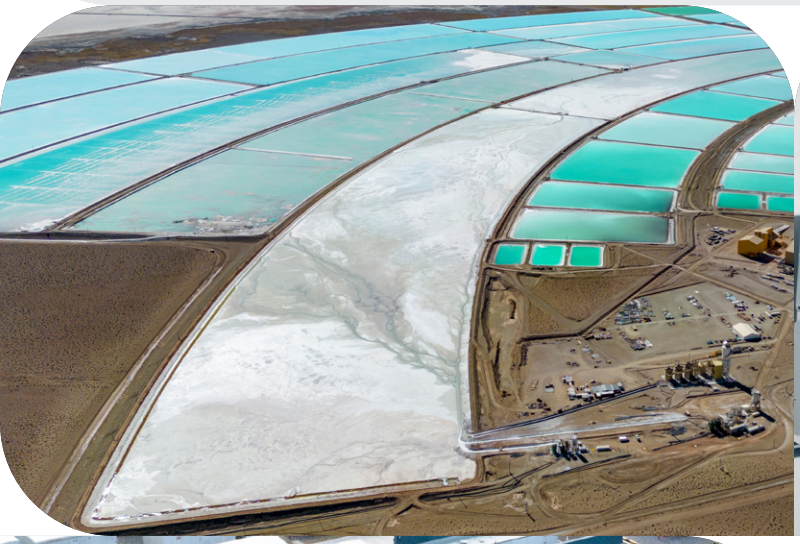
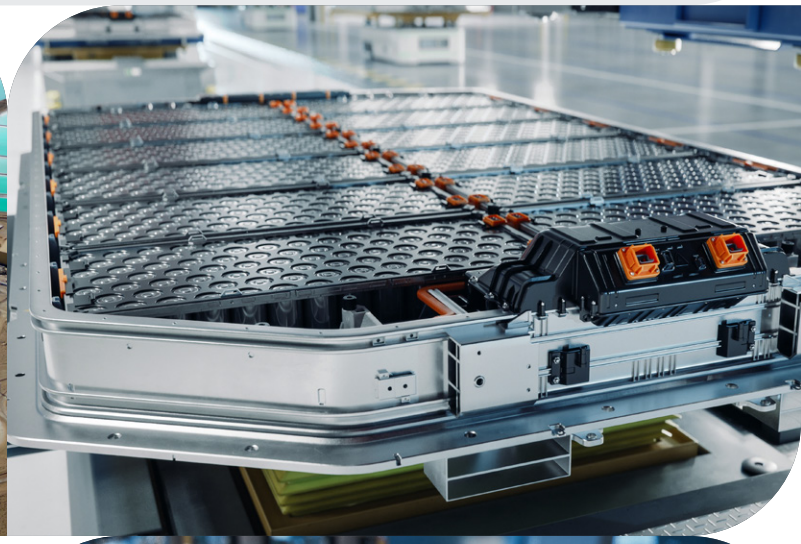
ELECTRIC MOBILITY TRANSITION & LOCALISATION

Towards Unlocking the NEV Value Chain for Africa

SITUATIONAL AND BASELINE ANALYSIS REPORT SERIES REPORT 5: BATTERY VALUE CHAIN



AIH GROUP

IDC
Industrial Development Corporation

September 2024

TABLE OF CONTENTS

TABLE OF FIGURES **4**

LIST OF TABLES **4**

1 INTRODUCTION **5**

2 BATTERY VALUE CHAIN **7**

2.1 Context 7

2.2 Battery Types 7

2.2.1 Smaller Mobility 7

2.2.2 Large Mobility 8

2.3 Some Key Mobility-linked Battery Studies Conducted for South Africa 11

2.3.1 Opportunities to Develop the Lithium-Ion Battery Value Chain in South Africa - TIPS 11

2.3.2 Technology Landscape Report and Business Case for the Recycling of Li-Ion Batteries in SA 12

2.3.3 SADC e-Mobility Outlook: Accelerating the Battery Manufacturing Value Chain 14

2.4 BESS Demand Profile 14

2.5 Chinese Market 15

3 ANNEXURE A – BATTERY VALUE CHAIN **16**

3.1 Circular Economy 16

3.1.1 Raw Materials Are Crucial for Battery Supply 16

3.1.2 Continuous Improvement 16

3.1.3 Recycling and Second Life Solutions 17

3.2 Examples of Batteries 17

3.2.1 Lithium-Ion Cell Type 17

3.2.2 Lithium-Ion Packs 18

3.2.3 Lithium-Ion Battery Assembly 19

3.2.4 Deployment Examples 20

3.3 SA Batteries Manufacturing/ Assembly 22

3.3.1 Blue Nova 22

3.3.2 FreedomWon 23

3.3.3 Polarium 24

3.3.4 Solar MD 24

3.3.5 i-G3N 25

3.3.6 Balancell 25

3.3.7 Hubble 26

4 PROJECT TEAM 28

4.1 Project lead 28

4.2 Contributing authors 28

4.3 Service provider contact details 28

TABLE OF FIGURES

Figure 1: NEV Situational Analysis Key Takeaways 6
Figure 2: Vehicle Size and Propulsion Challenges 9
Figure 3: Technology Readiness Level of hydrogen mobility applications 10
Figure 4: Battery Life Cycle, ... 16
Figure 5: Lithium-Ion Cell Type 18
Figure 6: Battery Pack Configuration 18
Figure 7: Lithium-Ion Battery - Small Mobility 19
Figure 8: Lithium-Ion Battery - Large Mobility 19
Figure 9: E-Bike Battery Configuration 20
Figure 10: 2-Wheeler Battery Setup 20
Figure 11: Forklift Battery Setup 21
Figure 12: Large Truck Battery Setup 21
Figure 13: Mining Equipment Battery Setup 21
Figure 14: Blue Nova MPS Series 22
Figure 15: FreedomWon Lithium Battery Range 23
Figure 16: Polarium Lithium Battery 24
Figure 17: Solar MD's Product Range 24
Figure 18: iG3N's LiFePO4 Battery 25
Figure 19: Balancell' 'Smart' Battery 26
Figure 20: AM Energy Storage Solution 26
Figure 21: S-Series Battery 27

LIST OF TABLES

Table 1: Advantages and Disadvantages Between Lead-acid and Lithium-ion Batteries 8
Table 2: BEV versus Hydrogen powered vehicles 9

1. INTRODUCTION

New Energy Vehicles (NEVs) are seen as an important step towards achieving global climate targets. This study has undertaken a comprehensive review of relevant literature pertaining to the current NEV industry globally, in South Africa and the Rest of Africa, identifying key players and stakeholders, as well as current and emerging gaps, and opportunities in the NEV market.

In order to assess the NEV segments, markets and policies along the value chain, the literature review has been structured as follows to provide a comprehensive overview of the key important NEV sectors in a logical framework:

1. **NEV Landscape Overview:** New Energy Vehicles (NEVs) are vehicles that are powered by on electricity or fuels made from non-fossil fuel sources. In May 2021, the dtic released the Green Paper on NEVs for public comment and the intention was clear that the South African Automotive Value Chain was ready to transition from 'Internal Combustion Engines' (ICE) to NEVs. The Just Energy Transition Implementation Plan (JET IP) provides a means to achieve the transition through investments spearheaded led by various government authorities, agencies, private institutions and development finance institutions (DFIs).

