and encasing.	(Ogunniyi & Pienaar, 2017).
Battery value chain (BVC)	The battery value chain includes all phases and the process of developing, producing, distributing, using, and disposing of batteries.	(Customised Energy Solutions, 2023)
Electrochemical storage	Electrochemical storage is a method of storing energy as chemical energy, which is then converted to electrical energy. Electrochemical cells have two or more electrodes (an anode and cathode) and a liquid between the two.	(Fourie, 2018)
Energy storage	Technologies that store energy including batteries, pumped hydro storage and so forth.	(Fourie, 2018)
Just energy transition	In the South African context , the change from fossil fuels mainly coal power plants to cleaner energy technology such as wind, solar and so forth , while bringing socio-economic benefits to society and communities.	(Bischof-Niemz & Creamer, 2018b)
Lithium-ion batteries	Lithium-ion batteries are widely deployed electrochemical storage devices used mainly in electric vehicles, portable	(de Sisternes et al., 2019)

Term	Meaning	References
	electronic devices such as mobile phones and for grid applications.	
Load shedding	A process of shutting down portions of electric load in a planned and controlled manner due to inadequate electricity capacity, to prevent a national blackout and damage to electrical infrastructure.	(International Institute for Sustainable Development, 2023)
Utility-scale energy storage	Large and centralized systems to store electrical energy for later use in the electricity grid, which includes technologies such as BESS and pumped hydro storage.	(Broughton & van der Walt, 2022)

1.8. Assumptions

The research was based on the following assumptions:

- Conceptual assumption that Li-ion batteries are proven technologies used worldwide and therefore can be used in South Africa.
- Conceptual assumption that Li-ion as a form of energy storage is economically feasible in South Africa, as demonstrated by Customised Energy Solutions (2023); Fourie (2018).
- The research participants possess sufficient experience and existing knowledge on battery energy storage technology and manufacturing.

CHAPTER 2. LITERATURE REVIEW

2.1. Introduction

This chapter provides an appraisal of the literature on the BESS value chain and the global landscape and advancements in battery storage system adoption. It aims to enhance the understanding of the technological, political, and various other risks and opportunities associated with BESS. The chapter delves into the existing battery storage policies, projects, and strategies in South Africa. Moreover, it explores literature on factors contributing to successful battery deployment and business models, such as policy support, market demand, and incentives. Lastly, it details the barrier-solution framework, which has been applied to BESS business models deployed in Hawaii.

2.1.1. *Energy storage technologies*

Energy storage is the storing of electrical energy so that it can be used when required (Fourie, 2018; Kebede et al., 2022). Battery storage technologies do not generate electricity but store it. As shown in Figure 2, the types of energy storage technologies currently available in the market include electrochemical, electrical, chemical, and mechanical forms.

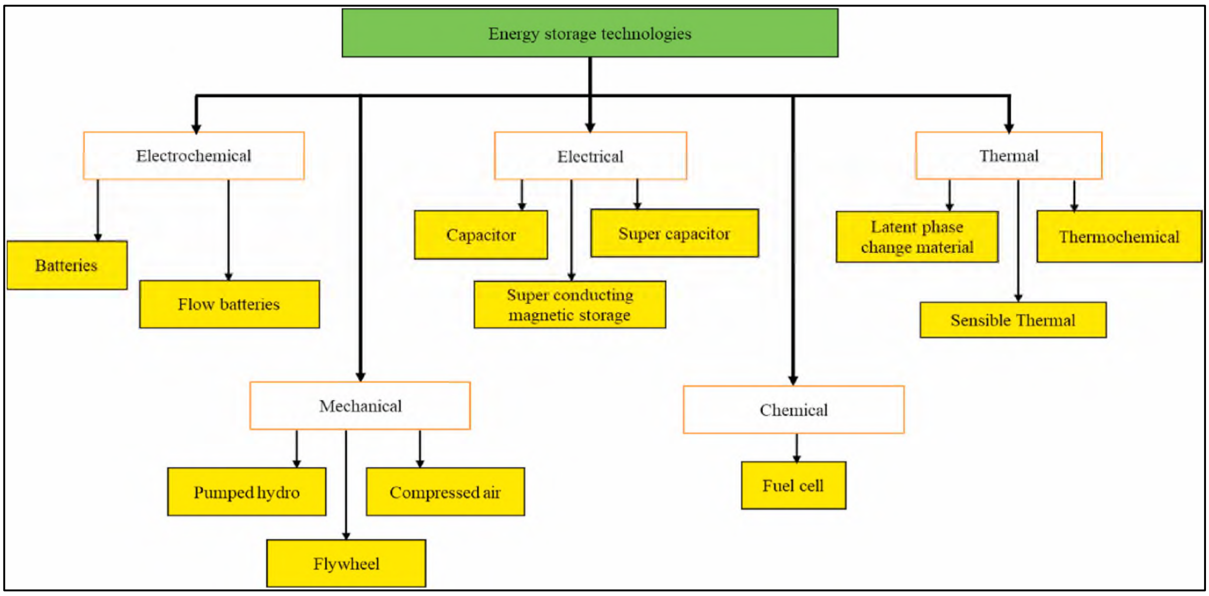

Figure 2: Main Energy Storage Technologies

Source: Kebede et al., (2022)

There is a wide range of electrochemical batteries as briefly discussed in this section. Electrochemical batteries are the most widely used energy storage device, wherein, chemical processes allow for the storage charge and discharge of electrical energy (Fourie, 2018). In this technology, a battery cell contains an anode, a cathode, electrolyte, and a separator membrane. Currently, the most dominant battery storage technologies are mainly the lithium, lead acid, silver and alkaline types. Ogunniyi and Pienaar (2017) have, however, noted that newer types of battery chemistries include flow batteries and sodium-sulphur batteries.

Despite the existence of numerous battery types, Li-ion batteries are rapidly being deployed globally and have proven technical and economic feasibility, particularly when paired with renewable energy sources such as wind and solar (Fourie, 2018; Hameer & van Niekerk, 2015; Ogunniyi & Pienaar, 2017; Thango & Bokoro, 2022; Van Der Walt, 2017). There are more than 10 distinct types of Li-ion battery chemistries as shown in Figure 3. The main Li-ion battery chemistries are described in Table 1.

Projections show that cathode chemistries with high nickel content such as Nickel Manganese Cobalt (NMC) 532/622, NMC high nickel, and Nickel Cobalt Aluminium (NCA), together with Lithium Iron Phosphate (LFP), will maintain a prominent position in the market until 2030 due to their widespread adoption in applications such as electric vehicles (Customised Energy Solutions, 2023).

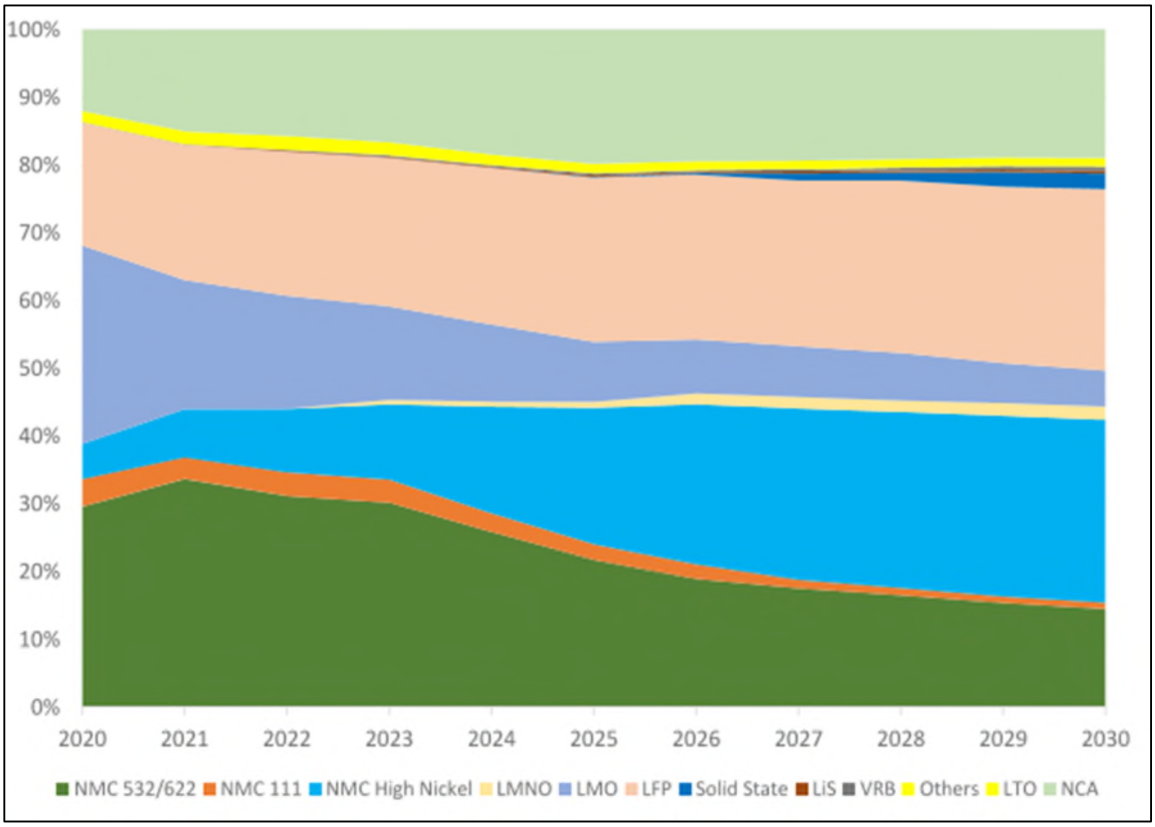

Figure 3: **Li-ion battery chemistries and expected market share between 2020 - 2030**

Source: Customised Energy Solutions (2023)

Table 1: Summary of the key Li-ion battery chemistries

Adapted from (Manthiram, 2020; Bridge & Faigen, 2022; Kebede et al., 2022)

Battery Type	Description	Main Manufacturers
Nickel Manganese Cobalt (NMC 532/622)	Cathode chemistry with high energy density, improved stability, and variable nickel content for optimisation between energy density and cost. Used in electric vehicles and consumer electronics.	LG Chem Panasonic Samsung SDI
NMC High Nickel	NMC cathode with a high nickel content and extremely high energy and reduced cobalt content, which can help address cost and mineral concerns. Used in electric vehicles and BESS.	Contemporary Amperex Technology Co. Limited (CATL) LG Chem Panasonic Samsung SDI
Lithium Manganese Oxide (LMO)	A cathode chemistry with manganese as the primary component. It offers good thermal stability but may have lower energy density compared to other Li-ion batteries. Used in power tools, medical devices, and other applications where safety and stability are critical.	Sony Toshiba Enbrel

Battery Type	Description	Main Manufacturers
Lithium Iron Phosphate (LFP)	A cathode chemistry with iron and phosphate. LFP batteries are known for high thermal stability, long cycle life, and safety. Commonly used in electric buses, stationary energy storage, and applications where safety is a priority.	BYD A123 Systems CALB (China Aviation Lithium Battery)
Nickel Cobalt Aluminium (NCA)	Cathode chemistry, which includes nickel, cobalt, and aluminium. NCA batteries are known for high energy density. Improved power capabilities therefore commonly used in electric vehicles.	Tesla Panasonic Samsung SDI
Vanadium Redox Flow Battery (VRB)	A type of flow battery that stores and releases electricity through the use of vanadium ions in different oxidation states. VRBs are known for their high cycle life and suitability for grid-based applications that require longer duration of storage.	Sumitomo Electric RedT Energy UniEnergy Technologies

2.1.2. *Applications of energy storage technologies*

Energy storage technology can be used in a variety of applications as detailed in this section. As shown in Figure 4, the International Institute for Sustainable Development (2023) has categorised the main energy storage markets into three, that is, consumer electronics, electric vehicles, and stationary energy storage.

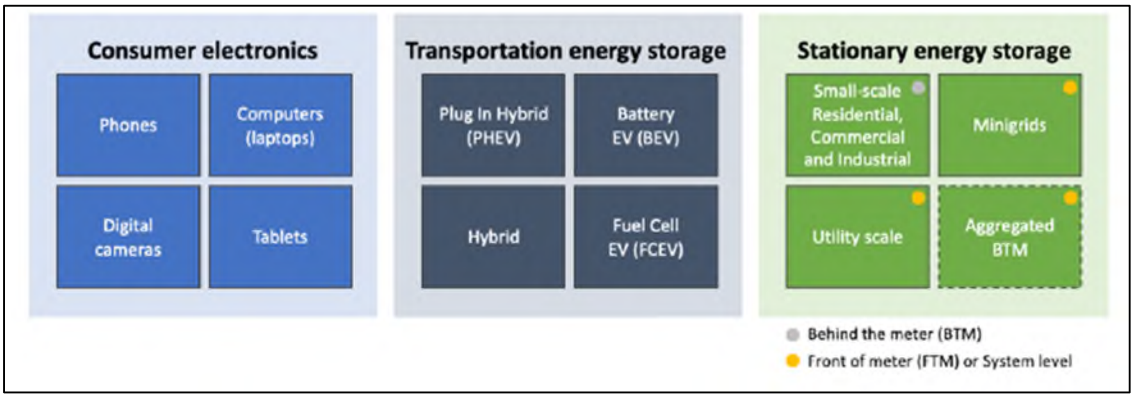

Figure 4: Battery energy storage applications

Source: Broughton and van der Walt (2022)

Battery energy storage systems can be used for a variety of applications, which is important to note when considering what technologies will be adopted or manufactured locally. It is important to distinguish between Behind The Meter (BTM) and Front of the Meter (FTM) systems in BESS applications (International Institute for Sustainable Development, 2023). As shown in Figure 5, if a BESS is considered BTM, it belongs to- or is used by energy consumers or individuals. An FTM energy storage device is linked to the national utility, such as Eskom, on the electrical grid and it is typically linked to large power plants. Both BTM and FTM could be relevant in the South African context of the power crisis and the need to ensure that sufficient electricity is stored in renewable energy generation systems.

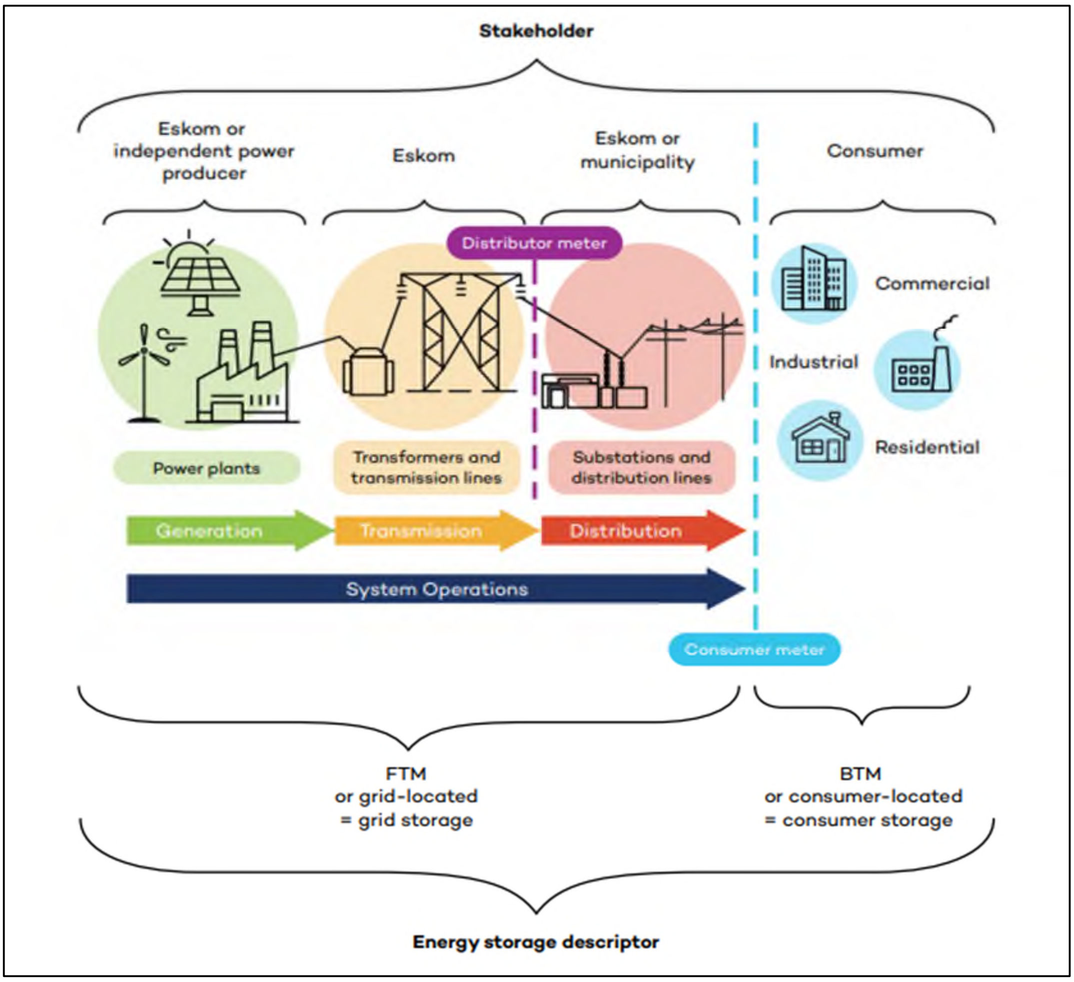

Figure 5: FTM and BTM

Source: International Institute for Sustainable Development (2023)

2.1.3. *Global and local battery demand*

Despite the estimated high capital costs, battery storage is playing a more prominent role in electrical power systems, and global demand for batteries is growing (Ogunniyi & Pienaar, 2017; Kebede et al., 2022). Between 2021 and 2022, there was a 60% increase in the number of BESS installed globally (Rystad Energy, 2023; Shuai & Raufer, 2021). While most installations occurred in North America, Europe, and Asia, future growth is expected on the African continent (World Economic Forum, 2021). Figure 6 shows that, in 2022, 43 GWh of battery energy storage systems was installed globally, and this is expected to increase to over 400 GWh installed by 2030 (Rystad Energy, 2023). Most anticipated battery installations are expected to occur in regions such as Europe, North America, and Asia, concentrated in countries such as the United States of America (USA), China, Germany, and South Korea (Jindal & Shrimali, 2022). Additionally, developing nations such as India are projected to witness a growth in battery storage installations.

