ELECTRIC MOBILITY TRANSITION & LOCALISATION

Towards Unlocking the NEV Value Chain for Africa

SITUATIONAL AND BASELINE ANALYSIS REPORT SERIES REPORT 4: INFRASTRUCTURE PROVIDING ENERGY FOR NEV



AIH GROUP

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1. INTRODUCTION

New Energy Vehicles (NEV) are seen as an important step towards achieving global climate change objectives. This study has undertaken a comprehensive review of the relevant literature as it relates to the current NEV industry globally, for South Africa and the Rest of Africa (RoA), whilst identifying key role players and stakeholders and highlighting current and emerging gaps and opportunities, in the NEV market.

To evaluate the NEV segments, markets and policy along the value chain, the literature review has been structured to provide a comprehensive overview of the most important NEV sectors in a logical framework as follows:

1. **NEV landscape overview:**
   New Energy Vehicles (NEVs) are vehicles that are powered by electricity or fuels made from non-fossil fuel sources. In May 2021, the dtic released the green paper on NEVs[1] 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 NEV. The Just Energy Transition Implementation Plan (JET IP) provides a means to achieve the transition through investments spearheaded by various government authorities, private institutions and development finance institutions (DFIs).

2. **Micro-mobility:**
   The context and rationale for micro-mobility, market developments and particularly the rise in electrified two and three-wheelers, four-wheeler 'last mile' delivery vehicles, conversions and eco-tourism markets, together with closing comments.

3. **Public transport:**
   This section reviews buses from a global perspective and for best practice lessons, 'battery swapping' as an emerging trend, South African trends and developments, minibus taxis and case studies for Kenya, Ghana, Rwanda and Zimbabwe for consideration.

4. **Machinery and equipment:**
   A review of the production and sale of zero-emission heavy-duty vehicles and equipment is undertaken, with trucks, mining equipment, agricultural equipment and the general electrification of various categories of machinery and equipment, together with ownership models being analysed. Conversion of fossil fuel-driven vehicles to NEV is also considered and then role players and stakeholders are identified, together with opportunities in the NEV value chains and for FCEV components.

5. **Infrastructure providing energy for NEV:**
   The NEV industry requires support infrastructure in the form of fuel supply infrastructure, charging stations and equipment, policy and incentives, together with other support and enabling investments, including finance and insurance. These issues are traversed and opportunities are identified.

6. **Battery value chain:**
   The batteries in various NEV are becoming an important technology in themselves and underpin certain elements of the NEV industry and opportunities. Battery types have been analysed with smaller and larger mobility issues traversed and a brief review of battery studies conducted in South Africa.

7. **Trade policy conformity:**
   A range of trade policies, incentives and tax schemes are considered that various countries employ to accelerate the transition to NEVs. Tariffs and regional integration for trade enhancement are considered, including Rules of Origin (RoO) and the implications of the African Continental Free Trade Agreement (AfCFTA) on the emerging NEV industry in Africa.

[1]DTIC, 2021. Auto green paper on the advancement of New Energy Vehicles in South Africa, the South African road to production of electric vehicles (The Roadmap, 18th May 2021)

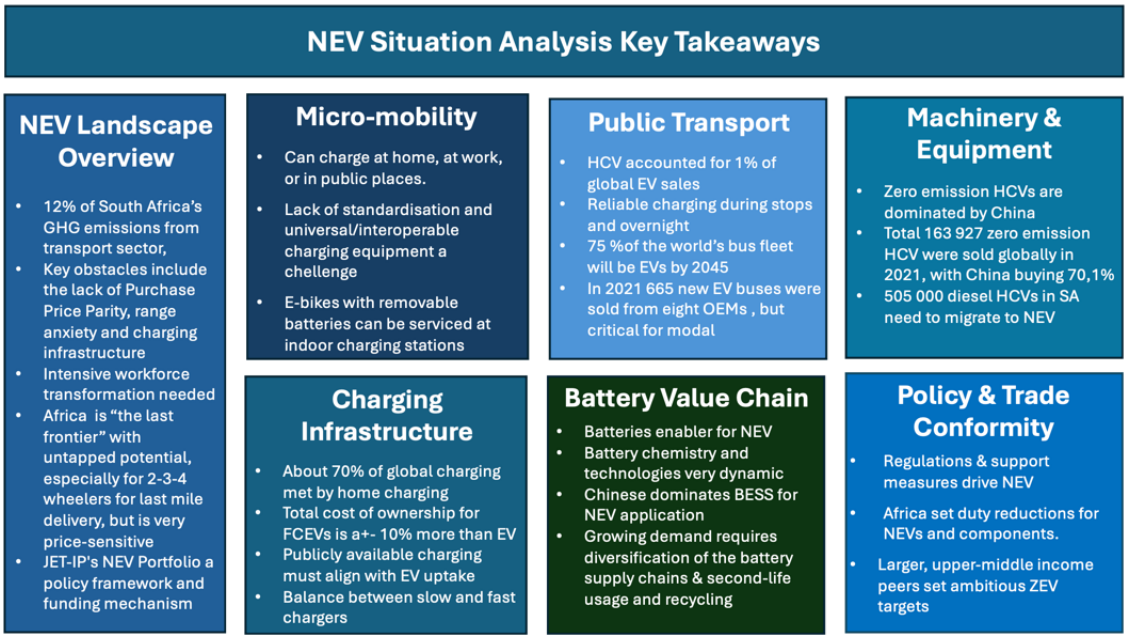


Figure 1: NEV Situational Analysis Key Takeaways

The key takeaways from each of the segments are summarised in the figure above. Each of these is dealt with in a separate chapter in the series review, highlighting key role players and stakeholders, culminating with an overview or statement of the opportunities which have been identified in the NEV segment considered.

2. INFRASTRUCTURE PROVIDING ENERGY FOR NEV

2.1 Infrastructure providing energy for electric vehicles

2.1.1 Introduction

When considering infrastructure for electric vehicles, the solution seems to be a type of charging facility that resembles a fuel pump that we find at filling stations for conventional internal combustion engine vehicles. However, there are numerous approaches to replenish the energy in an electric vehicle.

The vehicle can be charged at any plug point: household sockets, shopping centres, office parking spaces and dedicated charging stations on major highways. These plug points, or connectors, vary in capacity and speed of charging: a household socket can provide up to 7.4kW and a dedicated fast charger can charge the EV battery at up to 350kW[2]. Meaning, that a vehicle charging at home will charge for 8 to 16 hours, whereas a vehicle charging at a fast charger typically charges in 20 to 50 minutes, depending on the battery size.

About 70% of the global charging demand is currently met by home charging[3]. It is, however, becoming increasingly important to have publicly accessible charge points to provide for charging possibilities on longer-distance travel. The lack of publicly available charge points has been blamed for the low uptake of EVs. It is therefore important to develop an EV charging infrastructure network to support the unconstrained use of electric mobility by providing energy-replenishing services at all convenient spaces.

2.1.2 Battery Charging

2.1.2.1 The equipment and system overview

An electric vehicle charging infrastructure is a network of charging stations specifically built or designed to recharge the batteries of electric vehicles. These charging stations are typically described as Electric Vehicle Supply Equipment (EVSE), which is part of an electrical energy distribution system delivering energy to electric vehicle batteries.

The energy supplied to this system can come from the existing utility grid or a renewable energy generation source making use of wind and/or solar energy.

Charging Stations have EV chargers that are rated by the amount of energy delivered to the vehicle's battery per unit of time. These different chargers have varying power ratings (in kW) and charge times are dependent on the size of the battery and the amount of energy required to take the battery to a required state (%) of charge.

Typically, every EV has an onboard charger, built-in, that makes use of AC current to charge the battery. This slow charger is usually limited to a specific charge range of 7.4kW to 22kW AC power which is designed for home usage and workplace charging, from a wall box-type charge point. However, many of these can be strategically placed where electric vehicles will be parked for longer periods, such as workplaces and shopping centres.