2. **Micro-mobility:** The context and rationale for micro-mobility, market developments and in particular the rise of electrified two and three-wheel vehicles, four-wheel "last mile" delivery vehicles, conversions and eco-tourism markets, and concluding remarks.

3. **Public Transport:** This section discusses buses from a global perspective and in terms of best practise, 'battery swapping' as an emerging trend, South African trends and developments, minibus taxis and case studies for Kenya, Ghana, Rwanda and Zimbabwe.

4. **Machinery and Equipment:** An overview of the production and sale of zero-emission heavy-duty vehicles and equipment is provided, analysing trucks, mining equipment, agricultural equipment and the general electrification of different categories of machinery and equipment as well as ownership models. The transition from fossil fuelled vehicles to NEVs is also considered. Actors and stakeholders and opportunities in the NEV value chains and for FCEV components are then identified.

5. **Infrastructure for NEV energy supply:** The NEV industry requires supporting infrastructure in the form of fuel supply infrastructure, charging stations and equipment, policy and incentives, and other supporting and enabling investments, including financing and insurance. These topics will be explored and opportunities identified.

6. **Battery Value Chain:** Batteries in the various NEVs are emerging as an important technology and form the basis for certain elements of the NEV industry and opportunities. Battery types were analysed, addressing minor and major mobility issues. A brief overview of battery studies conducted in South Africa was also provided.

7. **Trade Policy Conformity:** A range of trade policies, incentives and tax regimes used by different countries to accelerate the transition to NEVs are considered. Tariffs and regional integration to promote trade are considered, including Rules of Origin (RoO) and the impact of the African Continental Free Trade Agreement (AfCFTA) on the emerging NEV industry in Africa.

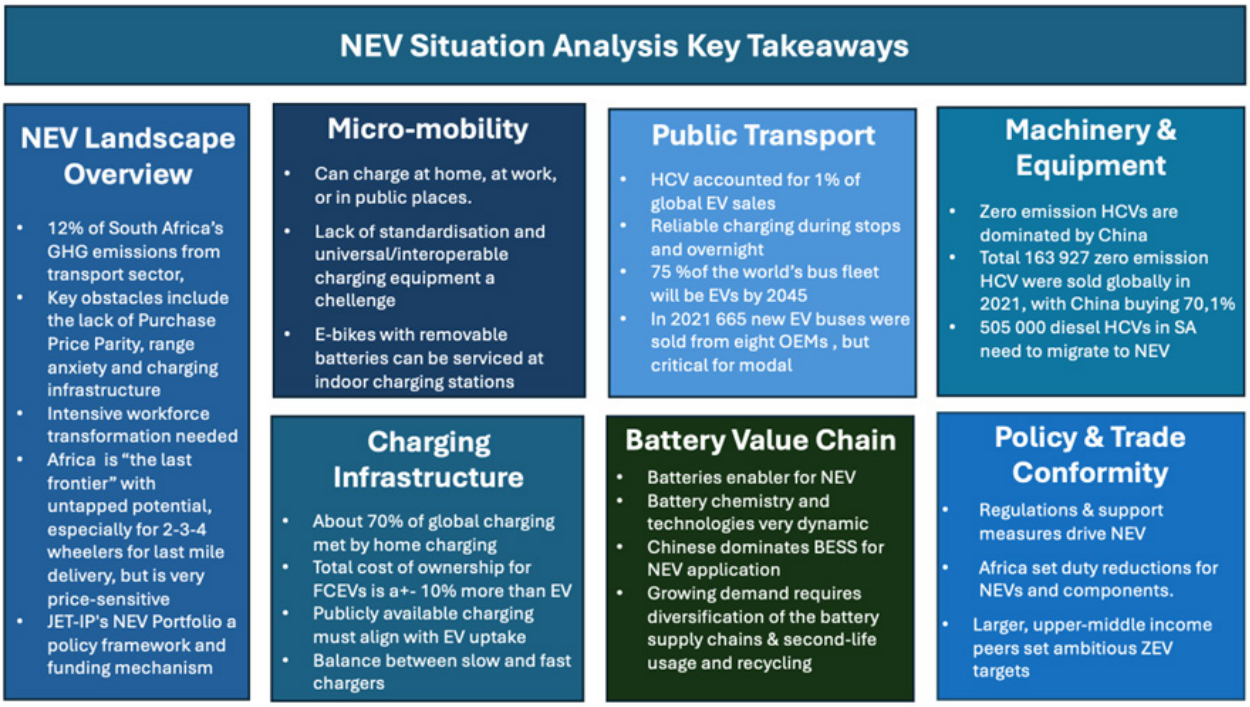


Figure 1: NEV Situational Analysis Key Takeaways

The most important findings from each of the segments are summarised in the figure above. Each of these segments is covered in a separate chapter of the series report, highlighting the key players, stakeholders and concluding with an overview or explanation of the opportunities identified in that NEV segment.

2. BATTERY VALUE CHAIN

2.1 Context

Batteries in the new electric mobility are a key technology and enabler to create an alternative, sustainable transport system that goes beyond NEVs for passenger transport and achieves the long-term climate protection goals in the transport sector.

The growing demand for alternative modes of transport triggers technological innovation, both in terms of mobility design and battery technology as well as subsequent production. The most important prerequisites for mobility innovations are that they are affordable, accepted by the market and achieve economies of scale. Growth and acceptance will depend on the quality of the batteries, their lifespan and the range they can achieve on a single charge. Growth will also have a direct impact on the size of batteries required to meet the corresponding market demand.

Growing demand will also require diversification of battery supply chains due to battery variations and increased production to mitigate the risks of supply shortages and ensure the sustainability of different mobility offerings. Production facilities, mining infrastructure and processing infrastructure will need to be expanded to meet growing demand. OEMs will need to build a strong battery network and work with a variety of experienced partners.

One consequence of the growing demand for batteries is the environmental and social risks posed by the extraction of more raw materials and the increasing production of batteries.

2.2 Battery Types

2.2.1 Smaller Mobility

Smaller new mobility vehicles such as two- and three-wheelers are mostly powered by lead-acid and lithium-ion batteries, which come in different shapes, sizes and power reserves. Each of these technologies has advantages and disadvantages.

Most electric vehicles are powered by lead-acid batteries or lithium-ion batteries. However, both are not suitable in certain circumstances, as lead-acid batteries have disadvantages in certain applications.

The general advantages and disadvantages of the two technologies that affect the choice for a particular mobility application are shown in Table 1 below.