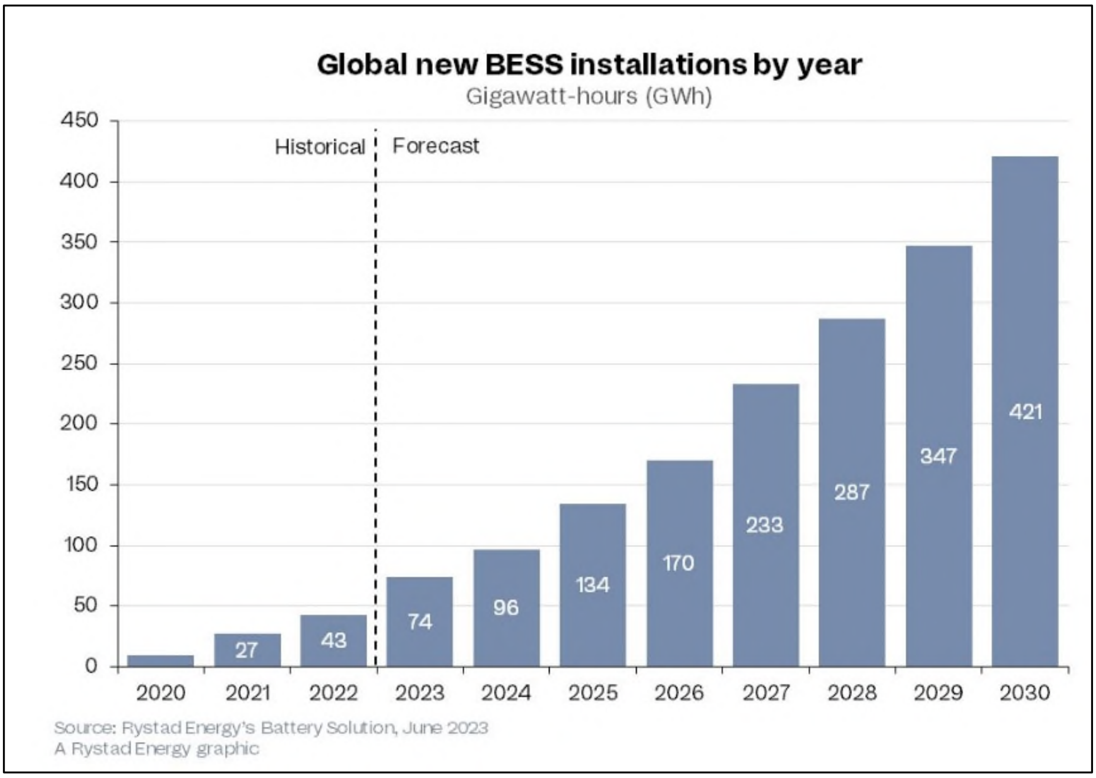

Figure 6: Historical and forecast global battery storage installations 2020 – 2030.

Source: World Economic Forum (2021)

The World Economic Forum (2021) predicts installation of 83 GWh of battery demand in Africa by 2030 as energy access improves. While South Africa has a small share of the global battery market, studies commissioned by the World Bank highlighted that the local battery storage market could grow from 0.27 GWh in 2020 to 15 GWh in 2030 under a best-case scenario, largely driven by electrical vehicles (Customised Energy Solutions, 2023). Despite South Africa's expected small share of around 0.04% of the global battery market in 2030, various authors argue that the adoption of battery storage technology could assist the country in managing the power crisis, particularly when coupled with renewable energy (Fourie, 2018; International Institute for

Sustainable Development, 2023; Thango & Bokoro, 2022; Van Der Walt, 2017). In the past ten years, the adoption of renewable energy has increased, globally. This has led to the growth of the BESS business driven by the need to manage intermittent renewable energy sources (Broughton & van der Walt, 2022). These developments are likely to drive exploration of implementation of BESS in South Africa, possibly mainly influenced by the renewable energy sector.

2.1.4. *Battery energy storage value chain*

The concept of an energy value chain refers to the entire process of producing, transporting, transforming, and using an energy source. This includes showing the various stages and processes involved. Like energy value chains, the Battery Value Chain (BVC) refers to the creation, manufacturing, distribution, use, and disposal of energy storage batteries. The BVC, however differs from the energy value chain in that it focuses on technologies used to store energy, but that do not generate energy. The most widely used electrochemical batteries, Li-ion batteries, find applications across electric vehicles, stationary, or stand-alone grid systems, as well as electronic devices. The Li-ion BVC is categorised into upstream, midstream, and downstream, as shown in Figure 7.

This study looks at the mid-stream to downstream of the generalised Li-ion BVC shown in Figure 7. Mid-stream refers to the stage between the upstream and downstream stages of the BVC and includes battery cell component production and the production of semi-finished parts of the battery cell such as the anode, cathode, and the electrolyte. Midstream of the BVC is essential for the transition of commodities into usable products. Downstream refers to assembly of the battery pack as well as delivery of the final product. This study focussed on battery cell production and battery pack assembly. Battery pack assembly involves packing and arranging multiple battery cells, in a casing or unit, including the cooling system and the battery management system (BMS). According to Customised Energy Solutions (2023), battery pack assembly could be feasible for a developing country such as South Africa as it costs more than five times less than setting up a battery cell production facility.

The Li-ion BVC is characterized as global and dynamic in nature. Battery minerals or raw materials are extracted from various parts of the world, notably Australia, Chile, Argentina, China, the Democratic Republic of the Congo (DRC), Indonesia, Brazil, USA, Zimbabwe, and South Africa. Battery cell production occurs mainly in China, Japan, and South Korea, with some production in Finland. Cell assembly is more widely distributed in regions with higher demand such as in Germany, Japan, South Korea, USA, and India (Bridge & Faigen, 2022).

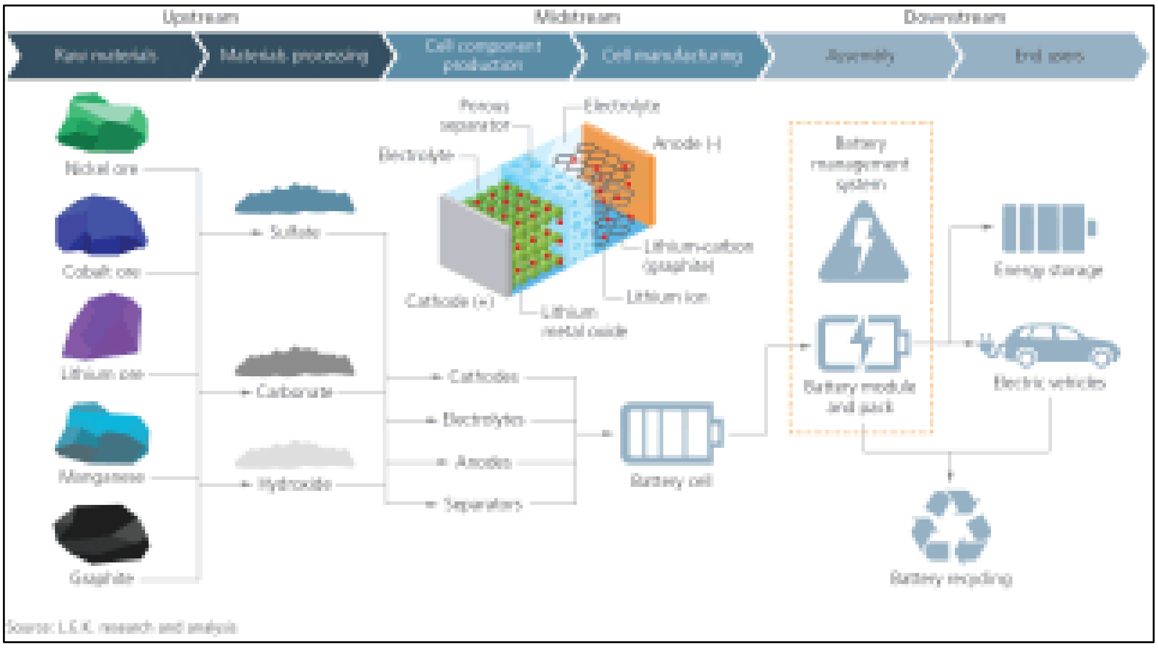

Figure 7: Li-ion Battery Value Chain

Source: Ciulla, Nilesh Dayal, and Amar Gujral (2021)

Battery cell manufacturing facilities are commonly referred to as giga-factories. A "Gigafactory" assembles and manufactures electric vehicle (EV) batteries, battery cells, and other energy storage devices. Giga-factories require high volumes of production to be feasible, with typical production outputs of between 5-10 GWh per year. Estimates indicate that capital of between R127 million to R163 million is required to establish a gigafactory, over and above policy and state support (Broughton & van der Walt, 2022; Customised Energy Solutions, 2023).

2.1.5. Downstream generalised battery manufacturing process for Li-ion batteries

A generalized process of the downstream stage of the BVC associated with battery cell production and battery pack assembly for Li-ion batteries is shown in Figure 8 and Figure 9. The smallest part of a battery is called a cell, which contains electrodes, a separator, and electrolyte. Multiple cells together make a battery module. In electric vehicles (EVs), cells can be grouped into modules or packs (Tishman, Phillips, & Jin, 2022). Cell production and battery pack assembly do not always have to occur in the same location or factory. In a generalised description, Li-ion batteries are produced by manufacturers using a variety of processes and procedures in four main stages: formation, pack production, cell assembly, and electrode fabrication (Liu, Ruihan, Wang, & Wang, 2021). Battery components are combined to make a slurry in the electrode production stage. This slurry is then coated onto aluminium and copper foils, rolled, sliced, and notched. Batteries are manufactured in the cell assembly process according to their shape, such as pouch or cylindrical, using different technologies for each kind. By ageing, charging, and discharging the battery, the formation stage activates and stabilises it. Finally, produced battery cells are assembled into packs to make modular batteries in the pack production stage. The battery pack also has other components, such as the BMS, and the cooling system and casing, depending on the application or use thereof (The Foundation for Science and Technology, 2023).

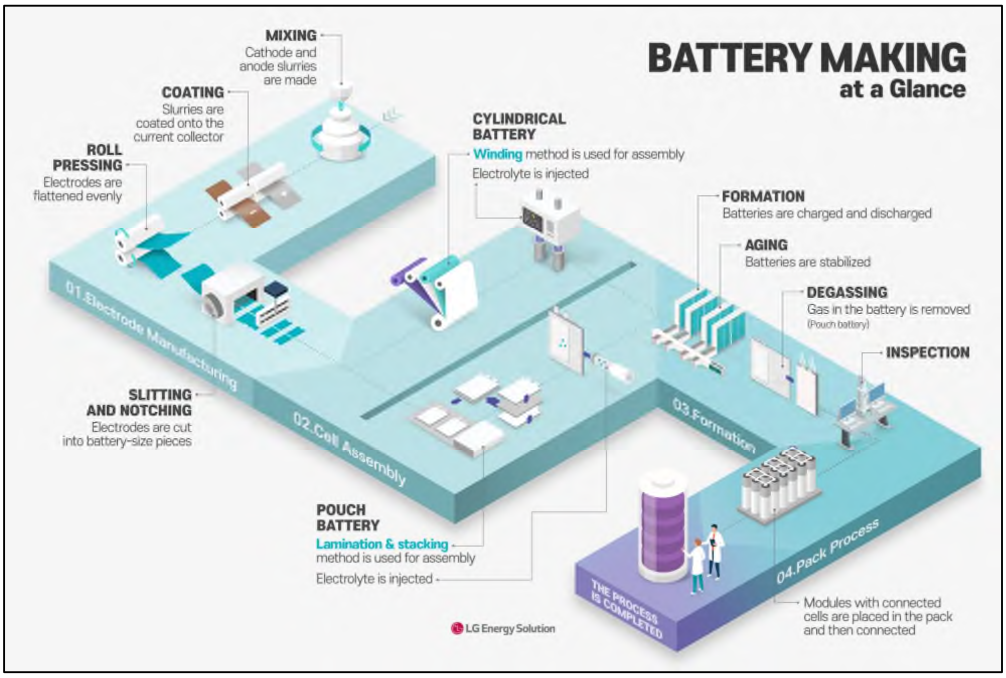

Figure 8: Generalised infographic of the manufacturing process of Li-ion batteries.

Source: LG Energy Solution (2023)

Figure 9: Li-ion batteries cell production process.

Source: The Foundation for Science and Technology (2023)

For stand-alone BESS, the system has various electrical components, including mainly the battery cells which are arranged in battery packs, and the BMS and cooling system, as shown in Figure 10. Six companies dominate the battery cell manufacturing market globally, that is, LG, CATL, Panasonic, Samsung, Build Your Dreams (BYD) and SKI (Bridge & Faigen, 2022).

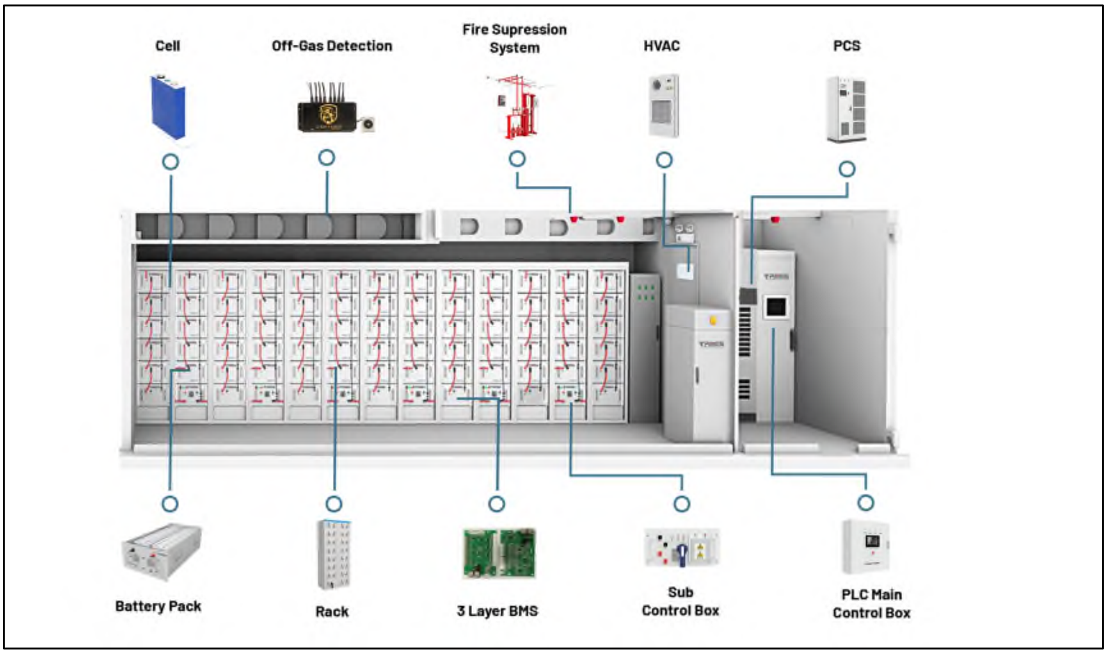

Figure 10: BESS components and arrangement

Source: TROES Corp (2023)

. Battery cell producers make individual battery cells, focusing on chemical formulation, performance, and quality control. Battery cell producers sell battery cells to battery storage manufacturers and to other players in industries like automotive and consumer electronics. Examples of Li-ion cell producers include Samsung, LG, CATL, BYD, and Automotive Energy Supply Corporation (AESC) (Bridge & Faigen, 2022). Li-ion battery storage manufacturers/assemblers specialize in assembling complete systems such as a BESS by integrating battery cells obtained from cell producers. Battery assemblers often also develop battery management systems, enclosure designs, and monitoring software. Examples include Sungrow, Fluence, Tesla, Huawei and BYD (Wood Mackenzie, 2023). Battery system integrators are companies or entities that specialise in assembling and integrating various components of a battery storage system into a cohesive and functional unit. This involves coordinating the selection, sourcing, and assembly of individual components such as battery cells, battery management systems, inverters, cooling systems, enclosures, and control software. Battery system integrators play a crucial role in the development and deployment of energy storage solutions. Battery system integrators often have an extensive global presence, enabling them to tap into a broader customer network and additional sources of revenue to make the business viable (Wood Mackenzie, 2023).

2.1.6 Battery landscape in South Africa

In 2020, South Africa's mature lead-acid battery market held a substantial 75% market share (Customised Energy Solutions, 2023). Lead-acid batteries served residential, rural microgrids, commercial, and automotive applications, primarily in BTM installations. Southern African countries' demand was 170 MWh of batteries in 2020, mainly for back-up power. Anticipated growth is substantial, with a projected 1.5 GWh market by 2030 (Customised Energy Solutions, 2023).

Notably, South Africa does not manufacture Li-ion battery cells, but several companies focus on Li-ion battery assembly components, indicating a small and emerging industry. Since 2012, the country has seen the emergence of at least five companies specialising in assembly and components within the Li-ion battery value chain. These companies, described in Table 2, are Balancell, Blue Nova Energy, Freedom One, Maxwell and Spark, and Solar MD. This suggests that local Li-ion battery assembly is still developing and is currently a relatively small industry in South Africa. Data recorded by Trade & Industrial Policy Strategies (TIPS) shows that there has been a sharp increase in import of Li-ion batteries in 2023, amounting to $1.75 billion or between 3.8 GW to 5 GW as shown in Figure 11 (Engineering News, 2024).

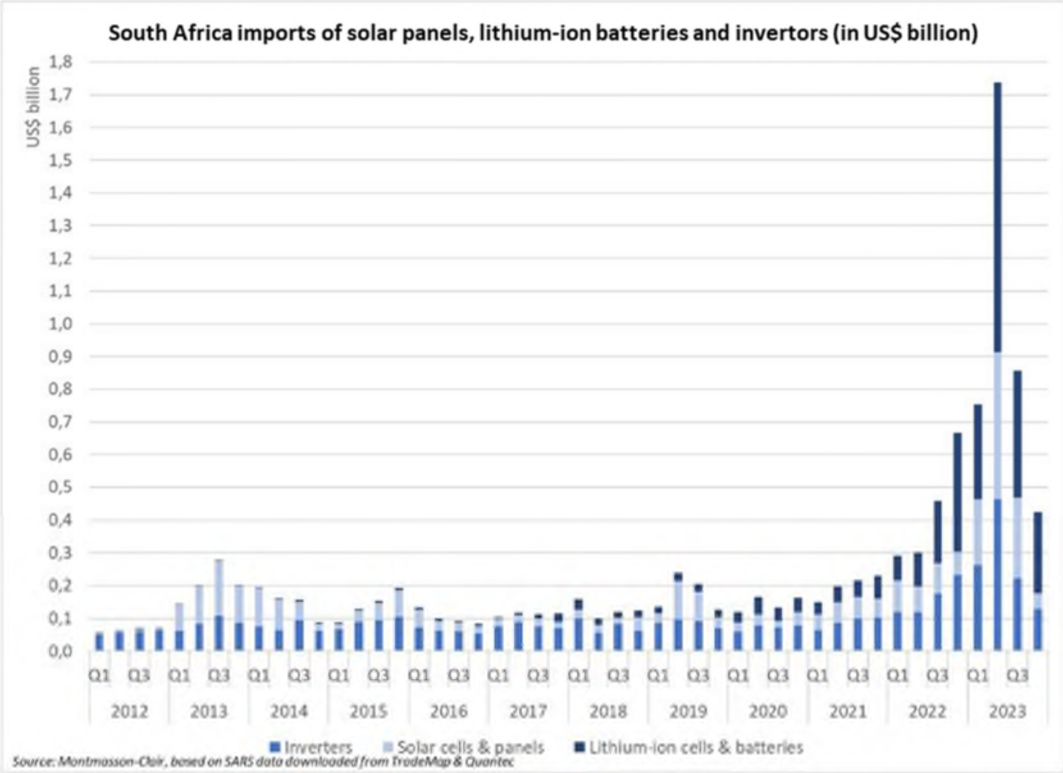

Figure 11: Value of solar panels, batteries, and inverter imports in SA from 2012 to 2023.