Fast charging, commonly known as "DC Fast Charging" (DCFC), can charge up to and beyond 800 Volts. For fast charging, higher power levels up to a rate of 350kW can be used. These require specific infrastructure beyond standard domestic or industrial socket outlets. This charging process makes use of DC but may include an AC connection between the vehicle and the charging point.

[2] EV Charge, AC vs DC, 2023
[3] IEA Org, Trends in Charging Infrastructure, 2023

Unlike fuel filling stations, EV charge points can be installed against walls or on pillars between parking bays. Some charge points found next to the road are fixed to lamp posts or parking meters.

Fast charging stations, making provision for the higher number of vehicles and higher turnover at the charge points, may resemble filling stations with multiple fast charge points and short stopping times.

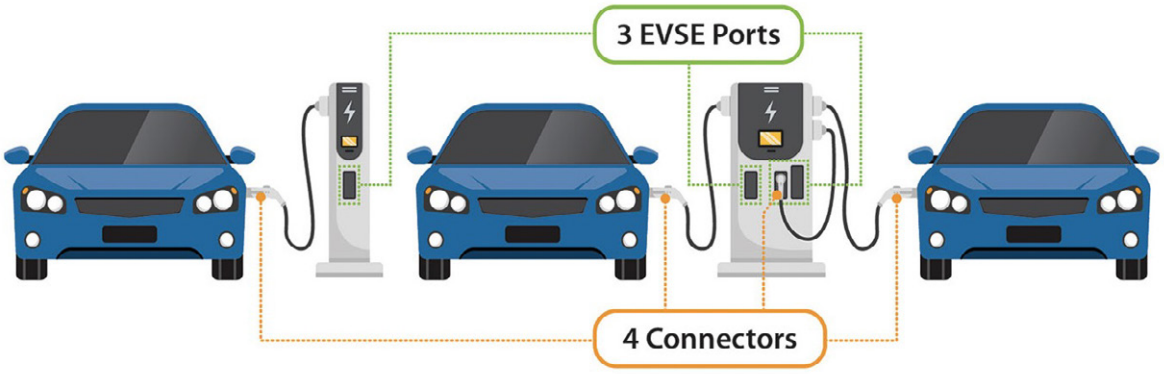


Figure 2: AC Charger & DC Charger

As shown in Figure 2 above, the AC charger on the left has one charge point and can have only one connector. The DC fast charger on the right has three charge points and three connectors: two DC connectors and one AC connector.

A charge station location is a site with one or more EVSE ports at the same address. Examples include a parking garage or a mall parking lot. Below is an example of a charge station and charge points.

2.1.2.2 Home chargers (2.3kW and 7.4kW)

Charging a vehicle at home is the most convenient way of replenishing the energy in the vehicle's battery. Typically, the vehicle will be left plugged in overnight to be fully charged the next day. This is also the time when the grid supplier (Eskom) sells less electricity and may make use of a lower tariff to encourage off-peak electricity consumption (for consumers having smart metres installed). With solar-powered chargers, the most effective time to charge will be in the middle hours of the day when radiation levels are at their highest.

2.1.2.3 AC charging stations (11kW and 22kW)

Charging is faster and more convenient than the standard 2.3kW and 7.4kW counterparts. As a reference: it is possible to charge the BMW i3 to 80% capacity in less than three hours. The charger has a colour screen for human interface and data visibility as seen in Figure 3. A charge card, smartphone app or remote operator can initiate and terminate the charge.



Figure 3: AC charging station

A typical specification for this type of charger is:

Voltage: 230V or 400V, 50Hz
Max Power: 22kW, 3 phase
Maximum Current: 32A per point/connector.
SANS: 62196-2 (Type 2 socket only)

2.1.2.4 Connector standards

The entering of EVs into the market in South Africa is implemented according to the European standard and has the following charge cable connector plug-in configuration shown in Table 1.

Table 1: Charge Cable Plug-In Configuration

Slow AC charge:	*Fast DC charge*
	
Mennekes (or Type 2)	CCS2

Therefore, the charge station connectors should be of the same standard to be compatible with the connector point on the vehicle.

2.1.2.5 The Charging Transactions Management System

The charging infrastructure industry has aligned with a common standard called the Open Charge Point Interface[5] (OCPI) open-source protocol. The OCPI supports connections between e-Mobility Service Providers who have EV drivers as customers and Charge Point Operators who manage charge stations. This protocol is independent and free to use. It can work both bilateral, as well as, in combination with roaming hubs. Everyone can participate in the development of OCPI.

Charge Point Operators are responsible for the smooth operation of:

- Determining the availability and functionality of the charge point
- Initiating and terminating charge sessions (remotely)
- Unlocking of the connector from the vehicle (remotely)
- Terminating active charge sessions (remotely)
- Viewing, recording, analysing and reporting on charge sessions
- Resetting and rebooting of charge stations (remotely)
- Manage and charge authorisation tags or activation codes
- Providing support to drivers via SMS, etc.

The charge management platform provides a central viewpoint of the installed charge point network while providing the tools to remotely manage these charge points and gain insights into the health of the EV charge point network. The charge network management system provides an easy-to-use system giving the network operator the ability to configure various charge point parameters remotely.

2.1.2.6 Payment for charging

To make use of a charge station, the user needs to not only connect the vehicle to the charge point but also connect to the system that records the amount of electricity used and manages to charge transactions.

This requires that an account needs to be set up with the charge point operator and funded before making use of a charge station. The charge point operator will make available to the owner an RFID card to be used at the charging station to initiate and pay for a charge session. These cards also need to be registered on the system.

An entity can have an account for more than one vehicle and register more than one card on the same account. It is good practice to use one card per vehicle and keep the card inside the vehicle. This is useful for fleet management reporting.

- **Monitoring & control of charging operations:**
  The charge point operator has full remote control over charging transactions and can be contacted to assist or resolve problems.
- **Smart phone and web app:**
  Smartphone apps from the EV manufacturer as well as from the charge point operator are available. This provides and records information on charging operations.
- **Analytics available:**
  Currently, the charge point operator app reports the charge session date, electricity dispensed and cost of each transaction.

[5] "https://evroaming.org/ocpi-background/"OCPI Background | EVRoaming Foundation

- **Maintenance of charging infrastructure:**
  General maintenance for charging infrastructure includes storing charging cables securely, checking parts periodically and keeping the equipment clean. Chargers may need intermittent repairs as well.

  While ongoing charging infrastructure maintenance can be minimal, repairing broken chargers can be costly if they are no longer under warranty. Therefore, it is critical to establish responsibility for maintenance costs and determine if the site host, charging network, or installer is responsible.
- **Marking of charge parking places:**
  Only vehicles that are charging their batteries must be parked in the places provided to reach and connect to the charger. Therefore, these parking places should be painted according to the national standard and the appropriate markings and signage used to deter other vehicles from occupying the charging bay.

2.1.2.7 Charge point energy supply

Grid supply to the charge station

The grid supply to the charging stations should be able to accommodate all charging stations and should also make provision for future expansion.

DC fast charge points have charge rates of up to 350kW currently, delivering a current of up to 500 amps each. The grid supply should have a higher capacity to deliver this demand for the charge station to operate.

Charge stations with multiple DC fast charge points may need dedicated substations to make provisions for future expansion.

Solar energy supply to the charge station

Solar panels:

- **Capacity requirements**
  As an indication: The number of full sun hours is estimated to be four hours in Cape Town (to compensate for winter days). With a solar installation of 125kWp, 500kWh of electricity can be produced to charge the battery.
- **Energy storage backup**
  When the grid supply to the station is not stable, or when charging happens at times when the sun does not shine, energy storage at the charge station can still provide uninterrupted charging.
- **Scalability of the site**
  The demand for charge points will grow as the number of EVs increases. With the installation of the first charge stations, future requirements need to be considered and provision made for increased electricity supply.