Table 1: Advantages and Disadvantages Between Lead-acid and Lithium-ion Batteries

Lead-acid batteries		Lithium-ion batteries	
Advantages	**Disadvantages**	**Advantages**	**Disadvantages**
The cheaper prices of the lead-acid batteries make them affordable.	Batteries are heavy with a low weight-to-energy ratio.	High-energy density batteries without being too bulky.	Lithium-ion batteries are expensive.
Lead-acid batteries are lower-cost mobility solution.	The weight of the vehicle significantly and reduce the distance.	Do not add extra weight to the vehicles and increase their mileage.	Increase the price of mobility solution.
Ease of recharging.	Slow charging (around 14 to 16 hours every time to recharge).	Charging time of 1.5 to 3 hours makes it easy for drivers to recharge.	Higher safety risk due to energy density.
Readily and easily available in the market.	High-maintenance batteries with a shorter life expectancy.	Lower self-discharge rate.	
	High-maintenance batteries with a shorter life expectancy.	Long life cycle- around 2000 cycles, and don't need to be changed frequently.	
		Low maintenance	

Source: Compilation by Futurus Advisory

The lead-acid batteries are becoming increasingly popular but, due to their disadvantages, the trend towards lithium-ion batteries is hampered by the higher cost of lithium-ion batteries. The only solution to achieving a greater move towards lithium-ion batteries is the ability to reduce production costs and associated prices of lithium-ion batteries.

2.2.2 Large Mobility

The biggest market debate around greater mobility is whether this greater mobility should be powered by battery electric, hydrogen (fuel cells) or hybrids. Figure 2 below reflects the thinking around the propulsion question.

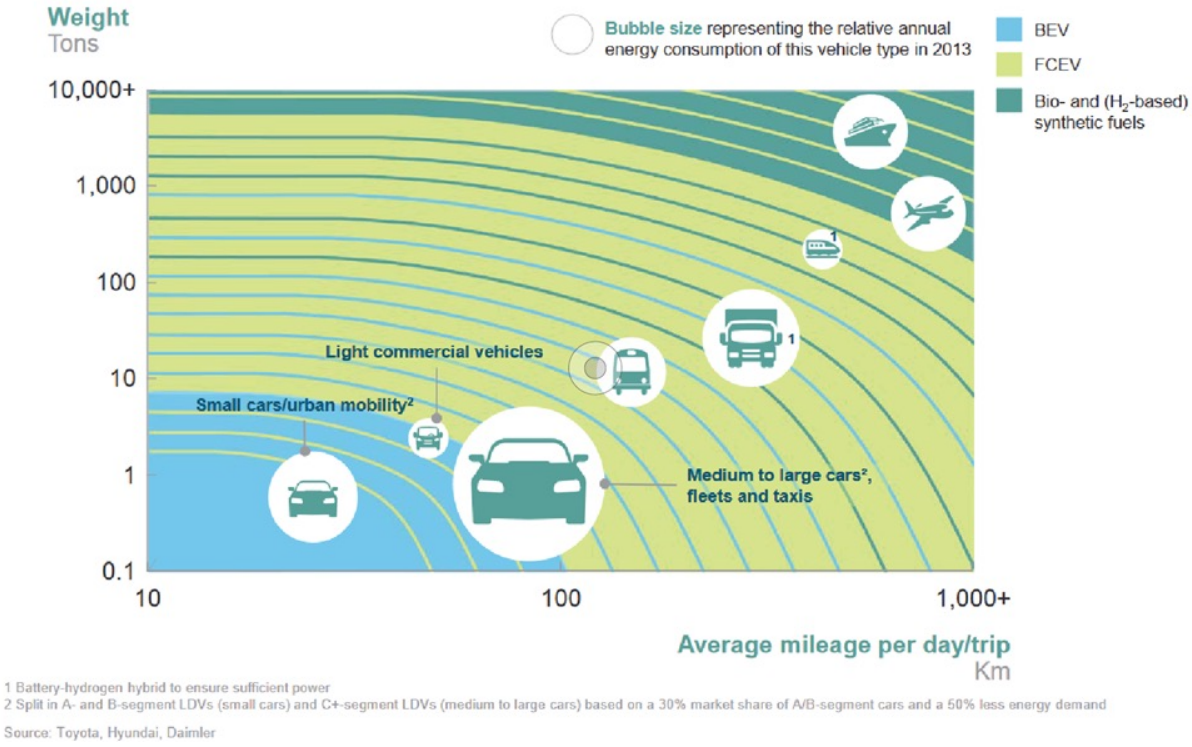


Figure 2: Vehicle Size and Propulsion Challenges[1]

The critical aspects that play a role in the discussion between battery-powered electric vehicles and hydrogen-powered vehicles are listed in Table 2 below.

Table 2: BEV versus Hydrogen powered vehicles

Consideration	Battery Electric	Hydrogen
Technology	Battery stores energy from an external energy resource which it then uses.	Hydrogen (fuel cell or electrolyser) generates energy by converting available fuel.
Range	Range depends on size, battery capacity but consider lower for compared to hydrogen.	Range provided is more as weight reduce as fuel source is consumed.
Cost	Cost is much less than hydrogen.	More expensive and estimated at twice the cost of EV.
Safety	Overcharging of batteries are a risk.	Hydrogen gas is highly flammable.
Charging station availability	Many stations are available and cold be localised at depots.	Less number of production facilities and transportation challenges.
Emissions	Battery production and charging emits CO_2.	Production of hydrogen fuel emits CO_2.
Weight	Batteries are heavy and for an 800 km range truck, the weight difference to hydrogen could be as much as 2 tons.	Hydrogen could be a gamechanger for heavy-duty, long-range trucks.

[1] N De Blasio, 2021 - The Role of Clean Hydrogen for a Sustainable Mobility https://www.belfercenter.org/publication/role-clean-hydrogen-sustainable-mobility

Consideration	Battery Electric	Hydrogen
Power to weight ratio	Design specific	Design specific
Refuelling / charging	A battery-powered electric truck may take hours to recharge (could also take only a few minutes with battery swop).	A class 8 truck on hydrogen / fuel cell technology is up and running again in 15 minutes.
Temperature sensitivity	Sensitive to cold temperatures.	Easily handle temperature changes during a long trip.

The debate is not yet settled, but hydrogen technology still has significant hurdles to overcome, mainly related to storage, infrastructure and costs, before it can become a real gamechanger in the field of large-scale mobility. The choice between battery and hydrogen depends on the specific application and the total cost of ownership, availability of refuelling infrastructure, refuelling times, weight, zero emissions, etc. The long-distance and heavy-goods transport segments offer potential for hydrogen solutions, but the delivery price for hydrogen must be reduced. Captive fleets could play an important role in improving the business prospects for both battery electric and hydrogen vehicles.

So far, efforts to decarbonise the transport sector have mainly focused on batteries in the light-commercial vehicle and passenger car segments. The main obstacle and challenge for hydrogen is its readiness level (see Figure 3 below).