Source: Engineering News (2024)

Table 2: Li-ion battery assembly companies present in South Africa

Source: Customised Energy Solutions (2023)

Manufacturer	Date Established	Profile
Freedom One	2012	Assembles LFP battery packs for various applications. Cells are imported from China, but other parts, such as wiring leads, electronics, and casings, are bought or made in the USA. The BMS is made in the USA

Manufacturer	Date Established	Profile
Balancell	2013	Located in Cape Town. Manufacturer of LFP batteries and BMS. Focus on batteries for industrial equipment, offer products for solar energy storage and refrigerated trucks, and import LFP cells from China while sourcing or manufacturing all other components locally. Balancell has a proprietary BMS software, including cell balancing technology and power electronics.
Solar MD	2014	Solar MD is a battery assembly company located in Cape Town, which specializes in LFP chemistry BESS for residential, commercial, and utility-scale use. Battery assembly takes place in the factory in Cape Town, with current build of a battery manufacturing and storage facility in Richmond, Cape Town (Solar MD Pty Ltd, 2022).
Blue Nova Energy	2015	Located in Centurion, Gauteng. Part of Reunert Group, offering LFP-based energy storage solutions and large intelligent energy storage systems. Employs around 70 staff. LFP batteries are sold for diverse applications.
Maxwell and Spark	2017	Located in Durban. Li-ion batteries manufacturer for LFP and NMC batteries. Employs around 50 staff. The company designs and assembles. Primarily focusing on LFP chemistry, while importing LFP cells from China. Expanded their presence internationally, in Australia and North America.

2.2. First research objective: Determine the benefits South Africa would derive from adopting battery energy storage

The following discussion expands on the benefits and services that BESS can provide for South Africa.

2.2.1. *The benefits or services that Battery Energy Storage can provide for South Africa*

Battery energy storage, specifically electro-chemical batteries, can provide various benefits and electrical services. Electro-chemical batteries are the most widely deployed, globally. South Africa could benefit from battery energy storage in numerous ways, including grid stability and resilience, integration of renewable energy, cost savings, mitigation of energy shortages, environmental benefits, and economic growth (Customised Energy Solutions, 2023; de Sisternes et al., 2019; Fourie, 2018; Ogunniyi & Pienaar, 2017; Van Der Walt, 2017). Figure 12 shows the various benefits of battery storage across applications and for diverse users including utilities and consumers. The specific benefits for South Africa are explained thereafter.

Figure 12: The significance and advantages of energy storage

Source: Mullendore (2015)

The key benefits of battery storage that are relevant to South Africa are as follows:

- Grid stability services: Utilisation of utility-scale and stationary storage systems to ensure the stability of electricity supply, thereby mitigating the risk of blackouts and enhancing the overall reliability of the power grid. BESS can be charged from the national grid and subsequently discharged as required (Van Der Walt, 2017).
- Enhanced renewable energy deployment: Batteries address the issue of intermittency that is associated with renewable energy (Thango & Bokoro, 2022), thereby enabling greater deployment of renewable energy technology.
- Energy arbitrage: One advantage of batteries is their potential to reduce costs by utilising stored energy during periods of high electricity demand such as peak hours (Van Der Walt, 2017).
- Energy backup systems: Batteries can provide a reliable source of electricity during periods of insufficient power supply or load-shedding, ensuring uninterrupted operation of various devices and systems (Broughton & van der Walt, 2022).
- Environmental benefit: Battery energy storage supports use of clean technologies such as renewable energy and electrical vehicles, which have a lower environmental impact than fossil fuels such as coal, oil and petroleum. The utilisation of batteries can assist in reduction of air pollution and the emission of greenhouse gases (Broughton & van der Walt, 2022).
- Economic growth and job creation: The participation of South Africa in the battery energy storage value chain could create employment opportunities and support economic growth (Customised Energy Solutions, 2023).
- Improving energy access: The utilisation of batteries can facilitate the provision of electricity to remote areas, thereby enhancing energy access in areas situated far from urban centres (Abid, Thakur, Khatiwada, & Bauner, 2021; Charles, Davies, Douglas, Hallin, & Mabbett, 2019).
- Consumers can control consumption and can become more self-sufficient (Broughton & van der Walt, 2022).

In summary, battery energy storage could assist in maintaining electricity supply or provision of electricity when there is lack of supply, in supporting renewable energy deployment, and in job creation. Strategic deployment of BESS could assist in addressing the nation's energy challenges and contribute to a more stable and sustainable energy future (Customised Energy Solutions (2023). While the adoption of BESS is likely to yield positive socio-environmental benefits, there is further research work required regarding how to manage BESS waste and to make waste management commercially viable (Charles et al., 2019).

2.2.2. *Battery energy storage value chain opportunities and benefits for South Africa*

Fourie (2018) conducted an empirical study utilising a Levelized Cost of Storage (LCOS) model. The study found that when solar photovoltaic (solar PV) is combined with utility-scale energy storage technologies such as vanadium, Li-ion, and sodium-sulphur (NAS) it is a more cost-effective choice in South Africa compared to using fossil fuels (coal and gas). This aligns with the views of Penisa et al. (2020) that Li-ion NMC battery prices would fall to below 100 $/kWh by 2024, making it an ideal time to invest in grid-tied energy systems that combine solar PV and wind technologies with Li-ion batteries, also known as hybrid power plants.

A study commissioned by the World Bank and conducted by Customised Energy Solutions (2023) estimated the potential monetary value if South Africa participates in the global battery value chain. In the short term, the “easy pickings scenario” could contribute R18.8 billion to GDP and create 25,500 jobs per year, expanding locally available reserves of battery minerals upstream, as well as downstream, by battery pack assembly for stationary and selected mobile applications. In the long term, “the whole nine yards” scenario, which includes battery cell production, could increase GDP by R43.6 billion and create 58,200 jobs per year. South Africa’s GDP was R4.60 trillion in 2022, which means fully exploiting the BVC in today’s real terms could mean a 1% increase in GDP every year, which is extremely positive considering that between 2019 and 2022, South Africa’s GDP grew by a mere 0.3% (Statistics SA, 2022).

According to Customised Energy Solutions (2023) and as illustrated in Figure 13, the parts of the BVC that could be highly feasible for South Africa include the following:

- Upstream: Expansion of mining of locally available battery minerals required for manufacturing BESS such as vanadium, nickel, manganese, and cobalt in South Africa.
- Midstream: Establish mineral refining hubs in South Africa for lithium, nickel, cobalt, copper, and graphite through a strategic regional partnership with African countries that have these minerals. Examples of those countries and associated minerals include lithium from Zimbabwe, graphite from Mozambique, Tanzania or DRC, and cobalt from DRC. Produce precursor metals such as aluminium cathode foil and electrolyte additives.
- Downstream: Battery pack assembly is feasible as it costs more than five times less than setting up a battery cell production facility.

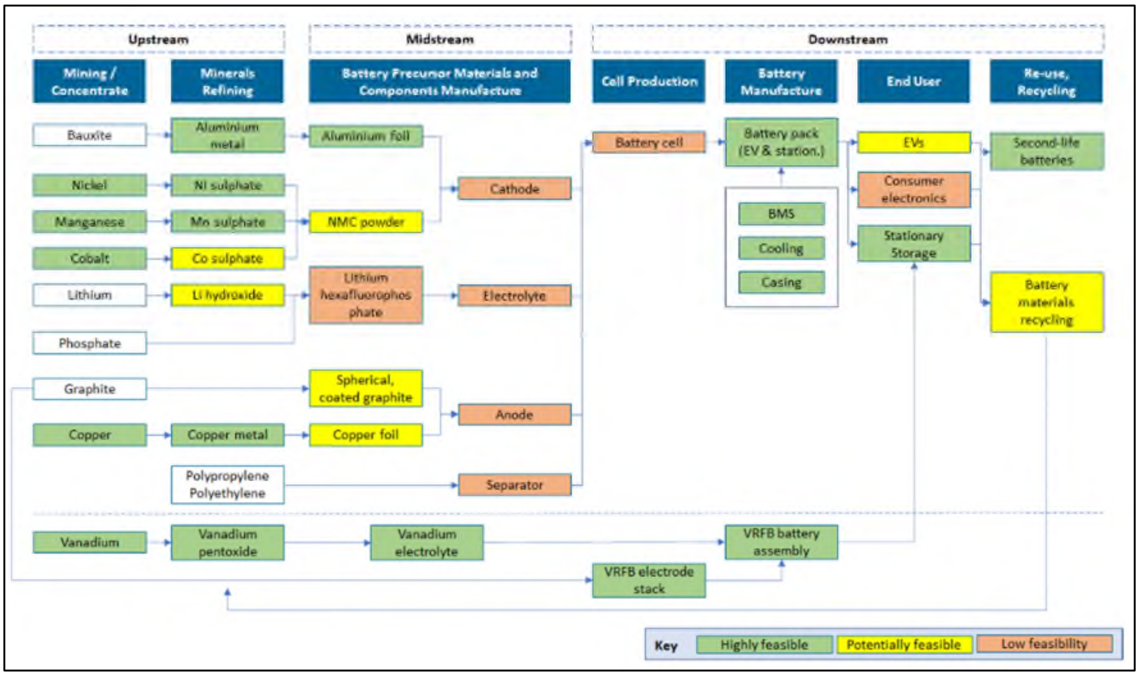

Figure 13: The Battery Value Chain and parts which are feasible in South Africa

Source: Customised Energy Solutions (2023)

The downstream stages of the BVC, which relate to making the battery cells as well as assembly of the different components that make up the battery pack and casing are the focus of this research report. The 2023 World Bank study highlights three scenarios for South Africa's participation in the BVC as shown in Figure 14.

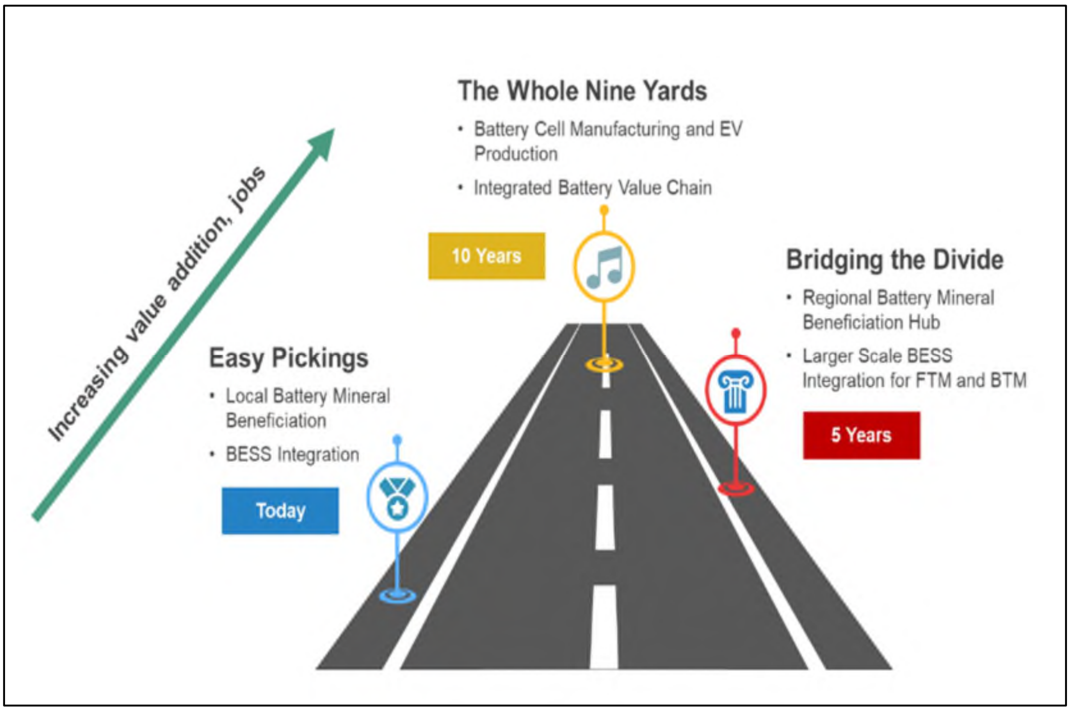

Figure 14: Battery Energy Storage Scenarios for South Africa

Source: Customised Energy Solutions (2023)

2.2.3. *Proposition 1*

Research objective #1	Determine the benefits South Africa would derive from adopting more battery energy storage.
Proposition 1 (P1)	Battery energy storage has a wide range of benefits and a positive role to play in South Africa by supporting grid stability, deployment of renewable energy, job creation and economic

	growth. Upstream, midstream, and downstream opportunities in the BVC exist for South Africa. In the long term, cell manufacturing is a potential opportunity for South Africa, however, the viability of Li-ion battery cell manufacturing in South Africa is not yet proven.

2.3. Second research objective: Identify the barriers and solutions for South Africa to participate in the global battery energy storage value chain

2.3.1. *Barriers and Solutions to BESS manufacturing*

The following section discusses the barriers to BESS adoption in developed countries and in South Africa as derived from existing literature. A report commissioned by the World Bank (Customised Energy Solutions (2023) identified eight key challenges to battery market development in South Africa which are detailed in Table 3.

Table 3: Key challenges indentified by the World Bank 2023 study

Source: Customised Energy Solution (2023)

Policy, Regulation and Planning challenges:
1. Lack of market scale to attract battery manufacturers.
2. The energy plan (IRP 2019) modelling forecasts 513MW of energy storage power capacity in 2022, and 1575MW of storage in 2029, with a gap of six years

	between. The report revealed that investors and market players require short intervals to be considered in any updates of the planning document.
3.	Unclear policy to support growth of the battery storage industry. The energy plan referred to as the Integrated Resource Plan 2019 (IRP 2019) states energy storage power capacity targets in MW, it should also state the energy capacity targets in MWh, for proper market sizing.
4.	Localisation requirements in government tenders for grid-scale battery projects tend to be low and limited to civil and electrical components.
5.	Business community is doubtful on localisation targets, and there is a lack of policy predictability and transparency.
Industry Development Challenges:	
6.	Government energy storage tenders have a short delivery timeframe of less than 18 months, and longer time is required for developing local manufacturing industry.
7.	No standards and facilities for battery product certification, testing and quality exist.
8.	Lack of skilled labour, power-electronic, software engineering and integration specialists.

Customised Energy Solutions (2023) further provided a detailed list of recommendations or solutions for South Africa. These included the following:

- A clear policy and strategy regarding the focus on refining of battery minerals, creation of a regional hub for refining, and building of an integrated battery value chain that includes cell manufacturing and electric vehicles.
- Further public and private sector engagement in policy, planning, and programme development, and possibly creating a dedicated directorate.
- Increase renewable energy in the country's energy mix.
- Establish battery testing and certification facilities.
- Collaborate with Zimbabwe, Mozambique, Tanzania, DRC, and Zambia in creating a regional hub for refining battery-related minerals.

- Increase demand and localisation in government tenders for battery storage.
- Explore establishing a BESS Special Economic Zone.
- Local skills development, battery industry training, and having a dedicated energy research programme (Customised Energy Solutions, 2023).

Research by de Sisternes et al. (2019) highlighted four key challenges that developing countries face in scaling up energy storage, which align to the South African context and study by Customised Energy Solutions (2023). These include:

- Lack of customised technological solutions specifically designed for developing countries.
- Insufficient capabilities and expertise to evaluate different options for energy storage.
- Policy, regulatory frameworks and market structures are not conducive and sometimes non-performing to ensure revenue certainty and lack of efficient permitting processes. Other research (Akin, 2020; Jindal & Shrimali, 2022; Retna Kumar & Shrimali, 2021a) also hold the similar view that a lack of policy and regulation is a key barrier for the deployment of battery storage.
- There is a scarcity of critical enabling factors, including trained personnel, international partnerships, and necessary resources.

de Sisternes et al. (2019) put forward four main research areas for developing countries to consider for increasing adoption of energy storage. Under the energy storage research track three, which is about further research on policy, regulation, and procurement, de Sisternes et al. (2019) recommended the following, which are relevant to this study:

- Research on strategies and roadmaps for national and regional energy storage that are critical for design of policy instruments. Research could include engaging stakeholders to inform the development of a country's energy storage strategy or roadmap. The World Bank 2023 study highlights case studies on policy and strategies for battery energy storage from countries such as Australia, Indonesia, India, and Thailand, as well electrical vehicle policies adopted by Rwanda, Uganda and Kenya (Customised Energy Solutions, 2023).

- Research on adapting policy and regulatory instruments to be suitable for BESS.
- Research on existing renewable energy policy instruments and their adaptability to energy storage.
- Review of business models for BESS, including challenges faced by businesses, good practices, and innovations.

The research areas of interest to South Africa include the following:

- A comprehensive review of the policy instruments in place in South Africa, and exploration of existing instruments, renewable energy or other systems which could be adapted to support the growth of the battery industry could be a next key. Policy toolkits that would be suitable for the process could also be considered (de Sisternes et al., 2019). A policy study by Broughton and van der Walt (2022) also indicated that for utility scale storage, policy, and regulation are the main barriers to scaling up grid-connected stationary energy storage in South Africa.
- Evaluation and research into the suitability of existing business models and potential new approaches like the Battery as a Service (BaaS) model would be important given the high initial investment needed for BESS and the limited financial resources available in developing economiesRetna Kumar and Shrimali (2021a) (Customised Energy Solutions, 2023; Retna Kumar & Shrimali, 2021a).

A policy-focussed study by Broughton and van der Walt (2022) on market development of utility-scale energy storage or FTM applications in South Africa, highlighted that cost and policy barriers need to be overcome for utility-scale BESS market development.