- **Specifications**
  A further requirement may be that the service provider, or a contracted (to the service provider) third party, has the necessary capabilities to operate and manage the charging transactions (to be negotiated between the relevant parties). These capabilities should include, amongst others:
  - the design of the charging stations,
  - installation and all related construction,
  - charge session transaction management, and
  - maintenance and fixing of any failures (SLA to be provided).
  - Parking areas for charge sessions

Painting of parking bays and the related signage should follow the national standard:

- Charge points connectors

For DC fast charging, CCS connectors are required; and for AC charging, Mennekes type (J1772) is required.

2.1.3 Global market

Slow chargers (11kW AC and 22kW AC)

Globally, more than 600 000 public slow charging points were installed in 2022, 360 000 of which are in China, bringing the number of slow chargers in the country to more than 1 million. At the end of 2022, China was home to more than half of the global public slow chargers. Europe ranks second, with 460 000 total slow chargers in 2022, a 50% increase from the previous year. In Korea, slow charging points have doubled year-on-year, reaching 184 000 charging points.

Fast chargers (50kW DC and higher)

Publicly accessible fast chargers, especially those located along major highways, enable longer journeys and can address range anxiety, a large barrier to EV adoption. Like slow chargers, public fast chargers also provide charging solutions to consumers who do not have reliable access to private charging, thereby encouraging EV adoption across wider groups of the population. The number of fast chargers increased by 330 000 globally in 2022, though again, the majority (almost 90%) of the growth came from China. The deployment of fast charging compensates for the lack of access to home chargers in densely populated cities and supports China's goals for rapid EV deployment. China accounts for 760 000 fast chargers.

In Europe the overall fast chargers totalled over 70 000 by the end of 2022, an increase of around 55% compared to 2021. The top three European countries having the fastest chargers are Germany (over 12 000), France (9 700) and Norway (9 000). There is a clear ambition across the European Union to further develop the public charging infrastructure, as indicated by provisional agreement on the proposed Alternative Fuels Infrastructure Regulation (AFIR), which will set electric charging coverage requirements across the trans-European network. An agreement between the European Investment Bank and the European Commission will see a €1.5 billion fund made available by the end of 2023 for alternative fuel infrastructure, including electric fast charging.

The United States installed 6 300 fast chargers in 2022, about three-quarters of which were Tesla Superchargers. The total number of fast chargers in the United States reached 28 000 at the end of 2022[6].

[6] IEA, Global EV Outlook (2023) - https://www.iea.org/reports/global-ev-outlook-2023/trends-in-charging-infrastructure

2.1.4 South Africa

The first charging stations in the charging network of South Africa were provided by GridCars. Today GridCars operates a growing network of 350 charging stations.[7]

GridCars also developed the first back-office transactional system handling all charging transaction records and payments for charging. This is an open-source system to enable sharing with partner companies that want to provide charging hardware and services to EV owners. This makes it possible for all brands and models of EVs to charge at any charge point as it makes use of the same standard protocols. The system is continually evolving as more experience and knowledge is gained.

Other companies that are also providing charging equipment and services for EVs include Rubicon, EV Charge, Breev and Zero Carbon Charge. Participating OEMs include BMW, Jaguar, Audi and Mercedes-Benz. The OEMs partner with the supplier of the EVSE and in many cases, sponsor the installation.

Zero Carbon Charge recently announced that they would be installing charge stations powered by renewable energy. They plan to roll out a national network of ultra-fast EV chargers at 150km intervals on strategic routes across all nine provinces.

This charging network is growing as more parties are entering the market with charge points (hardware). In September 2023 there were about 435 public and private charging stations in South Africa with another 100 to go live before the end of the year.[8] Not all charge points are for public use, however, as some fleet owners of logistics companies prefer to always have their own charge points available for their own fleet of electric vehicles.

Various apps exist that provide information about the location and availability of charge points. These include ChargePocket, Google Maps, Plugshare, ABRP and others.

2.1.4.1 GridCars

After years of research and learning from service providers in the USA, Europe and China, GridCars, in partnership with BMW in 2016, started to roll out charging stations at BMW dealerships and along major highways in South Africa. This made it possible for EV owners to travel longer distances. OEMs like Jaguar in 2018, Audi in 2021 and Mercedes-Benz in 2023, also sponsored chargers that were added to the GridCars network.

GridCars has developed a back-office system that is in line with worldwide best practices and standards in e-mobility. This system implements OCPP as the accepted standard for communication with Charge Point Infrastructure. Figure 5 shows GridCars' interaction between modules.

[7] GridCars - https://www.gridcars.net

[8] H Labuschagne - South Africa's electric car charging network among best in the world - September 2023 https://mybroadband.co.za/news/motoring/508418-south-africas-electric-car-charging-network-among-best-in-the-world.html

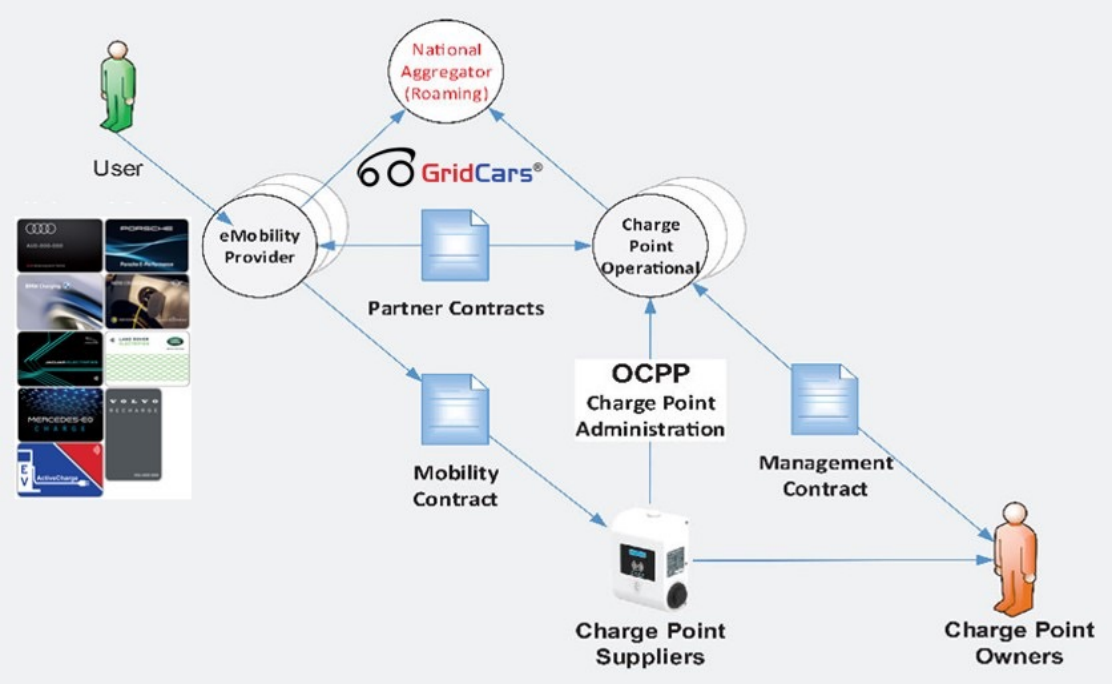


Figure 5: GridCars Interaction Between Modules

This consists of three primary modules. Interactions between these modules are controlled through contracts between the relevant parties:

- **E-Mobility provider**
  The management of billing, charge point access and authentication.
- **Charge point operations**
  The service that interfaces to the charge point, monitoring both usage and messaging.
- **Aggregator**
  This is a roaming service, allowing various charge point networks to be used through multiple e-mobility service providers. Figure 6 shows the GridCars charge station network below.