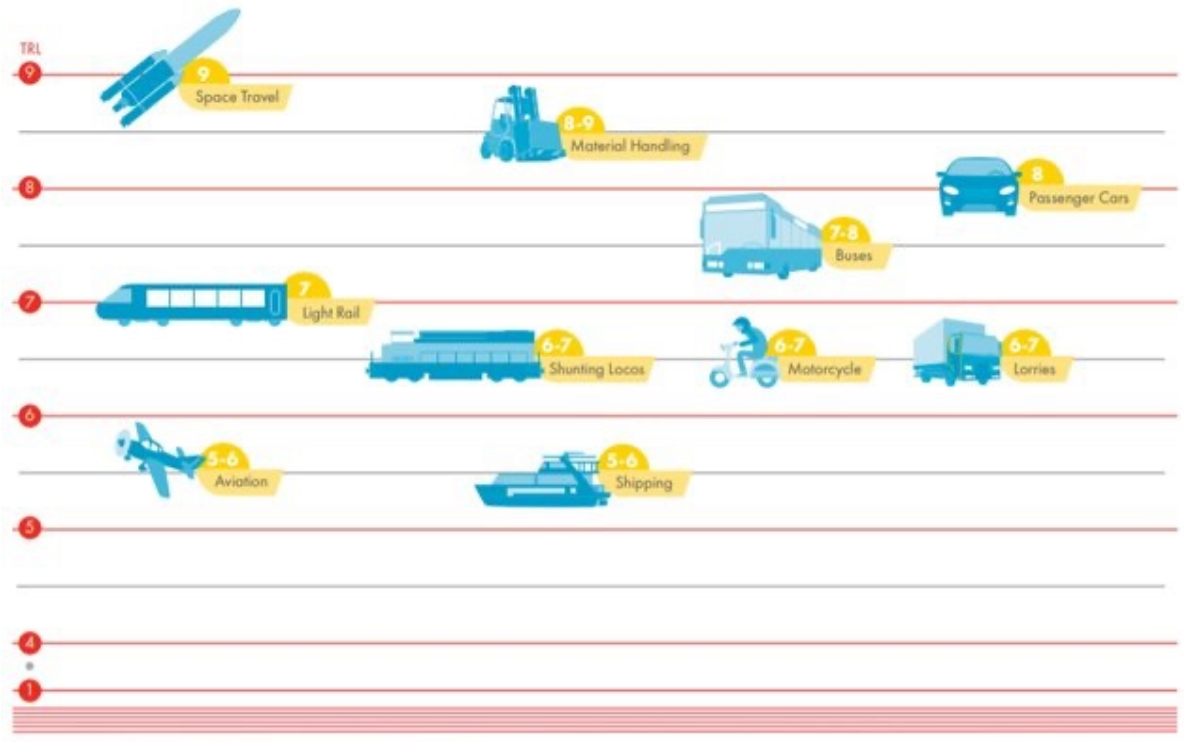


Figure 3: Technology Readiness Level of hydrogen mobility applications.[2]

[2] O, Tlili, 20219 - Hydrogen systems : what contribution to the energy system? Findings from multiple modelling approaches https://www.researchgate.net/figure/Technology-Readiness-Level-of-hydrogen-mobility-applications-20_fig1_338035906

If we focus more specifically on the battery segment within the large mobility solutions, the following key requirements and considerations can be emphasised:

- Battery capacity can be extensive depending on the type of mobility, based on the range and or working hours required.
- The production of lithium-ion batteries requires a lot of energy. Together with the emissions from charging, a 100 kWh battery emits an average of 77.5 g of CO_2 per kilometre.
- A huge capital-intensive infrastructure needs to be built to provide hydrogen, but electric vehicle charging can be more easily integrated into the electricity grid or with solar panels. Battery-based mobility with on-board chargers can be charged anywhere.
- The cost of electric vehicles is lower than that of fuel cell vehicles, the economic transformation for larger and heavier mobility as shown above.
- Battery electric vehicles are more efficient compared to hydrogen-based vehicles, but this could change as the technologies for both improve.
- Battery electric vehicles are expected to dominate by 2030, while the infrastructure that can support hydrogen-based mobility is being developed and deployed.

When a truck battery runs out, there are two options: either find an outlet to charge it or buy a new battery. It is therefore important to understand that companies with a fleet of battery-powered heavy-goods trucks are heavily dependent on the electricity grid. To avoid downtime during periods of high demand, planning for charging and the availability of such a space is crucial.

2.3 Some Key Mobility-linked Battery Studies Conducted for South Africa

2.3.1 Opportunities to Develop the Lithium-Ion Battery Value Chain in South Africa - TIPS[3]

The preamble to the study recognises that the world of mobility is changing rapidly and the market for electric vehicles (EVs) in all their forms is growing exponentially. The combination of technological upheaval in the energy sector and the emergence of EVs puts battery technologies at the heart of sustainable development, and multiple technologies and chemistries, each with their advantages and disadvantages, are competing in a market currently dominated by lithium-ion batteries.

The report confirms that both the South African government and industry have signaled their intention to position the local battery value chain as a key player in the mobility of the future. This is seen as crucial to ensure a just transition to e-mobility, which would, above all, maintain, if not increase, job creation. As South Africa is home to a vibrant indigenous industry for the automotive manufacturing value chain, which is based on internal combustion engine vehicles and components, it raised the question of the positioning South Africa in the value chain. This was the core question that the study intended to unpack.

The report focused on the lithium battery chain in the circular economy and came to the following summarised conclusions:

- Demand for batteries will increase as electromobility and energy storage capture ever larger shares of the transport and energy markets.
- Battery technology has already undergone significant technological improvements and, every year, batteries are becoming more powerful, more durable, safer, and cheaper to produce. Although there are other battery technologies, LIBs currently dominate the battery market.

[3] Gaylor Montmasson-Clair, Lesego Moshikaro and Lerato Monaisa, Trade & Industrial Policy Strategies (TIPS), Pretoria, South Africa; March 2021

- Looking at the lithium-ion battery value chain or ecosystem, from mining to waste management, including mineral beneficiation and manufacturing, the result reflects the capabilities of South Africa, which has a vibrant value chain, with not all stages at the same level of development.
- Mining and beneficiation of associated minerals, such as manganese, iron ore, nickel and titanium, are already underway in South Africa and the region, but the beneficiation of battery minerals up to battery grade is limited with some pockets of excellence such as manganese, and aluminium and interesting developments as far as lithium, nickel and titanium is concerned.
- The assembly/manufacture of batteries (from imported cells) and the reconditioning of batteries (second-life batteries) is carried out by several local companies that have unique expertise in the development of associated battery management system.
- The production of battery cells is being researched at the R&D level, but has yet to be prove commercially viable.
- The assessment has shown that it is important to identify where in the value chain South African industries are (or could be) competitive and sustainable in order to channel support and resources into the most sustainable activities.
- The following four avenues emerged as possible technical pathways to support value chain development in South Africa:
  - Battery assembly/manufacturing
  - Mineral refining
  - Cell manufacturing
  - Battery recycling

These opportunities are not mutually exclusive, but complementary, with only battery assembly/manufacturing and mineral refining at a stage that could be considered for scaling-up.

- The key to supporting the value chain is a long-term concerted effort that combines investment promotion and market development. In addition, policy frameworks that facilitate access to markets, finance and commercialisation support are considered essential.
- Strong partnerships and collaboration between public and private institutions, as well as between local and international players will be essential for building a competitive industry.
- A local value chain is expected to be crucial for the local development of both the (renewable) energy and (electric) transport industries; and
- Achieving a high share of local value creation in the renewable energy and automotive sectors will depend on the localisation of the battery value chain, which will depend on strong partnerships with anchor customers (i.e. battery buyers/users) from the automotive industry to the energy sector, to telecommunication and logistics companies.