The topic of Intellectual Property Rights (IPR) is relevant for all industries, including the battery industry (Tishman et al., 2022, p. 4). Intellectual Property Rights refers to the legal rights that safeguard creations of individuals, notably including patents and trade secrets, which are important protections for battery manufacturers (Metzger et al., 2023). Patents are intellectual property rights granted for inventions. Trade secrets are vital for maintaining a competitive edge in the battery industry by safeguarding confidential information (Tishman et al., 2022).

Patents play a significant role in securing competitive advantages and fostering innovation in battery technology, particularly with the advancement of electric vehicles and renewable energy solutions (Metzger et al., 2023). Access to patents is essential for battery manufacturing, although most patents originate from Asian and European countries, potentially posing challenges for South African manufacturers (Bican, Caspary, & Guderian, 2023; Metzger et al., 2023).

As companies endeavour to enhance battery performance and manufacturing methods, preserving trade secrets emerges as a prerequisite for sustaining market competitiveness for battery manufactures (Tishman et al., 2022). The unwillingness of battery manufacturers to share IP and trade secrets could be a barrier for South Africa in its quest to assemble batteries locally. It can be costly, time-consuming, and require specialist skills to handle the process of obtaining and maintaining IPR (Tishman et al., 2022; Unite Nations Trade and Development, 2012).

Beyond the legal protective function, IPR exerts substantial influence on international collaboration and cooperation in technology transfer and adoption (Unite Nations Trade and Development, 2012). How the IPR regime shapes the transfer of environmentally sustainable technologies to African countries like South Africa and whether this will be a challenge for the country has yet to be determined (Unite Nations Trade and Development, 2012).

IPR-related barriers to BESS manufacturing in South Africa may include the following:

- Limited access to patented technologies: The majority of battery patents originate from Asian and European countries (Metzger et al., 2023). The South African government or local companies may face challenges in accessing and leveraging patented technologies essential for BESS manufacturing.
- Technology transfer challenges: Transferring battery storage technofixes to African countries like South Africa can be hindered by the global IPR regime which is complex. Reforms may be necessary to facilitate technology transfer

and support industrial development within the BESS sector in African countries (Unite Nations Trade and Development, 2012).

- Lack of interoperability standards: The absence of standards to enable connectivity, such as charging protocols, and interoperability between batteries and electric vehicles (EVs) poses challenges for establishment of South African manufacturing. Without collaboration between battery companies and automakers to ensure interoperability, the industry risks becoming fragmented into non-compatible ecosystems (Bican et al., 2023).

Partnering with international original equipment manufacturers who have proprietary technology and intellectual property could be a potential solution to overcome the IPR barriers (Customised Energy Solutions, 2023). Table 4 provides a summary of the key barriers and enablers/solutions derived from the review of the literature.

Table 4: Summary of main barriers and enablers to energy storage from the literature

Barriers	Enablers/ Solutions	References
Cost barrier: High capital and investment costs of ES	Incentives by the government, such as tax incentives, rebate schemes, subsidised loans, grants, etc.	(Broughton & van der Walt, 2022; Jindal & Shrimali, 2022)
Cost barrier: Tariffs that penalise energy storage affect the economic viability of BESS projects.	Tariff structures modifications, for example, time variant tariffs for compensation of energy storage.	(Broughton & van der Walt, 2022; Jindal & Shrimali, 2022)

Barriers	Enablers/ Solutions	References
Cost barrier: Stacked benefits of ES services not compensated which discourages investment.	Revenue compensation mechanisms and digital platforms to adapt to market rules.	(Broughton & van der Walt, 2022)
Policy barrier: Incorrect classification in policy of energy storage as a grid asset.	Energy storage policy to clearly define the services that energy storage can bring to generation, transmission, distribution, and consumers.	(Broughton & van der Walt, 2022)
Policy barrier: Lack of best practice for grid integration of ES.	Amend or create regulations and technical standards for grid-applications in a transparent manner.	(Broughton & van der Walt, 2022)
Policy barrier: ES various stacked services benefit not catered for in electricity market structures.	Clear policy, rules and regulations setting out the system services of energy storage. Creating access to the market with clear and fair rules.	(Broughton & van der Walt, 2022)
Policy barrier: Lack of explicit policy support hinders ES technology adoption	Set targets and strategy for energy storage.	(Broughton & van der Walt, 2022; Customised Energy Solutions, 2023; de Sisternes et al., 2019;

Barriers	Enablers/ Solutions	References
Lack of market demand	Set targets and strategy for energy storage, in policy.	Jindal & Shrimali, 2022; Retna Kumar & Shrimali, 2021a)
Lack of capabilities and skills for developing countries, including lack of access to proprietary technology.	Capacity building and skills development initiatives.	(Customised Energy Solutions, 2023; de Sisternes et al., 2019; Jindal & Shrimali, 2022)
Lack of standards and certification facilities as well as streamlined permitting processes.	Develop standards, battery certification facilities, and permitting process or platform.	(Broughton & van der Walt, 2022)
IPR barriers included limited access to patented technologies, complex technology transfer challenges, and the lack of interoperability standards, potentially hindering local production.	Solutions may include partnering with international original equipment manufacturers possessing proprietary technology, fostering collaboration, and implementing policy reforms to facilitate technology transfer and overcome the barriers.	(Bican et al., 2023; Lubango, 2020; Metzger et al., 2023; Tishman et al., 2022; Unite Nations Trade and Development, 2012)

2.3.2. *The status of battery storage policy, projects, or strategies status in South Africa*

This section sets out the current battery energy storage programmes, policy, projects, or strategies in South Africa.

2.3.2.1 Integrated Resource Plan (IRP)

The draft IRP 2023 is a high-level policy framework for South Africa's energy planning including energy storage. The IRP 2023 forecasted 1403MW of battery storage in the power system in 2030 (DMRE, 2024). The DMRE launched the Battery Energy Storage Capacity Independent Power Producers Procurement Programme (BESCIPPPP), which is the tool to implement the battery storage capacity contained in the IRP 2023.

2.3.2.2 Just Energy Transition Investment Plan 2023-2027

The Just Energy Transition Investment Plan 2023 – 2027 makes investment provisions for decarbonisation and sustainable development of energy sectors in SA which includes electric vehicles and battery storage Presidential Climate Commission (2022). The Just Energy Transition Investment Plan prioritizes utility-scale BESS to stabilize renewable energy supply and support the electrical grid. It also highlights that battery manufacturing could boost job creation and establish South Africa as a hub for battery production. In terms of Electric Vehicles (EV) the plan supports the manufacturing of battery electric vehicles and new energy vehicles.

2.3.2.3 Battery Storage IPP Programmes / Initiatives in South Africa

The Department of Mineral Resources and Energy (DMRE) is the national arm of the South African government as custodiam of mineral and energy resources. Based on the IRP 2023, government programmes to procure renewable energy with battery storage and battery storage from IPPs have been launched in recent years, which include the following:

- The Risk Mitigation Independent Power Procurement Programme (RMIPPPP) was launched in 2020 by the DMRE and aimed at assisting to reduce the short-term power supply gap and usage of diesel-based power plants. The programme was open for any dispatchable generation technology, under which 640MW of battery storage was procured. The projects that include batteries are mostly coupled with wind and solar technologies and expected to come online between 2023 to 2024 (International Institute for Sustainable Development, 2023).
- The BESCIPPPP was launched by the DMRE in 2023 and is still under procurement. The first tender aims to procure 513MW of electro-chemical batteries, that should be in operation by 2026. The second and third tenders are in progress and aimed at procuring 1200MW of utility-scale stationary BESS projects in South Africa. The aim of these request for proposals is to secure storage capacity and grid ancillary services from the BESS. The BESS facilities are to be connected to five specific Eskom transmission substations in the Northern Cape that have constraints and no transfer capacity. By adding BESS linked to the substations, electricity transfer capacity is increased at those substations. The Northern Cape province, for example, has various solar projects, and the BESS will facilitate energy storage and dispatch from the existing or new solar facilities in this region (DMRE, 2023a).
- Eskom's BESS initiative was launched in 2022 aiming to build 500MW of BESS at Eskom distribution substations. Eskom awarded contracts for 343 MW of BESS under this initiative in 2022, which are under development and implementation at Eskom distribution substations in South Africa and expected to come online between 2023 and 2024. Batteries will be placed alongside solar PV plants at 12 sites in South Africa (Broughton & van der Walt, 2022). Phase 1 will build 99 MW/833 MWh of battery storage projects coupled with 2 MW of solar PV, while the second phase will install 144 MW/616 MWh of battery capacity coupled with 58 MW of solar.
- The government has plans to convert decommissioned coal power plants into solar PV with battery storage hybrid power plants. For instance, Komati coal power plant was decommissioned in 2022, with plans to convert it into a solar PV plant, with 224MWh of battery storage. This is a first flagship project, the

same could be implemented at three other coal power plants that will be decommissioned by 2025 (Broughton & van der Walt, 2022).

Most of the government initiatives are related to grid-scale or utility-scale, FTM applications of battery storage (Broughton & van der Walt, 2022). The success of the existing utility-scale BESS initiatives is yet to proven in South Africa (IRP 2019). The goal of deploying battery storage is to help with the integration of power plants and to help keep the South African power supply stable. To date, the 513MW of battery storage is still under procurement phase via the BESCIPPP Programme. This gap in new energy storage capacity is considered too long to attract battery manufactures and investors (Customised Energy Solutions, 2023).

2.3.2.4 South African Renewable Energy Master Plan (SAREM)

The SAREM, has been under development since 2022 and aims to guide South Africa in deploying renewable energy and battery storage (DMRE, 2023b). Released for public review in July 2023 (DMRE, 2023b), the draft proposes short-to-medium term interventions for battery manufacturing and mineral beneficiation of Li-Ion batteries. While the long-term potential for cell manufacturing is acknowledged, its viability in South Africa is uncertain. Political and economic factors, not within the master plan's scope, may impact industrial development.

The draft SAREM stresses alignment with other plans like the 2019 Automobile Master Plan, the 2021 Steel Master Plan, and the ongoing Battery Minerals Master Plan. It advocates for synergy between renewable energy, battery storage, and existing industrial policies. Quantifiable targets are yet to be defined and are expected in the final version. Despite the IRP 2019 setting stand-alone energy storage targets of 2.1GW by 2030, there is no comprehensive government policy for broader applications (Broughton & van der Walt, 2022). Positive signals for the battery storage market are lacking, and while energy storage imports are increasing, local policy remains limited in South Africa.

2.3.3. *Proposition 2*

Research objective #2	Identify the barriers and solutions for South Africa to participate in the global battery energy storage value chain.
Proposition 2 (P2)	Lack of policy, regulation and standards, market scale, skills and international partnerships, and high capital costs, are key barriers preventing South Africa from participating in the global battery energy storage value chain.

2.4. Third research objective: Explore the key factors that battery manufacturers consider when entering a new battery energy storage market such as South Africa

This section draws on the available academic literature on factors influencing business models that enable successful battery deployment, such as policy support, market demand and incentives, and other factors. This section also highlights the barriers-solution framework which was applied to the exploration of BESS business models in Hawaii.

2.4.1. *Policy support to enable a new industry*

The literature shows that new battery storage projects require policy support to be viable (de Sisternes et al., 2019; Jindal & Shrimali, 2022; Retna Kumar & Shrimali, 2021a). A study by Jindal and Shrimali (2022) found that renewable energy coupled with battery storage is financially attractive compared to building new coal-fired power stations in India. Similar research studies in South Africa have had the same findings (Fourie, 2018; Van Der Walt, 2017). Like South Africa, India is reliant on coal power plants, and attempting to adopt more renewable energy.

Jindal and Shrimali (2022) recommended that for India, given that renewable energy plans and administration are captured in regulations referred to as a renewable portfolio standard (RPS), battery storage should also have a regulation to capture storage targets, plans and administration, and could be referred to as battery portfolio standard (BPS). Jindal and Shrimali (2022) posit that regulation such as a battery portfolio standard under-pinned by policy transparency, certainty, and longevity, could enable BESS adoption and industry development.

2.4.2. *The main drivers to business models adopted for grid-scale battery energy storage projects*

Retna Kumar and Shrimali (2021a) undertook a study on Hawaii, a group of islands in western part of the USA, which aimed to understand the main barriers and drivers to business models adopted for grid-scale battery energy storage projects deployed in Hawaii. The research built on the application of the barrier-solution framework, developed by the same authors in an earlier study done in California, USA (Retna Kumar & Shrimali, 2021b). The barrier-solution framework hypothesis suggests that battery storage business models or projects must overcome certain key obstacles to ensure successful deployment. It is a framework that can aid policymakers in understanding barriers faced by projects and how to address them. According to the study by Retna Kumar and Shrimali (2021a) the barrier-solution framework consists of three main barrier categories which are as follows:

- Barrier Category 1: Absence of significant market (demand).
    - B1.1: Lack of short-term (1–4 years) market (demand).
    - B1.2: Lack of long-term (5–10 years) market (demand).
- Barrier Category 2: Lack of favourable project economics.
    - B2.1: High cost of storage with respect to the main revenue stream.
    - B2.2: Lack of multiple revenue streams to overcome the high cost of storage.
- Barrier Category 3: Physical/administrative hurdles to project feasibility.
    - B3.1: Lack of market(s) or well-functioning market mechanisms to provide one or more grid services.

- B3.2: Lack of permitting/interconnection process.

Retna Kumar and Shrimali (2021a) hypothesise that to address barrier categories 1 and 2, one sub-category must be overcome, and for barrier category 3, both sub-categories must be overcome. The authors applied this framework to grid battery storage projects and their associated business model used in Hawaii and California. The study in Hawaii (Retna Kumar & Shrimali, 2021a) found three business models for battery energy storage, similar to the earlier study by the authors conducted in California (Retna Kumar & Shrimali, 2021b).

The findings of the study revealed that Hawaii's initiatives to implement dispatchable renewable generation projects enabled co-located FTM battery storage projects using competitive bids and innovative contract structures. The BTM installations in Hawaii were driven by the need for energy bill reduction and financial incentives through an Investment Tax Credit. Hawaii's net energy metering (NEM) program and utilities' specialised programs helped to deliver grid services. This study applied the barrier-solution framework as well as collected data from battery manufacturers and key stakeholders to gather deeper insights and different perspectives on barriers and solutions to battery cell production and assembly in the South African context.

2.4.3. *Proposition 3*

Research objective #3	Explore the key factors that battery manufacturers consider when entering a new battery energy storage market such as South Africa.
Proposition 3 (P3)	The success of battery manufacturers' business models requires supportive policy, market demand, favourable project economics and revenue, effective and functioning market

	mechanisms and permitting processes.

2.5. Conclusion of Literature Review

This literature review provided background information on BESS technology, the global battery value chain, as well as the typical battery manufacturing process. The chapter also surveyed existing literature on the barriers and solutions for battery manufacturing for consideration in relation to the South African context. The main research objectives and propositions are laid out in Table 5.

Table 5: Consistency table: Research objectives and propositions

RQ #	Research Objective	Prop #	Proposition
1	**Determine the benefits South Africa would derive from adopting more battery energy storage.**	1	With growing adoption of batteries in South Africa, battery energy storage has a wide range of benefits and a positive role to play in the country by supporting grid stability, deployment of renewable energy, job creation and economic growth.
2	**Identify the barriers and solutions for South Africa to participate in the global battery energy storage value chain.**	2	Lack of policy, regulation and standards, market scale, skills and international partnerships are the key barriers and challenges preventing South Africa from

			participating in the global battery energy storage value chain.
3	**Explore the key factors that battery manufacturers consider when entering a new battery energy storage market such as South Africa.**	3	The success of battery storage business models requires supportive policy, market demand, favourable project economics and revenue, effective and functioning market mechanisms and permitting processes.

CHAPTER 3. RESEARCH METHODOLOGY

This chapter outlines the methodology used for investigating the propositions derived from the literature review. It covers key elements including the research design adopted, the study population, sampling, the research tools utilised, and the data collection and analysis procedures undertaken. Additionally, this section delves into research credibility, ethical considerations, and limitations.

3.1. Research approach

This research adopted a qualitative approach to explore both international and local battery manufacturers', and other key stakeholders', perceptions of the barriers and solutions to battery manufacturing in South Africa. Qualitative research prioritizes the quality of data over quantity (Rozakis, 2004). This method can facilitate the collection of diverse viewpoints and explanation of varied propositions (Silverman, 2013).

The research focused on obtaining perspectives from battery manufacturers as key stakeholders with expertise and sufficient experience in manufacturing battery cells and on deploying battery assembly plants. Qualitative research operates on the assumption that diverse perspectives exist among individuals and groups. It underscores the importance of context in understanding behaviours and experiences, offering adaptability in methodology, and is thus suitable for an exploratory study. The research approach focused on in-depth research and valued participant input (Creswell, 2003).

3.2. Research design

Qualitative research was well-suited for examination of the views of battery manufacturers regarding barriers and solutions for enabling manufacturing in new countries or markets like South Africa (Rozakis, 2004; Silverman, 2013). Qualitative research facilitates comprehension of contextual factors that influence manufacturing, accommodating the dynamic nature of the globally connected battery energy storage industry. Moreover, qualitative research is suitable since it encourages open dialogue with participants.

3.3. Data collection methods

Interviews, as a data collection method, provide a formal means of engaging with individuals or groups to solicit information primarily through the art of questioning. Interviews can take various forms, including in-person, telephonic, email, or virtual interactions (Rozakis, 2004). Semi-structured interviews were used for data collection in this study. While in-person interviews are considered optimal, technological advancements facilitate virtual or online meetings, expanding participation opportunities beyond local geographies, in this case South Africa, and this mode was adopted for this research (Gerson & Damaske, 2021). Interviews are pivotal in primary research as they offer the means to gain insights and valuable data from knowledgeable participants, enhancing the credibility of the research (Gerson & Damaske, 2021; Rozakis, 2004). The research instrument used to conduct one-on-one online interviews was an interview guide. Online interviews offer the advantage of communication with participants that are located anywhere in the world, which was particularly relevant for this study considering the absence of large-scale battery manufacturing in South Africa, and the limited presence of manufacturers in the country.

Semi-structured interviews were held with fourteen officials deemed to have vast experience in battery manufacturing or manufacturing related industries. Most of the participants possessed more than ten years of experience working in the battery manufacturing sector and this enhanced the validation and reliability of the information. Each interview lasted on average, 45 minutes, thus giving participants enough time to provide information relevant to the study.