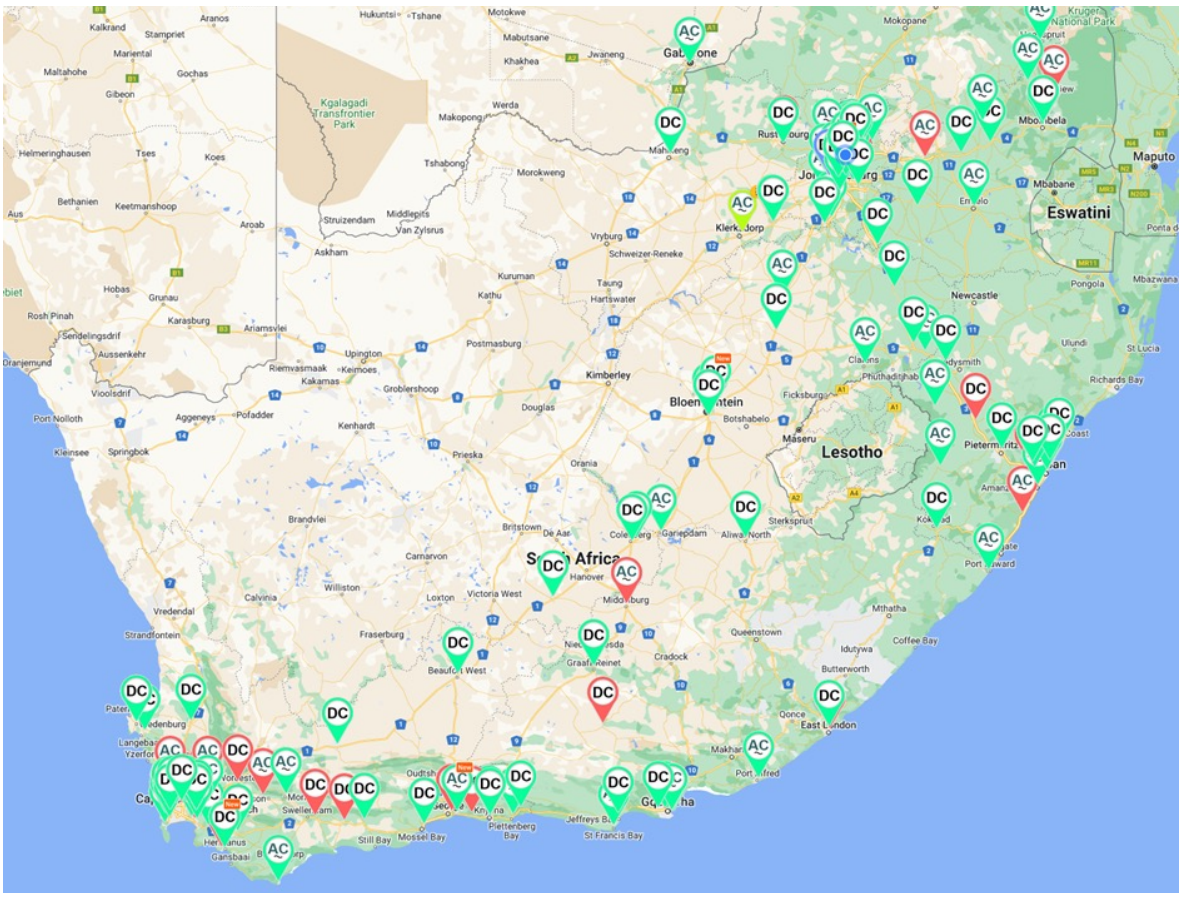


Figure 6: The GridCars charge station network in southern Africa. (1 in Windhoek and 1 in Gaborone)

2.1.4.2 Electric vehicle population

South Africa's EV market has been slow to take off due to several factors, such as high upfront costs (due to 7% higher taxation for EU imports, 43% in total), limited availability of EV models and a lack of charging infrastructure.[9]

According to the International Energy Agency's EV Outlook 2021, South Africa ranks fifth in the world in terms of the ratio of public chargers to the number of electric vehicles. This is mostly thanks to the work of GridCars sponsored by Jaguar that started in 2018 with the electrification of the N1 and later the Garden Route to Cape Town.

Servest reported on 17 April 2023[10] that South Africa's EV market was slow to take off, but with the evolution of electric vehicles and charging station technology, it should accelerate. It is mentioned that in the first three quarters of 2022, 3 092 EVs were sold. This is a significant increase compared to 896 for the same period in 2021. By September 2023 the number of EVs increased to about 2 200 vehicles.

2.1.4.3 Grid electricity supply infrastructure considerations[11]

To meet the demands of larger and faster charging installations—such as DCFC stations, medium- and heavy-duty EV charging sites and commercial EV fleet charging depots—it will be necessary to upgrade

[9] T Reynolds – April 2023, Electric Vehicle (EV) presents opportunities for improving EV infrastructure and charging stations https://www.engineeringnews.co.za/article/electric-vehicle-ev-presents-opportunities-for-improving-ev-infrastructure-and-charging-stations-2023-04-19

[10] Servest (2023) - Charging stations in South Africa are gradually improving the electric vehicle infrastructure https://www.servest.co.za/uncategorized/the-utilisation-of-charging-stations-in-south-africa-is-gradually-improving-the-electric-vehicle-infrastructure/

[11] US Department of Transportation (2023) - Implementation Challenges and Evolving Solutions for Rural Communities https://www.transportation.gov/rural/ev/toolkit/ev-benefits-and-challenges/challenges-and-evolving-solutions

the electrical service wiring running to a facility, or even upgrade certain components of the local power distribution infrastructure.

Such upgrades are more likely to be needed in rural areas, where the grid infrastructure may be less robust to begin with.

Local distribution network upgrades, such as the addition of a three-phase power service and the installation of transformers at DCFC sites, can add substantial costs and time to EV charging projects.

For more information on assessing the local grid infrastructure, including an explanation of three-phase power, see the written section titled "Utility Planning".

Utility pricing can also be a challenge for EV charging installations. Without external incentive programs, the revenue from DCFC stations typically covers only about one-third of their operating costs. This is largely due to utility demand charges, which are premiums charged by some utilities for using large amounts of electricity during peak hours or when high power is drawn at high rates that exceed certain thresholds.

Since rate and demand charge structures vary greatly between utilities and across provinces, these costs could have substantial effects on the business cases for deploying fast-charging EV infrastructure in rural communities.

Ultimately, both affordable charging rates and high station utilisation are essential for station operators to earn sufficient revenue to offset the costs of purchasing, installing and operating charging stations within a reasonable payback period (five years or less).

2.1.5 Additional charging technologies:[12]

2.1.5.1 Conductive charging

The charging stations, connectors and technologies described above are all part of conductive charging. This is where there is direct contact between the supply point and the receiving point via a connector plug and socket. It includes pantograph charging methods.

Conductive charging is the most popular way of charging batteries and is widely adopted. It is most simple and economically viable enabling the ability to charge quickly and most efficiently. There are additional methods to charge a battery which are shown in Figure 7 below:

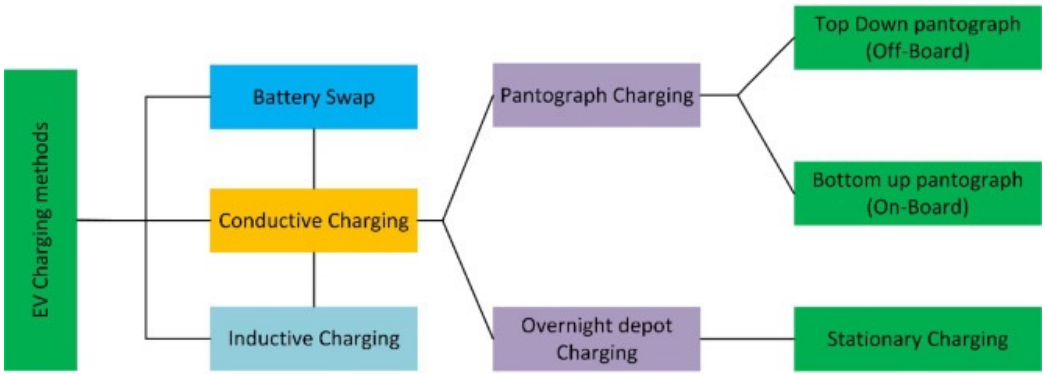


Figure 7: The various methods used to charge batteries of electric vehicles.

[12] Mastoi et al, 2022 - An in-depth analysis of electric vehicle charging station infrastructure, policy implications, and future trends https://www.sciencedirect.com/science/article/pii/S2352484722017346

2.1.5.2 Inductive/wireless power transfer (WPT)

A two-coil system is used in this technology. The receiving coil is installed in the vehicle, while the charging coil is placed on the road surface. As shown in Figure 8, the current that flows in the road surface excites a current in the vehicle's charging coil based on electromagnetic induction.

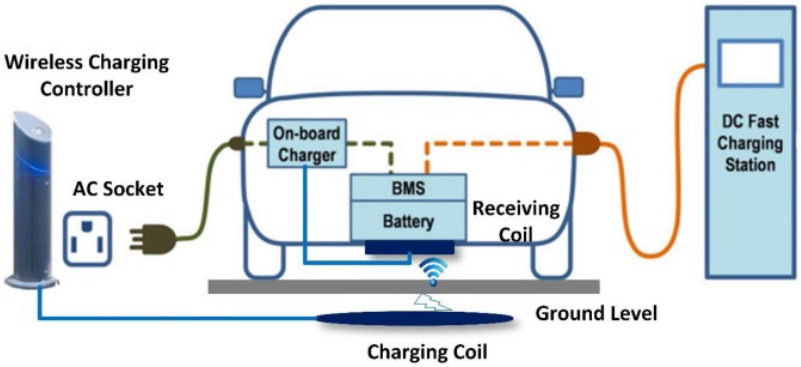


Figure 8: An example of inductive or wireless charging.

Inductive power transfer is not very efficient. The distance between the transmitter and receiver coils is critical. Should the two coils not be positioned closely or perfectly over each other, energy is lost.

2.1.5.3 Battery swapping

The principle here is that an empty battery in a vehicle can be exchanged for a full one. The batteries are then essentially rented from a supplier who then sells the energy in the battery instead of a complete battery itself.

Vehicles making use of battery swapping need to be designed specifically in a way to make it possible to remove the discharged battery and replace it with a fully charged one in a short time. One such company manufacturing EVs for battery swapping is the Chinese company, Nio. This is, however, for large electric vehicles.

Two-wheelers have been swapping batteries for a long time already. This is because the battery is small and easy to remove. It can be done by a single person. In many cases, the battery can then be charged in the office and returned after a full charge.

NIO Incorporated[13]

NIO Incorporated is a Chinese multinational automobile manufacturer headquartered in Shanghai, specialising in designing and developing electric vehicles. The company develops battery-swapping stations for its vehicles as seen in Figure 9.

In May 2018, NIO opened its first battery-swapping station in the Nanshan District of Shenzhen, Guangdong, China, dubbed the Power Swap Station.

In August 2020, Nio launched Battery-as-a-Service (BaaS) and formed a battery asset management company in collaboration with CATL and others. BaaS helps lower the purchase price of Nio EVs by about 25%.

[13] NIO Incorporated (2023) - https://www.nio.com/



Figure 9: A NIO battery swapping station

By April 2023, NIO's battery swapping station network completed initial coverage of the G3 Beijing-Taipei highway with 21 battery swap stations along the route. By then NIO has completed coverage of five major highways connecting to Beijing, the other four being the G1 Beijing-Harbin Highway, the G2 Beijing-Shanghai Highway, the G4 Beijing-Hong Kong-Macau Highway and the G5 Beijing-Kunming Highway. There are more than 320 000 NIO vehicles on the road that travelled about 10 billion kilometres and 95% of NIO customers prefer the BaaS option instead of charging the vehicle. The company aims to be on sale in six countries and to grow to up to 25 countries by 2025.[14]

NIO has now found a partner in Shell to expand the battery swapping stations in Europe.[15]

The charging process with swappable batteries can be much better controlled (during fast charging heat build-up can reduce the life of the battery). The battery swapping station can also act as an emergency supply point of electricity in the case of blackouts. Battery swapping works especially well with smaller vehicles such as two-wheelers.

2.1.5.4 Battery swopping stations for micro-mobility

International Council on Clean Transportation (ICCT) analysis[16] suggests that battery swapping for electric two-wheelers in taxi services (e.g. bike taxis) offers the lowest total cost of ownership (TCO) compared to point charging of battery electric two-wheelers, or petrol two-wheelers. In the case of last-mile delivery via a two-wheeler, point charging currently has a cost advantage over battery swapping, but with the right policy incentives and scale, swapping could become a viable option. In general, as the average daily distance travelled increases, the battery electric two-wheeler with battery swapping becomes more economical than point charging. In 2021, the Swappable Batteries Motorcycle Consortium was founded to facilitate battery swapping for lightweight electric vehicles by working together to standardise battery characteristics and specifications.

Battery swapping for electric two- and three-wheelers is gaining momentum in India. There are currently over ten different companies in the Indian market, including Gogoro, a Chinese Taipei-based electric scooter and battery-swapping technology leader. Gogoro claims its batteries power 90% of electric scooters in Taipei and the Gogoro network has more than 12 000 battery swapping stations to support over 500 000 electric two-wheelers across nine countries, mostly in the Asia Pacific region. Gogoro has now formed a partnership with India-based Zypp Electric[17], which runs an EV-as-a-Service platform for last-mile deliveries; together, they are deploying 6 battery swapping stations and 100 electric two-wheelers as part of a pilot project for business-to-business last-mile delivery operations in the city of

[14] https://cleantechnica.com/2023/05/12/nio-10-billion-kilometers-driven-20-million-battery-swaps/
[15] https://electrek.co/2023/05/16/nio-and-shell-open-first-ev-battery-swap-station-in-europe/
[16] https://theicct.org/wp-content/uploads/2021/12/cost-compare-india-ice-2ws-ldvs-nov21.pdf
[17] Gogoro, Gogoro Led Taiwan in Electric Scooter Sales, 2023

Delhi. At the beginning of 2023, they raised US$ 25 million, which they will use to expand their fleet to 200 000 electric two-wheelers across 30 Indian cities by 2025. Sun Mobility has a longer history of battery swapping in India, with over 210 swapping stations across the country for electric two- and three-wheelers, including e-rickshaws, with partners such as Amazon India. Thailand is also seeing corporate interest in battery-swapping services for motorcycle taxis and delivery drivers.[18]

While initially more popular in Asia, battery swapping for electric two-wheelers is also now spreading to Africa. For example, Rwandan electric motorbike start-up Ampersand[19] operates battery swap stations, with a focus on serving motorcycle taxi operations that require long daily ranges. Ampersand has built ten battery swap stations in Kigali and three in Nairobi, Kenya. These stations perform close to 37 000 battery swaps a month.

Gogoro

Gogoro is a Taiwanese company founded in 2011, that developed SmartScooters together with a battery-swapping recharging platform for urban electric two-wheel scooters, mopeds and motorcycles as depicted in Figure 10 and Figure 11. In April 2021, Gogoro announced a strategic partnership with the world's top two-wheel vehicle maker, Hero MotoCorp, to roll out its Gogoro network battery swapping in India.



Figure 10: Gogoro Recharging Platform for Uban Electric Scooter

According to Gogoro, by April 2021, in its pilot market of Taiwan, the Gogoro Network had 370 000 riders and managed more than 175 million battery swaps, 265 000 per day, throughout its 2 000 GoStations.

Gogoro is active in Taiwan, China, Indonesia, Singapore, Israel, India and the Philippines. The Gogoro scooters share the following specifications:

- Top speed: 95km/h
- Acceleration: 0 to 50km/h in 3.7 seconds
- Motor power: 7.2kW @ 5 000 rpm
- Maximum torque: 27Nm @ 2 250rpm
- Range: 100km+ when travelling at 40km/h.

[18] Gogoro, Gogoro Led Taiwan in Electric Scooter Sales, 2023
[19] CleanTechnica, Ampersand Partners With TotalEnergies Kenya To Roll Out Electric Motorcycle Battery Swapping Stations In Kenya, 2022



Figure 11: Gogoro Charging Stations

"Taiwanese two-wheeler battery swapping company Gogoro has a plan to give energy back to Taiwan's electrical grid and make money while doing it."[20] The company is partnering with Enel X, an energy services provider, to integrate 2 500 of its GoStations in Taiwan into Enel X's Virtual Power Plant (VPP) as shown in Figure 12 below.

A VPP is a collection of small-scale energy resources that have been joined together and coordinated with grid operations to provide the grid with reliable and affordable sources of energy. In this case, Enel X is providing power back to Taiwan Power Company, Taiwan's public electric utility. The state is supporting Enel X's VPP as it works to reach net-zero emissions in 2050. One way Taiwan hopes to implement its energy transition is through improving energy system resilience.

"We are entering a new era of smart energy infrastructure and by integrating the Gogoro Network with the Enel X Virtual Power Plant (VPP) in Taiwan, we are providing a new energy resource," said Horace Luke, Gogoro's CEO and founder, in a statement. "It is the first time this technology has been deployed this way in the world and it creates a new Gogoro revenue stream beyond mobility."

[20] Techcrunch, Gogoro's battery-swapping stations in Taiwan are now virtual power plants, 2023

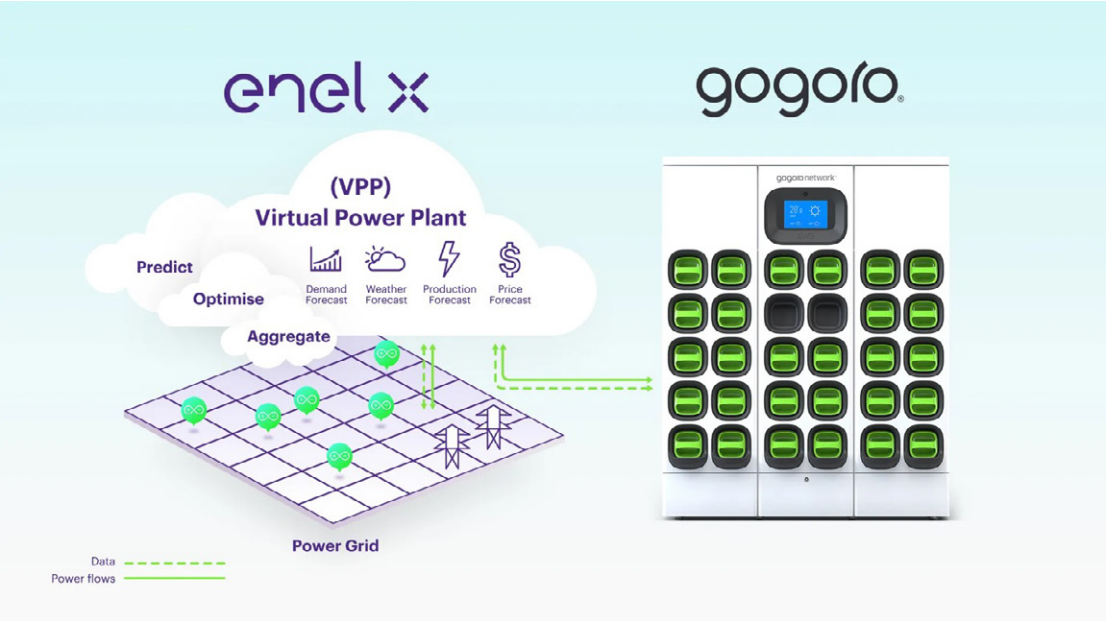


Figure 12: Enel x Venture With Gogoro

Gogoro's stations collectively hold nearly 2 gigawatt hours. The capacity of the 2 500 GoStations that will be part of the Enel X integration is about 150 megawatt hours of battery capacity.[21]

Valternative

Valternative is a new company in South Africa founded in 2022 and plans on providing last-mile delivery solutions with battery swopping as its main area of focus. As with Gogoro above, the service areas include food deliveries, daily commuter transport and rentals for tourists at points of interest.

Currently, Valternative plans to roll out two scooter models: Valtbike V1 and Valtbike V1-Max as shown in Figure 13. The former employs a 1.5kWh battery to power the scooter to a maximum speed of 45km/h and an 80km driving range; whereas the latter, being more powerful, uses a 4kWh battery to power the scooter to a maximum speed of 80km/h and a 100km driving range. Valternative provides dedicated rider management services to collect its revenue through scooter rentals, battery swopping subscriptions, rider commission fees and vehicle advertising.

Using the BaaS model, the battery swop-and-go stations will be strategically placed at shopping centres and larger office parks to ensure riders can swap out their depleted batteries for fully replenished ones. These swop-and-go stations will be monitored by intelligent software which will manage the charging and security. The software is hosted on Amazon's cloud server providing fast access to monitor charging progress and security, as well as manage the riders and the assets to their best performance and safety.

[21] TechCrunch – Bellen, 2023 - Gogoro's battery-swapping stations in Taiwan are now virtual power plants https://techcrunch.com/2023/04/18/gogoros-battery-swapping-stations-in-taiwan-are-now-virtual-power-plants/



Figure 13: Valtbike Prototype

2.2 Hydrogen infrastructure considerations

2.2.1 Spatial/Location recommendations

The selection of the geographic location of potential green hydrogen hubs[22] is a significant contributor to the feasibility of green hydrogen opportunities. The DTIC's Green Hydrogen Commercialisation Strategy for South Africa (2022) proposes the following potential hubs and provides an overview of the holistic approach to industrialisation, as illustrated in Figure 14.

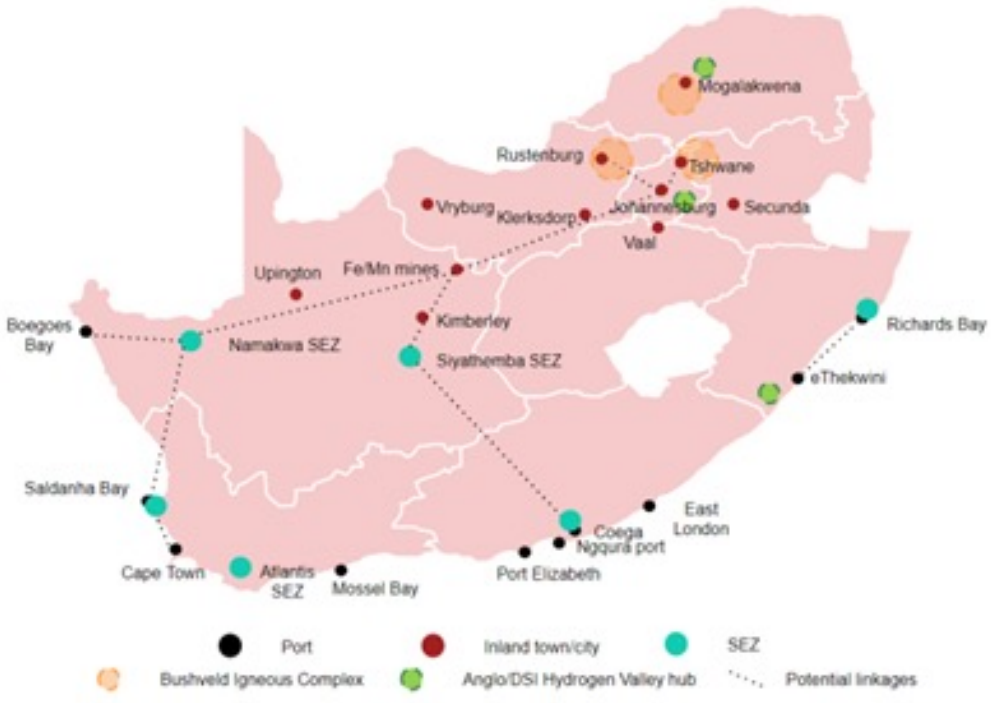


Figure 14: Prospective locations for South Africa's hydrogen hubs[23]

Table 2: Overview of potential green hydrogen hubs[24]

Potential green hydrogen hubs	Overview of options
West Coast	• A hub could link to the Northern Cape's extensive solar resources and present an opportunity to drive exports to the European Union and the Americas. • Saldanha Bay is an IDZ, with well-established port infrastructure, which may support local demand and support logistics infrastructure. • Boegoe Bay is a green-field port development with a current pre-feasibility study currently underway.

[22] Department of Trade, Industry and Competition. 2022. Green hydrogen commercialisation strategy for South Africa: Final report. November 2022. http://www.theDTIC.gov.za/wp-content/uploads/Full-Report-Green-Hydrogen-Commercialisation-Strategy.pdf

[23] Ibid

[24] Ibid

Eastern Cape	• A hub could link to the Eastern Cape's wind energy resources. • The Coega IDZ is served by a well-established port and can provide access to logistics routes to most South African industrial hubs
KwaZulu-Natal	• Port of Durban (eThekwini) is a well-established muti-sector trading port, however it encounters significant congestion in the surrounding area. • The Port Authority has indicated a focus on container traffic and a view to relocate the energy cluster from South Durban to Richards Bay. Additionally, Richards Bay's offshore wind resources are the most effective in the country.
Inland (Vaal)	• The Vaal Triangle presents a unique opportunity due to the sophisticated industrial capacity which already lies in the region, including but not limited to the Sasol Sasolburg plant, Safripol's polymer production plant and AMSA's steelworks. • According to the Sedibeng District Municipality, this area is well-placed to support domestic demand for hydrogen.

The DTIC's Green Hydrogen Commercialisation Strategy for South Africa (2022) evaluates locations in Table 2 against the following technical requirements to support the development of a green hydrogen hub:

1. Access to a renewable energy resource.
2. Availability of renewable energy development zones (REDZ).
3. Market positioning of the hydrogen hub; export, domestic, or both.
4. Existing infrastructure including logistics networks, transmission corridors and port access.
5. Existing industries which could serve as anchors for the local deployment of hydrogen i.e., demand proximity.
6. Access to resources, including human capital, components and equipment.
7. Purpose of the hydrogen hub, which could either be:
    - To serve an export market; or,
    - To develop a domestic market alongside the export infrastructure; or,
    - To anchor local hydrogen deployment in the PGM industry.

The DSI's Hydrogen Valley report (2021)[25] identifies Johannesburg (with spokes extending to Rustenburg and Pretoria), Durban, Richards Bay and Mogalakwena as prospective hydrogen hubs and part of a proposed Hydrogen Valley due to the relative characteristics of these regions. These include:

- High concentration of future hydrogen demand
- Prospects to produce hydrogen (i.e. due to availability or access to solar and wind energy, or water infrastructure)
- Socio-economic development outcomes which would support marginalised communities and contribute to a just transition.

[25] Department of Science and Innovation (DSI). 2021. South African Hydrogen Valley Final Report. https://www.dst.gov.za/images/2021/Hydrogen_Valley_Feasibility_Study_Report_Final_Version.pdf

It is expected that the Hydrogen Valley could cumulatively contribute roughly 185 kilotons of hydrogen by 2030 which represents 40% of total hydrogen demand under a low use case and 80% under a high use case.[26] From an economic contribution perspective, the DSI (2021) estimates that the Hydrogen Valley project could create between 14 000 and 30 000 jobs per year and could contribute between US$ 3.9 billion to US$ 8.8 billion to South Africa's GDP by 2050[27]. The Hydrogen Valley concept includes nine pilot projects to launch hydrogen activities and this includes mobility projects related to mining trucks, as well as buses.

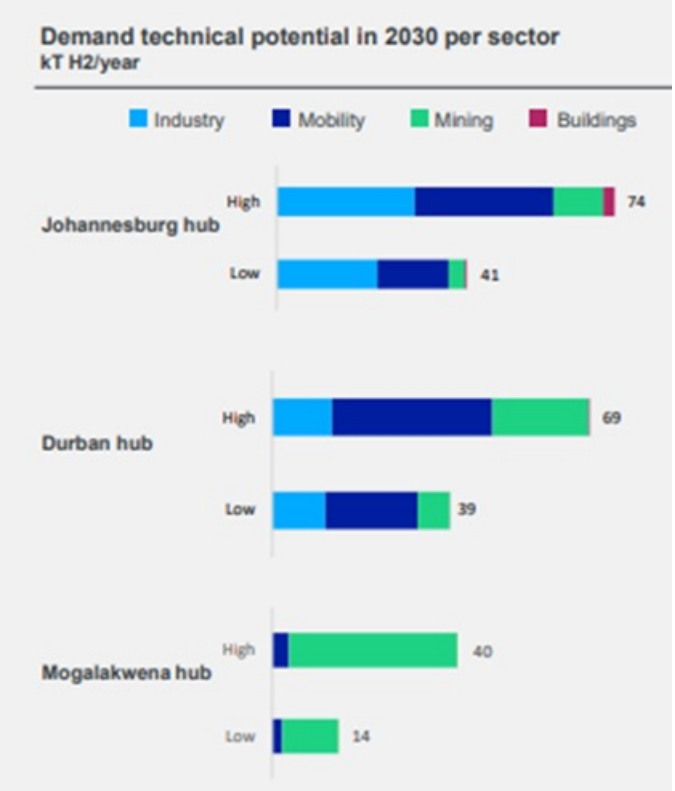


Figure 15: Illustration of estimated demand for hydrogen, per sector, of potential hydrogen hubs[28]

The DSI (2021) utilising a bottom-up assessment of the potential for demand call-offs, as shown in Figure 15 and considering the competitiveness of hydrogen in the relevant application, suggests that the Johannesburg hub will have its demand driven by the industrial sector and the Mogalakwena hub's demand will be driven by the mining sector (mining trucks specifically). The Durban hub's demand will mainly be driven by increasing penetration of FCEVs for MCV and HCV trucks, as they begin to reach price parity with diesel trucks. The DSI (2021) also notes the potential for port operational vehicles (e.g. forklifts) to be powered by FCEVs.

[26] Department of Science and Innovation (DSI). 2021. South African Hydrogen Valley Final Report. https://www.dst.gov.za/images/2021/Hydrogen_Valley_Feasibility_Study_Report_Final_Version.pdf

[27] This includes indirect contributions to GDP.

[28] Department of Science and Innovation (DSI). 2021. South African Hydrogen Valley Final Report. https://www.dst.gov.za/images/2021/Hydrogen_Valley_Feasibility_Study_Report_Final_Version.pdf

2.2.2 Gas pipelines and associated investment

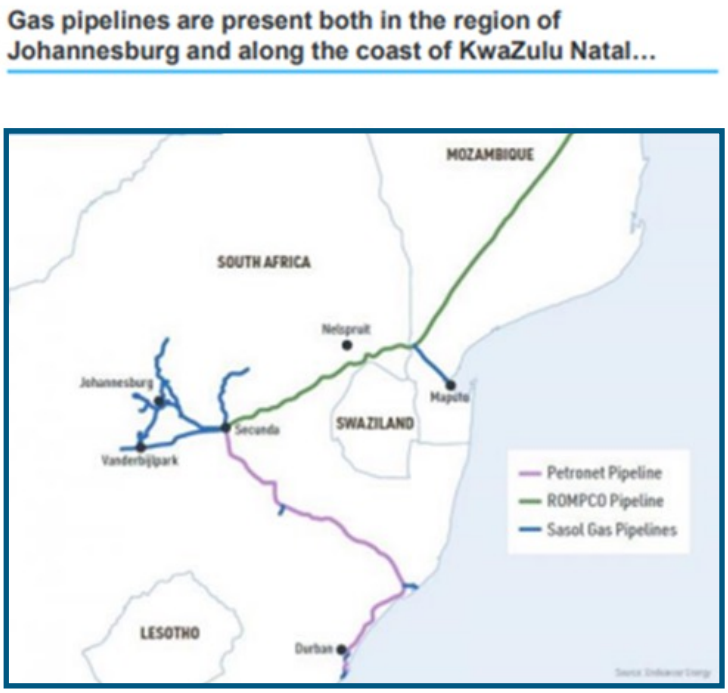


Figure 16: Existing gas pipelines in South Africa[29]

To support the transition to FCEVs in South Africa, it is not only the investment in manufacturing or acquisition of the vehicle which must be considered but also the investments required to support the supply, distribution and storage of green hydrogen. The DSI (2021) indicates that whilst Johannesburg has an existing gas distribution network which will require minimal technical upgrading and Durban also has one coastal transmission pipeline which would require minimal upgrading, Mogalakwena/Limpopo does not have any existing gas distribution network, as indicated in Figure 16 above.

The DSI (2021) suggests that between US$ 3 billion to US$ 6 billion worth of investment in hydrogen equipment will be required for a successful transition to the use of green hydrogen. This investment requirement is unbundled into discrete categories:

- 50% of production investment costs relate to electrolyser costs,
- 45% of the production investment costs relate to electricity sourcing (from renewable sources),
- 2% of production investment costs relate to water treatment.

[29] Department of Science and Innovation (DSI). 2021. South African Hydrogen Valley Final Report. https://www.dst.gov.za/images/2021/Hydrogen_Valley_Feasibility_Study_Report_Final_Version.pdf

2.2.3 Considerations for Hydrogen Re-Fuel Stations

Following the development of hydrogen production hubs, the next significant investment to consider is that associated with setting up hydrogen re-fuel stations, as a minimum station density network is required for the TOC of a vehicle to become economically viable. Hydrogen refuelling stations often do not need to be standalone infrastructure and can be part of an existing diesel fuel station.

The IEA (2015)[30] notes that the daily hydrogen demand, the phase and the pressure of hydrogen stored on the vehicle being re-fuelled and how the hydrogen is produced and delivered to the refuelling station are all critical success factors in setting up the refuelling station. Small stations with an average daily capacity of 50kg to 100kg of hydrogen are usually only feasible when there is on-site hydrogen production (a mine would be a plausible example), whilst, for road freight trucks, refuelling stations will likely need a daily capacity in excess of 2 000kg of hydrogen[31].

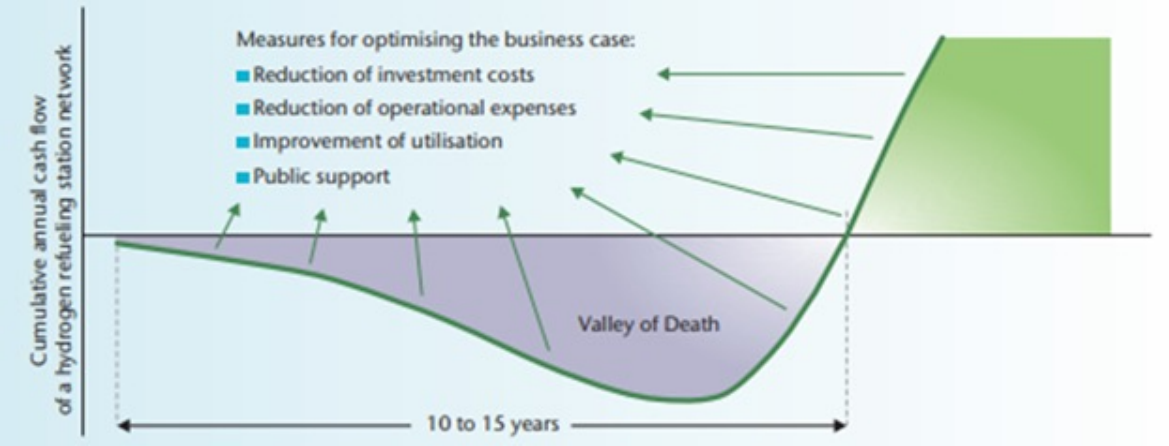


Figure 17: Illustration of the cumulative cashflow associated with the establishment of a hydrogen re-fuel station

As seen in Figure 17, negative cashflow may persist for between 10 and 15 years after establishing a new hydrogen refuelling station. To promote capacity utilisation of stations, stations must be clustered to support the main anticipated demand centres and the connecting supply corridors. The IEA (2015) notes that globally, organisations such as the California Fuel Cell Partnership, H2Mobility in Europe and Japan's Fuel Cell Commercialisation Conference have all developed proposals on a framework for the optimal roll-out of refuelling stations which could potentially provide extensive coverage, at reduced costs.

[30] International Energy Agency (IEA). 2015. Technology Roadmap: Hydrogen and fuel cells. https://iea.blob.core.windows.net/assets/e669e0b6-148c-4d5c-816b-a7661301fa96/TechnologyRoadmapHydrogenandFuelCells.pdf

[31] Ibid

2.2.4 Considerations for demand-side policy support to promote FCEV adoption

FCEVs in mobility applications (buses, mining trucks, forklifts and HCV trucks) will only be encouraged if there are appropriate demand-side strategies and incentives in place. The DSI (2021) proposes the following, as outlined in Table 3:

Table 3: Conditions that are likely to promote the adoption of FCEVs[32]

'Enabling' conditions for FCEVs[33]	Description
Encourage H2 applications through financial incentives	• CAPEX subsidy or state tax exemption for FCEV and re-fuelling stations • Low-interest funding for hydrogen mobility projects • Repurpose subsidies for diesel trucks into H2 trucks
Create momentum for future demand to scale up the hydrogen economy	• % target for FCEV vehicle target • The government to lead the way with its own fleets (e.g., buses) to build economies of scale • Leverage on Green Transport Strategy to further deploy fuel cells in the public transportation sector
Formalise the hydrogen sector through standards and labels	H2 safety and quality standards e.g.: • Hydrogen pressure in vehicles • Hydrogen pressure in charging station

The cost of hydrogen infrastructure versus EV cannot be forgotten: the total cost of ownership for FCEVs is around 40% higher than a comparable ICE vehicle and about 10% more than an EV[34]. Another major and crucial, advantage that EV holds over FCEV is the nationwide electrical system. Even if solar would not be used for the charging stations, electricity from the national grid can be used making it a plug-and-play solution. However, with hydrogen, such a network and system does not exist; this can be attributed to the fact that the demand for hydrogen is still in the infancy stage. Furthermore, if one considers the extremely high costs of setting up a hydrogen-producing plant (electrolysis of seawater), transportation of the gas, the storage of the gas and finally the dispensing thereof, it is difficult to justify these costs given the very low demand for hydrogen for fuel cells specifically at this point in time in South Africa.

[32] Department of Science and Innovation (DSI). 2021. South African Hydrogen Valley Final Report. https://www.dst.gov.za/images/2021/Hydrogen_Valley_Feasibility_Study_Report_Final_Version.pdf

[33] Ibid

[34] Why have EVs won out over hydrogen cars (so far)?, 2023, https://climate.mit.edu/ask-mit/why-have-electric-vehicles-won-out-over-hydrogen-cars-so-far#:~:text=They%20found%20the%20total%20cost,percent%20more%20than%20an%20EV.&text=EVs%20have%20another%20crucial%20advantage,nationwide%20electrical%20system%20already%20exists.

3. PROJECT TEAM

3.1 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.

3.2 Contributing Authors for the Study Phase 1

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

3.3 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