2.3.2 Technology Landscape Report and Business Case for the Recycling of Li-Ion Batteries in SA[4]

The aim of the study was to assess whether the construction of a recycling plant for lithium-ion batteries in South Africa is economically viable. The study focused on:

- An overview of the current state of the lithium-ion recycling industry in South Africa.

[4] Gericke, M., Nyamjowa, W. and Robertson S.; Mintek for Dept of Science and Innovation; 31 March 2021

- An evaluation of currently available commercial recycling technologies and an assessment of the extent to which these technologies can be adapted to South African conditions; and
- A techno-economic assessment of the business case for the establishment of a lithium-ion recycling plant in South Africa.

The study has shown that there are three recycling processes for processing spent lithium-ion batteries: Pyrometallurgy, Hydrometallurgy and Direct Recycling. The pyrometallurgical and hydrometallurgical technologies are already commercialised, while direct recycling is still at the research stage. Mintek concluded that the hydrometallurgical route is favoured for new plants in China, the United States and Northern Europe.

A market assessment found that only between 6-10 tonnes (very small quantities) of lithium-ion waste is collected annually in South Africa, representing approximately 1% of the estimated lithium-ion waste generated annually in South Africa. This waste comes mainly from the consumer electronics and ICT equipment sectors. The small quantities are not sufficient to enable local recycling facility and as a result waste is either stockpiled, landfilled, or shipped to recycling facilities abroad.

The study concluded that at current collection rates, there is no business case for the establishment of a commercially viable lithium-ion recycling plant in South Africa. The biggest driver for the establishment of such a facility would be the expected growth of the EV market and the use of these batteries in renewable energy storage applications, which are currently in their infancy and where the current installed base has not yet reached end of life.

The impending implementation of Extended Producer Responsibility (EPR) by the Department of Environment, Forestry and Fisheries (DEFF), the ban on landfilling battery waste that came into effect in August 2021 and the environmental and safety risks associated with storage and landfilling (fires caused by lithium-ion batteries stored in material recovery facilities and landfills) are further reasons for developing a local processing plant in South Africa.

The recommendation of the report included the following:

Short to medium term:

- Strategies should be implemented to increase the collection of lithium-ion batteries.
- Government should promote the uptake of EVs in South Africa by accelerating the implementation of the South Africa's Green Transport Strategy, and creating fiscal incentives to make EVs more competitive and stimulate market penetration; and
- Resolving issues related to the availability of charging stations, reliable electricity supply and possibly setting manufacturing and sales targets, as is already happening elsewhere.

Longer-term:

- When the collection volumes reach 500 tonnes per year, a small mechanical plant could be built to pre-process the lithium-ion waste to produce black mass. The black mass can be treated locally through partnerships with metallurgical companies or exported to international refineries for metal recovery.
- Once a reliable supply of sufficiently large quantities of lithium-ion waste has been collected, a hydrometallurgical plant can be considered for the treatment of lithium-ion batteries to produce either metal precipitates or high-purity battery materials.
- The quantities of lithium-ion battery waste available for local treatment can be increased by accepting regional or international lithium-ion battery waste by creating a favourable economic and regulatory environment for battery recycling. However, this is the case, questionable if South Africa could be competitive in a market currently dominated by China.

2.3.3 SADC e-Mobility Outlook: Accelerating the Battery Manufacturing Value Chain[5]

The predicted uptake of EVs around the world will further increase the demand for lithium-ion batteries. At the same time, the electrification of transport will create an estimated 10 million jobs worldwide. The SADC region is endowed with all the raw minerals required for the production of lithium-ion batteries. However, most of the mined minerals are exported as raw materials, depriving member states of the opportunity to earn higher revenues through the production and export of value-added products for the lithium-ion battery manufacturing value chain. The current landscape of battery manufacturing in SADC shows potential for the development of raw material beneficiation, cell component manufacturing and cell production.

The aim of this study was therefore to provide a SADC outlook on e-mobility to accelerate the battery manufacturing value chain. The study outlines the benefits, opportunities and barriers to accelerating the lithium-ion battery manufacturing value chain in Southern Africa.

The recommendations for the development of the lithium-ion battery manufacturing value chain in SADC include:

- Member states should align their policies with the SADC Industrialisation Strategy Roadmap and SADC Vision 2050 to accelerate the adoption of EVs in the region.
- Formation of a regional battery alliance.
- Capacity building measures in the private and public sectors and the establishment of a regional body for the testing and accreditation of lithium-ion cells and batteries.
- A transition must also be prioritised in all regulatory frameworks for the manufacture of lithium-ion batteries in SADC.

2.4 BESS Demand Profile

The BESS demand profile for the period 2025 to 2050 cannot be determined in isolation from the respective demand profiles of the individual NEV categories and will effectively be a follower. The value chains for the respective NEV categories will most likely also be different and will be influenced by the following considerations:

- Market size: the individual NEV categories should be able to achieve economies of scale at a local level that could justify local manufacturing/assembly capacity. If this is not possible for each category, it will be necessary to consider whether synergies can be created between the BESS requirements of the NEV categories to achieve economic scale.
- Cost: The BESS capacity, distance, technology and life expectancy will determine the BESS cost. The main objective is to determine the different price ranges for NEV prices per category and to ensure affordable BESS costs (acquisition and replacement) in relation to NEV prices.
- Infrastructure: The availability of infrastructure, such as charging stations, power availability (including the impact of load shedding), will inform whether the BESS market can be based on the direct sale of BESS or whether leasing or a BESS exchange model can be implemented. According to current estimates, the latter is possible for smaller NEVs, but not for large NEVs such as buses, mining machines, etc.
- Geographical location: geographical concentration will be a key factor and consideration needs to be given to whether it is fleet (depot based charging) or a decentralised model and the concentration of NEVs within a geographical area. As examples:
- Mining equipment is likely to be in rural, mining-related areas and most likely to be site-specific. However, centralised manufacturing/assembly of the BESS solution may be located elsewhere or as part of the NEV production facility.

[5] Edem Foli; South African Institute of International Affairs; Occasional Paper 316; December 2020

- Smaller NEVs in high concentration areas (many NEVs) could be recharged at home, or a BESS exchange model or hybrid.
- BESS capacities: Different NEVs will have different BESS capacities and voltages, depending on the energy and power requirements of each NEV, which will impact standardisation and economics.
- Policies and incentives: Policies and incentives will play a key role in the adoption of NEVs in certain categories such as taxis. BESS demand will depend on daily distances travelled, charging infrastructure at home as well as tax brackets, charging costs and government support for taxi owners to switch from petrol to a BESS NEV as taxi owners cannot afford to do so.
- Ability to utilise/adapt/expand existing capacity: The BESS value chain(s) will depend on whether existing assembly capacity (as in Appendix B) can be utilised or whether entirely new capacity is required. It is assumed that some leverage is possible for smaller NEVs, but new capacity will be required for larger NEVs and this capacity will depend on the likely uptake in the different categories.

2.5 Chinese Market

The Chinese market is leading and dominating BESS for NEV applications, as small NEVs are widely used in the country's cities and residential areas. Small NEVs have become the norm in residential areas for families as there are restrictions on the purchase of passenger cars. Two and three-wheelers are also safe to drive. For smaller NEVs, there are already established charging stations, exchange models and a sales and spare parts market.

The conversion of public transport in China's major cities to environmentally friendly modes of transport such as BESS, hydrogen and the solutions presented depends on the specific technology used by the respective OEMs. China is also the global leader and dominates the manufacturing of BESS across the entire value chain, although raw materials such as lithium, cobalt, etc. are sourced from around the world through long-term contracts.

3. ANNEXURE A – BATTERY VALUE CHAIN

3.1 Circular Economy

It is important to think about batteries as a circular economy. A simplified illustration is shown in Figure 4 below:



Figure 4: Battery Life Cycle[6],

Key aspects of this circular economy that need to be highlighted are the following:

3.1.1 Raw Materials Are Crucial for Battery Supply

Volatile commodity markets affect everyone, both from a supply/demand and a cost perspective. Commodity producers are increasing their capacity (especially for the passenger car and stationary vehicle market) to relieve pressure on the battery supply chain and fulfil OEM requirements. For example, the demand for battery-grade lithium has increased by up to 95% since the beginning of 2022.

As battery chemistry is constantly evolving and improving (especially in terms of energy density, lifespan and cost), there is also a degree of uncertainty regarding the future composition of batteries and changes could be mitigated. Future lithium-ion batteries may require less nickel and cobalt demand as alternative solution is pursued for high-cost raw materials.

This creates uncertainty about the level of new investment in mining, processing and refining capacity that will be required over time. In addition, the secondary recycling market could become a substitute for primary mining and processing, potentially be at lower cost.

3.1.2 Continuous Improvement

Battery designs will continue to change and adapt as the market grows, the demand profile changes and costs need to be reduced. Therefore, future battery cell manufacturing gigafactories must not only be flexible and scalable, but also able to accommodate changes in future battery technology.

[6] https://europe.autonews.com/sponsored/circular-economy-spurring-new-thinking-ev-batteries

The exchange of information between various players within the battery value chain will become increasingly important. Traceability from raw material source to the final products will become a reality to manage and control performance shortfalls and associated accountability. Blockchain is likely to play an increasingly important role in the future.

3.1.3 Recycling and Second Life Solutions

End-of-life scenarios are increasingly becoming the focus of companies in order to demonstrate their social and environmental responsibility and accountability. Battery value chains are no exception. The design and manufacturing processes of future batteries will be critical to consider and enable proper recycling, but it will still take some time for such recycling infrastructure to be developed and matured.

South Africa also still lacks a holistic assessment and evaluation as well as an appropriate global approach to recycling and second life use. However, the importance of a strong, collaborative ecosystem to address end-of-life challenges cannot be overemphasised.

Economic improvements to the comparatively high costs of realising end-of-life use cases, as well as process engineering benefits, are required to realise large-scale adaptation. Building strategic partnerships and sourcing strategies will enable players to jointly offer and expand second-life applications and recycling facilities.

It must be recognised that the end-of-life solution and processing for small and large mobility projects may be different due to the size, composition of batteries and different technological solutions. The key will be to find the "common thread" between all solutions.

It must be clear that second-life applications and recycling are not scalable within a short timeframe and are subject to cost constraints. In addition, there are a growing number of legal requirements and compliance regulations that govern this industry, either with positive or negative effects.

3.2 Examples of Batteries

Below are illustrations that give an overview of the development of lithium-ion batteries from cells and battery packs to complete battery systems for mobility solutions:

3.2.1 Lithium-Ion Cell Type

A Lithium-Ion cell, Figure 5, is the basic building block for Lithium batteries, battery packs and complete battery systems. Lithium is chosen because of its high energy density, as it is the lightest metal but has a high electrochemical potential.[7] Lithium-Ion cells are especially favourable for use in EVs due to their stability and safety compared to lithium batteries.[8]

[7] U.S. Geological Survey; Thomas G. Goonan 2012 https://pubs.usgs.gov/circ/1371/pdf/circ1371_508.pdf
[8] U.S. Geological Survey; Thomas G. Goonan 2012 https://pubs.usgs.gov/circ/1371/pdf/circ1371_508.pdf

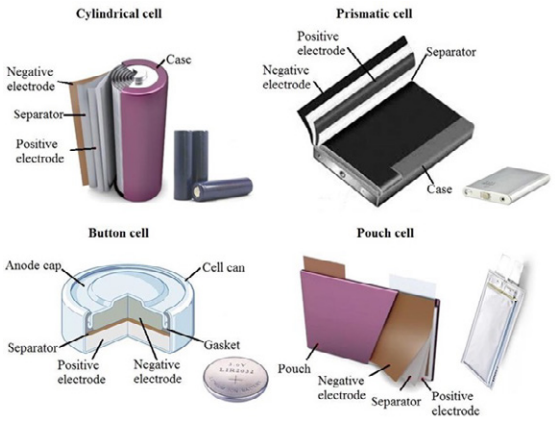


Figure 5: Lithium-Ion Cell Type[9]

3.2.2 Lithium-Ion Packs

A lithium-ion battery consists of several individual cells that are individually managed and controlled via the integrated battery management system. Figure 6 shows a typical cell and pouch-based battery pack configuration.

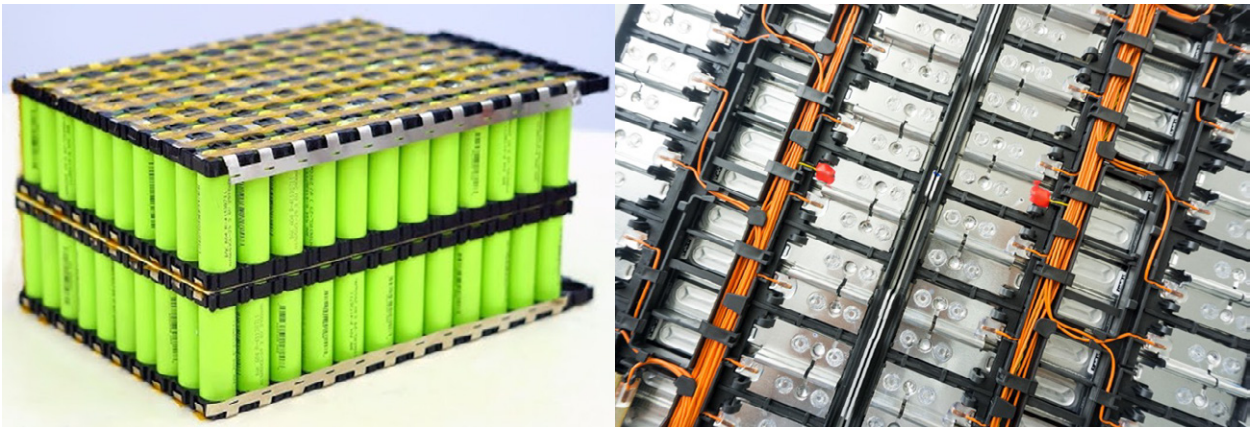


Figure 6: Battery Pack Configuration[10]

[9] https://www.researchgate.net/figure/The-most-common-lithium-ion-cell-types_fig2_304023316
[10] https://solutions.covestro.com/en/highlights/articles/stories/2021/plastic-parts-for-battery-pack-design

3.2.3 Lithium-Ion Battery Assembly

Figure 7 below shows a typical structure of a battery pack for battery-powered electric mobility.

Smaller mobility:



Figure 7: Lithium-Ion Battery - Small Mobility[11]

Large mobility:

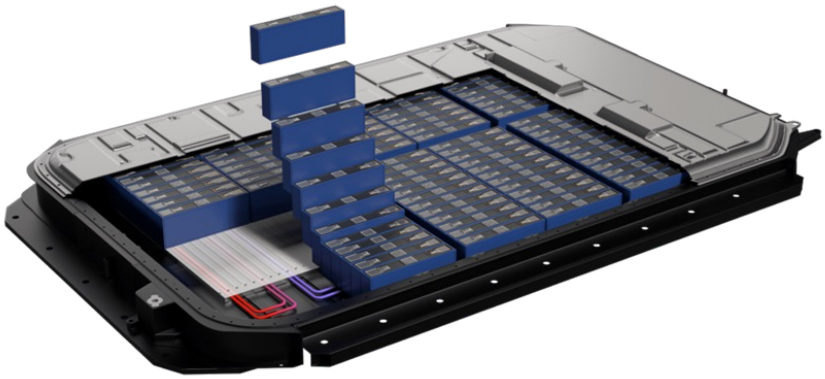


Figure 8: Lithium-Ion Battery - Large Mobility[12]

[11] https://coslight.en.made-in-china.com/
[12] https://www.emobility-engineering.com/cell-to-pack-batteries/

3.2.4 Deployment Examples

Figure 9, Figure 10, Figure 11, Figure 12 and Figure 13 show some examples of the use and positioning of batteries in e-mobility solutions:

E-bike



Figure 9: E-Bike Battery Configuration[13]

Two-wheeler



Figure 10: Two-Wheeler Battery Setup[14]

[13] https://cycle-now.com/ebike-battery-replacement/
[14] https://electrek.co/2021/10/10/gogoros-swappable-ev-batteries-enter-china-scooter-makers-unveil-compatible-new-models/

Material handling equipment



Figure 11: Forklift Battery Setup[15]

Large truck

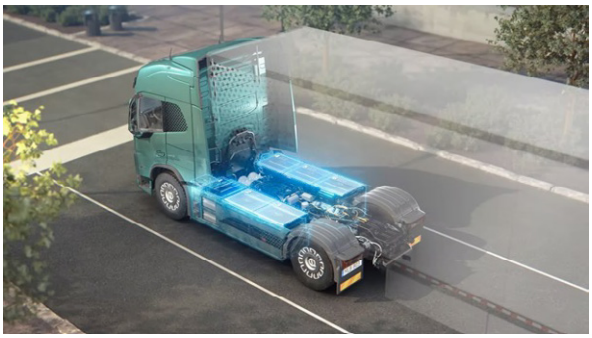


Figure 12: Large Truck Battery Setup[16]

Mining equipment



Figure 13: Mining Equipment Battery Setup[17]

[15] https://www.tmhnc.com/blog/convert-to-lithium-ion-forklift-battery
[16] https://www.volvogroup.com/en/news-and-media/news/2022/may/battery-packs-for-electric-vehicles.html
[17] https://energyandmines.com/2023/05/sandviks-new-battery-for-bevs-has-36-higher-capacity/

3.3 SA Batteries Manufacturing/ Assembly

There are currently several manufacturers of lithium-ion phosphate batteries in South Africa. Although primarily dominated by stationary applications, some of these companies are also present in the mobility market, albeit to a limited extent. None of these companies manufacture their own batteries cell and all use imported cell for their respective applications.

3.3.1 Blue Nova

Blue Nova Energy (Pty) Ltd was founded in July 2015 and specialises in the development and manufacture of energy storage solutions. The company is developing market opportunities for the application of stationary LiFeYPO4 battery storage solutions in the Southern African region.

BlueNova has recently entered a partnership with Reutech (Pty) Ltd. Reutech (Pty) Ltd is part of the JSE-listed Reunert Group and are looking at providing energy storage solutions to residential, commercial, industrial and utility customers.

Blue Nova not only focuses on the stationary market but also offers a Mobile Power Series (MPS) designed for seamless swap-out of 12V and 24V lead-acid batteries in most existing applications. The MPS batteries shown in Figure 14 are high-quality, lightweight and highly reliable solutions to powering home and business security systems (gate motors, alarm systems) and are also used by outdoor and 4x4 enthusiasts in secondary (standby) vehicle applications and for powering camping equipment.



Figure 14: Blue Nova MPS Series[18]

Depending on the battery specification for smaller mobility applications, these Blue Nova batteries could be used.

[18] https://www.bluenova.co.za/products/mps-mobile-power-series/

3.3.2 FreedomWon

Freedom Won is a privately owned South African company that assembles stationary energy storage systems in South Africa. FreedomWon offers a wide range of leading lithium battery solutions under the brand name Lite, covering needs from 7Ah 12V gate drive batteries to its largest 5MWh containerised expandable grid support solution. FreedomWon uses only lithium iron phosphate chemistry (LiFePO4) cells, Figure 15.

FreedomWon has also developed a lead replacement solution with its range of 12V lithium batteries. Sizes range from 7.5Ah to 200Ah for a variety of applications, from alarm and gate operators to high-end boat and RV energy storage. However, these batteries are not suitable for engine starting or other applications with extremely high current draw.



Figure 15: FreedomWon Lithium Battery Range[19]

Freedom Won also has roots in EV technology with its lithium traction battery solutions covering various applications such as forklifts, golf carts and mining locomotives.

- Forklift battery solution: These are available in various voltages and capacities and reduce battery costs, improve operational efficiency (through fast charging and no battery replacement), and eliminate battery maintenance.
- Golf carts: They are suitable for twice the range of carts, halve the weight of cart batteries and extend the service life by up to six times compared to lead-acid systems.
- Mining locomotives: Extend life by six times or more, reduce charging four times, integrate the smart battery into the locomotive control system, remove hazardous acid and gases from the charging bays and eliminate battery maintenance.

In 2021, Freedom Won has ramped up its production to an output of almost 20MWh per month. Freedom Won's presence extends across Africa and beyond to several other key markets.

The joint development of Freedom Won's packaged solutions integrates large commercial ATESS inverters with Freedom Won Lite High Voltage batteries. Freedom Won has developed its own BMS that monitors the health and performance of the installed BESS system.

[19] https://www.freedomwon.co.za/energy-storage/

3.3.3 Polarium

Polarium is a Swedish company dedicated to providing the most powerful, safe, and sustainable energy storage solutions based on lithium-ion technology.

Since 2015 Polarium has expanded from its headquarters and R&D in Sweden to include manufacturing in Mexico, Vietnam and South Africa, as well as sales offices on all continents. The company focuses on lithium batteries, Figure 16.

The factory is located in Cape Town and was built in close partnership with American Tower Corporation (ATC) in Africa to provide lithium-powered battery backup solutions for Telkom towers in ATC Africa's markets. The annual production potential of the factory is more than 300 000 batteries, equivalent to 4 GWh per year. The factory is powered by a combination of solar energy and Polarium's energy storage solutions, making a positive contribution to the South African energy grid. More than 200 people are directly employed at the factory and with additional employment opportunities have been created for subcontractors.



Figure 16: Polarium Lithium Battery[20]

It is currently not clear whether battery technology could be adapted for mobility applications.

3.3.4 Solar MD

Solar MD, based in Richmond Park, Cape Town, specialises in lithium-ion battery storage for residential, commercial, and public applications. Solar MD uses cells based on the most advanced lithium Iron Phosphate chemistry. The factory has capacity to produce around 100 lithium-ion batteries per year using its own intellectual property. Solar MD has developed the intelligent battery management system in-house. This design enables the monitoring, protection, and control of the cells as shown in Figure 17.

Solar MD's solution is focused on the stationary market such as residential and small business, commercial and utility scale as well as mini grids. Solar MD does not currently offer any applications for mobility.



Figure 17: Solar MD's Product Range[21]

[20] https://polarium.com/telecom/
[21] https://www.solarmd.com/

The company employs 120 people and has started an expansion programme to increase capacity to 300 batteries per year. The batteries are made from lithium-ion cells imported from abroad.

3.3.5 i-G3N

IG3N (Pty) Ltd is a start-up company that manufactures LiFePO4 batteries in South Africa, as shown in Figure 18. The company's core market is stationary storage in conjunction with photovoltaics. The company focuses on high-quality products and incorporating the latest technologies into battery functionality. One of the main areas of focus is exporting to the SADC region and the rest of Africa, as there are exceptional opportunities in the rest of the continent, particularly in the development of mini and micro grids, which are influencing development.

iG3N is currently involved in a turnkey project with Murray & Roberts Power & Energy to deliver a 1.2MWh battery storage solution for an industrial customer.

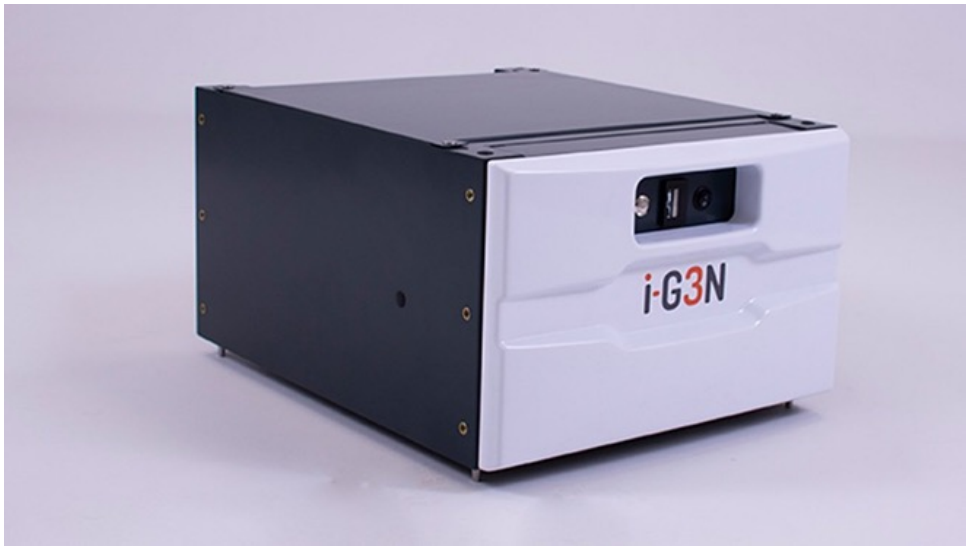


Figure 18: iG3N's LiFePO4 Battery[22]

3.3.6 Balancell

Cape Town- based Balancell has developed 'smart' lithium-ion phosphate 'batteries (see Figure 19) that can manage and protect themselves and report their usage and status remotely. The solutions are based on more than two decades of development and operational excellence. The company has been manufacturing these smart lithium batteries since 2009. Balancell is ready to unleash the power of renewable stored energy on the global market by making it a more practical, economical and accessible energy solution for all organisations.

Intrinsically safe and exceptionally robust, the batteries are recognised as maintenance-free batteries that provide an immediate return on investment in the workplace. Balancell has become the battery of choice for some of the world's leading automotive brands and logistics companies, delivering higher productivity, lower operating costs and a cleaner, more reliable power source every day.

Balancell batteries are used in forklift trucks, heavy duty forklifts, scissor lift trucks, cleaning machines and refrigerated vehicles.

[22] https://www.i-g3n.co.za/

The modular design of the batteries makes them easily accessible in the field for service and repair. Battery diagnostics can be performed both on-site and remotely, and software updates can be reconfigured and deployed over the air (OTA). The entire power electronics and cells can be safely replaced by a trained technician.



Figure 19: Balancell 'Smart' Battery[23]

3.3.7 Hubble[24]

In just two years, Cape Town-based Hubble has become one of the leading manufacturers of lithium-ion phosphate batteries (LiFePO4) for stationary applications in South Africa.

The AM energy storage solutions range from 2.6kWh to 5.5kWh and are compatible with most leading inverter brands (Figure 20). The batteries can be easily wall-mounted or rack-mounted, making them a practical, clean solution for installers.

Hubble also offers lead-acid replacement batteries with the S-100A (Figure 21). These 12 V lithium batteries can be connected in parallel with up to 16 batteries to form a 48 V battery or connected in series as 12, 24, 36 or 48 V batteries.

AM energy storage solutions



Figure 20: AM Energy Storage Solution

[23] https://balancell.com/industrial-and-commercial-battery/
[24] https://www.hubblelithium.co.za/products

S-series battery



Figure 21: S-Series Battery

4. PROJECT TEAM

4.1 Project lead

Industrial Development Corporation of South Africa Ltd. (IDC)
Name: Nathan Fredericks
Designation: Senior Industry Development Planner
E-mail: nathanf@idc.co.za

Service Provider Project Lead – AIH Group
Name: Owen Smith
Email: owen@autoih.co.za

Steering Committee Members:

INTERNAL	EXTERNAL
Riaz Haffejee* Tsakani Manyike **SUB-COMMITTEE** Nnzeni Netshitomboni Pamela Mondliwa	Hlengiwe Mkhize (NAACAM) John Oliver (Industry Expert) Grant Leppan (NAAMSA) Dr. Norman Lamprecht (NAAMSA) Prian Reddy (Green Cape)

*Left the IDC in November 2023 to join Toyota South Africa.

4.2 Contributing Authors for the Study Phase 1

Carl Snyman
Shivani Singh
Bertie Strydom
Kobus Boshoff
Paul Vorster
Prof. Anthony Black
Derek Zimmerman
Theuns Wilkens
Lehanri van der Westhuizen
Marie-Claire Steynberg
Paul Vorster
Owen Smith
Tshiamo Motau

4.3 Service provider contact details

Lynnwood Bridge
Building A, 1st Floor
4 Daventry Street
Lynwood Glen
Pretoria
0081

Tel: +27 12 346 9047 (Head Office)
Fax: +27 86 219 0100
Mobile: +27 76 754 0014
Email: owen@autoih.co.za, melt@autoih.co.za
Address: P O Box 35501, Menlo Park, 0102
Web: www.autoih.co.za