3.4. Population and sample

3.4.1. *Population*

Sampling determines who is likely to provide robust and honest information and should participate in the study (Salmons, 2015). A sample of battery manufacturers which represents the larger research population of global battery manufacturers was selected. The sampling strategy included purposive sampling, that is, intentional selection of participants to be interviewed. Purposive sampling is a non-probabilistic sampling technique used in qualitative research. In this sampling method, the researcher deliberately selects participants or cases based on specific criteria that are relevant to the research question or objectives (Salmons, 2015).

In this study, the criteria for selecting research participants included:

- Industry professionals focusing on battery manufacturing, cell production or assembly companies, with a few additional participants including those from the energy utility company and key associations, financiers, and policymakers.
- A representative of either a battery cell producer or cell assembly company involved in manufacturing of Li-ion batteries technology.
- Participants that have experience in the Li-ion batteries industry or energy industry.
- Professionals with at least a university degree.
- Ability to speak in English.

The aim was to conduct interviews with at least 12 participants. In all, 14 participants were interviewed. A general check was performed on the experience of each participant and whether they met the criteria above by consulting online profiles such as on LinkedIn, or any publications and documents published by the participant (Rozakis, 2004).

3.4.2. *Sample and sampling method*

A total of 14 participants were interviewed as outlined in Table 6. There are more than 100 known battery manufactures in China alone where the top ten companies had more than 86% market share in 2022 (Smartpropel, 2023). Therefore, purposive sampling of up to three of the top ten global manufacturers, should allow for a representative sample. In addition, interviews were also conducted with representatives of at least two of the existing Li-ion assembly companies that are present and active South Africa. Furthermore, interviews were conducted with representatives from the electricity utility, the energy department of the government, academic research institutes, and a funding institute, to obtain diverse views on the subject. The sample size of 14 was deemed appropriate because of the qualitative nature of the research to collect in-depth views from a sample of participants with a focus of quality over quantity (Gerson & Damaske, 2021). Furthermore, practical considerations such as availability of participations and the research to conduct interviews played a role in the sample size.

Table 6: Profile of participants

Description of participant type	Number interviewed
Global Li-ion Battery Manufacturers not present in South Africa	5
Li-ion Battery Assembly active in South Africa	2
Government: Local electricity utility company of South Africa	2
Research institutes	2
Government: Policymakers	2
Financial institute	1

Total number of participants	**14**

3.5. The research instrument

A semi-structured questionnaire was used as the data collection instrument in this study. The interview guide presented in Annexure A served as a framework for the semi-structured interviews. The interview questions were guided by the literature review and each part of the questionnaire addressed a specific issue in the research. Use of a semi-structured questionnaire allowed for probing of participants' responses on specific topics and on issues related to the South African context.

3.6. Procedure for data collection

Participants were contacted over either LinkedIn, email, or telephone, and by sharing an introductory letter to establish trust and credibility (Gerson & Damaske, 2021). Interviews were conducted via Microsoft Teams, with automatic transcription which produced verbatim transcripts of the interview. The interview style was conversational, using open-ended questions (Gerson & Damaske, 2021); Silverman, 2013). Online interviews, while advantageous, present certain challenges such as reduced intimacy compared to in-person interactions (Salmons, 2015). Notwithstanding, the method utilised in this research was deemed both effective and appropriate for the investigation.

3.7. Data analysis and interpretation

Data analysis was conducted through thematic analysis and using ATLAS.ti software to code and sub-code data. The auto-transcribed text underwent editing and cleaning. The analysis systematically followed the thematic process as outlined by (Creswell, 2003) and illustrated in Figure 15.

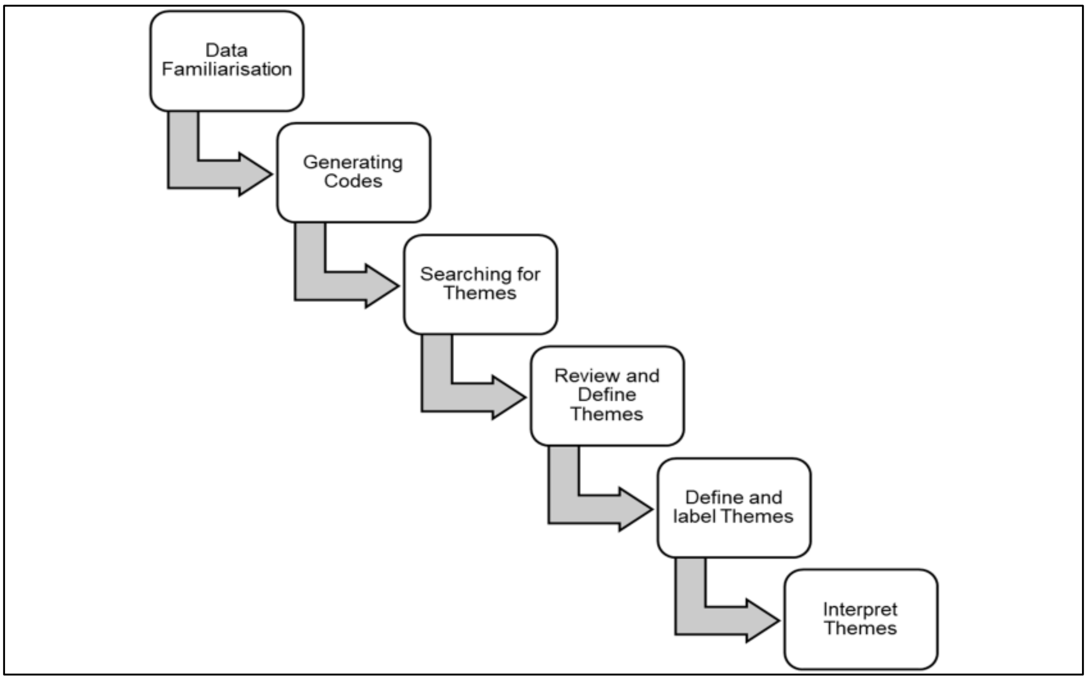

Figure 15: Thematic analysis process followed in the study

Source: (Creswell, 2003)

This method facilitated the systematic organisation of data for in-depth analysis. All interview responses were imported into *ATLAS.ti 23* software which is one of the leading coding software suitable for this type of data analysis (Barry, 1998; von Soest, 2023). The data was coded, and themes were created to understand the patterns. Thematic analysis assisted in analysing the substance of the participants' comments as well as the underlying trends in the data. Thematic analysis was done to find, examine, and present patterns or themes in the dataset of written or visual data (Peel, 2020). The data analysis entailed meticulous classification and categorisation of data to enable identification of reoccurring themes, concepts, or ideas. The themes were further defined and grouped according to their similarities in the *ATLAS.ti 23* software. Interpretation was done using network diagrams and tables using both *ATLAS.ti 23* software and excel to illustrate the results.

The analysis ensured the anonymity of participants by attaching descriptors to their data, such as P1/14, denoting participant one out of fourteen (total).

3.8. Limitations of the study

- Data was limited to only that from companies involved in Li-Ion technology who were consulted.
- In certain circumstances, participants were unavailable or reluctant to divulge information that contradicted the interests of their respective organisations.
- There were language barriers as many international battery manufacturers were in China and other parts of Asia.

3.9. Trustworthiness

3.9.1. *Transferability*

Transferability entails determining how easily research findings may be applied to different contexts and populations of individuals who are not identical to those who participated in the initial study (Silverman, 2013). The point of this qualitative study was not to find out if the results can be replicated. Instead, the study sought to give a full description of the sample and the research setting so that other researchers could figure out how the findings might be useful in other contexts.

3.9.2. *Credibility*

Credibility is whether the inferences made by the research are supported by the data and sensible (Silverman, 2013). According to Silverman (2013, p 286), “there is no golden key to credibility”. Silverman (2013) suggested five ways to establish credibility of the research which were considered during data analysis in this study and include the following:

- Application of the referability principle, which relates to avoiding rushing to conclusions.
- Adopting the constant comparative method which entails considering other cases to test the hypotheses.
- Repeated inspection of the data.
- Appropriate tabulations and avoidance of over-simplified tabulations.

Deviant case analysis to consider outliers, anomalies, and exceptions. Cases that did not support established associations were identified. An exercise was conducted, early on, after a few interviews had been conducted and transcribed, during which (i) a dataset was selected from the interviews; (ii) the number of themes related to the research propositions were counted; and (iii) assessment was done on what the data can show and what associations could be established from it. All interviews were recorded and transcribed to increase accuracy of data collection. Participants were asked to check that the transcripts recorded their views correctly. A copy of the research report was offered to all participants and their feedback on the findings of the report was welcomed.

3.9.3. *Dependability*

Dependability refers to the degree of consistency in the categories achieved by different observers. Dependability was achieved by documenting procedures followed during data collection and video recording of the interviews (Silverman, 2013). The transcripts were checked and rechecked to ensure they reflected what was expressed by participants.

3.9.4. *Confirmability*

On-going researcher self-reflection was undertaken to determine if any bias existed (Creswell, 2003). The researcher is an active professional in the field of battery energy storage and was therefore aware of maintaining objectivity during the research and data collection process. The interview transcriptions were shared with participants to validate the accuracy and interpretation of the data, with participants invited to confirm or provide corrections to the interpretations offered.

3.10. Ethical considerations

Yin (2009) emphasises that a study that involves human interactions should explain how the human subjects will be protected. Bless, Higson-Smith, and Sithole (2013) argued that the responsibility of ensuring that participants are protected against abuse, or any form of risk lies with the researcher. It was therefore deemed important to obtain ethical clearance from responsible authorities representing various participants in this study. In addition to ethical clearances, the following were maintained throughout the study:

- Clear explanation of the purpose of the study to ensure it was understood by the participants.
- Obtaining informed consent from all participants or organisations in the study.
- Maintenance of participants' privacy and confidentiality.
- Provision of the platform for- and respect of the decision of any participant to withdraw from the study.
- Assurance to participants that the information they provided was to be used for research purposes; and
- Protection of data by storage on a password-protected computer and a password-protected cloud format.

To ensure the ethical conduct of this research, informed permission was acquired from participants. Consent was sought for online interviews, with sensitivity to potential privacy and confidentiality concerns. In cases where participants declined recording or use of video, handwritten transcription was done (Gerson & Damaske, 2021). Formal consent was obtained prior to conducting each interview using a consent form (Annexure B) that was signed by participants. The research aims were explained, and participants informed that they had the right to withdraw at any time during the interview. Confidentiality safeguards were strictly implemented, including data anonymisation, secure storage, and restricted access. To guarantee conformity with the University's ethical requirements, an ethical assessment and approval by the university's ethics committee was obtained as contained in Annexure C. The researcher was employed in the energy sector this was disclosed to participants during interviews.

3.11. Consistency table

Table 7 illustrates how the data collection and analysis method are aligned with the previously stated research objectives and their respective propositions to demonstrate that the research is aligned and coherent.

Table 7: Consistency table: research questions, propositions, data collection and data analysis

RQ #	Research Objective	Prop / hyp #	Proposition	Data collection detail	Data analysis method
1.	Determine the benefits South Africa would derive from adopting more battery energy storage.	1	Battery energy storage has a wide range of benefits and a positive role to play South Africa, by supporting grid stability, deployment of renewable energy, creating jobs and economic growth.	Open-ended interview using semi-structured questionnaire.	Thematic Analysis using ATLAS.ti software.
2.	Identify the barriers and solutions for South Africa to participate in the global battery energy storage value chain.	2	Lack of policy, regulation and standards, market scale, skills and international partnerships are the key barriers and challenges preventing South Africa from participating in the	Open-ended interview using semi-structured questionnaire.	Thematic Analysis using ATLAS.ti software.

RQ #	Research Objective	Prop / hyp #	Proposition	Data collection detail	Data analysis method
			global battery energy storage value chain.		
3.	Explore the key factors that battery manufacturers consider when entering a new battery energy storage market such as South Africa.	3	The success of battery manufacturers and investors business models requires supportive policy, market demand, favourable project economics and revenue, effective and functioning market mechanisms and permitting processes.	Open-ended interview using semi-structured questionnaire.	Thematic Analysis using ATLAS.ti software.

3.12. Conclusion

This chapter elaborated on the research methodology employed during the research process. The chapter presented an overview of the qualitative research strategy and the research design adopted, and the data gathering and sampling techniques employed. Additionally, the limitations associated with the chosen research approach, the ethical considerations observed, strategies adopted for data analysis, and the maintenance of research quality standards and ethics were discussed.

CHAPTER 4. FINDINGS AND DISCUSSION

4.1 Introduction

This chapter outlines the perceptions of the research participants on the benefits, barriers and solutions towards manufacturing and adoption of BESS in South Africa (SA) for acceleration of a just energy transition and increased electricity reliability. The findings presented in this chapter are based on the views of the 14 experts interviewed during the study.

4.2 Demographic profile of respondents

Interviews were held with officials possessing vast experience in the battery manufacturing industry. On average, the participants boasted more than 10 years of experience working in this sector, which enhanced the validity and reliability of the information they shared. Each interview lasted on average 45 minutes, giving participants enough time to provide more information relevant to the study and ensuring that all questions were answered. Table 8 presents the participant demographic profiles. Semi-structured interviews were conducted with representatives of five global battery cell manufacturers, two BESS assembly companies present in South Africa, and seven key local stakeholders including government, policymakers, research institutes and a financial institution.

Table 8: Interviewees demographic information

Source: Author

Respondent	Role/Sector	Qualifications	Age (years)	Experience (years)
1	Battery cell manufacturer	First degree	40-49	8
2	Battery cell manufacturer	Postgraduate	30-39	9

Respondent	Role/Sector	Qualifications	Age (years)	Experience (years)
3	Battery cell manufacturer	Postgraduate	50-60	20
4	Research Institute	Master's degree	30-39	10
5	BESS assembly company present in South Africa	Master's degree	30-39	2
6	Government	Master's degree	40-49	8
7	Financial institution	Postgraduate	50-60	23
8	Research Institute	First degree	40-49	14
9	BESS assembly company present in South Africa	Honours degree	30-39	4
10	Government	Matric	40-49	3
11	Battery cell manufacturer	Postgraduate	40-49	11
12	Government	Master's degree	50-60	33
13	Government	First degree	50-60	9
14	Battery cell manufacturer	Postgraduate	40-49	10

The majority of respondents held postgraduate qualifications and many had vast experience in the sector, with one respondent having 30 years' experience in the field. von Soest (2023) observed that having participants of sufficient experience and relevant qualifications in the field strengthens or validates the correctness of the information they provide. Similarly, the findings presented below are considered informed and reliable, having been derived from the perspectives of educated and experienced respondents.

4.3 Codes and main themes from the data

Based on the output from the software used, there were seven themes associated with 47 codes that emerged from the data as listed in Table 9. The most frequent codes related to battery manufacturing in South Africa include policy uncertainties, insufficient battery demand, slow adoption in SA, lack of skills and labour for manufacture, cost competitiveness to produce in SA, intellectual property rights, uncertain market conditions in Africa, and the need for partnership and collaboration. These codes are highlighted in bold in the table. The code with the highest frequency suggests that these issues are most prevalent, and they were mentioned by most of the respondents. The most prevalent theme was on benefits and barriers to battery manufacturing in SA.

Table 9: Codes and their related themes

Source: Author

Code group/Theme	Associated codes	Grounded / Frequency
Adoption	1. Massive adoption in SA	3
	2. SA leading in Africa	1
	3. Slow adoption in SA	**5**
Benefits	4. Batteries are part of the future energy mix	1
	5. Grid stability	2
	6. Lots of pros than cons in manufacturing	1
	7. Batteries can help manage excess renewables	1
	8. Manufacturing in an opportunity for SA	1

Code group/Theme	Associated codes	Grounded / Frequency
	9. Provide hybrid energy solution	1
	10. Useful in energy storage	1
	11. SA has key minerals for battery production	2
	12. Logistical advantages in SA	1
Barriers	13. Batteries are expensive	2
	14. Expensive to manufacture	1
	15. Raw material supply constraints	1
	16. SA lack capacity	2
	17. SA lack skills and labour to manufacture	**4**
	18. No government support of battery manufacturing	2
	19. Instabilities like electricity supply and market structure	1
	20. Technology barriers	1
Market barriers	**21. Insufficient demand of batteries in Africa to setup local manufacturing**	**4**
	22. Market is uncertain in Africa	**4**
Factors perceived as important to manufacturers	23. Electrochemical battery appropriate for SA	1
	24. Need for clear vision in adoption.	
	25. Need for relevant technology.	1
	26. Need for skills individuals.	2
	27. Need for value adding	**4**
	28. Need to recycling batteries	1
	28. Need for incentives	1
	30. Continuous investment in research	1
	31. Assessment of intellectual property	**5**
	32. Securing patents for unique technologies	1
	33. Government to lead	2
	34. South Africa to draw lessons from Australia.	1
	35. Need for investors	1
	36. High risk of theft of batteries	1

Code group/Theme	Associated codes	Grounded / Frequency
Perceived Risks by manufacturers	**37. Policy uncertainties**	**4**
	38. Safety in logistics	1
	39. Battery tariff uncertainty	1
Stakeholders buy-in	40. Lack of enabling policy	1
	41. Lack of understanding from government	1
	42. Need for government to lead	1
	43. Need for partnership and collaboration	**5**

4.4 Findings and discussion pertaining to RO 1: Benefits South Africa would derive from adopting more battery energy storage

4.4.1 *Benefits South Africa would derive from adopting battery energy storage*

As the first objective, the study seeks to determine the benefits South Africa would derive from adopting battery energy storage. This research objective aligns well with salient aspects of the existing literature, which underscores the multifaceted advantages batteries can provide. As outlined by Van Der Walt (2017), Ogunniyi and Pienaar (2017), Fourie (2018) and Customised Energy Solutions (2023), battery energy storage systems can contribute significantly to various aspects of South Africa's energy landscape. Battery energy storage systems can help stabilise the grid by providing frequency regulation and voltage support, thus enhancing the reliability of electricity supply. Given that South Africa has significant renewable energy potential, particularly solar and wind, batteries would enable the integration of renewable energy sources into the grid by storing excess energy during periods of low demand or high generation and releasing it during peak demand periods or when renewable generation is low (Van Der Walt, 2017). Furthermore, battery energy storage could assist in maintaining electricity supply or by providing electricity when there is lack of supply, and through supporting renewable energy deployment and associated job creation. Customised Energy Solutions (2023) states that strategic deployment of BESS could assist in addressing the nation's energy challenges and contribute to a more stable and sustainable energy future. This observation is supported by the response from Participant 1/14 who argued that:

> *"Batteries will form part of future energy mix, they are very diverse in the functionality, …they play many different roles and … have been not historically valued in the power system." Participant 1/14*

Furthermore, Participant 5/14 said*:*

> *"…I believe the benefit outweigh all the negatives that we need to put in place to establish these [battery] facilities in South Africa." Participant 5/14*

In addition, storing energy during off-peak hours when electricity rates are lower and discharging it during peak hours when rates are higher can help reduce overall energy costs for consumers and utilities. Fourie (2018) based on a Levelized Cost of Storage (LCOS) model as discussed earlier highlighted the sustainability and cost effectiveness of pairing solar PV with utility-scale energy storage technologies compared to fossil fuels-based electricity generation.

Furthermore, battery storage systems have the potential to provide backup power during grid outages, which is critical for industry, hospitals, and other essential services. This enhances the resilience of the electricity supply infrastructure, as supported by Broughton and van der Walt (2022) who argued that batteries can provide continuity and reliability of electricity during periods of insufficient power supply or load-shedding. Meanwhile, the respondents acknowledged that battery storage adoption would come with a lot of pros and cons when it comes to manufacturing batteries locally. Benefits identified by participants as related to adoption of batteries are presented in Figure 16 below.

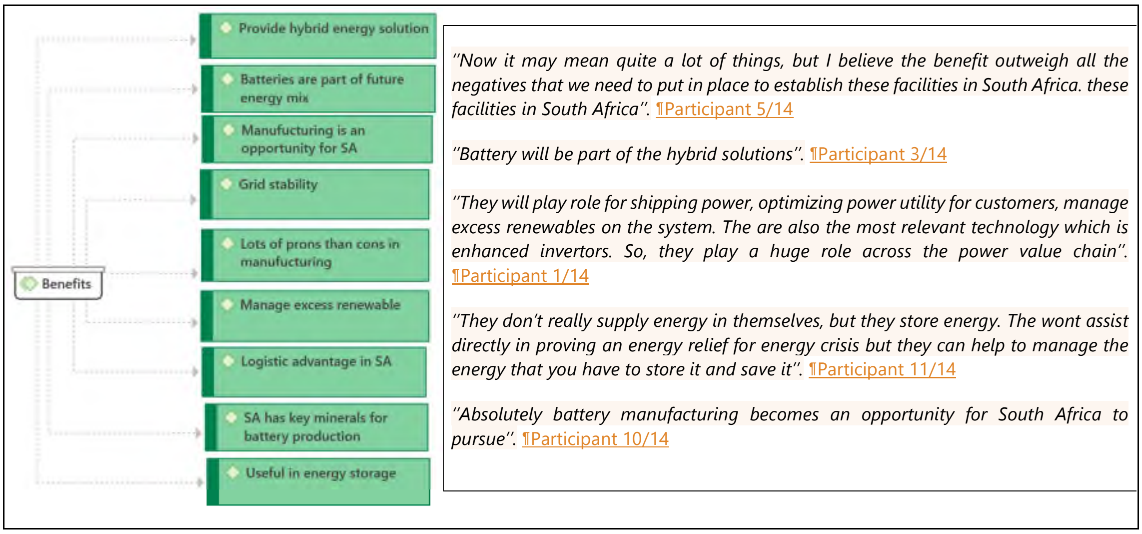

Figure 16: Findings from the research on benefits of battery energy manufacturing in SA and their associated codes

Source: Author

Key to highlight is that, as indicated by the respondents, batteries cannot fix the South African electricity supply crisis and loadshedding as batteries can store electricity but do not generate it. This important contribution and benefit were also highlighted by Customised Energy Solutions (2023). The local availability of minerals required for manufacturing BESS, such as vanadium, nickel, manganese, and cobalt, in South Africa means that refining of pre-cursor materials is an opportunity and could be a competitive advantage for the country (Customised Energy Solutions, 2023), including in enabling deployment of BESS in the country.

4.4.2 *Pace of adoption of batteries in South Africa*

Beside these stated benefits, respondents held contradictory perspectives on the pace of battery energy storage adoption in South Africa. Two participants said there was massive adoption of batteries, most participants (eight) said the adoption pace was slow, while some indicated that the pace of adoption is beginning to grow. Figure 17 shows a network diagram with codes and quotes from participants on their perceived view of the pace of battery adoption in South

Africa. Generally, most participants perceive that the country is witnessing slow but growing pace of adoption of batteries.

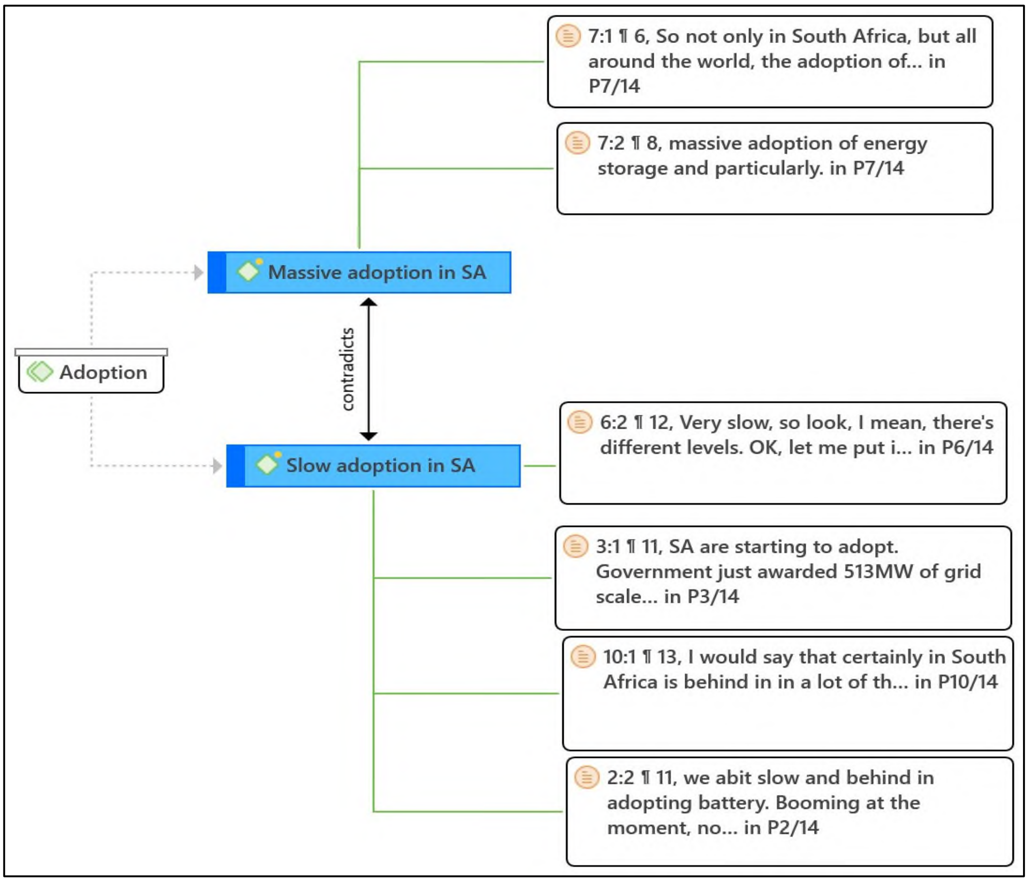

Figure 17: Respondents perception on the adoption of battery energy storage

Source: Author

South Africa registered the highest frequency of load shedding in 2023, the same year in which available data shows that the country's imports of Li-ion batteries, were at an all-time high of $1.75-billion or 3.8 GW to 5 GW (Engineering News, 2024). Some participants indicated that an increase in load shedding has resulted in an increase in the use of batteries and invertors for back-up power across commercial, industrial, and residential sectors. Despite predictions of South Africa having a small share of the global battery market by 2030, various authors have argued that batteries coupled with renewable energy is an appropriate technology for the country (Fourie, 2018; International Institute for Sustainable Development, 2023; Thango & Bokoro, 2022; Van Der Walt, 2017).

4.5 Findings and Discussion pertaining to RO 2: The barriers and solutions for battery manufacturing in South Africa

Considering the benefits and positive impact that BESS could potentially bring to South Africa, research objective 2 aimed at identifying the barriers and solutions for South Africa’s participation in the global battery energy storage value chain. Existing literature revealed various potential barriers to battery manufacturing in the country, including lack of policy, regulation and standards, market scale, and limited skills and international partnerships (Broughton & van der Walt, 2022; Customised Energy Solutions, 2023; Retna Kumar & Shrimali, 2021a; Sioshansi, Denholm, & Jenkin, 2012). Perceptions of the participants on key barriers are shown in Figure 18, with these largely aligned to the above-mentioned barriers as identified in the literature. The most frequently coded themes included lack of skills and labour for the manufacture of batteries, and lack of government support for battery manufacturing initiatives and facilities. The section which follows elaborates.

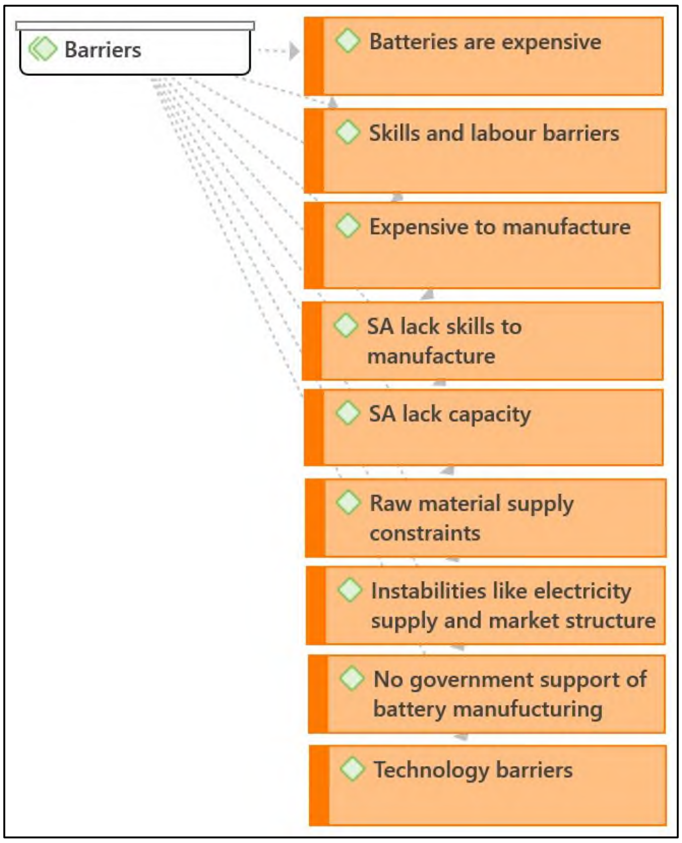

Figure 18: Participants' perceptions of the barriers to battery manufacture in South Africa

Source: Author

4.5.1 *Market barriers*

Manufacturing of batteries in South Africa faces several market barriers that hinder the development and growth of the industry. Findings by Broughton and van der Walt (2022) on utility-scale energy storage or FTM applications in South Africa, corroborated by Jindal and Shrimali (2022), and arguing that cost and policy are the biggest barriers, found resonance with Participant 1 who argued that:

> *"…the entire [battery] market size and the power utilities are full [of] uncertainties even in terms from policy level….". Participant 1/14*

Perceived limited domestic demand for batteries in South Africa is a challenge which may discourage investment in manufacturing facilities for battery cells or components of the battery, such as BMS related manufacturing facilities. This perception often stems from concerns about market demand uncertainty and the lack of awareness of the potential applications and benefits of battery technology within the country.

Additionally, the high initial investment costs and the absence of a well-established local supply chain for battery components contribute to the overall market barriers, as supported by the views of Participant 2 who stated that:

> *"The problem is the question of costs of batteries, will they be cheaper to produce? Although there might be initiatives, the market barriers are not avoidable, provided also the cost of electricity being a sensitive issue in South Africa. I think there are many barriers to manufacture in South Africa." Participant 2/14*

Without robust domestic demand and supportive market conditions, manufacturers have been reluctant to establish production facilities in South Africa, further exacerbating the challenge of building a sustainable battery manufacturing sector. Furthermore, regulatory and policy uncertainties, along with competition from established global manufacturers, pose additional barriers to entry into manufacturing locally. Unclear regulations, tariffs, and trade barriers can create obstacles for companies looking to establish battery manufacturing operations in South Africa. Moreover, competing with well-established global manufacturers, particularly from countries with mature battery industries such as China, presents a significant challenge for local companies. Most participants indicated that the market demand for batteries in South Africa and Africa is uncertain. This corresponds with the views of Retna Kumar and Shrimali (2021a, 2021b) who postulate that a lack of short term (1-4 years) and long term (5-10 years) market demand for batteries is a key barrier to the success of battery services business models as observed in other parts of the world such as California and Hawaii. Some participants emphasised that to create a battery cell manufacturing plant, large-scale and continuous demand is required. Other participants were of the view that beside South Africa, there is no major demand for batteries in Africa or regionally. Furthermore, participants mentioned that there was no data on projected demand for the region to guide investors.

4.5.1.1 Solutions to market barriers

Participants indicated that a clear policy, plan, and vision for adoption of batteries and demand projections should be developed by the government. Participants suggested that entities such as the DMRE, Department of Trade, Industry and Competition and the Department of Science and Innovation should lead this activity. Furthermore, one participant suggested that regional demand in Southern Africa should be investigated further. Some participants suggested that existing policy such as the SAREM should set out the need and plan for battery adoption in South Africa.

Two participants highlighted that partnership between automobile and electric-vehicle (EV) companies could be a successful strategy for South Africa, considering that the country has an established automobile manufacturing and assembly industry. This is a global trend observed in the USA, for example, where it has been observed that automobile companies such as Ford and General Motors are partnering with battery manufacturers such as Tesla, leading to creation of jobs (Tishman et al., 2022). For South Africa, such partnerships would require first an EV policy and promotion of such partnerships by government. Already, projections by point to possible growth in the local battery storage market of up to 15 GWh by 2030 largely driven by electrical vehicles, giving credence to participants' views on the significant potential of automobile and electric-vehicle (EV) company partnerships(Customised Energy Solutions, 2023).

Furthermore, the value of batteries in the provision of "stacked services" need to be recognised. Currently batteries are seen as a generator or load. A market mechanism is needed that recognises the stacked services that batteries can provide as argued by several researchers (Broughton & van der Walt, 2022; Customised Energy Solutions, 2023; Shuai & Raufer, 2021; Van Der Walt, 2017).

Respondents from battery manufacturers also raised the need for value addition to be recognised. This relates to the various services that batteries offer which, respondents argue, need to be recognised and accounted for in market or tariff structures. For example, the current electricity tariff it not adapted to cater for battery storage charges or rebate. The barrier-solution framework propounded by (Retna Kumar & Shrimali, 2021b), identifies the lack of market(s) or well-functioning market mechanisms to provide one or more grid services, as key challenge for grid-scale battery energy storage projects. Furthermore, as argued by Broughton and van der Walt (2022), the stacked benefits of energy storage services are not compensated and this can discourages investment. This suggests the need for market structure and tariff reforms in the BESS system adoption, as proposed by the study respondents.

4.5.2 *Financial / Cost barriers*

The high cost of Li-ion batteries is a well-known barrier to their widespread adoption. The battery cell itself represents a significant portion of the overall cost of the BESS rendering them expensive for both manufacturers and end-users. This cost was identified as a barrier within the South African context from interviews held with BESS manufacturers. According to Broughton and van der Walt (2022) and Jindal & Shrimali (2022), tariffs that penalise energy storage influence the economic viability of energy storage projects. This align with the views of Retna Kumar and Shrimali (2021b) who argued that the high cost of storage is a key barrier to the success of battery storage projects. In addition to the cost of raw materials, manufacturing batteries entails high capital and operational expenses.

As outlined earlier, establishment of a gigafactory requires significant capital investment, which could impact the competitiveness of South African manufacturers in the global market. Establishing and operating battery manufacturing facilities requires significant investments in infrastructure, equipment, and skilled labour which the study found South Africa still lacks. Participant 4 argued:

> *"There are no investors yet in SA to venture in battery manufacturing industry. Without sufficient investment, local manufacturers may struggle to scale up production and innovate, hindering the development of robust battery industry." Participant 4/14*

Most participants were sceptical on whether battery cells, or BESS can be produced in South Africa at the same price or cheaper than in China. Furthermore, the findings show that South Africa may face challenges in securing a stable and cost-effective supply of the raw materials required to produce a battery, as they are globally distributed, although the country has some minerals such as manganese. The battery value chain is geographically dispersed, battery minerals or raw materials are sourced from in several parts of the world, while cell production is concentrated in China (Bridge & Faigen, 2022). Having to import raw materials can increase manufacturing costs, present supply chain risks, and leave the country vulnerability to market fluctuations, all of which would impact the competitiveness of battery manufacturing in South Africa. However, the fact that South Africa produces some of the raw materials needed to make batteries could ameliorate some of the challenges of battery manufacturing, while costs associated with manufacturing would have to include mining.

Limited manufacturing capacity, infrastructure investments, technology, and a constrained workforce in South Africa poses a significant barrier to scaling up battery production locally. Existing facilities may lack the scale and efficiency required to meet growing demand for batteries domestically and internationally. Increasing manufacturing capacity requires substantial development to overcome these constraints. According to DMRE (2023b), the SAREM draft policy suggests short- to medium-term interventions for Li-Ion battery manufacture and mineral beneficiation. Although cell manufacturing has been shown to have long-term potential, its viability in South Africa is uncertain. Economic and political variables outside the purview of the master plan could influence industrial development. However, despite high capital costs and these constraints, battery storage is playing a more prominent role in electrical power systems and demand for batteries is growing (Kebede, Kalogiannis, Van Mierlo, & Berecibar, 2022; Ogunniyi & Pienaar, 2017)

4.5.2.1 Solutions to financial barriers

Several participants mentioned the success of government incentives that promote manufacturing in other countries, as is the case in China. One solution was to create tax incentives that can promote local manufacturing. Another solution mentioned was provision of government subsidies for battery manufacturing. Furthermore, according to Customised Energy Solutions (2023) South Africa could expand mining of locally available battery minerals required for manufacturing BESS such as vanadium, nickel, manganese, and cobalt. The same study also recommends establishment of mineral refining hubs in South Africa for minerals such as lithium, nickel, cobalt, copper and graphite through strategic regional partnerships with African countries that possess such minerals, as identified earlier. The study further recommends consideration of production of battery precursor metals such as aluminium cathode foil and electrolyte additives (Customised Energy Solutions, 2023).

4.5.3 *Lack of a skilled workforce*

Developing a skilled workforce with expertise in battery manufacturing processes and technologies is crucial for building a competitive industry in South Africa. The shortage of skilled labour and technical expertise presents a significant capacity barrier, as manufacturers may struggle to recruit and retain qualified personnel in the country. Participants highlighted that producing a battery cell is a highly mechanised process, so skills in the field of mechatronics, robotics, artificial intelligence and electrical research and development are required.

4.5.3.1 Solutions to lack of skilled workforce

Investing in education, training, and workforce development programs can help address skills shortages and build local manufacturing capacity. Building a skilled workforce and fostering a culture of innovation are critical for the long-term success of battery manufacturing initiatives. Investing in education, training programs, and vocational courses helps develop a talent pool with expertise in battery manufacturing. According to one participant:

> *"Specialized training programs focused on battery manufacturing technologies are essential. These programs should cover areas like battery chemistry, manufacturing processes, quality control, and safety standards. Higher education institutions can play a vital role by offering courses and degrees specific to battery technology and renewable energy. Collaborations between universities and the battery industry for research and development can also foster innovation and provide practical training opportunity for students."* Participant 9/14

Participants emphasised that collaboration and partnership between government and cell manufactures is also a solution. Such partnerships could address lack of access to proprietary technology as well as enable access to IP (de Sisternes et al., 2019; Jindal & Shrimali, 2022; Customised Energy Solutions, 2023).

4.5.4. *Lack of policy and incentives*

All participants mentioned that there is a need for stronger government policy support to grow the battery manufacturing industry in South Africa. Barriers in this regard include a lack of explicit policy support for BESS adoption, incorrect classification of BESS within policy frameworks, absence of policies addressing battery manufacturing, inadequate incentives for energy storage development and deployment, and unclear guidelines regarding the provision of system services by energy storage systems (Broughton & van der Walt, 2022; Customised Energy Solutions, 2023; de Sisternes et al., 2019; Van Der Walt, 2017). These factors collectively contribute to an uncertain policy landscape, impeding the progress of BESS technology in South Africa's energy sector.

4.5.4.1 Solutions to lack of policy

The study found that a strategy for battery manufacturing or assembly facilities would be needed, as also found in the literature (Broughton and van der Walt (2022) Customised Energy Solutions (2023). This involves defining concrete goals and strategies to integrate battery technology into various industries such as the automotive, renewable energy, and consumer electronics sectors. With a well-defined vision, stakeholders can align their efforts and investments towards common objectives, fostering collaboration and synergy across the supply chain. This clarity of purpose also enables policymakers to develop supportive regulatory frameworks and incentives that encourage investment and innovation in battery manufacturing. Participants highlighted that South Africa would need a clear plan for manufacturing batteries and that government, led by agencies such as the DMRE and DTIC should lead these initiatives.

4.5.5 *Response rates and unanswered questions*

During the data collection process, BESS manufacturers and all other participants did not answer some specific questions. The unanswered questions and the frequency of non-responses are detailed below:

- Unanswered Question D1: What range of return on investment is required for a cell manufacturing factory to be economically feasible?
- Number of non-responses: Majority, thirteen participants.
- Possible Reasons: Commercially sensitive question therefore BESS manufacturers did not answer. Also, in a rapidly growing and competitive sector such as BESS, where feasibility studies are still being done, it is not easy to have accurately calculated return on investments. Once the sector reaches a certain maturity level, answers would emerge with accurate predictions on the return on investment expectations. Therefore, the conclusion would be that to have financially sustainable battery systems, it is important to ensure proper research and development to support the technology and financial sustainability of the manufacturers.

4.6 Findings and discussion pertaining to RO 3: Key factors that battery manufacturers consider when entering new battery energy storage markets such as South Africa

Research objective three explored battery manufacturers' perspectives on what factors they would consider salient when entering a new market such as South Africa, based on their experience in the battery cell and assembly industry in other parts of the world. Therefore, most of the respondents, seven out of fourteen comprised representatives of battery cell producers, battery system integrators or battery assembly companies. The research identified several factors considered important to battery manufacturers' consideration of expansion or set up in South Africa. The key factors are listed in Table 10 and explained in the subsequent discussion.

Table 10: Key factors that battery manufacturers raised as important consideration for battery manufacturing in South Africa

Source: Author

Key Factors
1. **Intellectual Property Protection**
2. Infrastructure Limitations
3. Raw Material Accessibility
4. Cost Control and Competitiveness
5. Comparison with China
6. Challenges in Market Entry
7. Recycling and Disposal
8. Government Policy and Investment
9. Market Potential by EV adoption and stationery storage
10. Suggestions for Development

1. **Intellectual Property Protection**: Manufacturers recognise the significance of protecting intellectual property, leveraging skilled individuals, adding value to products, and seeking government support and guidance. This is consistent with findings in the literature (Bican et al., 2023; Metzger et al., 2023; Reichman, 2009; Tishman et al., 2022)

2. **Infrastructure Limitations:** The existing transportation and logistics infrastructure in South Africa may not fully support large-scale battery cell manufacturing due to constraints in road, rail, and port capacities. Manufacturers must consider these limitations when planning production facilities.

3. **Raw Material Accessibility:** Manufacturers need to ensure easy access to necessary raw materials like manganese and lithium carbonate. Evaluating current and future battery demand is crucial for sourcing these materials efficiently, which aligns with research findings by Customised Energy Solutions (2023); Retna Kumar and Shrimali (2021a, 2021b). South Africa would develop mineral refining capabilities based on locally available minerals.

4. **Cost Control and Competitiveness:** Key considerations include cost control, competitiveness enhancement, and continuous investment in research and development. Initial capital expenditure for battery manufacturing is high, covering land, building, and manufacturing line costs.

5. **Comparison with China:** While South Africa has advantages such as abundant mineral reserves and potential growth in domestic demand, China's cost effectiveness advantage due to economies of scale poses a challenge. China's success in Li-ion battery manufacturing is attributed to substantial government support, supporting the development of local capabilities, and a robust supply chain ecosystem. This is consistent with existing literature (Broughton & van der Walt, 2022; Customised Energy Solutions, 2023; Rodrik, 2006) .

6. **Challenges in Market Entry:** Challenges related to market entry include government requirements for local ownership in battery storage programs and the need to assess demand, incentives, and government promotion of electric vehicles before entering new markets.

7. **Recycling and Disposal:** Recycling is not a significant cost for battery manufacturing, typically amounting to around 2% of capital expenditure.

8. **Government Policy and Investment:** South Africa's success in battery manufacturing depends heavily on government policy and significant investment from large international companies. Government support, particularly for utility-scale projects, is crucial for attracting manufacturers.

9. **Market Potential by EV adoption and stationary storage:** Despite challenges, South Africa has significant opportunities for battery storage and electric vehicle manufacturing. Recommendations include incentivising the transition to electric vehicles, stimulating domestic EV demand, refurbishing manufacturing facilities, and establishing a Gigafactory once sufficient demand is generated. SA should start with battery assembly, then system integration, then battery cell manufacturing, consistent with the recommendations by Customised Energy Solutions (2023).

10. **Development of battery minerals and refining sector:** Recommendations focus on leveraging mineral refining capabilities, fostering international collaborations, and balancing collaboration and intellectual property rights.

In summary, participants emphasised the need for strategic planning, government support, and international collaboration to overcome challenges and position South Africa for success in the battery manufacturing industry. Factors perceived as important to manufacturers and the themes most frequently identified included assessment of intellectual property, need for skilled individuals, need for value addition and government leadership in driving the adoption of battery energy storage systems. Manufacturers recognised the significance of protecting intellectual property, leveraging skilled individuals, adding value to products, and seeking government support and guidance in navigating the market and regulatory landscape.

Perceived risks by manufacturers and the most frequently identified theme was policy uncertainty, as discussed previously in Section 4.5.4. Lack of policy and incentives. Policy uncertainty emerged as a significant concern for manufacturers, highlighting the need for clarity and stability in regulatory frameworks to mitigate risks and facilitate investment and development in battery energy storage projects. Political barriers affect stakeholder buy-in, indicating potential obstacles related to government policies, regulations, and political dynamics that may hinder the advancement of battery energy storage initiatives in South Africa. Overall, the data suggests that while there is recognition of the importance of factors such as intellectual property protection, skilled workforce, and government leadership, challenges related to policy uncertainty and political barriers remain prominent concerns that need to be addressed to foster a conducive environment for the adoption of battery energy storage systems in South Africa.

4.6.1 *Risks and stakeholder buy-in*

Participants highlighted that energy storage projects typically require significant upfront capital investment, and there are financial risks associated with project financing, including cost overruns, revenue uncertainty, and return on investment. Changes in regulatory frameworks, policies, and incentives can impact the economics and viability of energy storage projects. Uncertainty about future regulatory developments, including tariffs, grid connection requirements, and market rules, can create risks for stakeholders and affect project feasibility. Energy storage projects depend on market demand for services such as grid support, peak shaving, and renewable energy integration (Broughton & van der Walt, 2022; Retna Kumar & Shrimali, 2021a). Fluctuations in electricity prices, demand patterns, and market dynamics can affect the revenue streams and profitability of storage projects, posing risks to investors and developers.

Additionally, partnerships between public and private stakeholders, along with international collaborations, can further drive the deployment of battery energy storage solutions in the country (Customised Energy Solutions, 2023).

Considerations related to countries leading in battery manufacturing, such as China, Japan and South Korea (Bridge & Faigen, 2022), also emerged. One respondent indicated that China has more than 15 cells manufacturers, because the domestic markets is big enough to make the business viable. Participant 1/14 said:

> *"Only three countries have the cell capability, China, Japan and South Korea only. That's how it's done, for lithium-ion batteries. Geographically, only RSA demand and projects may come. Need regional demand, not so easy right now without demand. Demand in RSA itself is not big enough to do cell production. Maybe other opportunities for vanadium redox batteries. Battery price is reducing now, 70% of battery's is for EV, only 20-30% is BESS. Their big client in EVs".* Participant 2/14

The success of manufacturing batteries in China was linked to the support from the government as various participants expressed in the quotes below.

> *"China is a global leader in lithium-ion battery manufacturing. Key factors contributing to its success include substantial government support, large-scale production facilities, and a strong focus on research and development".* Participant 7/14

> *We need partner and add value, we don't have to go blindly and say we are going to do this, but instead we need to partner and add value.* Participant 8/14

> *Policies, tariffs, regulatory uncertainties, they are very slow in our context"* Participant 14/14

Many participants emphasised the potential benefits of employing incentives such as tax incentives to help boost manufacturing in the country. The participants' views corroborate academic literature (Broughton & van der Walt, 2022; Customised Energy Solutions, 2023; Jindal & Shrimali, 2022; Retna Kumar & Shrimali, 2021a).

Drawing upon successful implementation in other countries such as China, participants suggested that similar strategies could be adapted for South Africa with promising results. Furthermore, there was widespread support among participants for the notion of forging partnerships between battery manufacturers and the government to facilitate the development of the industry. In particular, the perspectives in this regard viewed collaborative efforts between private entities and the state as a viable pathway for nurturing battery manufacturing capabilities. Moreover, participants expressed a preference for initially focusing on battery assembly rather than directly venturing into cell production, citing its comparatively higher feasibility and potential for successful implementation.

> *"International partnership can bring advanced technologies and expertise to South Africa, this knowledge transfer is crucial for building local capacity in high-tech manufacturing processes, partnerships can open doors to international markets access, thereby enhancing export potential."* Participant 10/14

Other factors which battery manufacturers considered important relate to the environmental and social impacts of batteries, such as water consumption, and emissions associated with the battery manufacturing process. A participant highlighted that it is expected that China will have the major share of the battery recycling market, and that there is no existing recycling facility for batteries in South Africa or Africa. A respondent from a BESS assembly company active in SA mentioned that the company aspires to open a battery recycling facility in next three years in the country that requires approximately R1 billion in investment and this facility will be able to recycle 550,000 tons of batteries. This highlights that the facilities for recycling of batteries are a key factor for manufacturers to consider as well.

Amid all these barriers, South Africa has the potential to sustain the battery manufacturing sector because of its rich mineral resources such as manganese which are critical raw materials for the value chain. Respondent 2/14 and 3/14 indicated that:

> *"South Africa's rich mineral resources, including manganese are attractive, but manufactures also consider the availability and sourcing of other essential components like lithium carbonate not locally available."*
> Participant 2/14

> *"The lithium-ion battery sector is at the intersection of technology, environmental policy, economics, and geopolitics, making it a critical area of focus for a sustainable future. As the sector continues to grow and evolve, staying abreast of these multifaceted aspects will be crucial for stakeholders involved."*
> Participant 3/14

4.6.2 *Technology buy-in*

The Risk Mitigation Independent Power Procurement Programme (RMIPPPP) and the Battery Energy Storage Capacity Independent Power Producers Procurement Programme (BESCIPPPP), launched by the DMRE in 2020 and 2023, respectively, indicate a growing stationary energy storage market in South Africa. A government official also mentioned that the BESCIPPPP programme requires 40% local, South African ownership in the utility-scale battery projects.

4.7 Summary of the findings

The research findings on the barriers and solutions for battery manufacturing in the South African context are shown in Table 11, which also includes the barriers-solution framework to battery business models as developed by Retna Kumar and Shrimali (2021a); (2021b).

This study revealed five key categories of barriers to manufacturing of batteries locally, namely, market barriers, financial/ cost barriers, skills barriers, technology barriers and policy barriers. These are discussed briefly below and detailed in Table 11.

First, in terms of adoption of batteries, participants concurred that there is uncertainty or a lack of significant market demand in South Africa. To address this, comprehensive estimation of battery demand and integration into energy storage plans is essential, alongside the development of the electric vehicle (EV) market.

Second, most participants mentioned that the absence of policies supporting battery manufacturing and adoption in South Africa is a major obstacle. Implementing a dedicated government strategy and policy framework is necessary, along with reforming the electricity market to recognise battery services.

Third, all participants highlighted those financial barriers, such as high battery costs and reliance on imported raw materials, hinder local manufacturing competitiveness. BESS manufacturers and cell producing companies' testaments were that tax incentives and subsidies are proven solutions, especially in China.

Fourth, infrastructure and workforce limitations, coupled with a shortage of skilled labour, pose challenges for production or assembly of BESS in South Africa. Government-led initiatives and partnerships for technology transfer are vital, as is investment in education and training programs focused on relevant fields.

Lastly, technology and policy hurdles, such as limited access to proprietary technology and an uncertain policy landscape, require collaboration with patent holders and policy reforms to integrate battery technology effectively and develop supportive regulatory frameworks.

Table 11: Tabulation of this research findings on the key barriers and solutions for battery manufacturing in South Africa

Source: Author

CATEGORISATION OF BARRIERS	BARRIERS	SOLUTIONS
Market barriers	Absence of significant market demand for batteries in SA, regionally and Africa.	Estimate demand for batteries in SA, regionally, and in Africa and document it in local and regional storage plans. Develop electric-vehicle (EV) market alongside stationary and mobile batteries applications in SA. More detailed regional level (southern Africa) assessment of the demand for batteries in Southern Africa.
	No policy that promotes battery manufacturing or adoption in SA.	Develop and implement government strategy and policy for battery manufacturing in SA.
	No well-established market mechanism that recognises the stacked services that batteries provide.	Reform electricity market to recognise batteries' multiple services.

CATEGORISATION OF BARRIERS	BARRIERS	SOLUTIONS
	- Current electricity tariff does not cater for battery storage charges or rebate.	- Restructure electricity tariff to cater for battery storage charges or rebates to release battery power into the grid.
Financial/ Cost Barriers	- High cost of batteries and how to compete with China to produce batteries at the same or cheaper cost in SA.	- Tax incentives for local manufacturing. - Government subsidies for battery manufacturing. - Partnerships between auto-mobile and EV companies.
	- Importing raw materials can increase manufacturing costs.	- Expand local mining of battery-related minerals such as vanadium, nickel, manganese, and cobalt. - Establish mineral refining hubs in SA for lithium, nickel, cobalt, copper and graphite through strategic regional partnerships with African countries that have these minerals, such as Zimbabwe (lithium), Mozambique (graphite),

CATEGORISATION OF BARRIERS	BARRIERS	SOLUTIONS
		Tanzania (graphite) and DRC (graphite and cobalt). ✅ Produce precursor metals such as aluminium cathode foil and electrolyte additives used in batteries in SA (Customised Energy Solutions, 2023).
	⛔ Limited infrastructure and technology know-how in SA to make batteries.	✅ Government-led initiatives to stimulate infrastructure and manufacturing sector development in the battery value chain. ✅ Partnership between the government and battery companies for technology-transfer. Start with local assembly of batteries.

CATEGORISATION OF BARRIERS	BARRIERS	SOLUTIONS
Lack of a skilled workforce	Shortage of skilled labour and technical expertise in SA.	Investment in education, training, and workforce development programs in the field of battery energy storage; focus on mechatronics, robotics, artificial intelligence and electrical engineering.
Technology barriers	Lack of access to proprietary technology	Collaboration and partnership with patent holders.
Policy barriers	Uncertain policy landscape, including no policy or incentives for battery manufacturing or adoption.	Policy and plans that have clear goals and targets to integrate battery technology into various industries such as automotive, renewable energy, and consumer electronics. Develop supportive regulatory frameworks and financial incentives on battery manufacturing, assembly as well as battery-related mineral beneficiation in SA.
	Incorrect classification of ES within policy	Update Electricity Regulation Act and

CATEGORISATION OF BARRIERS	BARRIERS	SOLUTIONS
	framework, storage is seen as a generator or load.	Energy Policy and regulations to cater for energy storage and services (Broughton & van der Walt, 2022).

The findings highlight several factors perceived as important by battery manufacturers regarding manufacturing batteries in South Africa. These factors include the need for a clear vision in adoption and manufacturing of batteries, relevant technology, need for skilled individuals, value-adding initiatives, battery recycling capabilities, incentives for investment, continuous research, and the importance of intellectual property rights and securing patents for BESS technologies. Additionally, government leadership was emphasised, with suggestions for South Africa to draw lessons from China and Australia's experiences. Manufacturers also perceived various risks, such as the high risk of battery theft, policy uncertainty, safety concerns in logistics, and uncertainty surrounding battery tariffs. These findings underscore the complexity and multifaceted nature of factors influencing local manufacturing of batteries in South Africa's context.

4.8 Comparison of literature review and study findings

Table 12 sets out the study's research objectives and compares the literature review to this study's own findings.

Table 12: Comparison of literature review and findings

RO #	Research Objective	Prop #	Proposition (Literature review response to RO)	Findings from own study
1	Determine the benefits South Africa would derive from adopting more battery energy storage.	1	With growing adoption of batteries in South Africa, battery energy storage has a wide range of benefits and a positive role to play South Africa, by supporting grid stability, deployment of renewable energy, creating jobs and economic growth.	Slow but expected growth in battery adoption in SA. In alignment with literature, battery energy storage can offer a diverse range of services as per the literature review, provide grid services and back-up power, especially during load-shedding, and provide hybrid energy solutions.
2	Identify the barriers and solutions for South Africa to participate in the global battery energy storage value chain.	2	Lack of policy, regulation and standards, market scale, skills and international partnerships are the key barriers and challenges preventing South Africa from participating in the global battery	SA specific challenges include financial/cost barriers, lack of market structures for storage, and lack of skills.

RO #	Research Objective	Prop #	Proposition (Literature review response to RO)	Findings from own study
			energy storage value chain.	
3	Explore the key factors that battery manufacturers consider when entering a new battery energy storage market such as South Africa.	3	The success of battery manufacturers business models requires supportive policy, market demand, favourable project economics and revenue, effective and functioning market mechanisms, and permitting processes (Retna Kumar & Shrimali, 2021a).	The study found that beyond barriers and solutions identified in literature, SA requires strong partnerships between government and battery manufacturers, policy development that includes EV adoption, tariff reform, incentives, intellectual property protection, development of battery minerals processing, and political support to produce or assemble batteries locally.

4.9 Conclusion

The chapter discussed the benefits of battery storage technologies in South Africa, the barriers to manufacturing batteries in the country, and the factors battery manufacturers consider salient when entering new markets. The study findings demonstrate that slow growth in battery adoption in South Africa is a key barrier to an accelerated adoption BESS. This barrier was also found to further restrict the potential benefits of battery energy storage for grid stability, renewable energy deployment, job creation, and economic growth. Key impediments to manufacturing batteries include market, financial, skills, technology, and policy-related barriers. Solutions include fostering partnerships, policy development, incentives, tariff reforms, and regional demand validation. Key factors for battery manufacturers to set up a local battery factory include intellectual property protection, infrastructure improvements, access to raw materials, market entry challenges, cost competitiveness, government support, domestic demand for electric vehicles, and mineral refining capabilities. These findings add to existing literature on the South African context.

CHAPTER 5. CONCLUSIONS

5.1 Introduction

This chapter presents the conclusions drawn from the foregoing presentation and discussion of the research study's findings.

5.2 Conclusions regarding the benefits South Africa would derive from adopting more battery energy storage

The study found that battery energy storage presents substantial opportunities for South Africa. The research revealed that adoption of batteries can significantly contribute to grid stability, renewable energy integration, job creation, and economic growth in the country, which is consistent with existing literature (Abid et al., 2021; Charles et al., 2019; Customised Energy Solutions, 2023; de Sisternes et al., 2019; Fourie, 2018; Ogunniyi & Pienaar, 2017; Thango & Bokoro, 2022; Tshivhase, Hasan, & Shongwe, 2021; Van Der Walt, 2017). Despite the high costs associated with importation of batteries, in 2023 alone South Africa imported $1.75-billion or 3.8 GW to 5 GW of batteries, proving existing need. The study corroborates the existence of growing demand and has shown that while adoption of batteries has been slow in South Africa the pace is growing, opening up the potential to seize on numerous benefits for the country's energy sector and broader socio-economic development.

5.3. Conclusions regarding the barriers and solutions for battery manufacturing in South Africa

This study revealed five key categories of barriers to manufacturing of batteries locally in South Africa, namely, market barriers, financial/ cost barriers, skills barriers, technology barriers and policy barriers. Key potential solutions to these barriers include fostering strong partnerships between government and battery manufacturers, battery manufacturing and EV policy development, manufacturing incentives, tariff reforms, and regional demand validation to encourage local battery production or assembly. These findings corroborate existing literature which places emphasis on policy and regulatory support, as well as the need for significant battery demand and market structures for battery market development (Broughton & van der Walt, 2022; Customised Energy Solutions, 2023; de Sisternes et al., 2019; Jindal & Shrimali, 2022; Retna Kumar & Shrimali, 2021a). The study also showed that, in the South African context, lack of skills and international partnerships are also key barriers to battery manufacturing in the country.

5.3 Conclusions regarding key factors that battery manufacturers consider when entering new battery energy storage markets such as South Africa

Battery manufacturers identify several key factors necessary for establishing local battery manufacturing facilities, including overcoming challenges related to market entry, ensuring cost competitiveness, intellectual property protection, infrastructure improvements, access to battery-related raw materials and government support on which to leverage. Government leadership in the promotion of battery manufacturing was considered a crucial factor for successful development of the battery manufacturing industry. Moreover, the study recommended specific strategies aimed at capitalising on market potential and fostering industry growth in the country. These strategies include stimulating domestic demand for electric vehicles, developing mineral refining capabilities, partnership between government and battery manufacturers, and skills development.

In addition to these factors, strategic interventions such as strong partnerships, policy development, tariff reform, and regional demand stimulation were emphasised by the industry participants who participated in the study. These findings complement existing literature while also highlighting unique interventions that are suited to the South African context, as perceived by stakeholders in the battery industry.

To conclude this section, Table 13 contains a consistency table that sets out and draws linkages between the study's research objectives, the literature, the research findings, and the study's contribution to knowledge.

Table 13: Consistency table: research questions, conclusions, and contribution to knowledge

RQ #	State Research Objective	State literature-based proposition	Conclusion or answer based on own research	Key differences between initial propositions and study findings – contribution to knowledge
1	Benefits South Africa would derive from adopting more battery energy storage	Battery energy storage presents substantial opportunities for SA, contributing to grid stability, renewable energy integration, job creation, and economic growth. Despite slow adoption pace, benefits are significant.	Battery energy storage presents substantial opportunities for SA, contributing to grid stability, renewable energy integration, job creation, and economic growth. Despite slow adoption pace, benefits are significant.	While existing literature emphasises the benefits of battery energy storage for South Africa, this research highlights the slow pace of adoption in South Africa compared to other countries. This underscores the need to address barriers to adoption and recognition of the substantial benefits it offers.
2	Barriers and solutions for battery manufacturing in SA	Identified barriers include market, financial/cost, skills, technology, and policy barriers. Solutions involve partnerships, policy development, manufacturing incentives,	Identified barriers include market, financial/cost, skills, technology, and policy barriers. Solutions involve partnerships, policy development, manufacturing incentives,	This research identifies barriers to battery manufacturing in South Africa and proposes solutions that align with existing literature. However, it also highlights specific challenges unique to the South African context, such as the lack of skills and international partnerships, emphasising the need for tailored approaches.

RQ #	State Research Objective	State literature-based proposition	Conclusion or answer based on own research	Key differences between initial propositions and study findings – contribution to knowledge
		tariff reforms, and regional demand validation.	tariff reforms, and regional demand validation.	
3	Key factors considered by battery manufacturers	Key factors include market entry challenges, cost competitiveness, intellectual property protection, infrastructure, access to raw materials, and government support. Recommendations are consistent with existing literature and emphasise tailoring strategies to the local context.	Key factors include market entry challenges, cost competitiveness, intellectual property protection, infrastructure, access to raw materials, and government support. Recommendations are consistent with existing literature and emphasise tailoring strategies to the local context.	This research underscores the importance of key factors considered by battery manufacturers, showing how they align with existing literature. Additionally, it emphasises the need for strategic interventions tailored to the South African context, such as partnerships, policy development, and regional demand stimulation, to foster local battery production or assembly.

CHAPTER 6. RECOMMENDATIONS

This chapter offers recommendations to various stakeholders as arising from the study. The chapter also provides suggestions for further research.

Government

The government plays a pivotal role in driving the adoption and manufacturing of BESS in South Africa. This research underscores the importance of developing and implementing dedicated strategies and policies to support battery manufacturing and adoption. Government initiatives should focus on creating a conducive regulatory environment, providing financial incentives such as tax incentives and subsidies, and fostering partnerships between industry stakeholders to address market barriers, financial challenges, skills shortages, and technology hurdles. Furthermore, the government can leverage the insights from this research to strengthen collaboration with international partners, enhance local mining and refining capabilities for battery minerals, and invest in education and training programs to build a skilled workforce. By prioritising the growth of the battery manufacturing industry, the government can stimulate economic growth, create jobs, and contribute to the stability and sustainability of the country's power grid.

Academics

This research provides insights and data in a developing country context for academics interested in the growth of the battery energy storage manufacturing industry in developing countries or in Africa. By addressing the gaps in the current understanding of the enabling factors for battery manufacturing, academics can further contribute to the knowledge base in this field, paving the way for more comprehensive studies and informed policy recommendations.

Battery-related Companies/ Manufacturers/ Corporations

Battery companies or corporations, particularly those interested in South Africa's energy sector or the African energy sector, can use the findings of this research to inform their strategic decision-making. The study's insights into the market barriers, financial challenges, skills shortages, and policy hurdles can guide them in developing robust business strategies, exploring partnerships, and advocating for supportive policies to foster the growth of battery manufacturing in South Africa, the African continent and in other developing countries.

Small Businesses and Entrepreneurs

Small businesses and entrepreneurs looking to enter the battery manufacturing market in South Africa can leverage the recommendations provided in this research to navigate the complexities of the industry. Understanding the key barriers and solutions can help them develop viable business plans, seek funding opportunities, and establish partnerships to overcome challenges and seize growth opportunities in the nascent BESS market.

Energy Leaders and Practitioners

Practitioners involved in energy storage projects and policy development can use the insights from this research to inform their initiatives and advocacy efforts. By understanding the specific barriers and solutions identified in the South African context, practitioners can tailor their interventions to address the most pressing challenges, advocate for supportive policies, and promote investments in battery manufacturing infrastructure and workforce development.

6.1. Suggestions for further research

Possible further research could include assessing the long-term impact of government policies and initiatives on the battery manufacturing industry. Tracking the implementation of policy frameworks over time could offer insights into their effectiveness in fostering sustainable growth and innovation within the sector. Additionally, comparative analysis with other developing nations that have successfully established battery manufacturing industries could provide valuable lessons and best practices applicable to various contexts. Exploring the entire supply chain of battery manufacturing, from raw material extraction to end-product assembly, could identify optimisation opportunities and strategies for enhancing local sourcing of battery minerals and improving logistics infrastructure.

Conducting a comprehensive local techno-economic analysis would be instrumental in evaluating competitiveness in battery manufacturing locally compared to global counterparts. This analysis would assess factors such as production costs, labour expenses, infrastructure investments, and potential economic benefits, aiding informed decision-making regarding the feasibility and sustainability of the industry. Moreover, a deeper examination of strategic initiatives and mechanisms that governments could utilise to support battery manufacturing would be beneficial. Other research could explore policy instruments, funding mechanisms, public-private partnerships, and regulatory frameworks aimed at stimulating investment, fostering innovation, and generating employment within the battery manufacturing sector.

Addressing these research gaps would contribute to a better understanding of the opportunities and challenges associated with battery manufacturing globally, ultimately supporting transitions towards sustainable and resilient energy futures in various countries.

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ANNEXURE A: INTERVIEW GUIDE

RESEARCH TOPIC: MANUFACTURERS PERSPECTIVES: OVERCOMING BARRIERS AND UNLOCKING SOLUTIONS FOR BATTERY MANUFACTURING IN SOUTH AFRICA

Section A: Demographic information of participants

A1: Age Grouping

Question A1: Select your age group?

20 years or below	
20 to 29 years	
30 to 39 years	
40 to 49 years	
50 to 60 years	
60 years plus	

A2: Highest Educational Qualification

Question A3: Select your highest level of education qualification?

Grade 12	
Certificate	
Diploma	
First Degree	
Post-graduate	

A3: Working Experience in the battery energy storage manufacturing sector and electro-chemical battery technologies.

Question A3: Select a fitting range of experience in the battery energy storage manufacturing sector and electro-chemical battery technologies.

0 to 1 year	
2 to 5 years	
6 to 10 years	
11 to 20 years	
20 or more years	

Section B: Research Objective 1

B1: From your experience, what benefits can battery energy storage have in general, but to South Africa, specifically?

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____

B2: In your view, can battery energy storage technologies adoption address the current electricity crises in South Africa. If yes, how?

____

____

Section C: Research objective 2

C1: What are your thoughts on the pace of adoption of battery energy storage technology in South Africa?

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____

C2: In your view, what would some of the main barriers to development of battery cell manufacturing and assembly factories in South Africa? Please share your insights.

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C3: Are there challenges related to market entry?

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C4: Are there any specific technological challenges that manufacturers face in the production process?

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____

C5: Are there financial or economic challenges that need to be addressed to developing battery cell manufacturing facilities in South Africa?

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C6: How do supply chain logistics and transportation challenges impact the feasibility of battery cell manufacturing in South Africa, especially considering the need for raw materials?

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Section D: Research objective 3

D1: What would battery manufacturers look for before entering new markets, like South Africa?

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D2: What is the key to sustain healthy revenues of a battery manufacturing factory?

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D3: Is there a minimum battery demand or production output required, in GWh, to sustain a cell manufacturing factory?

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D4: From your experience, could you elaborate on the capital and financial costs, generally associated with setting up a battery cell manufacturing factory or assembly factory?

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D5: What range of return on investment is required for a cell manufacturing factory to be economically feasible?

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____

D6: Is the cost and need for recycling and safe disposal of batteries a big factor that affects the financial viability of battery cell production? Is it a significant operational cost, please provide more details.

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D7: What are the typical sources of financing for battery cell production and assembly facilities? From your experience, what financing mechanism works well?

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D8: Are there successful examples or best practices related to local battery cell production or manufacturing from other regions that South Africa could learn from?

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D9: Given China Japan, and South Korea’s dominant position in lithium-ion battery manufacturing globally, how do industry stakeholders perceive South Africa's ability to compete in terms of production efficiency, cost-effectiveness, and quality?

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D10: What specific advantages or challenges does South Africa face when compared to China in the context of lithium-ion battery manufacturing and assembly?

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____

Section E: Research objective 4

E1: Are you aware of any battery energy storage initiatives, policy, or incentives on battery cell manufacturing in South Africa. If yes, please provide details.

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E2: How do existing government policies support the growth of lithium-ion battery manufacturing in South Africa?

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E3: Are there specific policy recommendations or changes that industry stakeholders believe would be beneficial?

E4: Can you share your experiences on how well government incentives, grants, or subsidies in supporting battery cell manufacturing investments? What else can government do to enable the industry, apart from policy?

E5: What would be required to attract cell manufacturing or cell assembly in South Africa?

E6: What strategies can South Africa adopt to attract battery manufacturers and investors to set up in South Africa?

E7: To what extent can collaborations or partnerships with international companies play a role in promoting lithium-ion battery manufacturing in South Africa

E8: Are there issues related to accessing intellectual property needed to manufacture batteries technology. Please elaborate?

____

____

E9: Given the global nature of the lithium-ion battery industry, how do manufacturers approach collaboration and the sharing of intellectual property with international partners or other industry stakeholders?

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E10: From the perspective of a battery cell manufacturer, what specific intellectual property considerations are crucial to ensuring comfort and confidence in engaging with partners, suppliers, or collaborators in the manufacturing process?

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E11: Are there particular strategies or safeguards that the manufacturer finds important when navigating intellectual property issues, especially in a collaborative or supply chain context?

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____

E12: What type of local workforce development or education initiatives are necessary for battery manufacturing to happen in South Africa?

E13: What research and development areas related to battery manufacturing would be key focus area for South Africa?

E15: What potential solutions or strategies could address the identified barriers to lithium-ion battery manufacturing?

E16: Are there emerging trends or technologies that could shape the industry in the coming years?

E17: Is there anything else you would like to add or share about this topic?

Thank you for your participation.

ANNEXURE B: PARTICIPANT CONSENT FORM

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

School of Commerce, Law and Management

Private Bag 3, Wits Johannesburg,

Participant Information Sheet

Research Title	*Manufacturers Perspectives: Overcoming Barriers and Unlocking Solutions for Battery Manufacturing in South Africa*
Ethics Clearance Reference Number:	*WBS/EL2398269/959*
Supervisor	*Dr Steven Mathetsa*

3 December 2023

Dear Sir/Madam,

I, Ravisha Shantikumar, am a student pursuing a Master's degree in Energy Leadership at the University of the Witwatersrand in Johannesburg, South Africa. My current research project focuses on the challenges and solutions in battery manufacturing, for example in South Africa. The outcomes of this study will play a pivotal role in considering solutions to the electricity and economic issues faced by the country.

I am genuinely interested in hearing your views as an experienced professional in the battery manufacturing industry. I cordially invite you to participate in a one-hour interview. This conversation can be conveniently conducted online using platforms such as Microsoft Teams or Google Meet. Your identity and any identifying information will remain confidential. Your personal data will not be shared with any third parties, and interview recordings will be securely stored with restricted access. Hence, your participation poses no risks to you. A code will be used to represent your contribution anonymously in all documents.

I kindly ask for your permission to record the interview to ensure the accuracy of our data. The recording will be deleted upon the completion of my research and publications.

However, if you prefer not to have the interview recorded, detailed notes can be taken instead. Your participation is entirely voluntary, and you have the freedom to decline any questions or withdraw at any time.

Should you have any questions or wish to receive a summary of our findings once the research is complete, please do not hesitate to reach out to me or my supervisor using the contact details below.

I genuinely appreciate your time and insights and eagerly anticipate the opportunity to connect with you regarding this critical research.

Warm regards,

Researcher: Ravisha Shantikumar

Email: 2398269@students.wits.ac.za

Phone: +27843000660

Supervisor: Dr. Steven Mathetsa

Email: steven.mathetsa@wits.ac.za

Phone: 011 717 3314

ANNEXURE C: ETHICS CLEARANCE CERTIFICATE

Graduate School of Business Administration
University of the Witwatersrand, Johannesburg

Wits Business School

Wits Business School Ethics Committee
Constituted under the University Human Research Ethics Committee (Non-Medical)

Ethics Clearance Certificate

Ethics protocol number: WBS/EL2398269/959

This certificate is only valid with a legitimate ethics protocol number and signed by the Researcher (below)

This certificate is only valid if accompanied by formal permission from the relevant stakeholder(s).

Project title	Overcoming barriers and unlocking solutions for battery manufacturing in South Africa
Investigator / Researcher	Mrs Ravisha Shantikumar
Nature of Project	MM (Energy Leadership)
Decision of the Committee	Approved, provided stakeholders and participants are guaranteed confidentialty.
Issue Date of Certificate	2023/11/30
Expiry date	Date of submission of the project / research report
Chairperson	Dr Pius Oba ☎ +27 11 717 3976 +27 82 733 6587 pius.oba@wits.ac.za

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Declaration by Researcher

One copy must be signed by the Researcher and returned to the Chairperson of the Wits Business School Ethics Committee.

I fully understand the conditions under which I am authorized to carry out the abovementioned research and I guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I undertake to resubmit the protocol to the Committee.

Signature

3 December 2023
Date: