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VEHICLE-TO-GRID TECHNOLOGY IN SOUTH AFRICA'S ENERGY TRANSITION

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A research report submitted to the Faculty of Commerce, Law and Management, University of the Witwatersrand, in partial fulfilment of the requirements for the degree of Master of Management in Energy Leadership.

Johannesburg, 2023

ABSTRACT

The energy sector in South Africa has been undergoing a transition to a low-carbon economy and a shift in its energy structure. This transition emphasises the need for renewable energy sources and the advancement of new energy vehicles to meet the country's climate change mitigation commitments. Conversely, the growing use of renewable energy and electric vehicles (EVs) raises concerns about energy security and the need for increased power-generating capacity. Intending to find a solution to the abovementioned concerns, the subject of this study was the role that vehicle-to-grid (V2G) technology could play in the energy transition. The theories underpinning this research were the diffusion of innovation and the multi-level perspective. Qualitative data were collected using semi-structured interviews. Thirteen (13) experts purposively selected from the automotive industry, national energy department, regulator and utility, research institution, independent power producers, charging infrastructure provider, and an EV owner participated in this research. According to the study, V2G technology could contribute to South Africa's energy transition in the long run. For the technology to drive a meaningful change, subsidies, local manufacturing of electric vehicles, and consumer-awareness campaigns will be required to encourage investments in EVs and change public perceptions. The study also emphasized the need for public charging infrastructure, affordable EV models, and supportive government policies. Several challenges were identified that may hinder the adoption of this technology. These challenges included the need for an increase in generation capacity to handle EV charging, smart meters for billing purposes, and the inability of the current electricity grid to support V2G. Although the potential of V2G technology is enormous, it requires substantial collaboration between the government and private sector, investment in charging infrastructure, and modernisation of the electricity grid.

Keywords: Vehicle-to-grid technology (V2G), electric vehicles (EVs), energy transition, multi-level perspective (MLP), diffusion of innovation theory

DECLARATION

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

Name: Machwene Thelma Ramutla Signature: 

Signed at: Modderfontein

On the 20th of January 2023.

DEDICATION

I dedicate this research work to the God Almighty for giving me the strength, wisdom, and patience I needed to accomplish this goal.

To my loving parents (Nchimane and Kgaudi Ramutla),

I know that your prayers are the cornerstone and guidance of my accomplishments.

To my handsome brothers (Archiebald, Donald, and Lethabo Ramutla),

thank you for your love and consistent support throughout the journey.

To my cousins, shareholders of my soul (Lebogang and Charles Mokgotho),

thank you for providing me with unfailing support and continual encouragement.

To my late grandmother, who could not live to see me complete this milestone,

thank you for your infinite love and wisdom.

Robala ka Khutso Mokone Wa Ntsi Dikgolo!

.

ACKNOWLEDGEMENTS

This research report marks the end of my journey pursuing a Master of Management in Energy Leadership at the University of Witwatersrand. I am proud to present a report exploring prospects for vehicle-to-grid in South Africa as part of my contribution to the energy transition.

I owe a debt of gratitude to several people who helped me complete this project.

As the first point of gratitude, I would like to thank my social-academic advisor Dr Fanny Saruchera for providing me with excellent guidance and feedback on short notice when I needed it the most.

During my research, I had moments when I considered giving up. In light of this, I am grateful to my family, mentor, and friends for encouraging me to find a path when I did not think there was one. Again, thank you to my friends for distracting me when necessary.

In closing, I want to thank the interviewees for taking the time for me to interview them and for participating in my research.

I hope you enjoy reading my research report.

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LIST OF ACRONYMS

CCS	Combined Charging System
CHAdeMO	CHArge de MOve
CO_2	Carbon Dioxide
DMRE	Department of Mineral Resources & Energy
EAF	Energy Availability Factor
EU	European Union
EVs	Electric Vehicles
GHG	Greenhouse Gas
IEA	International Energy Agency
IRP	Integrated Resource Plan
POPIA	Protection of Personal Information Act
V2G	Vehicle-to-Grid

CHAPTER 1. INTRODUCTION

1.1 Purpose of the study

The purpose of the study is to explore the role that vehicle-to-grid (V2G) technology could play in South Africa's energy transition. The qualitative study sought to identify the enabling factors that will facilitate the adoption of vehicle-to-grid (V2G) technology in South Africa's energy transition. As the technology is still in its infancy, this qualitative study aimed to gain insight into the factors that may facilitate the adoption of electric vehicles (EVs) and (V2G) technology in South Africa. Furthermore, the study aimed to reveal how stakeholders in the (V2G) value chain can help promote this technology in the country.

1.2 Context of the study

1.1.1. The global need for decarbonisation

The excessive dependence on fossil-fuelled energy sources such as coal, oil, and natural gas threatens our existence and future generations. However, these fuels have long played a role in the global energy system and will continue to do so in the foreseeable future (Jezard, 2017; Yıldız, 2018; Ritchie et al., 2020). They have adverse environmental implications since they emit carbon dioxide (CO_2) during energy production; and are the primary contributor to global climate change, local air pollution and cause millions of premature deaths each year (Wang et al., 2018; Ritchie et al., 2020; Finkelman et al., 2021).

Climate change and its consequences and threats—both present and future—have dominated public policy discussions at the local, national, and global stages over the last few decades. As a result of these concerns, the European Union (EU) and other member countries have set ambitious targets for transitioning their energy sector from fossil fuels to zero-carbon energy between 2020 and 2030,

with a goal of carbon neutrality by 2050 (International Energy Agency [IEA], 2021; International Renewable Energy Agency [IRENA], 2021). Climate change poses a serious threat to South Africa. Besides frequent droughts, the country faces flooding, extreme weather events, and wildfires because of climate change (Centre for Environmental Rights [CER], 2021). According to Lukey (2020), South Africa is a responsible global citizen with moral and legal duties under the United Nations Framework Convention on Climate Change (UNFCC) and its Kyoto Protocol dedicated to contributing its fair share of greenhouse gas (GHG) reduction efforts to keep global warming below 2°C. However, several authors criticised the country's mitigation measures, labelling them as slow and unambitious (Chersich & Wright, 2019; CER, 2021).

As global and local pressure grows for sustainable energy solutions, (V2G) technology is gaining traction globally and in South Africa. The technology enables EVs to participate in the energy market with the energy stored in their batteries (Geske & Schumann, 2018; Wellings et al., 2021). Zagrajek et al. (2021) found that with the support of an appropriate legal framework, V2G technology has the potential to accelerate the electrification of private transport. It may also encourage citizens to create and develop energy communities that will lead to sustainable development. The transportation sector alone accounts for 24% of carbon emissions, so Turton and Moura (2008) estimated that V2G could reduce CO2 emissions by 6.5% by 2100. When offered to EV owners, V2G contracts have the potential to reduce carbon emissions in the future, according to a study by (Teter et al. (2020). Considering the potential benefits of V2G, this study sought to understand how this technology may be adopted in the energy transition. In the context of EV adoption, the diffusion of innovation theory (DOI) might help policymakers to identify and understand diffusion parameters. Such as what they are, how they work, and why worthy innovations are not adopted rapidly (Rezvani et al. 2015).

1.1.2. South Africa's energy landscape

As depicted in Figure 1 below, South Africa is highly dependent on fossil fuels, with coal accounting for 69% of its energy needs (Department of Mineral Resources & Energy [DMRE], 2019) and meeting approximately 74% of the nation's installed electricity generation capacity (Eskom, 2021)**.** Renewables and waste energies accounted for 11% of the South African energy mix, crude oil 14% and nuclear and gas contributed 3%. The energy sector accounts for about 80% of total emissions, with electricity generation and liquid fuel production accounting for half of it due to Eskom's coal-fired generation fleet (British Petroleum [BP], 2020).

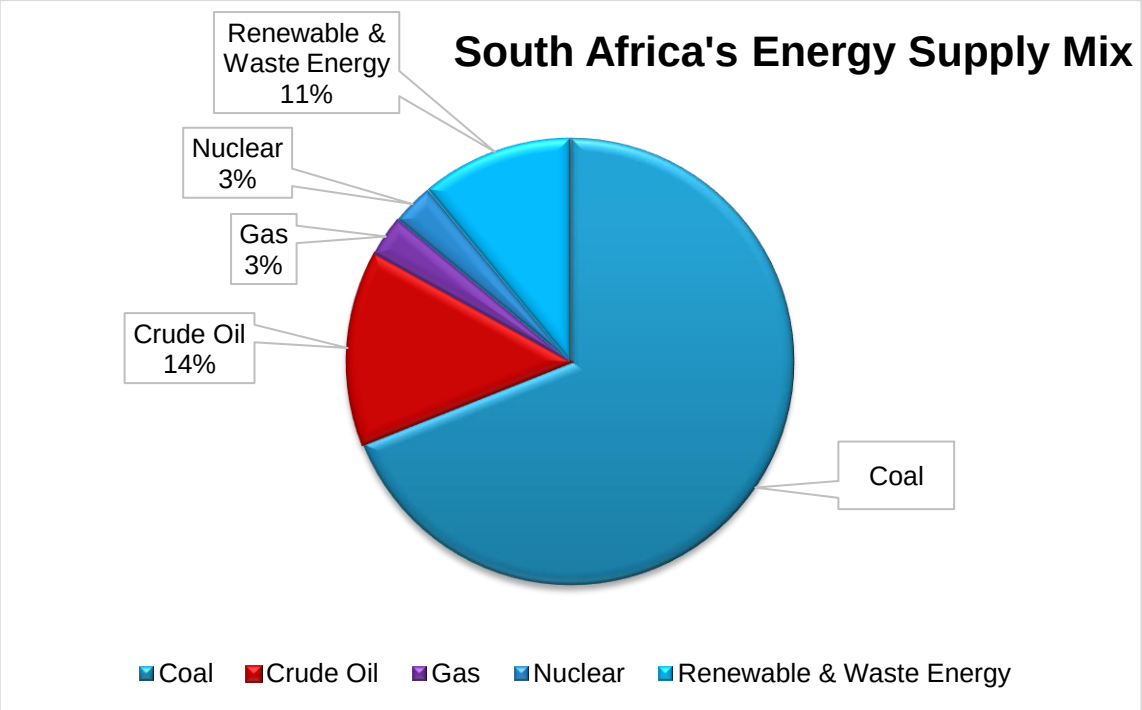


Figure 1: South Africa's Total Primary Energy Supply
Source: Department of Energy (2019)

In addition to the challenge of climate change, the energy sector is facing an energy crisis as the electricity demand outstrips the supply (Moleko & Swilling, 2020; Zimm, 2021). These significant electricity shortages have been ongoing since 2007, with the most severe Stage 6 occurring in December 2019 (Wright & Calitz, 2020). No new generation plants were built, resulting in the current shortages. The existing generating fleet is aged, with the energy availability factor

(EAF) worsening progressively, as depicted in (Appendix A)**.** The EAF is a measurement of the availability of an electrical generation plant, encompassing scheduled and unexpected maintenance, as well as energy losses not under plant management control (Eskom, 2022). The history of the system (EAF) is shown in Annexure A, indicating that unplanned outages are increasing and degrading plant performance.

Furthermore, these outages will continue to decline with a slight improvement until 2030. Some authors (Amin, 2018; ÓhAiseadha et al., 2020; Roff et al., 2020) claim that electrifying road transportation and decarbonising the energy generation sectors can reduce emissions. In 2019, the South African Integrated Resource Plan (IRP) called for a significant increase in renewable energy such as wind and solar, small-embedded generations and gas to replace coal for electricity generation by 2030, as the service life of existing power stations is nearing an end. South Africa's switch to renewable energy will lead to a reduction in emissions, according to Lawan and Abidin (2020) and Zhang et al. (2020). However, instability will also lead to significant challenges, as most renewable energies have unpredictable fluctuations. Consequently, battery energy storage or other storage capacities will be required to assist with the intermittency limitations of renewables (Lawan & Abidin, 2020).

Research on the global electric vehicles (EVs) market estimates that EVs will play an increasingly important role in the future of transportation and stationary storage services to electricity network operators (IEA, 2020). According to Bloomberg, EVs will account for 10% of global passenger car purchases in 2025, 28% in 2030, and 58% in 2040 (Bloomberg New Energy Finance [BNEF], 2020). Barkenbus (2020) reported that several automakers plan to release EVs in the next five years, with the Volkswagen Group alone planning to launch eighty (80) models by 2025. Table 1 below shows the number of major automakers that have publicly announced producing a certain number of electric vehicle models by 2025. A total of twelve (12) BMW models will be available by 2025, while Ford targeted forty (40) models this year. Mercedes Benz expects EV sales to

contribute 15-25% of its total sales by 2025. It is worth noting that these automakers have considerable market share and production facilities in South Africa. Thus, the worldwide legislative support for switching to EVs is already affecting the local automobile industry, which exports internal combustion engine (ICE) vehicles to European nations (Department of Trade Industry & Competition [DTIC], 2021).

Table 1: Key automaker announcements for EVs.

Automakers	Announcements
BMW	Plans to offer 12 EVs by 2025
Ford	Plans to offer 40 EVs by 2022
General Motors	Plans to offer 20 EVs by 2023
Mercedes	EV sales are estimated to comprise 15-25% of total sales by 2025
Volkswagen	Plans to offer 80 EVs by 2025
Renault-Nissan	EV sales are estimated to comprise 20% of total sales by 2020

Source*:* Barkenbus (2020), p. 2.

The Department of Transport (DoT)'s Green Transport Strategy supports the use of EVs and has agreed to reduce emissions from the transport sector by 5% by 2050 (DoT, 2018). The recently updated National Determined Contributions (NDC) plan calls for implementing green transportation strategies to achieve the goals of the Paris Agreement (DTIC, 2021). Noticing that EV transition is inevitable, the DTIC recently released the New Energy Vehicle Green Paper advocating the adoption and local manufacturing of EVs (DTIC, 2021).

Dane (2014) advocated for the adoption of EVs, claiming that they would reduce South Africa's dependence on imported crude oil and emissions from the transport sector. However, the 2019-2030 (IRP) failed to include the uptake of EVs in any of its future scenarios (Calitz, 2019). The IRP, therefore, overlooked the possibility of a change in the electricity demand profile. As a result, the

adoption of EVs also poses a risk for South Africa because they put pressure on the power grid both on the demand and the supply side (Jones et al., 2021). EV critics argue that they exert an extra burden on the electricity network, thus compromising their reliability (Hashim et al., 2021).

This finding is validated by Bibak and Tekiner-Moğulkoç (2021), who pointed out that a concentration of EVs in one location will result in a rise in electricity consumption, causing supply fluctuations during peak periods. Although EVs are viewed as a solution to reduce GHG emissions and dependency on imported crude oil in the transportation sector, their adoption in South Africa is slow. This technology currently suffers to different degrees, from lack of comprehensive policies, public charging infrastructures, unstable electricity supply, range anxiety, vehicle cost, and a general lack of knowledge and confidence in the technology (Bokopane et al., 2019; Montmassin-Clair et al., 2020).

V2G is an emerging technology with high potential to overcome South Africa's barriers with renewables and EVs. The technology unlocks the energy stored in EV batteries, allowing households and fleets to support the power grid (Skouras et al., 2019). Through the bidirectional energy flow between the EV's battery and the electricity network (known as V2G), several solutions exist that could mitigate some of the risks associated with integrating EVs and renewables (Gschwendtner et al., 2021). However, this technology is hampered locally to varying degrees by the lack of market experience, regulation, low EV adoption, and high pricing (Bokopane et al., 2019; Montmassin-Clair et al., 2020).

V2G is a new technology that, if explored and promoted, can benefit South Africa significantly. The availability of V2G technology has positively influenced the adoption of EVs in countries such as China and Norway (Wang et al., 2018; Chen et al., 2020; Ziegler & Trancik, 2022). According to a scientific study conducted by Calitz (2019) on the impact of future EV charging on the least-cost electricity generation portfolio in South Africa, a V2G configuration led to lower system costs and a slightly higher energy share from solar generation. Cenex (2021) reported

that customers participating in the test run in the United Kingdom (UK) received approximately 380 Euros each year for providing electricity to the power grid.

V2G is one of the niche innovations investigated scientifically on a global and local scale (Sovacool et al., 2018; Calitz, 2019; Mkhize & Dorrell, 2019). The present study, therefore, looks at the social conditions and enabling mechanisms that will accelerate the diffusion of V2G in South Africa's energy sector. This study uses the multi-level perspective theory to explore how V2G technology could play a role in South Africa's energy transition. As a result, contextual factors, social and institutional environment, power dynamics, and vested interests surrounding V2G adoption and dissemination mechanisms will be explored. EVs and renewables present challenges for which V2G can provide a solution (Wei et al., 2022).

Since V2G is a new technology viewed with scepticism by various stakeholders in its value chain, the multi-level perspective (MLP) framework will aid in understanding the importance of bringing society together in developing strategies for promoting the adoption of this technology. The next section presents and describes the research problem, which leads to the research questions.

1.3 Research problem

Extant literature has revealed that V2G technology has revolutionised the sector and promises to offer a lasting solution to the current pollution challenges the world is facing. While clean energy transitions in Africa have gained attention in developed countries (Broto, 2017; IRENA, 2019), very little is known about these transitions in terms of policy and knowledge (Broto, 2017). Ampah et al. (2022) and Tunçel (2020) state that most EV-related studies occur in countries with developed economies, most notably in the US and Germany, followed by the UK. A review of the literature on EV and V2G in Africa, particularly in South Africa, reveals the importance of understanding the technological transition's political

and socio-cultural dimensions (Ampah et al., 2022). Fewer authors have explored these aspects empirically (Ockwell et al., 2018).

As indicated by the current literature on V2G technology, there has been a bias in the following areas: system services and flexibility by EVs, economic evaluation of V2G and business models thereof, the legal implications of EV battery services and user privacy concerns (Lawan & Abidin, 2020; Wang & Sun, 2021). The adoption of V2G in developing countries still requires a great deal of exploration. Thus, this study aimed to fill a knowledge gap on the role of V2G technology adoption in South Africa's energy transition and the factors influencing its adoption. Further, the scientific and in-depth study of the mechanisms of diffusion underlying advanced technologies in the new energy sector is crucial for promoting the diffusion of advanced technologies in an international context of energy conservation and emission reduction (Wang & Sun, 2021).

1.4 Research questions

The study sought to address the following research questions:

i. How can V2G adoption play a role in South Africa’s energy transition?
ii. Based on theory, what factors are influencing the adoption of EV adoption in South Africa?
iii. What role can different stakeholders in the V2G value chain play in promoting V2G in the country?

1.5 Significance of the study

This study sought to add to a growing body of research on leveraging EV battery storage for power grid services via V2G technology (Englberger et al., 2021; Tepe et al., 2022). Literature available in South Africa examines how EVs will affect the smart grid or how ready the grid is for EV adoption (Bokopane et al., 2019; Calitz, 2019; Mkhize & Dorrell, 2019). The in-depth analysis of the role this technology could play in the energy transition remains under-addressed. This study is one of

the few to propose V2G technology as a solution to the expected challenges of integrating more EVs and renewable energy into the South African electricity grid. Future studies on emerging EV technologies can potentially be based on the findings of this study and serve as a cornerstone for a sustainable energy transition.

To evaluate the market's readiness for V2G adoption, the diffusion of innovation theory and multi-level approach was applied. Since the widespread adoption of V2G requires considerable engagement among different stakeholders and the acceptance of the EV driver, a better understanding of these players is of vital importance (van Heuveln et al., 2021). This study could provide valuable insight and implications into the diffusion of EVs to energy planners, regulators, the national utility, electric vehicle manufacturers, fleet owners and lobbyists, energy professionals, and EV charging suppliers. Further, this investigation may help them devise and implement efficacious strategies to support South Africa's transition to a more efficient energy system.

1.6 Delimitations of the study

For this study, boundaries were established based on the industry of focus and level of interpretation of data points. An emphasis was on the electricity market of the South African energy sector. The following reasons led to the selection of this market:

i. It is the highest contributor to greenhouse gas emissions in South Africa.
ii. As a result of poor planning and path dependency on coal, the country faces electricity generation capacity issues.
iii. With the EV evolution comes a need for new business models and modernising the current electricity network.

The study did not cover other types of energy, such as oil and gas. Also, the study used a qualitative approach which may be a stumbling block for researchers

hoping to use a quantitative approach. There was no focus on any particular process or technology for generating electricity, such as coal, nuclear, hydro, solar, or wind; the entire energy mix was evaluated. Although there is considerable debate about the suitability of these diverse technologies, this study considered EVs to include hybrid-electric vehicles (HEVs), fuel cell vehicles (FCVs), and battery electric vehicles (BEVs).

1.7 Definition of terms

A list of the definitions of key terms is outlined in Table 2 below.

Table 2: Definition of Terms

Term	Meaning	References
Baseload Power	It is the bulk electricity generation that is running most of the time.	Kempton et al. (2001)
Electric Vehicles	They are vehicles that solely use an electric motor and battery as a source of energy. These vehicles do not emit emissions, so they are also known as green cars, zero-emission, or eco-friendly cars.	Skouras et al. (2019)
Energy Transition	Involve the transition from fossil fuel-based energy and economic schemes toward renewable ones.	Bompard et al. (2022)
Peak-Demand	A time when electricity is projected to be delivered in a considerably greater quantity than average.	Liu et al. (2020)
Renewable energy	Refers to energy derived from renewable resources that replenish themselves over time. These include solar power, hydropower, wind, geothermal, biomass, and ocean-based energy sources such as wave and tidal energy.	Yasmeen et al. (2022)
Power Grid	There is a network of electrical conductors called the power grid to distribute electrical power to consumers.	Butt et al. (2021)
Vehicle-to-Grid Technology	It is the flow of energy, information, and money between EVs, aggregators, and the electricity grid to balance the demand and supply.	Nunes and Brito (2017)

1.8 Assumptions

This study was based on the following assumptions:

- Participants found the interview questions easy to understand.
- There were enough responses from multiple viewpoints for the study to be valid. The researcher recruited thirteen (13) participants involved in the V2G value chain.
- The participants had enough expertise and knowledge of the South African energy and electric vehicle sector to provide suggestions and thoughts on mechanisms that could work in this country.

1.9 Structure of the report

The research process followed the following structure:

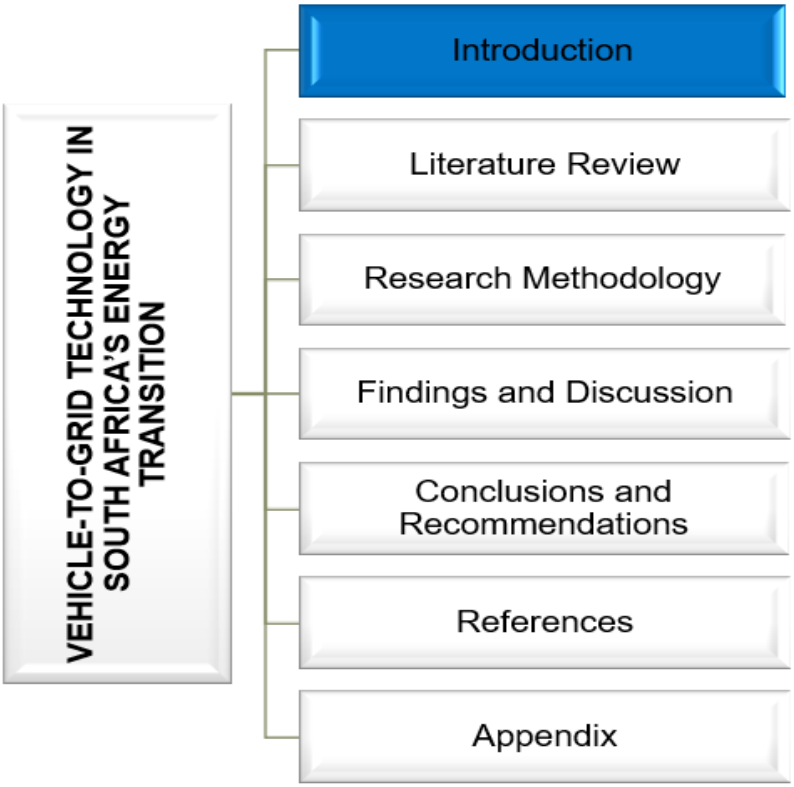


Figure 2: The research process
Source: Developed by author

Chapter 1: Introduction

In this chapter, the basis for the study was presented through the research purpose, the context of the study, the research problem, the research questions, and the significance of the study. Definitions of key terms used in the study were provided.

Chapter 2: Literature review

This chapter reviews studies that have explored the subject of EV and V2G technologies and their adoption thereof. The research questions guided the literature review.

Chapter 3: Research Methodology

The key methodological processes and choices made during the research journey are explained. These processes and decisions include the research approach, research design, data collection methods, population and sample, research instrument, the procedure for data collection, data analysis and interpretation, limitations of the study and data trustworthiness.

Chapter 4: Findings and Discussion

A detailed analysis of the findings and discussions from the interview sessions is presented in this chapter. In order to analyse qualitative data, themes will be identified, categorised into codes, and their frequency will be measured to make concepts easier to comprehend. Furthermore, the chapter compared the findings with the theory derived from the literature review.

Chapter 5: Conclusions and Recommendations

Based on the findings, conclusions and recommendations are made regarding the role of V2G technology in South Africa's transition to a low-carbon economy. In addition, research areas that need further exploration are discussed.

CHAPTER 2. LITERATURE REVIEW

2.1 Introduction

This chapter reviews existing literature around V2G as a possible solution to accelerate South Africa's energy transition. The section provides background information on V2G technology. In addition, the role V2G will play in the energy transition based on scholarly research is analysed. The key focus of the reviewed literature is the factors affecting the adoption of EVs while examining the role that the different actors in the V2G industry can play in promoting technology in South Africa. Lastly, the theoretical framework underpinning this study is presented and critiqued.

2.2 Background on V2G technology

The V2G concept, EV controllers, charging stations, and the grid-integrated vehicle platform was invented in 1997 by Professor Willet Kempton and his colleagues (Roberts, 2016). The thinking behind the development and promotion of V2G was that vehicles are generally on the road 5% of the time, while 95% are in parking lots, garages, or near a building with an electrical connection point (Pasaoglu et al., 2014; Sovacool et al., 2017; Ravi & Aziz, 2022). This idea makes it impulsive to harvest energy from these vehicles (Bibak & Tekiner-Moğulkoç, 2021). As depicted in Figure 3, V2G fits into a larger field of emerging charging technologies (IRENA, 2019). A variety of terms classify the charging and discharging of an EV. In managed charging systems, EVs are referred to as V01, while owner-charged systems are termed V0G. On the other hand, EVs may discharge to a home (V2H) containing a single customer, to a building (V2B) containing several customers, to the grid (V2G) or many things (V2X). According to Jones et al. (2021), it is possible to use these charging technologies to manage energy consumption in a home (V2H), a building or microgrid (V2B), the grid (V2G), and in a variety of other applications (V2X).

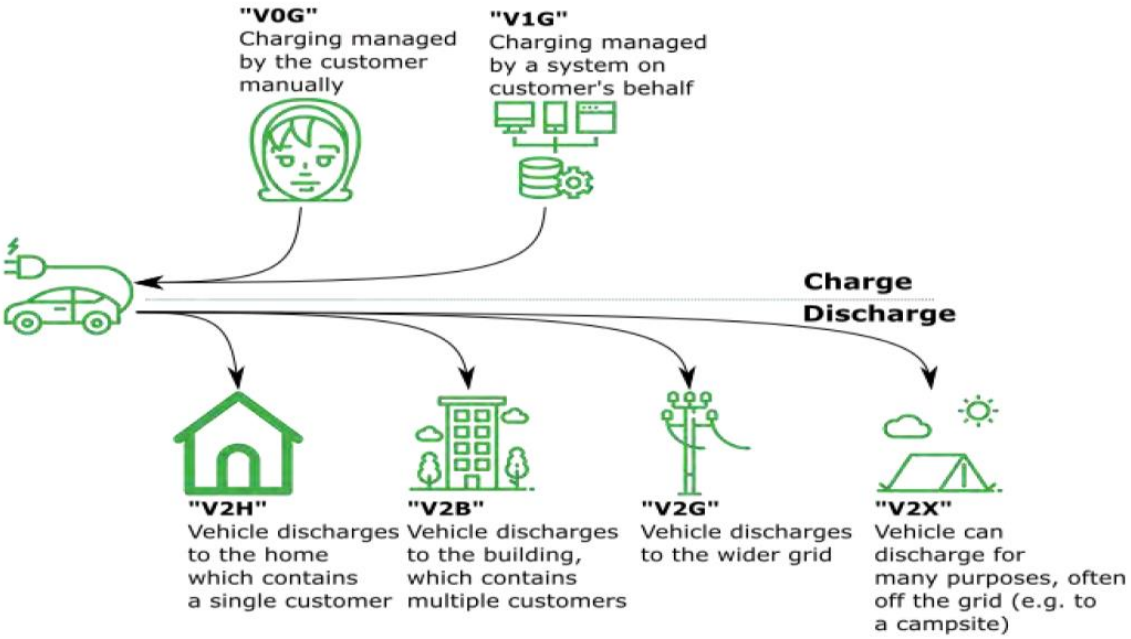


Figure 3: The EVs smart charging landscape
Source: Jones et al. (2021)

Even though V2G has been around since the 1990s, it has not yet been fully commercialised and has not seen mainstream popularity, even in areas where EV adoption is strong (Jones et al., 2021). Thus, it remains a niche product. Fulari and van de Kaa (2021) state that although V2G technology has many benefits, it is not widespread due to a universal dominant charging standard. The authors claim that the technology is not widely adopted because two well-known charging protocols, CHArge de MOve (CHAdeMO) and Combined Charging System (CCS), are competing for dominance (Fulari & van de Kaa, 2021). According to Un-Noor et al. (2017), these charging protocols are incompatible and are each supported by different automakers.

Moreover, Tesla also introduced its supercharging system, which speeds up charging time. There is no way to determine which will prevail or if both will co-exist (Un-Noor et al., 2017). As shown in (Appendix B), several V2G trials and commercialisation projects are underway in the United States of America (USA), Denmark, Japan, the Netherlands, and the United Kingdom (Sovacool et al., 2018; Olsson, 2019; Nuvve Holding Corp, 2021; Jones et al., 2021). However, in South Africa, there is only one experiment conducted through *uYilo*, which uses

V2G technology in its smart grid ecosystem live demonstration project. The project provides automakers, utilities, and energy companies with valuable information to evaluate and improve EV charging techniques and manage energy (Cornell, 2017; uYilo, 2021).

While experimentation is necessary to determine the feasibility of V2G, identify obstacles, and investigate its narratives, V2G still needs a widely adopted approach, along with the trial runs, to reap its benefits (Hirsh & Sovacool, 2009; Gschwendtner et al., 2021). The history of energy transitions in the past, especially the development of emerging technologies, suggests that social and technological institutional barriers may be equally vital or cumbersome for the V2G transition (Sovacool & Hirsh, 2009; Bürer et al., 2021).

2.3. The role of V2G in the energy transition

The role that V2G can play in the energy transition is mainly related to the support and services it can provide to stabilise the power grid (Peters et al., 2020; Ravi & Aziz, 2022). Some of these services may offer revenue for EV owners or reduce electricity supply and operating costs (Sarparandeh & Ehsan, 2017; Abito & Salant, 2019). The following section will look at the role V2G can play in the energy transition.

2.3.1. Manage renewable energy intermittencies

Several studies have investigated the feasibility of V2G technology in dealing with the intermittency of renewable energy (Kempton et al., 2002; Mwasilu et al., 2014; Guo & Zhou, 2016; Child et al., 2018; Di Natale et al., 2021). According to Lund and Kempton (2008), V2G is one of several energy storage technologies that have the potential to create a flexible energy system that can make better use of fluctuating renewable energy. They discovered that integrating V2G into national energy systems permits considerably higher levels of wind electricity to be integrated without additional electricity generation, resulting in significant

reductions in national CO2 emissions (Lund & Kempton, 2008). Considering that the stored energy is not just for power grid uses in the future, through V2G, EV batteries can also serve as a buffer between intermittent renewable energy generation and its end-use (Krueger et al., 2021).

Despite the benefits that V2G offers, Mwasilu et al. (2014) and Zhang et al. (2021) argued that there are other energy technologies, such as specialised battery storage systems, pumped hydroelectric storage, flywheel, and concentrated solar power (CSP) that can be used to balance the power grid. These are in direct competition with the expansion of V2G in the energy sector. In 2014, the CSP integrated with an energy storage technology showed greater efficiency of up to 99 per cent and can store energy for extended periods than an EV battery (Mwasilu et al., 2014). Furthermore, pumped hydroelectric storage, for example, is regarded as a considerably less expensive alternative than V2G. However, Newbery (2018) revealed that recent rapid reductions in battery costs increased expectations that chemical storage, rather than water storage, offers an appealing storage alternative. Thus, the bulk of recent work in this direction was concerned with the feasibility of the technology in terms of its costs, value risks, complexity, suitability for developing countries, and whether it is competitive with other technologies that can offer similar grid services (Brown et al., 2021; Zhang et al., 2021). Al-Ghussain et al. (2022) showed that coupling thermal storage with renewable power generation systems in Jordan is feasible and can also cover 100% of the country's energy needs. This integration can also help to eliminate the need for more common but dangerous alternatives (Li-ion batteries).

2.3.2. Provide ancillary services to the power grid

V2G can help power grids be more efficient, stable, and secure (Kempton & Kubo, 2000; Turton & Moura, 2008; Niesten & Alkemade, 2016). When there is a concentration of EVs parked in one location, V2G can also offer distribution system support services to the power grid (Kempton et al., 2008; Wang & Craig, 2021). These EVs can integrate ancillary services such as voltage and frequency

regulation and spinning reserve into the grid through V2G technology (Triviño-Cabrera et al., 2019; Wu & Lin, 2021).

For three years, Lund and Kempton (2008) calculated the economic potential of EVs providing grid support services. The services of EVs in the three power markets: peak power, spinning reserve, and regulation services, were shown to be more appealing and promising (Lund & Kempton, 2008; Abito & Salant, 2019; Taliotis et al., 2020). Considering that EVs are parked most of the time, they represent idle assets (Zhang et al., 2020; Zhou et al., 2020; Wellings et al., 2021). So, the aggregators may use this part of the schedulable resources to participate in the regulation services and generate revenue for EV owners (Zhou et al., 2020).

According to recent studies by Di Natale et al. (2021), Alotaibi & Eltamaly (2022), and Aghajan-Eshkevari et al. (2022), EV owners can earn revenue by selling excess electricity during peak and by signing up to provide ancillary services to the power grid (Wang & Craig, 2021). However, the actual value that electric vehicle owners may derive from V2G technology depends on the business model established and the local electricity market conditions (Høj et al., 2018; Wang & Craig, 2021).

Despite the above advantages, one of the biggest constraints for V2G to provide ancillary services is the battery degradation cost (Bishop et al., 2013; Mwasilu et al., 2014; Wu & Lin, 2021; Dioha et al., 2022). Because of these multiple usages, EV batteries will degrade faster. This issue led (Bishop et al., 2013) to investigate the effects of V2G services on battery deterioration, and the outcome confirmed that batteries are more vulnerable when delivering ancillary services. Due to this, V2G without considering battery degradation is not feasible (Uddin et al., 2018). According to Rangarajan et al. (2022), the pros of developing the battery technology outweigh the cons in contrast to the expected drawbacks.

While there is a need for research on the quantification of battery degradation (Smith et al., 2015; Pastor-Fernández et al., 2019), many cities in China have

begun to study the V2G model as the trend of new infrastructure (Zhou et al., 2020). The North China Grid Corporation formally incorporated the V2G charging pile resources in the ancillary service market and was settled in April 2020 (Zhou et al., 2020). Also, the testing of EVs utilising V2G to engage in auxiliary services such as real-time frequency control and peak reduction was completed in May by State Grid Tianjin Electric Power Company (Zhou et al., 2020). In this case, EV fleets could be a viable solution to provide dynamic electricity storage systems in the V2G context.

2.3.3. Carbon emission reductions

Since V2G integration is dependent on the battery storage of an EV, several studies on the possible environmental advantages of V2G did not focus solely on the technology but assessed the benefits of V2G-enabled EVs (Sovacool et al., 2018; Baumgartner et al., 2022). Jochem et al. (2015) reported that although the indirect emissions from EVs might be enormous, they are still regarded as zero-emission vehicles by European legislation. In contrast, Milev et al. (2021) argued that EVs do not release emissions but require electricity. Hence, many consider them an eco-friendly solution for the ever-growing demand for more vehicles and fuel (Milev et al., 2021). In a study by Wei et al. (2022), the authors state that an integrated energy system (IES) with V2G results in lower cost and emission than a standalone IES or EV.

EVs typically produce fewer life cycle emissions than conventional vehicles because most emissions are lower for electricity generation than gasoline or diesel (Milev et al., 2021; Ampah et al., 2022). In contrast, Yilmaz & Krein (2013) and Mclaren et al. (2016) oppose that EV emissions benefits depend on the vehicle itself, battery specifications, charging and recharging frequency, and approaches. On the other hand, (Archsmith et al., 2015; Jochem et al., 2015) reported that assessing the CO2 emissions of EVs is a difficult task because the emissions impacts are directly related to the country's electricity generation mix that varies geographically (Woo et al., 2017; Whitehead & Washington, 2018).

Woo et al. (2017) conducted a more recent analysis that found that EVs were ineffective in reducing emissions in seventy countries, including South Africa, with a fossil-fuelled electricity generation mix. Based on the adverse footprint of EVs, regulations for these countries need reassessment. Mohammad et al. (2020) supported that EV emission benefits cannot be exploited if charging comes from non-renewable energy sources. Therefore, using renewable energy to charge EVs will reduce GHG emissions.

2.3.4. Proposition 1

V2G technology adoption positively influences South Africa's transition to zero-carbon energy.

2.4. Factors influencing the adoption of EVs

EVs are perceived as a viable option for reducing greenhouse gas emissions in both the electricity and transport sectors (Brückmann et al., 2021; Kannangara et al., 2021; Rüdisüli et al., 2022). However, several roadblocks impede the adoption of this technology, prompting numerous writers to investigate the subject (Adhikari et al., 2020; Brown et al., 2021). The following section reviews some of the factors impacting EV adoption.

2.4.1. Policy

Although technical defects and high purchase prices are still the main obstacles to the widespread use of EVs, the most compelling driver for early adoption is government policies related to EVs (Rezvani et al., 2015; Mastoi et al., 2022). Purchase subsidies, on the other hand, would not stimulate the adoption of EVs without a legislative structure and political will (Harrison & Thiel, 2017; Li et al., 2019; Alotaibi & Eltamaly, 2022). However, given that EVs are still new in many countries, the lack of comprehensive regulations to support adoption cannot be

ignored (Egn´er & Trosvik, 2018; Muller, 2019; Adhikari et al., 2020; Brückmann et al., 2021). The following are some of the most common policy obstacles.

- ***Lack of long-term planning***

In most countries, the government is responsible for sourcing, authorising, and developing new energy technologies (Ragland et al., 2011; Liu et al., 2020; Peters et al., 2020; Candra, 2022). Therefore, the growth of EV usage at the national level should relate to the country's sustainable development visions (Nykvist & Nilsson, 2015; Ford & Hardy, 2020). California and China have policies that compel vehicle manufacturers to sell more ZEVs, whilst the EU has introduced a voluntary target framework (Priessner et al., 2018; Rokadiya & Yang, 2019; Dioha et al., 2022). Other countries with growing policy activities to promote electric cars are Canada, Chile, Costa Rica, India, and New Zealand (IEA, 2020).

2.4.2. Economic

Because EVs seem more expensive than ICEs, people are less eager to purchase them (Goel et al., 2021; Gunawan et al., 2022; Candra, 2022). This perceived advantage is often considered a significant impediment to the widespread adoption of EVs. As previously indicated, many countries now provide different economic incentives to encourage consumers to purchase EVs. These experiences have demonstrated that economic challenges may be overcome with the appropriate incentives (Adhikari et al., 2020; Rajper & Albrecht, 2020; Sanguesa et al., 2021). The study explored the following economic factors: purchasing price, battery replacement costs and electricity charging costs, which are potential roadblocks to EV adoption.

- ***Higher purchase price***

Even though the purchasing price of EVs is a concern for consumers, they are slightly higher than ICE vehicles due to the high costs of manufacturing (Adhikari et al., 2020; Tongwanea & Moeletsi, 2021). In many countries, subsidies for the

purchase of EVs are a popular strategy for increasing their appeal (Wang & Craig, 2021; Murugan & Marisamynathan, 2022). Langbroek et al. (2016) questioned whether subsidies offered had the same impact on different customer groups. Research in Spain and Pakistan found that range, incentives, and reliability are the best predictors of EV purchase intentions (Ghosh, 2020; Higueras-Castillo et al., 2020; Shakeel, 2022). Due to the EV pricing problem, limited numbers of luxury electric vehicles are available, resulting in most EV sales from affluent households (Bauer et al., 2021). In addition, the authors emphasise that the used EV market holds enormous potential for increasing EV affordability.

2.4.3. Social Barriers

Recent studies (Egbue & Long, 2012; Habich-Sobiegalla et al.,2018; Rajper & Albrecht, 2020) show that social hurdles to EV adoption may be as significant as technological reasons. Customer knowledge of the attributes of EVs is an essential influential factor in their decision to choose EVs over ICE vehicles (Rezvani et al., 2015; Kumar & Alok, 2020; Krishna, 2021). Consequently, recognising customer social aspects should become increasingly important. In this sense, communication of related information is critical. Rezvani et al. (2015) reported that customer knowledge, experience, environmental concerns, and perceptions of EV quality influence the customer's decision to buy an EV. Therefore, different stakeholders within the EV value chain should communicate these attitudes by expanding advertising and launching more information campaigns (Taliotis et al., 2020; Broadbent et al., 2021; Talantsev, 2017).

2.4.4. Technological

Even though EVs can reduce emissions and increase the transportation economy, they face significant adoption hurdles (Muller, 2019; Adhikari et al., 2020). Some of the most common technical obstacles this technology faces are expanded below.

- ***Range anxiety***

Due to range anxiety, EV sales are fewer than projected (Bonges & Lusk, 2016). Adhikari et al. (2020) claim that users who do not need to drive great distances regularly are more likely to be interested in EVs. However, according to a study conducted in Beijing by Zhang et al. (2021) and Ziegler et al. (2022), the charging speed is negatively connected to an EV's state of charge, implying that fast charging might increase charging rate while lowering the range anxiety. Also, Di Natale et al. (2021), Mashhoodi & van der Blij (2021), and Laffont et al. (2022) reported that several prior studies have found that as the number of charging stations rises, range anxiety decreases.

- ***Availability of public charging stations***

As a result of their simulation model, Tran et al. (2013), Lopez-Behar et al. (2019), and Ledna et al. (2022) showed that large-scale charging networks are essential for the mass adoption of EVs. Sierzchula et al. (2014) and Kim et al. (2022) found that charging infrastructure (relative to population) positively correlates with EV market share. Due to the low number of EV users, both the public and private sectors are hesitant to invest in charging stations (Egn´er & Trosvik, 2018; Pavlenko et al., 2019; Adhikari et al., 2020). On the other hand, automakers believe that government should be responsible for constructing the required infrastructure, such as charging stations and repair facilities, and vice versa (Adhikari et al., 2020).

2.4.5. Proposition 2

The MLP and diffusion of innovation theoretical lenses explain the adoption of V2G technology.

2.4.6. Proposition 3

EV and V2G technology adoption will lead to a reduction in CO2 emissions.

2.4.7. Proposition 4

A poor energy policy, lack of awareness, and undesirable economic and regulatory environment negatively affect the adoption of EVs and, thus, V2G technology in South Africa.

2.5. The role of different stakeholders in the V2G value chain in promoting V2G adoption

In the multi-level perspective framework (MLP), the transition to sustainability involves various processes and stakeholders. The theory indicates the interaction of actors, environments, and innovations (Dane, 2014). Noel et al. (2019) pointed out that most of the socio-technical elements for adopting V2G technology depend on electric vehicle owners, aggregators, power grid operators, governments, electric vehicle manufacturers, and power producers.

The actors involved in this study are primary actors, who play a direct role in the bidirectional flow of power, and secondary actors, which do not play a direct role in the system but facilitate the contribution of V2G technology to the grid (Forrest et al., 2016; Noel et al., 2019). These actors must interact in some way for the value chain to work. As shown in Figure 4 below, the different actors, such as the government, the national utility which generates, transmits, and distributes electricity, the regulator, the industry, the independent energy producers (IPPs), EV owners and EV charger suppliers, all need to work together to develop the V2G technology system. The following section describes the relationship between these different actors in the system.

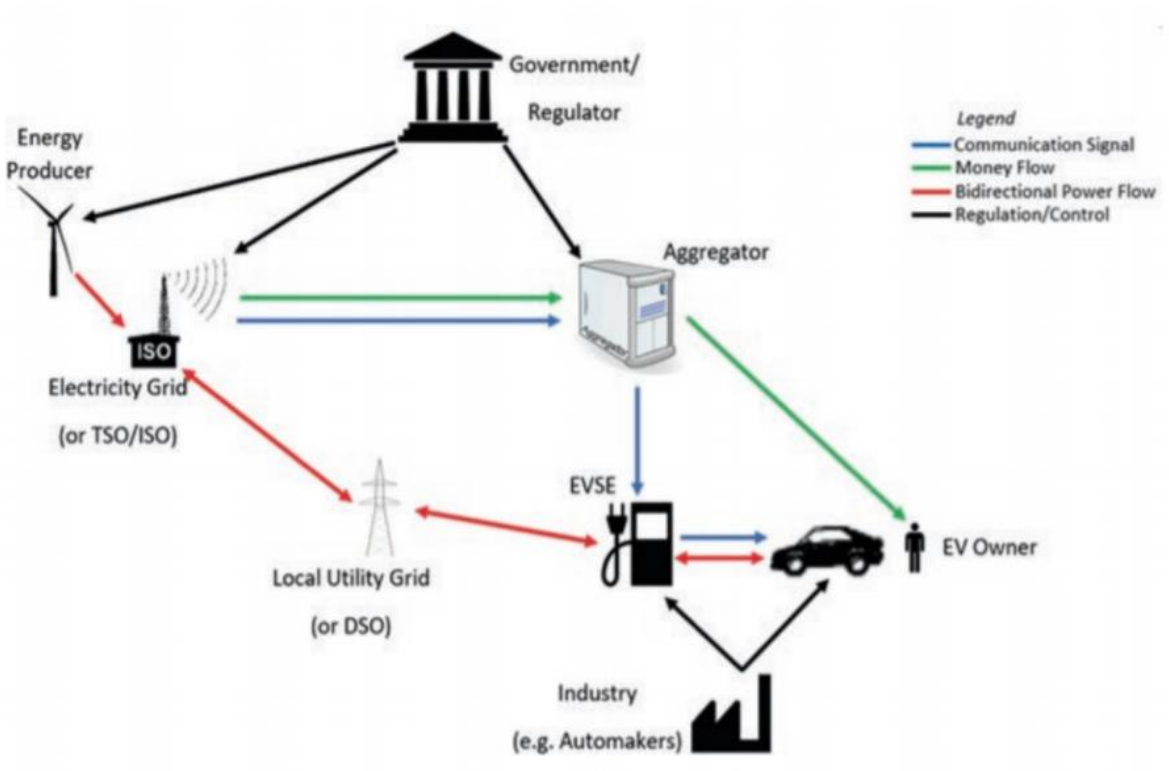


Figure 4: Illustration of actors in the V2G system
Source: Noel et al. (2019)

2.5.1. Primary actors

- ***EV owners***

The term vehicle-to-grid effectively consists of three terms: "vehicle", "to", and "grid". Each of these terms represents one of the primary actors (Noel et al., 2019). Firstly, there is a vehicle that belongs to the EV owner. The only action required of EV owners is to plug their vehicles into a charging station and let the aggregator know when they will need them again (Sun et al., 2021). In this sense, the EV owner's vehicle is a very active asset in the system since it communicates with the aggregator and provides electricity to the grid.

- ***Aggregator***

An aggregator is an intermediary in the V2G system (Bessa & Matos, 2010; Adnan Khan et al., 2019). Their primary function is to group EVs based on their

owner's willingness to take advantage of business opportunities in the electricity market (Lopes et al., 2011). Aggregators receive signals from the power grid when capacity is demanded and then communicate with the fleet of EVs to deliver that capacity (Noel et al., 2019; Gunawan et al., 2022). Sovacool et al. (2020) state several reasons why using an aggregator instead of direct communication from the grid operator to each EV may be advantageous. Usually, markets where V2G may be beneficial (like frequency control) require a minimum power capacity, typically 100 kW or, worse, 1 megawatt (MW).

- ***Power grid operators***

In the old days, when electric utilities were vertically integrated, the same company usually carried out power generation, network operation, and supplying final customers (Koch, 2015; Habla et al., 2020). In recent years, the term "grid" represents grid actors. The Transmission System Operator (TSO) is responsible for the supply and demand of electricity over high-voltage transmission lines (Noel et al., 2019). Additionally, the local utility or Distribution System Operator (DSO) receives electricity from the Transmission System Operator (TSO) and transmits it to end-users, such as households or industries (Johansson et al., 2020). Even though the TSO provides the ancillary markets, the DSO network is also needed as EVs will mainly be at the end-use of electricity and, thus, impact local grids (Habich-Sobiegalla, 2018; Archsmith et al., 2018; Noel et al., 2019).

2.5.2. Secondary actors

- ***Government***

The government is the foremost secondary actor in this system since they regulate storage markets and are responsible for the regulatory framework around ancillary markets (Noel et al., 2019). They can also encourage TSOs and DSOs to develop their policies and regulations. They are also responsible for the tax settings around the system and the policy around the development of the power grid by requiring more renewable energy sources, which are in line with climate agreements and provides a market for storage options such as V2G.

Additionally, inflicting taxes on fossil fuels can make V2G more economically viable for users (Noel et al., 2019; Ghazouani et al., 2020).

- ***EV-industry***

The second important secondary actor in the system is the EV industry (Noel et al., 2019). Not that they play an active role on the operational side of the system, but they are responsible for manufacturing EVs and charging poles that support the V2G application. V2G technology cannot spread without an adequate supply of EVs enabled for bidirectional charging (Noel et al., 2019). Most major automotive Original Equipment Manufacturers (OEMs) currently do not supply V2G-enabled cars (Sovacool et al., 2020; Hatt et al., 2020). Nissan provides a V2G-enabled EV in the Leaf, while other manufacturers, such as Mitsubishi, BMW, Volkswagen, Renault, and Tesla, sell EVs with straightforward V2G configurations. Given the scale of the automotive sector (more than 73 million commercial vehicles manufactured by 47 OEMs in more than 40 countries in 2017) and the projected expansion of the international EV market (an estimated 130 million EVs will be on the road by 2030), the potential size of a V2G-capable EV market is enormous (Hu & Li, 2020; Sovacool et al., 2020).

- ***Electricity producers***

Finally, electricity producers are another relevant secondary actor because electricity production is a crucial determinant of the balance of the power grid (Noel et al., 2019). Also, when electricity producers stimulate renewable energy sources, they support V2G services by directly lobbying for storage markets or indirectly making V2G services more valuable (Brown & Soni, 2019; Noel et al., 2019).

2.5.3. Proposition 5

EV adoption accelerates the adoption of V2G.

2.5.4. Proposition 6

Energy industry actors have strategies to adopt and promote EVs and V2G as part of their contribution towards zero-carbon energy.

2.6. Theoretical Framework

Technology innovation, policies and economic development are some of the most prominent factors shaping energy transitions. Therefore, to better understand energy transitions, researchers should combine knowledge from various disciplines (Cherp et al., 2018). Multi-level perspective (MLP), strategic niche management (SNM), diffusion of innovation (DOI), and transition management (TM) are frameworks commonly used to analyse and understand energy transitions (Bilali, 2018; Clark & Harley, 2020). SNM examines the circumstances under which niche emergence occurs and uses policy to guide sustainable innovations to wider adoption (Stiles, 2020). According to Van Welie and Romijn (2018), TM addresses complex societal problems and governs societies in a way that allows for adaptive and forward-looking development. DOI focuses on the social processes which occur when people learn about a new technology or innovation (Dearing & Cox, 2018). DIO and MLP are overarching frameworks for assessing transitions as interactions and processes between actors in the sector and development phases (Bilali, 2019; Stiles, 2020).

The MLP framework has proven effective in studying large-scale sector developments, while many technology-adoption studies have employed the DOI framework (Boumaiza et al., 2018; Bilali, 2019). Application examples include sectors such as energy, transportation (Geels, 2012), agro-food systems (Bilali, 2018), innovations such as solar PV adoption (Boumaiza et al., 2018), and municipal solid waste management (Iyamu et al., 2022). As a result of this encompassing view, these two frameworks are relevant to generate insights on

enabling factors for V2G adoption in the country. These theories, detailed in this section, inform the conceptual framework developed for the study.

2.6.1. Multi-Level Perspective Theory (MLP)

The Multi-level perspective theory (MLP) theory was developed by Arie Rip and René Kemp and further refined by Frank Geels and Johan Schot (Bilali, 2019). MLP is based on a socio-technical approach to understanding energy transitions. As a result, energy transitions can be explored using interaction factors such as technology, industry, markets, policy, society, and culture.

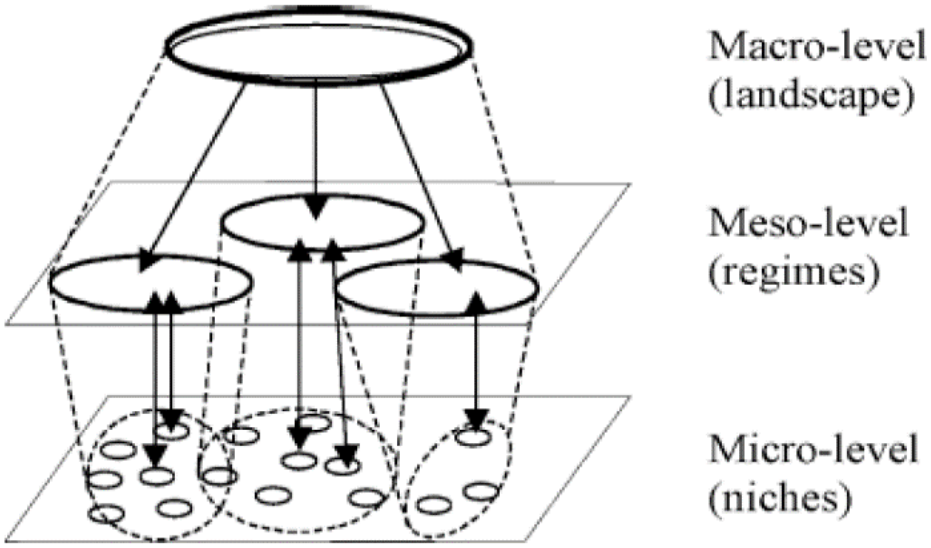


Figure 5: Multi-level perspective framework
Source: Geels (2002)

As depicted in Figure 5, the MLP suggests transitions occur due to the interactions within and amongst three analytical levels: niches, regimes, and a socio-technical landscape (Geels, 2011; Bilali, 2019; Iyamu et al., 2022). These levels are first shortly introduced to get insight into the big picture, after which they are explained more thoroughly and applied to the transition discussed in this study, being the role that the V2G adoption could play in South Africa's decarbonisation plan.

The macro-level encompasses the socio-technical landscape, including macro-economy, demographics, macro-politics, and natural environment (Archsmith et al., 2018; Bilali, 2019; Rajper & Albrecht, 2020; Laffont et al., 2022). The dynamics and trends of these developments are slow. The Meso-level refers to the regime, which is the dominant structure in our society, including regulations, favourable institutional arrangements, actors, norms, and basic assumptions (Geels, 2011; Sanguesa et al., 2021). The regime also guides public actions and policies, which tend to optimise rather than completely change the existing system (Lachman, 2013; Bilali, 2019; Liu et al., 2020; Li et al., 2021). Consequently, regimes often act as the stumbling block for transitions. Institutions also have a crucial influence on this level since regimes guide our private activities. Geels (2011) defines niches as “protected areas” such as R&D facilities, funded demonstration projects, or small markets for new and developing technologies at the micro-level. Individuals or organisations create and develop niches, new ideas or innovations that vary from the current system. The landscape puts pressure on the current system at the meso-level. At this stage, windows of opportunity can be created, and niches can break through these windows and become part of the regime (Geels, 2012).

As a result of the constant interplay between the macro, meso and micro-levels, a transition might occur (Grin et al., 2010). Slow long-term changes alter the socio-technical landscape on a macro level, putting external pressure on the meso-level via top-down developments. So, existing regimes get pressurised to respond to these developments (Patwardhan et al., 2012). Consequently, the landscape may cause changes in the “regimes” through behavioural or policy changes. These alterations might occur during the take-off phase, signalling the beginning of a transition. Niches produce novel procedures and practices that depart from the status quo on a micro level, putting downward pressure on regimes.

As shown in Figure 5, the regime is a group of institutions contributing to the current South African electricity landscape and is notoriously difficult to alter. This

regime affects the electricity and fossil-fuel-dominated transportation sectors (Lopez-Behar et al., 2019; Rajper & Albrecht, 2020). The regimes are generally established through path dependence and positive feedback mechanisms (Geels, 2010). Path dependence refers to the early economic and social factors that favour continuing with the previously chosen path (Klitkou et al., 2015) and, as a result, impede the energy transition. It denotes society's reliance on specific circumstances and situations that have shaped the regime into what it is now. In the context of this study, examples could be infrastructures already in place, such as coal-fired power plants, single-buyer models, and the current transmission grid. The positive feedback mechanism refers to the increasing income remaining with the existing system (Klitkou et al., 2015). An example might be the learning effect of ICE vehicles in South Africa. In this case, the government support and the profitability of traditional ICE vehicle production encourage the automotive industry to continue using current technology (Dane, 2014; Krishna, 2021).

Given that there is no historical path dependency on renewable energy sources, alternative solutions should be explored rather than focusing only on intermittent energy sources in South Africa. Also, the national utility is under high pressure from the regulator to keep electricity tariffs low. As a result, new investments must be compatible with the future energy system to avoid wasting resources. Emerging technologies might be classified as niches and may or may not join the market and become a participant in the regime. However, they are unquestionably vital in the energy transition (Kumar & Alok, 2020). Most "niches" have low market penetration, typically due to poor economic conditions. However, subsidies often make niche technology competitive with the regime, which is part of the protection. Using the MLP theory, this study reviewed the development of this technology to understand how the country can transform its existing regime and act to support the adoption of this technological niche. In addition, the study explored how V2G technology as a niche innovation can exert bottom-up pressure on the current "regime" to force change.

2.6.2. Diffusion of Innovation Theory (DOI)

The Diffusion of Innovation Theory (DOI) can be used to explain how technology has evolved and been accepted in the energy sector. Everett Rodgers developed the DOI intending to explain the pace and path of acceptance of new ideas and innovations (Taherdoost, 2018). Figure 6 presents the DOI model.

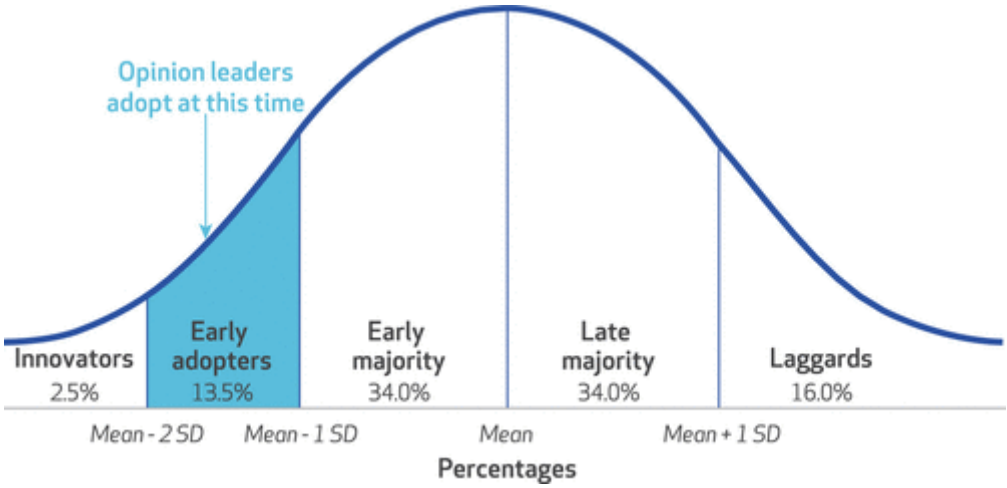


Figure 6: Diffusion of innovation theory
Source: Rogers (2003:150)

The theory describes how the diffusion of innovation happens as people undergo a five-step process to assess the impact of change on their work and lives (Lamorte, 2019; Zimm, 2021). The theory proposes four key elements that determine the spread of innovation: the innovation itself, communication processes, the time taken for the necessary innovations to be accepted and adopted and a social system that includes internal and external influences.

The successful acceptance of technology innovation depends on the presence of human capital (Mkhize et al., 2016; Joshi et al., 2022). Without the people or a critical mass that understands, adopts, and spreads the innovation, a technological innovation's sustainability is not ensured (Douglas et al., 2015). Users can accept new technologies within the energy sector, such as V2G if they are confident it is convenient for their needs. More importantly, it safeguards them from infringement of privacy, security, and fraud.

Diffusion is the process of communicating an innovation using various channels among members of a social setting (Mkhize et al., 2016). The adoption of new technological innovation begins with a small number of innovators. The DOI model has five different segments based on people's propensity to adopt a specific innovation: Innovators are the early adopters, followed by early majorities, late majorities, and laggards (Douglas et al., 2015). The adoption as a decision process requires the potential adopter to collect information regarding the technology, examine the technology, and consider whether it provides sufficient improvement to deserve the investment of energy and time that is needed to add it to his/her range of skills (Woodside et al., 2017). Most of the current literature on the adoption of V2G technology focuses on the efficacy of this technology and how this efficacy can be a driver for the adoption of the technology (Sovacool et al., 2018; Das et al., 2020; Kongklaew et al., 2021)

Diffusion is the mechanism by which an innovation is communicated over time among members of a society (Rogers, 2003). The diffusion of innovation (DOI) theory asserts that the primary determinants of innovation diffusion are innovation characteristics such as observability, trialability, complexity, relative advantage, and compatibility (Woodside et al., 2017). These attributes increase the chances of the technology being adopted except under conditions of complexity, given their tendency to discourage adoption.

2.6.3. A conceptual framework for the study

The multi-level perspective theory (MLP) and diffusion of innovation theory informed the conceptual framework. Figure 7 indicates the conceptual framework for the study, supported by the propositions.

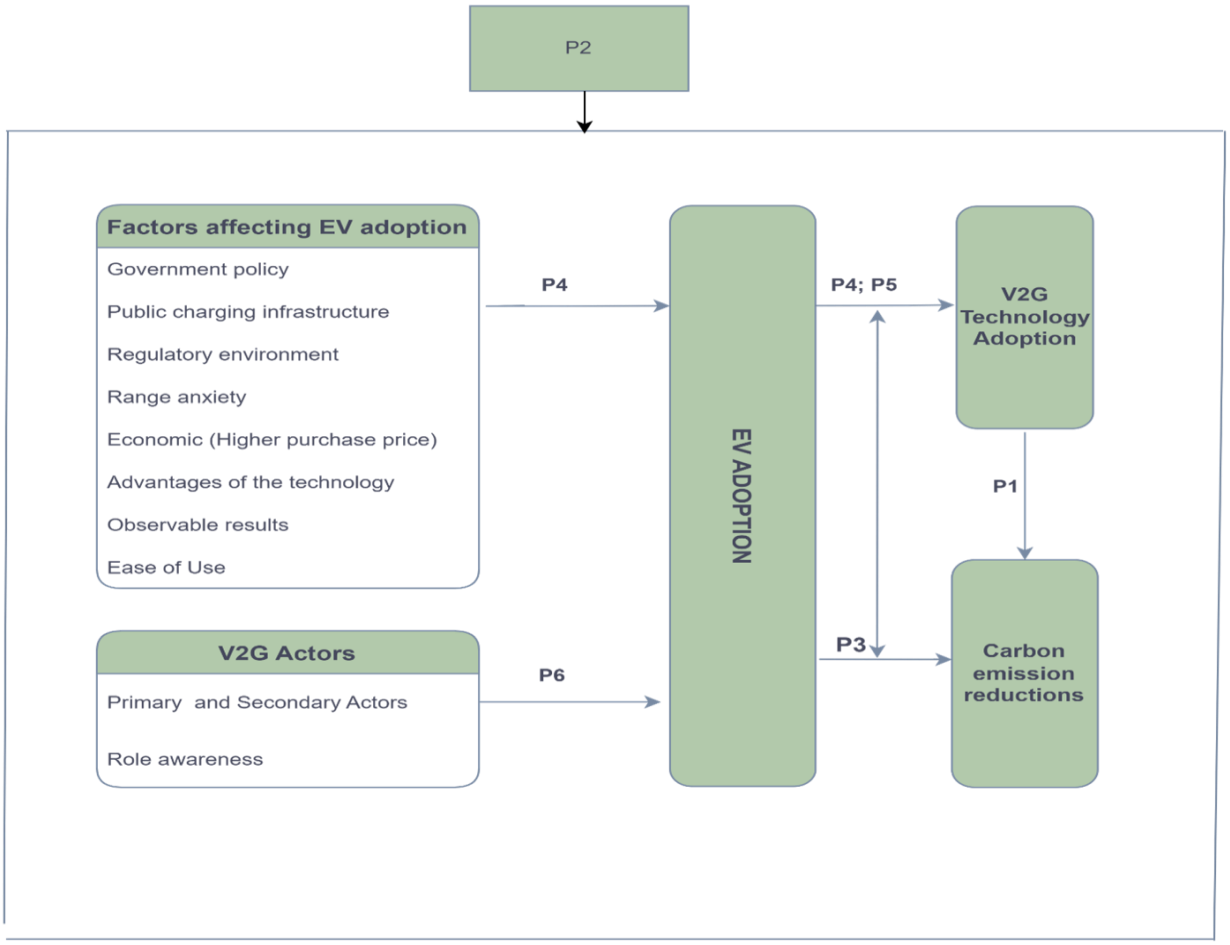


Figure 7: Conceptual framework of the study
Source: Developed by the author

A combination of strong and favourable policy measures, incentives to address cost and awareness gaps to grow the market, cheaper EVs, and the availability of public charging infrastructure is likely to increase EV adoption. Also, understanding the role of primary and secondary actors in the V2G system is crucial to promoting EVs. These elements must be balanced to achieve a transition to an ultra-low carbon future for the South African energy sector while keeping its position as the primary driver of the domestic economy's industrial development (DTIC, 2021). Figure 7 illustrates the driving force behind V2G technology adoption: reducing carbon emissions. The automotive industry must commit to manufacturing low-emission vehicles as emission standards tighten and trends in urbanization and car ownership shift. Failure to act will significantly

impact export volumes, earnings, and output, contributing to job losses and economic growth (DTIC, 2021).

2.7. Conclusion of the literature review section

The purpose of this chapter was to present and discuss previous and current debates about V2G technology. A focus was on the global development of these technologies and how they are integrated into other countries' power grids. The MLP framework and diffusion of innovation theory, which ground the study, were used to generate insights into factors that could hamper the adoption of EVs and V2G technology in South Africa's energy transition. Additionally, actors that can promote the development of a V2G system in the country were identified and formed as part of the study participants. The consistency Table 3 below illustrates the link between the propositions and the research questions.

Table 3: Consistency table: Research objectives and propositions

RQ #	Research Objective	Prop #	State Proposition
1	**To investigate the role of V2G in the energy transition.**	1	V2G technology adoption positively influences South Africa's transition to zero-carbon energy.
2	**To examine the factors affecting EV adoption.**	2	The MLP and diffusion of innovation theory are theoretical lenses that explain the adoption of V2G technology.
		3	EV and V2G technology adoption can lead to a reduction in CO2 emissions.
		4	A poor energy policy, lack of awareness, and undesirable economic and regulatory environment negatively affect the adoption of EVs and, thus, V2G technology in South Africa.
3	**To examine the role the stakeholders in the V2G value chain can play in promoting V2G.**	5	EV adoption accelerates the adoption of V2G.
		6	Energy industry actors have strategies to adopt and promote EVs and V2G as part of their contribution towards zero-carbon energy.

CHAPTER 3. RESEARCH METHODOLOGY

3.1 Introduction

This chapter describes the methodology used in conducting this study. Data collection methods, including sample size and instrument used, are discussed. Detailed information will also be provided on the collection of data and how the data was analysed and interpreted. This section will conclude with a discussion of the research limitations, validity, and reliability.

3.2 Research approach

Vaismoradi et al. (2013) define a research approach as a method for gathering and analysing data to find the solution to a problem. Qualitative, quantitative, and mixed methods are the three most common approaches and should be selected according to the research problem to develop appropriate research instruments to collect data that pertains to the research topic (Busetto et al., 2020; Chivanga & Monyai, 2021).

In this study, qualitative research was deemed appropriate because it allowed for more detailed data in words than numbers (Vasileiou et al., 2018; Busetto et al., 2020). Rather than recording numbers, this technique focuses on the "why" of social phenomena than the "what" and emphasises the role of human beings as meaning-makers in their everyday lives (Ahmad et al., 2019). Although qualitative research is often criticised for bias, small scale, and a lack of rigour, it can provide detailed, subjective findings that can be used to develop theories (Rudestam & Newton, 2015 as cited in Carmichael & Cunningham, 2017; Crick, 2021). One of the strengths of qualitative research is its capacity to explain patterns and processes of human behaviour that are difficult to quantify (Foley & Timonen, 2015). Thus, qualitative research provided an opportunity to garner insights from experts in the EV, V2G, and energy sectors rather than presuming that V2G technology will help the country achieve its energy transition goals.

3.3 Research design

In order to gain a better understanding of South Africa's EV and V2G technology landscapes, an exploratory study was conducted (Rahi, 2017). This research design aimed to delve deeply into a previously unexplored topic and assist the researcher in gaining a greater understanding of the subject (Rahi, 2017; Creswell, 2013). South Africa is still in the infancy of V2G technology, and little is known about it. Thus, this design was suitable for research on this topic because it allowed for probing questions and evaluating phenomena from different points of view (Rahi, 2017).

3.4 Data collection methods

Data collection should be systematic and accurate to ensure the research's validity and quality (Milev et al., 2021; Windrim & Higgins, 2022). This study drew both primary and secondary data to analyse and draw comparisons of views from different data sources. The use of multiple data sources, such as primary and secondary data, is known to bring together a diversity of perspectives which can strengthen the validity or credibility of research findings by adding texture, depth, and a diversity of insights to the data (Bhattacherjee, 2012; Kumar, 2019).

According to Tenny et al. (2021), an interview is well-suited to elicit the subject's opinions, knowledge, and beliefs on specific details, allowing for greater insight than might be acquired using quantitative approaches such as a survey. Open-ended, emerging data was collected from themes and developed during data analysis (Creswell, 2013; Sutton & Austin, 2015). Semi-structured interviews were therefore preferred for this study because they can be divided into various themes and allow the interviewer to deviate from the questions when required to dig further into given remarks (Dejonckheere & Vaughn, 2019). Additionally, the interviewer and interviewee can clarify questions, which is impossible with a structured interview or a questionnaire (Dejonckheere & Vaughn, 2019). However, semi-structured interviews are sometimes costly and take longer to

conduct and analyse (Adhabi & Anozie, 2017). However, they provide rich data since additional information may be gathered through non-verbal means (Farooq & de Villiers, 2017).

3.5 Population and sample

3.5.1 *Population*

In this study, the population of interest consisted of individuals, dyads, groups, organisations, or other entities that the study aimed to understand and to whom the study results were to be generalised or transferred (Casteel & Bridier, 2021). Clearly defining the study population sets the boundaries for the scope of a study enabling the researcher to properly focus their research so as not to conduct too broad an analysis (Salkind, 2010; Casteel & Bridier, 2021). A total of thirteen (13) primary and secondary actors with a vested interest in the V2G value chain participated in this study. The participants consisted of a diversity of entities such as an EV automaker and fleet owner, EV charging equipment supplier, electricity generation, transmission and distributors, energy regulators, green energy independent power producers, EV lobbyists, energy policymakers, and energy researchers in South Africa.

3.5.2 *Sample and sampling method*

The study participants were thirteen in total, comprising twelve managers with at least five years of experience from twelve organisations active in the energy sector, as well as an owner of an EV in South Africa. They were selected based on their knowledge, affiliation and expertise related to the research topic using a non-probability sampling technique (Palinkas et al., 2015; Carmichael & Cunningham, 2017). Finding the appropriate participants to interview is critical in qualitative interviews since it impacts how relevant and valuable the collected information can be (Bolderston, 2012). As such, the participants were selected based on their experience in the energy sector, particularly the electricity and EV

technology field. Figure 4 illustrates the selection strategy used for experts in the V2G system. In choosing participants, the researcher sought out individuals who would provide rich information and challenge or enrich the understanding of the subject under investigation while honouring their voices (Dawadi et al., 2021).

Data were collected from thirteen experts at management levels in their respective organisations, with more than five years of work experience and exposure to energy technology policy, planning, or implementation. These energy experts represented primary and secondary actors in the V2G technology system and understood South Africa's electricity supply sector. To manage the complexity of the analysis, Vasileiou et al. (2018) recommend a sample size of no more than fifty. Thirteen interviews were conducted, and the rationale for choosing this number was that the information gathered during the interviews was sufficient to answer the study's research questions. Table 4 below lists the institutions from which the researcher secured expert participants for the study.

Table 4: Profile of institutes from whom representative expert participants were drawn

Target Institute	Number Of Participants	Participant Level
Industry/ Private Sector (EV Automaker & V2G Technology Supplier)	2	Management
State-Owned Enterprise (SOE) (National Utility)	3	Management
National Energy Department	1	Management
National Energy Regulator	1	Management
Metropolitan Municipality	1	Management
EV Lobby Group/ NGO	1	Management
Academia/ Research Institute	1	Management
Independent Power Producers (IPPs)	2	Management
EV Owner	1	Management
Total Participants	**13**	

Source: Compiled by the author

3.6 The research instrument

A research instrument or tool is any device/means of collecting quantitative or qualitative information (data) to answer the research questions (Zohrabi, 2013; Milev et al., 2021). Depending on the study's objectives, questionnaires, observation, and interviews are commonly used methods for qualitative research (Jamshed, 2014; Denzin & Lincoln, 1998, as cited in Hammarberg et al., 2016). As part of the research process, the researcher developed and employed an interview guide for gathering adequate data (see Appendix C for the interview guide). This interview technique was beneficial for enhancing the literature review, gathering multiple perspectives on the subject, and it provided flexibility by allowing for clarity on responses provided by participants and probing lines of thought throughout the interview (DeJonckheere & Vaughn, 2019; Jamshed, 2014). The interview guide was partly created based on the theoretical framework, deductively and inductively, and on the researcher's prior experiences. In the interview guide, there were four sections. Section A provided demographic information about the participants. Sections B to D comprised semi-structured questions emerging from the literature review and grouped into the following categories as defined in the research framework:

- The role of V2G technology adoption in the energy transition (Kempton et al., 2002; Sovacool et al., 2018; Aghajan-Eshkevari et al., 2022).
- The factors affecting EV adoption (Ragland et al., 2011; Adhikari et al., 2020; Shakeel, 2022; Kim et al., 2022).
- The role stakeholders in the V2G value chain can play in promoting V2G (Noel et al., 2019; Sovacool et al., 2020).

The interview guide was first tested with three highly knowledgeable energy professionals who were not part of the main study but represented the same population. It was crucial to conduct pilot interviews to identify shortcomings early

on and rectify them before using the tool in the main study. The research instrument did not show any limitations when tested.

3.7 Procedure for data collection

Semi-structured interviews were employed to collect empirical data for this study. Virtual interviews via "Microsoft Teams" were adopted since they were more efficient and cheaper than in-person interviews (Krouwel et al., 2019). The use of audio and video recordings was permitted to ensure data accuracy. While focus groups could have allowed for more engagement and debate among energy experts on possible energy transition technologies, they could distort the results and create bias because other experts' viewpoints may be easily imposed (Acocella, 2011; Busetto et al., 2020). Furthermore, some experts might have had difficulty discussing different issues with their peers during their interviews (Nyumba et al., 2018).

Procedurally, the energy experts were contacted individually and invited to a virtual “Microsoft Teams” meeting, considering COVID-19 safety standards and any privacy considerations they had. The meeting invitation included a participant information sheet, the interview guide, and a consent form. The letters outlined the purpose of the study, participant expectations, and ethical considerations relating to the research (Appendix D contains the participant information sheet, and Appendix E contains the consent form). Before the start of the interview, the participants had to sign the consent form and return it to the researcher. The researcher asked the participants if they had carefully read the consent form and the information sheet shared. Then proceeded to ask if they had any questions. Data collection considered the participant's demographics, background knowledge of the technologies in question, and potential relevance to South Africa's energy sector. The research took place between June 16 and September 23, 2022, and each interview lasted about an hour so that all respondents could adequately respond. The researcher ensured that there was room for flexibility

during interview sessions. Also, the participants were allowed to express themselves and share their ideas and experiences.

3.8 Data analysis and interpretation

An essential element of credible qualitative research is data analysis, and for this study, thematic analysis was used to analyse the interview data (Creswell, 2013; Silverman, 2015; Maguire & Delahunt, 2017). According to Nowell et al. (2017), thematic analysis is a highly flexible approach that can be tailored to fit the needs of many studies, providing a rich and detailed explanation of the data. Qualitative researchers have recommended that certain sections of the data be analysed and labelled using a themed statement rather than a shorter code so theming the data provides a brief description of the data (Saldaña, 2021; Kiger & Varpio, 2020). This is a way of categorizing data into a statement representing a set of recurring themes. Braun and Clarke (2019) developed a three-stage qualitative interview analysis method to code the data. This study categorised data into specific themes and ideas to identify patterns and consensus among participants. The following are the steps taken to analyse the data:

- Transcripts of interview recordings were first constructed in Microsoft Word and then transferred to Excel for initial analysis.

- The comments were then entered into codes, as shown in Appendix F.

- Analysis of comments was conducted to identify themes and emergent themes.

- The researcher became immersed in the data to identify themes. A detailed description of the study outcomes is provided in Chapter 4. The study sought to establish and describe the significance of the research findings. The results were related to broader theoretical and practical issues, and it was crucial not to draw unnecessary inferences and generalisations. The study endeavoured to provide sufficient evidence for any claims or interpretations made in a clear, credible, and convincing manner.

3.9 Limitations of the study

Like many other investigations, this study faced the following limitations:

- The number of participants was modest, with only thirteen people taking part. A larger number of participants could improve the study's trustworthiness.
- Also, measurement of the problem under investigation was not possible with qualitative research.
- Other variables not stated in this project may impact the study of V2G's involvement in South Africa's energy transition,
- Some participants were unavailable or refused to speak against their organizations in some circumstances.

3.10 Data trustworthiness

The evaluation of the quality is essential in qualitative research if the findings are to be able to stand up to scrutiny or to be useful in practice. Some scholars use the term ‘rigour’ to describe the desirable characteristics of qualitative research from a process and end-result perspective, an adherence to high standards of research conduct (Roller & Lavrakas, 2015).

The trustworthiness of qualitative research is sometimes questioned by positivists, with some critics reluctant to accept the concept (Shenton, 2004; Noble & Smith, 2015). To ensure trustworthiness in qualitative research, Lincoln and Guba combined reliability and validity with "trustworthiness," which incorporated four factors: credibility, transferability, dependability, and confirmability, as aspects that qualitative researchers should consider (Morse et al., 2002).

The researcher used methodological strategies that ensure ‘rigour’ and credibility during research design and implementation to ensure that the research results are reliable and valid (Johnson et al., 2019). Validity and reliability can be

established by conducting a participant check which may give the researcher feedback that they can use to refine their findings (Ravitch & Carl, 2016). The interview guide was pre-tested through a pilot study to ensure that they were valid and that all difficulties would be addressed. The researcher also considered how her background influenced the study results' reliability and validity. Record-keeping was done meticulously, and a clear decision trail was demonstrated (Noble & Smith, 2015). The research procedures were fully described and documented, and the data used was available to enable others to inspect and review it. Care was taken to minimise errors and biases at both the participant and the researcher levels.

3.10.1 *Transferability*

Transferability relates to the extent to which a study's findings can be used in similar situations and other people, equivalent to generalisability in quantitative research (Roller & Lavrakas, 2015). This study was qualitative, and its results were not intended to be generalized. Therefore, the study provided a detailed description of the sample and the research context to allow others to judge the extent to which the study findings could be generalised (Carminati, 2018). Sharing this information will allow any researcher who wishes to duplicate the study to do so in their context.

3.10.2 *Credibility*

Lincoln and Guba (1985), as cited in Roller and Lavrakas (2015), state that one of the most vital factors in creating trustworthiness is ensuring credibility. For this study, several strategies were employed to enhance credibility. The first step was to ensure that participants participated in the study voluntarily. All participants signed Informed Consent forms to confirm their willingness to participate in the study. Secondly, data was collected from a manageable sample of thirteen participants. Participants were interviewed with the sessions recorded to preserve first-hand information. Lastly, before the data was analysed, participants

were requested to double-check their transcripts for correctness. In addition, participants were asked to review the preliminary study findings, ask for their feedback, and incorporate their views to enhance the study's credibility, as suggested by Tappen (2011).

3.10.3 *Dependability*

According to Tobin and Begley (2004), as cited in Nowell et al. (2017), dependability is the degree to which the research process is documented, allowing people outside the research to monitor, audit, and criticize the research process. It is seen as equivalent to 'reliability' as used in quantitative research (Tappen, 2011). For this study, an audit trail and a comprehensive record of the techniques and methods were used, allowing readers to judge the extent to which appropriate research procedures had been followed (Shenton, 2004; Tappen, 2011). The study allowed for an inquiry audit, in which an external researcher assessed and analysed the research method and data analysis used to guarantee that the results were consistent and replicable (Rodgers & Cowles, 1993; Leung, 2015).

3.10.4 *Confirmability*

According to Guba (1981), as cited in Moon et al. (2016), confirmability is the qualitative investigators' counterpart of neutrality. Confirmability is concerned with demonstrating that the data and interpretations of the findings are drawn from the experiences and ideas of the informants and are not the result of the qualitative inquirer's imagination (Ravich & Carl, 2016; Shenton, 2004). For this study, the researcher actively considered how her background could influence the confirmability of the study results and found no influence or bias.

Member checking was done to guarantee that the researcher's perception of the data that emerged from the interviews was correct (Birt et al., 2016). In addition,

copies of the transcripts were issued to the participants after completing transcription to confirm authenticity.

3.11 Ethical considerations

Ethical issues are important throughout research, and they should benefit and empower participants while calling for high ethical integrity on the part of the researcher and other people involved (Saunders et al., 2007; Creswell, 2013).

- To ensure high ethical standards for this study, the researcher obtained ethical clearance from the Post-Graduate Committee (PGC) before any data could be gathered (see Appendix F for the Ethical clearance certificate). Since the researcher did not collect data from a single company, permission letters were not required.
- Guided by the National Protection of Personal Information Act (POPI Act), the researcher requested the participant's consent to collect and retain the data and clarified what data was being collected, how it would be stored, and what it would be used for.
- The participants were informed about the study's objectives and assured that their responses were to be kept confidential and used solely for academic purposes for this specific study. To safeguard the interviewee's identities and to protect them, pseudonyms were used. For example, EX1 is an alias for Energy Expert 1. As a result of this principle, participants felt comfortable providing information since they knew it would be kept confidential (Ummel & Achille, 2016).
- Participants were asked to sign a formal consent form to acknowledge their participation in the research before any data was gathered.
- Participants were notified in writing that participation in the study was voluntary and that they could withdraw at any time. In addition, they were told that they could choose to refuse to answer any questions or to be recorded at any time during the interview process.

- Written transcriptions and interpretations of the data were made available to the participants. All data (transcripts & recordings) were stored and will be destroyed according to the University's research data management protocols.
- Finally, the researcher created and maintained a comfortable environment for participants by not asking sensitive questions during the interviews. During the discussion, participants were allowed to express themselves in their own words and way.

3.12 Consistency table

The consistency table below illustrates how the collected and analysed data align with the research questions.

Table 5: Consistency table: Research questions, propositions, data collection and data analysis.

RQ #	State Research Question or Objective	Prop	State Proposition	Data Collection Detail	Data Analysis Method
1.	How can V2G adoption play a role in South Africa's transition?	1.	V2G technology adoption positively influences South Africa's transition to zero-carbon energy.	Semi-structured Interview	Thematic Analysis
2.	Based on theory, what factors affect EV adoption in South Africa?	2.	The MLP and diffusion of innovation theory are theoretical lenses that explain the adoption of V2G technology.	Semi-structured interview	Thematic Analysis
		3.	EV & V2G technology adoption leads to a reduction in CO2 emissions.	Semi-structured Interview	Thematic Analysis

RQ #	State Research Question or Objective	Prop	State Proposition	Data Collection Detail	Data Analysis Method
		4.	A poor energy policy, lack of awareness, and undesirable economic and regulatory environment negatively affect the adoption of EVs and, thus, V2G technology in South Africa.	Semi-structured Interview	Thematic Analysis
3.	What role can different stakeholders in the V2G value chain play in promoting V2G in the country?	5.	EV adoption accelerates the adoption of V2G.	Semi-structured Interview	Thematic Analysis
		6.	Energy industry actors in South Africa are unsure about their role in promoting V2G, thereby affecting the adoption of EVs.	Semi-structured Interview	Thematic Analysis

3.13 Conclusion of Research Methodology Section

This chapter covered the research methods and methodology used during the investigation. In addition, it provided explanations and justifications for the study design, data collection, and sampling methods to be followed. Well-defined, static measures were applied throughout the research, and the operationalization table was outlined and discussed. Finally, the chapter provided in-depth information on the limitations of the selected research method, ethical considerations, data analysis, and research quality standards.

CHAPTER 4. FINDINGS & DISCUSSION

4.1 Introduction

Based on the research framework and methodology introduced in Chapter 3, this chapter presents the conclusions drawn from the interview data collected. Next, the three research questions are analysed based on the results of the interviews and the literature on the role of V2G technology adoption in the energy transition (research question 1), factors affecting the adoption of electric vehicles (research question 2), and how stakeholders in the V2G value chain can contribute to its promotion (research question 3).

4.2 Findings on Proposition 1: V2G technology adoption positively influences South Africa's transition to zero-carbon energy

4.2.1 *Alternative power supply*

Most participants indicated that introducing V2G technology would provide alternative green energy sources. They felt that V2G's increased use would be a timely intervention to the electricity shortages that the country faces as the national utility (Eskom) is failing to meet demand. The participants admitted that V2G technology is expensive, but it facilitates a transition from traditional to greener energy sources in the long run. The participants commented thus:

> *Yes, there will come the point where the role starts as small until it gets big. It will happen in the near future. We have challenges with the metering systems in terms of billing. We also have infrastructure problems. It looks like a drop in the ocean, but it will assist a lot in public sector vehicles and hospitals. When these vehicles are idling at night, they can assist in lighting and security.* **(EX1/Senior Electrical Technologist)**

> *Connecting to the grid and charging your home. Reduce the load on the national grid. There will be less load shedding. Environmentally, it's green. The Eskom load will be reduced, leading to less load shedding.* (**EX3/Chief Executive Officer)**

Participant 4 shared similar sentiments and indicated that South Africa is currently facing electricity shortages, as evidenced by the frequent load shedding. Therefore, V2G provides an avenue for new and green energy alternatives.

> *In my view, I think it is good, especially in South Africa, looking at the situation we are sitting in right now, with not having enough electricity generation capacity. This will definitely help in terms of making sure that we have enough supply of electricity for the country.* (**EX4/Senior Electrical Engineer)**

Participant 4 added that V2G technology supported existing green energy solutions, such as solar, to help South Africa move from traditional energy sources.

> *It is like your solar solutions. It gives a variety of options. Let us say, in my house, I use this V2G. This means I will be reducing the bill for Eskom electricity.* **(EX4/Senior Electrical Engineer)**

Participant 8 indicated that while V2G technology was essential in aiding South Africa's energy transition, currently, there were no mechanisms to ensure that it does not overload an already struggling Eskom. The argument put forward by Participant 8 is that currently, no infrastructure caters for EV power supply, meaning they will strain existing energy sources which are mainly dependent on Eskom. The participant commented thus:

> *EVs will put a strain on the grid. Let us say there are a lot of EVs out there, and there is very little infrastructure. It is obvious we will depend more on the grid, which in turn will put a strain on the grid.* **(EX8/Project Engineer)**

However, with the increased adoption of V2G technology, there could be a long-term benefit as the V2G will feed into the grid. Participant 8 added:

> *It can also relieve the stress on the utility grid because then you need to consider other energy sources like renewable energy sources; mostly, that is how you see the EVs and V2Gs technology playing a role in the energy sector because you need different energy sources to charge your vehicles so that is how it can be viable to use the V2G technology as well. (***EX8/Project Engineer)**

Participant 10 indicated that V2G provided an alternative energy source to fill the gap left by Eskom's load shedding. In addition, Eskom's failure to provide electricity aided the transition to V2G.

> *EVs are convenient for personal use. A mind-set change is needed. You charge whenever you want. There can be many batteries to support the grid at the community level. The fact that you are using your vehicle for household (working from home) power when there is no power could be a new door opening to the country. However, with the current load shedding, it might not work.* **(EX10/Division Leader)**

> *I see EVs helping in terms of grid stabilization and transport if it's properly rolled out. It could stabilize the grid more than we think. If done correctly, it helps reduce waste, such as capturing solar at a commercial building that could go unused.* **(EX11/Chief Engineer)**

> *It will drive the shift in the energy mix towards renewables as more people become cognisant of the fact that a BEV or PHEV is only as green as the energy source.* **(EX12/ Production Engineering manager)**

Based on the views expressed by the participants regarding the role of V2G in South Africa's energy transition, the overwhelming view was that South Africa's Eskom is currently struggling to fulfil its energy commitments; thus, this is the perfect opportunity for V2G technology to fill the gap and eventually dominate the

energy market. Wang & Craig (2021) and Baumgartner et al. (2022) support the assertion made in this study that bidirectional charging (V2G) is widely used because it enables the storage of extra energy. This has a significant chance of easing the pressure on traditional energy sources by moving more demand to times when electricity generation is strong and lowering net demand in the evening (Di Natale et al.,2021). Alotaibi and Eltamaly (2022) found that the negative impacts of burning fossil fuels are largely avoided when charging electric vehicles (EVs) with renewable energy systems. In addition, the more EVs on the road, the greater the number of alternative energy sources available to replace traditional energy sources. The study's findings also concur with Dioha et al. (2022), who established that EVs could help nations utilise their variable renewable resources more effectively. However, the cost of EVs will probably need to drop compared to rival technologies in order for them to play this function effectively.

4.2.2 *Increasing power supply*

The incessant load shedding that South Africa faces as a result of Eskom's failure to provide adequate electricity has opened a window of opportunity for V2G as an alternative energy supply. Most participants indicated that V2G could be appropriated to enhance the energy supply already in short supply from Eskom. Commenting on the role of V2G in increasing energy supply, the participants expressed the following sentiments:

> *We need an energy mix that is reliable at all times – seasons – day and night. The V2G will help the transition.* **(EX1/ Senior Electrical Technologist)**

> *You know, because we have a shortage in terms of power, if we have so many devices injecting back into the grid, it means we will increase the supply, so it will definitely help to cover the demand that we have.* (**EX4/ Senior Electrical Engineer)**

I see EVs helping in terms of grid stabilization and transport if it is properly rolled out. It could stabilize the grid more than we think. **(EX5/ Head of Operations and Maintenance)**

We have actually done two studies on the electric vehicle cycle. Moreover, many seem to think we will have 50 000 EVs by 2025. I think that number is way underestimated. I think that EVs are going to pick up tremendously. One of the things that are causing people not to adopt this is the security of the supply problems we currently have. Now an EV can solve that problem almost immediately. **(EX11/Chief Engineer)**

We have a 275 000 Volt input from the national utility, and the transformer capacity is there at 750 Megawatts firm as they always put it. Meaning, take that 275 KV and convert it to 88KV. And we retransmit it if you like to other substations, and those are the 88KV to 11KV substations. You know what? The capacity at that level is double the capacity at the 275KV level. And then when you come down with the distribution network to 11KV to 400 Volt. In other words, in the final transformer, the capacity doubles again. **(EX11/Chief Engineer)**

At the moment, we have load-shedding. The strain, if reduced there, will be very little load-shedding. **(EX7/Chief Operating Officer)**

V2Gs also stabilise the grid, so if there are so many cars connected that are using the V2G technology, it stabilises the utility grid. This will help to mitigate the current electricity challenge in South Africa because there will be less strain on the grid. **(*EX8/*Project Engineer)**

It can benefit in terms of energy access. Currently, we are at 80 percent in terms of access. **(EX9/Director)**

V2G doesn't generate any additional energy but just allows for dynamic storage and usage on demand. V2G would support reducing Peaks and Valleys, but we need to drastically increase generation as the energy the

vehicles give to the grid has to be generated somewhere. **(EX3/Chief Executive Officer)**

The data revealed that V2G is seen as a panacea to South Africa's energy shortages which is currently heavily dependent on Eskom. To that end, it is seen as an alternative energy source that can assist households with electricity and limit reliance on Eskom. The findings of this study show that when V2G is integrated into the grid, there is an increase in energy supply. The findings of this study concur with Di Natale et al. (2021), who argued that if EVs were operated under controlled conditions, they could provide large amounts of energy to the national grid. In addition, EVs can offer enormously large storage for the electricity supplied by intermittent RES, and these two technologies can complement one another (Peters et al., 2020; Taliotis et al., 2020; Zhang et al., 2020).

4.3 Findings on Proposition 2: The MLP and diffusion of innovation theory are theoretical lenses that explain the adoption of EVs

4.3.1 *Economic benefits*

Several factors influence the adoption of EVs. The participants indicated both the positive and the negative factors related to EV adoption. One major driver of EV adoption is the economic benefits associated with the technology. The majority of participants indicated that the economic benefits of EVs were attractive. They felt that if EVs are effectively adopted, the national economy could benefit from the EV market across the entire value chain. The participants echoed the following sentiments:

Firstly, if we invest in V2G, it means our economy will grow in terms of that. In addition, V2G will assist us in terms of our power crisis when we inject back into the grid (**EX4/Senior Electrical Engineer)**

Here`s the strange part, in the areas where development is going forward very rapidly, we have electricity problems. We do not have enough electricity for the grid, but businesses have left in places like Benrose, which used to be an industrial place. There is a lot of grid infrastructure we could use for charging vehicles such as trucks. **(EX6/Senior Engineer)**

Transport even in poor communities. Electric public transport will benefit them by reducing the cost of taxi transport. We have innovative plans to utilize renewable energy. It is significantly cheaper to charge it. **(EX11/Chief Engineer)**

It will definitely benefit ordinary citizens. The petrol price is currently terrible. Obviously, if the EVs come in, the demand for petrol is lowered, and the price will go down. There will be more investment in the energy sector. We need more private-sector participation. If it happens in the next 5-10 years, I think 25 percent will be EVs on the road. **(EX13/ Principal Researcher)**

From the above transcripts, it can be established that EV adoption helps to create a huge market which can contribute to the national economy. In addition, the EV adoption will increase the adoption of V2G, thus supporting industries whose growth has been slowed down because of the current electricity shortages affecting Eskom. The findings are consistent with those of other research (Abito & Salant, 2019; Wellings et al., 2021; Ziegler & Trancik, 2021), which revealed that EVs are perceived as minimising EV owner expenditures, particularly comfort-related costs, from the customer's perspective. Additionally, traditional energy sources, which generate pollutants including SO2, NOx, CO2, Co, and TSP, are reduced due to the adoption of EVs (Archsmith et al., 2018). This lowers the environmental cost.

4.3.2 *Usefulness of Evs*

As indicated by the TAM model, one factor that motivates one to adopt technology is perceived usefulness. In line with this construct, most participants indicated that they would adopt EVs because it would resolve the current electricity shortages they are facing. In addition, they felt that the technology would diffuse to the public transportation system, reducing fares. The participants echoed the following perspectives:

> *Evs can provide cheaper and more efficient transport even in poor communities. In addition, electric public transport will benefit commuters by reducing transport fares.* **(EX5/Head of Operations and Maintenance)**
>
> *What is valued highly is the ability to plug the vehicle into the house. The vehicle can supply energy to the house when there is an outage. Suppose the option is available to the consumer to buy a vehicle that works as a UPS (Uninterrupted Power Supply) system for his/her house. In that case, many people will be willing to adopt that.* **(EX6/Senior Engineer)**
>
> *You can use your EV to charge appliances at home – it is a selling point. People see how it can actually help. You can use that battery as an energy source in the house. The benefits are attractive.* **(EX7/Chief Operating Officer)**
>
> *If done properly, it will stabilize the grid. Allowing vehicles to charge and recharge dynamically.* **(EX11/Chief Engineer)**

The study establishes that participants looked at how they would personally benefit from EV adoption. They found that EVs have direct benefits to themselves, so they found the technology useful. In addition, EVs would help to solve the country's energy crisis. The maintenance and fuel savings of the EV are participant advantages and are received by the vehicle owner, according to the findings, which are consistent with findings from other researchers on the subject (Hatt et al., 2020; Sriram et al., 2020). Additionally, the benefits to

society's environment, health, national security, and economic development are spread out across society and are not now immediately realised by any one group (Talantsev, 2017). The study's findings agree with research on the acceptability of EV technology (Muller, 2019; Gunawan et al., 2022), which discovered that the usability of EV technology is a predictor of Perceived Usefulness. Consequently, EV's usability can help lower so-called "access hurdles" to technology use (Gunawan et al., 2022).

4.3.3 *Ideal charging infrastructure for EVs*

Most participants expressed that, currently, there is no infrastructure to accommodate EVs. They pointed out that the current grid utilized by Eskom is fraught with problems. The participant indicated that EV adoption into the grid faced synchronisation problems. Other participants said thus:

> *The technology is well-researched, but we, South Africans and infrastructure are not ready to receive it. The metering is not ready – the municipality will not know how much power they have given you. The* users can claim they are the ones providing it. **(EX2/Engineering Manager)**

The question is, do we have the charging infrastructure to bring them in? If SA is serious, the gap will be closed. In terms of electricity capacity, that is where we are lacking in terms of charging. **(EX5/Head of Operations and Maintenance)**

> *Yes, so it is both the charging stations and also to charge these vehicles; you need a renewable energy source so that we do not rely mostly on the ESKOM grid because now, if there is an influx of these EVs, then we are already going to strain the grid. Even now, the grid cannot accommodate South Africa at the moment, so if we add more EVs today in the mix, then obviously, we will strain the grid.* **(EX7/Chief Operating Officer)**

> *Before everything, we need to see infrastructure management. We need infrastructure such as electric vehicle chargers. Currently, there is no*

adequate infrastructure from Johannesburg to Cape Town. ***(*EX10/ Division Leader)**

The question is, do we have the infrastructure to bring them in? If SA is serious, the gap will be closed. We are lacking in terms of the provision of charging infrastructure. **(EX13/ Principal Researcher)**

From the responses above, it is apparent that one of the main obstacles to adopting electric vehicles in South Africa is the lack of ideal charging infrastructure across the country. Similarly, (Habla et al., 2020) found that consumers often request public charging stations at more locations to cater to long-distance driving needs. Moreover, Mastoi et al. (2022) assert that establishing a charging infrastructure will ease consumers' concerns about electric vehicles, allowing them to compete against internal combustion engines. Despite private companies setting up charging stations, including some charging structures, in various public areas such as malls and office parks in the country. Moeletsi (2021) reports that governments of countries with developing electric vehicle industries have started building charging infrastructure. So, charging infrastructure spending should not solely be the private sector's responsibility. However, setting up a charging network is very expensive (Brückmann et al., 2021). As a result, the expansion of the charging station infrastructure in South Africa has now become questionable.

4.3.4 *Electricity generation capacity*

A major concern that participants raised on using EVs was electricity generation capacity challenges. They indicated that Eskom’s grid is unable to accommodate EVs; thus, there was a need for new technology to be introduced. In addition, the participants felt that EVs required electricity, yet currently, Eskom has no generation capacity to fulfil national energy requirements. The participants commented as follows:

There is some serious investment in the grid. You need to protect the grid. That is the most important thing. Unfortunately, we do not have enough generation capacity. (**EX2, Engineering Manager)**

I don't think V2G will help overcome this, but it will alleviate the energy strain. It could support the base load. **(EX3/ Chief Executive Officer)**

If we look at infrastructure right now, EVs will strain the grid. It can also relieve the stress on the utility grid because we will be looking at many other sources of renewable sources. **(EX7/ Chief Operating Officer)**

*We don't have electricity capacity, but now you have a vehicle that charges. There is less demand on the grid. (***EX10/ Division Leader)**

It will accelerate the inevitable energy crisis as customers begin to draw 100-120A from the grid as they charge their vehicles. **(EX11/ Chief Engineer)**

We need to review the current generation capacity to establish whether the grid can absorb or maintain what the EVs will require. Currently, the market, in terms of investors, only sees energy in households and industry consumption. **(EX13/ Principal Researcher)**

As the participants indicated, Eskom cannot provide enough electricity for everyone, and adding EVs to the grid would worsen the situation. The study revealed that Eskom has no generation capacity to accommodate a large-scale electricity supply for EVs due to its current electricity shortages. As a result, EVs, which depend on the availability of electricity, will be grounded while simultaneously putting a strain on Eskom's limited power supply. The lack of electricity generation capacity to accommodate EVs into national grids is widely documented in literature from other countries (Lopez-Behar et al., 2019; Brown et al., 2021), which found that the current EV sector has numerous technical challenges, a lack of convenient charging options, a constrained driving range, and lengthy battery recharging times. Additionally, the connectivity of EVs to the

power grid for charging has harmed how the power grid functions (Kumar & Alok, 2020). Existing literature supports the findings of our study regarding the electricity generation capacity issues preventing EV adoption (Rajper & Albrecht, 2020; Rajper & Albrecht, 2020).

4.4 Findings on Proposition 3: EV and V2G technology adoption can lead to a reduction in CO2 emissions

4.4.1 *Reduction of carbon emissions*

The adoption of V2G technology can be seen as not just technological innovation but compliance with the global call for the adoption of sustainable energy. Most participants shared this opinion, indicating that V2G technology could reduce pollution if combined with renewable energy sources. The participants supported the adoption of V2G as it was environmentally friendly. Commenting on V2G as green energy, the participants said:

> *Ideally, it should help reduce carbon emissions and other environmental effects.* **(EX1/Senior Electrical Technologist)**
>
> *They will definitely open other avenues and create more interest. Clean technology will change the energy profile. It plays a big role.* (**EX2/ Engineering Manager)**
>
> *I had the opportunity to drive a Tesla. You won't have emissions, and it does not need any petrol attendants. If we have fewer vehicles polluting, then we can reduce pollution.* (**EX7/ Chief Operating Officer)**
>
> *As a clean solution, this would definitely work because the more we get feedback, the less we depend on coal power. So, it will definitely have an impact there. It doesn`t use fuel emissions, so that also helps on its own with the decarbonisation strategy.* (**EX4/ Senior Electrical Engineer)**

Environmental benefits are there as EVs do not have internal combustion engines. There is a cleaner, more sustainable future for transport. Remember, our overall goal is to go renewable, and if we over-invest in renewables, that surplus can be sucked up by EVs, which would make the business so much better. **(EX6/ Senior Engineer)**

The Department of Transport mentioned that in their Green Transport Strategy, but they are contributing more greenhouse gas emissions. If you think about it, if all citizen's cars are electrified, we can support their strategy. **(EX7/Chief Operating Officer)**

If you think about the transport sector, where everything is electrified, we will cut greenhouse gas emissions, which then helps in the decarbonisation strategy. **(EX*8/* Project Engineer)**

*V2G reduces potential stress on the environment. In terms of costs, it makes perfect sense because fuel prices frequently go up more than electricity. (***EX10/ Division Leader)**

The above transcripts reveal an increased awareness of the role of green energy solutions. The participants expressed awareness that V2G was not only cost-effective in the long run but also helped in the decarbonisation strategy as it has low pollution levels. The results are consistent with Hu and Li's (2020) research, which found that EVs bring two distinct emission reduction measures for electric vehicles: the emission reduction achieved by electric vehicles in place of fuel locomotives and the overall reduction of V2G (Vehicle-to-Grid) peak-shaving. Other studies have discovered that EVs can contribute to reducing emissions associated with transportation by using electricity as a source of energy and that the provision of V2G services can lead to even more significant emissions reductions (Forrest et al., 2016; Liu et al., 2020; Peters et al., 2020; Laffont et al., 2022).

Compared to traditional automobiles that run on fossil fuels, using electric vehicles produces less pollution, and electric vehicles can be 3-5 times more

efficient than conventional automobiles at using energy (Olsson, 2019). The only power source for full-electric vehicles (FEV) is a battery charged by the power grid. They are thought to be up to 85% energy efficient. They present a possibility for zero-emission automobiles because they do not produce their local pollutants through fuel combustion (Cornell, 2017). The study's findings showed that using EVs can reduce the amount of CO2 and other greenhouse gases in the air and other air pollutants. The implications of the low carbon emissions from EVs include increased efforts to promote sustainable and effective mobility through various efforts, particularly through tax incentives, buying aid, or other unique measures, like free public parking or free use of highways, in order to encourage the adoption of EVs (Tongwanea & Moeletsi, 2021).

4.5 Findings on Proposition 4: A poor energy policy, lack of awareness, and undesirable economic and regulatory environment are negatively affecting the adoption of Evs and, thus, V2G technology in South Africa

4.5.1 *Policies relating to EVs*

Most participants criticized the government for failing to develop robust policies promoting EV adoption. The participants attributed the current electricity challenges faced by Eskom as a pointer to a lack of a policy framework that accommodates EVs in the grid. The participants echoed the following sentiments:

> *The government doesn't allow us to feed into the grid. The power is also limited to certain megawatts. Ideally, on paper, they are supporting, but there is a problem with the implementation.* **(EX1/ Senior Electrical Technologist)**

> *The grid is one of the reasons we have load shedding. Once we have small players, it means a city can be provided by a single service provider. We need to do away with monopoly.* (**EX2/ Engineering Manager)**

National electricity rules obstruct grid services. It is not that easy to be synchronized into the grid harmoniously. The infrastructure is not ready. **(EX3/ Chief Executive Officer)**

The government is not having a clear plan of what to do. The government is also very slow in some respect because we still have a very high import tax on EVs. We have strange legislation that does not apply to real situations. The government should immediately review the whole import duty and get it in line with the real EV industry for proper import tax to protect the local industry. **(EX6/ Senior Engineer)**

The private sector is hesitant in terms of investing or promoting the technology as they lack confidence in the government. You need assurance in terms of regulation and guaranteed returns. Because of load shedding, investors are sceptical. The security of supply is questionable. The country loses 700 million a day due to load shedding. **(EX9/ Director)**

Government is the stumbling block. All the vehicles are imports, yet there is no government intervention in terms of price point. There is still range anxiety. In addition, the government does not offer incentives for EVs. **(EX 10/ Division Leader)**

Based on the views expressed by the participants, it can be concluded that the government's lack of clarity on EV policy negates efforts to adopt the technology on a wide scale. Key policy gaps highlighted include the lack of policy guiding the inclusion of EV charging to the national grid, the metering system, EV technology taxes, and incentives. The lack of a clear EV policy framework delays the EV technology adoption rate. Ghosh (2020) and Kongklaew et al. (2021) highlight the importance of the government in formulating policy. Regulation, subsidies, and tax incentives are examples of current policy instruments that guide economic activity toward environmental sustainability (Alotaibi & Eltamaly, 2022). Industrial policy's primary goal is to integrate environmental preservation with competitiveness, which aids the government in gaining the cooperation of private

sector partners (Habich-Sobiegalla, 2018; Candra, 2022). Consequently, the government's role in adopting EVs goes beyond just directing markets to introduce additional and fundamentally new regulatory instruments (Krishna, 2021).

4.5.2 *Affordability*

Most of the participants felt that EV technology was the technology of the future which should be adopted. However, they indicated that the exorbitant cost of EVs relegated the majority, making it only accessible to the rich elites. The participants expressed the following sentiments:

> *The EVs operate at a charge at a specific km – which can limit people who want to travel long distances- it can be hard for poor communities. I'm struggling to find the benefits. It lacks the basic points of interest. I haven't heard that an EV is faster because It's an EV.* **(EX1/ Senior Electrical Technologist)**

> *The petrol price is currently terrible. If the EVs come in, the demand for petrol is lowered, and the price will go down. There will be more investment in the energy sector. We need more private-sector participation. If it happens in the next 5-10 years, I think 25 percent will be EVs on the road.* (**EX2/ Engineering Manager)**

> *It is not cost-effective because, currently, it is not based on supply versus demand. Currently, it is based on what Eskom is asking as the price.* (**EX2/ Engineering Manager)**

> *The cars are quite expensive. To synchronize, you will be looking only at the household, not the nation as a whole. I can't say it will help the problem but maybe at the residential level. The grid is a mess. It is good to try to alleviate, but it will not completely solve the problem. We have to fork out*

more money for infrastructure. It looks exciting, but it's not. (**EX3/ Chief Executive Officer)**

The price may be the other issue, and I do not think the benefit is emphasized to the public. So, we need to engage more on these topics of EVs. We need to hear about it on radios, TVs, and stuff like that, so it is normal. (**EX4/ Senior Electrical Engineer)**

It is generally a high-end market. It is going to take time for the industry to produce EV components. **(EX5/ Head of Operations and Maintenance)**

However, the problem is the price. I think the electric vehicle price needs to decrease significantly before we can assume much movement there. You can look at the current market at the moment; they are all R750 000+, okay? I think the minute you have an attractive EV come in, in the price range of R250 000 to R400 000, I think it will take off. **(EX6/ Senior Engineer)**

The biggest challenge is the market. To whom are they going to sell these EVs? They are expensive because even the cheapest EV currently goes for between 500 000 and 600 000 there. **(EX8/Project Engineer)**

At the moment everything is just expensive. Things can be cheaper, though. It can benefit every South African. You can demarcate the time frames you're using and charging, peak and off-peak. V2G can also stabilise the utility grid. **(EX7/Chief Operating Officer)**

*It will benefit the ordinary South African, especially at the moment; you know everything is so expensive I am sure with time, when we have enough V2Gs and EVs, all these things will be cheaper for every ordinary South African. (***EX10/Division Leader)**

They have fewer moving parts and are cheaper to run for the customer. **(EX12/ Production Engineering Manager)**

The dominant sentiment that emerged from the participants was that the cost of EVs was still beyond the reach of many people in South Africa. In addition, with the cost of electricity going up, the cost of using EVs also goes up, making it unsustainable. This study's results align with those of other studies (Li et al., 2019; Krishna, 2021), which discovered that the high cost of an EV purchase is frequently identified as a significant barrier in consumer survey surveys. The pricey technology required to produce electric vehicles drives up the cost of the car (Noel et al., 2020). The complexity of the battery material (Lithium-ion batteries) employed rises as continued attempts, and new technologies are made to extend the range of EVs (Rangarajan et al., 2022). As a result, battery prices increase (Noel et al., 2020).

4.6 Findings on Proposition 4: Different stakeholders in the V2G value chain can play a role in promoting V2G in the country

Stakeholders identified as major players in the V2G value chain are government and the national utility, electricity distributors, EV owners, V2G technology manufacturers and EV automakers. This study divided them into two groups, the government, and the private sector.

4.6.1 *The role of government*

With the government being the biggest stakeholder, most participants indicated it was not doing enough to promote the adoption of V2G. Therefore, the participants indicated several actions that government can do to promote V2G technology growth. Participants commented as follows:

> *The government owns a good number of vehicles, so they are capacitated to do campaigns and support other manufacturers. They can flood the market with the EVs, and when they de-fleet, they can sell to other citizens – the ordinary citizen can be influenced. They have got the power and resources.* (**EX1/Senior Electrical Technologist)**

The government should introduce incentives for EVs as they are expensive and look luxurious. (**EX2/Engineering Manager)**

Participant 4 indicated that the government was solely responsible for spearheading EV adoption through policies. For instance, develop interventions that make EV charging easy for users.

They need to keep the conversation going. They need support in terms of charging; every petrol station should have at least one charging system so that if you buy the car, you will have support. You won`t be stranded while out of power. So, we have got quite a number of these vehicles that were bought by the company. We even have charging stations here at work, so they are promoting the adoption of this thing. (**EX4/Senior Electrical Engineer)**

So obviously, the government needs to be involved in policymaking. They need to make policies that encourage the uptake of EVs, especially, you know, import tariffs. They need to reduce all those tariffs to attract EV owners or buyers to import EVs or even manufacturers so that they can make a good business. **(EX*8/* Project Engineer)**

Government can create incentive programs for local manufacturers. We rely on imports with regard to components of EVs. Special economic zones could go a long way. They should open a new value chain that allows companies to participate. **(EX11/Chief Engineer)**

Most participants indicated that introducing incentives would significantly reduce the cost of EVs, allowing more people to buy them. In the end, the V2G will become a reality. The participants commented thus:

Even also incentives, you know, for the production of EVs. So, if these big companies, if, they say if we, start manufacturing the EVs in South Africa, how many people are going to buy, how much is it going to cost us to manufacture these EVs? **(EX*8*/Project Engineer)**

They can create incentive programs for local manufacturers. We rely on imports with regard to components of EVs. Special economic zones could go a long way. Regarding tax, there is a need to open a new value chain that allows companies to participate. **(EX5/Head of Operations & Maintenance)**

Government incentives will go a long way. Some states give subsidies if you want to buy an electric vehicle. The more people buy these vehicles, the more awareness. There needs to be action taken by the government on taxes and tariffs. **(EX7/Chief Operating Officer)**

It is too early, but we are supporting the introduction of key value chain items and monitoring signals and start-up businesses activity to make a move at the right time. **(EX12/Production Engineering manager)**

The study established that the government is the biggest stakeholder in adopting EVs and V2G technology. It is responsible for ensuring favourable policies that make EVs affordable to many. This can be done by incentivising EV activities. The study findings are similar to recent studies on the role of government in EV adoption. These studies found that EV stakeholders involved must endeavour to make EVs more affordable by lowering the price through government incentives to increase the intention to adopt them (Pavlenko et al., 2019; Joshi et al., 2022). Additionally, these incentives would reassure the manufacturers investing heavily in developing EVs (Ghosh, 2020; Kongklaew et al., 2021).

4.7 Findings on Proposition 5: EV adoption accelerates the adoption of V2G

4.7.1 *Rate of adoption of EVs*

The rate of adoption of EVs is dependent on several factors. Some of the main factors that participants raised related to Eskom's capacity, government policy on EVs and the cost of EVs. Firstly, the participants indicated that currently, EV

technology is expensive and cannot be afforded by many. Participant 1 expressed the following sentiments:

> *On the rate of adoption, firstly, I will say that EVs are expensive, and SA is an unequal society. A high majority cannot afford it. It is slow because it is seen as a luxury. If it were a cheaper model, the pace would increase. The overall packaging must be attractive for all South Africans.* **(EX1/Senior Electrical Technologist)**

> *Whether it's Tesla or Hyundai? They are taking too long. It took the government more than 15 years to create the grid. Government has a lot of interest in Eskom; therefore, it will take longer to push this type of technology. People are not flexible enough to the changes happening every day. And also, the amount of charge one person should get per day. It is another barrier.* (**EX2/Engineering Manager)**

> *The affordability is my concern. I think that is my number one concern. It is those with high-level skills that will be able to stay. I saw a couple but not a lot because of affordability. We would like it, but it is not possible.* **(EX3/Chief Executive Officer)**

> *Yeah, slow, it's slow. I do not think we are anywhere with this technology in South Africa because we don't even hear about this thing anywhere. Okay, I will still say it's low even if you go to dealerships; you will find two or three electric vehicles, and then the rest it's the normal cars. So, maybe out of 100% of the cars within the dealership, only about 10% are EVs. In some dealerships, there is not even a single one, so I will say it's slow.* (**EX4/Senior Electrical Engineer)**

> *Yes. I think so. There is another aspect that came across quite strongly in the studies. You know this whole issue of ESKOM is unreliable because if it was reasonably reliable, I do not think you'd have a problem charging an EV. Even with the load shedding that we have got, that is a perception in people's minds.* **(EX6/Senior Engineer)**

The demand exceeds supply without a supportive structure to offset the price premium to consumers. **(EX12/Production Engineering Manager)**

They are taking too long. It took the government more than 15 years to create the grid. Government has much interest in Eskom; therefore, it will take longer to push this type of technology. **(EX13/ Principal Researcher)**

Some participants felt that the slow adoption of EVs was influenced by the national and local governments, which were resistant to the new technology. The participants reported that city officials were reluctant to facilitate the use of EVs. In addition, EV automakers were sceptical of this new technology; hence they were not introducing as many EVs into the market. Commenting on resistance to change, Participant 6 indicated:

Maybe the other barrier is the slowness of municipal distributors to adopt new technology. That can be a problem. Even at work, I struggle with my colleagues at times. We have all these new technologies available, but we are not using them. **(EX11/ Chief Engineer)**

So, slow uptake by the distributors could be a barrier, maybe a shortage of funds. We have come through a 30-year history where every time there is a change in government, business or industry, everybody stops the investment they should be making. **(EX11/ Chief Engineer)**

The uptake of these EVs is quite slow, so we need a lot of these EVs so that the V2G technology can be used. Currently, they are very expensive, and they do not make sense for an ordinary South African. It`s only for the rich that can afford to buy EVs. That is why it is very slow and also the infrastructure is as well. **(EX8/ Project Engineer)**

It is a question of time. Right now, no. in the future, it will definitely play a role. We do not have enough EVs. There is also a price barrier and access barrier. It is generally a high-end market. It is going to take time for the industry to produce EV components. If manufactured locally, maybe they

can help. I do not have enough information on government policies. **(EX11/ Chief Engineer)**

Participants also felt that EV adoption rate was slow because of the skills gap and lack of awareness about the technology. They indicated that more awareness campaigns are needed to make more people aware of EV, V2G technology and the benefits of these technologies. The participants commented as follows:

Most South Africans know, but a lot are not aware. Maybe only middle-income earners are aware. There is always an economic side. We are the jobs. We are the skills. I cannot ignore the local context. We import and assemble, which lessens job security. It is scary; one has to think about it, and our economy will not hold it. **(EX3/ Chief Executive Officer)**

You know, if we were somewhere with it, we would be; if you ask any ordinary citizen about this thing, they probably don`t even know what you are talking about. So, we haven`t done much in this space in South Africa. **(EX4/ Senior Electrical Engineer)**

From the above transcripts, the study established that the high cost of EVs, resistance to new technology and lack of awareness were the biggest causes of the slow take-off of the EV technology. Humans make judgments based on logical assessments of stimuli and the likely repercussions of those decisions, claims the Theory of Planned Behaviour (Ajzen, 1991). Customer expertise and experience impact attitude (Li et al., 2021; Sriram et al., 2022). Gender, age, income, degree of education, preferences, and environmental consciousness are additional characteristics that affect EV adoption. In addition, Peters et al. (2020) state that a buyer of an EV with a strong commitment to environmental preservation does so for two reasons.

4.8 Findings on Proposition 6: Energy industry actors have strategies in place to adopt and promote EVs and V2G as part of their contribution towards zero-carbon energy

4.8.1 *Awareness campaigns by the government*

Most participants indicated that the government should lead in popularising EVs and V2G technologies. Few people are aware of the technology; hence it will take a long time for EVs to be adopted. Regarding awareness of EVs and V2G, the participants commented:

> *The awareness is below par. Campaigns about electric vehicles are non-existent, so we need TV shows about these technologies. The government and industries need to do more. People ask themselves questions about these technologies, and there is no one to tell them. There is a need for explanations about these small parts, the range of the cars, and battery degradation. What if I was supplying the grid and there was no power in the morning? How does the battery perform? Is it not these things that people want to know? The campaigns should increase to enhance people's knowledge.* **(EX1/ Senior Electrical Technologist)**

> *One thing we need to do in promoting these technologies. Looking into the South African market, we need to guarantee that these technologies can last you ten years, but unfortunately, it is not happening. Campaigns are not fully promoting this.* **(EX2/ Engineering Manager)**

> *There should be work on better awareness. They are not promoting. It is not in the solution now. I do not think anybody is taking it seriously. There is nothing that has been addressed. It is overlooked. They need to be studies showing the benefits. Not everybody is aware.* **(EX3/ Chief Executive Officer)**

So, on government-run awareness, I haven't seen any government-run awareness campaign that talks about EVs. I do not know if they are there, but I haven`t seen them talk about them much. We need things like webinars. I am saying webinars because they are educational, so at least we can educate people while they are there in the webinar. You advertise while you also educate at the same time. **(EX4/Senior Electrical Engineer)**

We just need awareness- people talking about electric vehicles and actually using them. There is some improvement in awareness. It comes down to product availability. **(EX5/ Head of Operations and Maintenance)**

The government is putting in the effort to raise awareness, and we, the private sector, are involved in the initiatives. Several initiatives are being implemented as part of the government's Green Transport strategy. We hosted lecturers and did a presentation on electric vehicles to incorporate them into the student's curriculum. Students can also share their knowledge. We have an electric vehicle battery facility at the campus that gets awareness. The awareness still needs a boost. There is still a lot to be done for the majority. **(EX8/ Project Engineer)**

People think ah, okay, if I buy my EV, how am I going to charge my EV, and how many chargers are there? So, most people do not have that knowledge, they do not know, but the biggest barrier that I see here is the price, so obviously, the government needs to intervene when it comes to the uptake of EVs. I think the government is putting in effort in terms of raising awareness. Our organization is part of that government initiative to raise awareness. And there is also awareness run by industries, so we have the EVRT. The EVRT, so it`s like all the EV owners, they come together, they drive around South Africa to showcase the EV technologies. These green transport strategies are also being put in place by the

government to try and support the uptake of EVs in South Africa. **(EX3/ Chief Executive Officer)**

Other stakeholders can take advantage of social media to raise EV awareness. Also, outdoor marketing – billboards. **(EX9/ Director)**

The study established that awareness about EVs has not been satisfactorily done. Some organisations have begun awareness campaigns, but as the participants indicated, more still needs to be done. According to (Sanguesa et al., 2021; Wang et al., 2017), customer perceptions of the EV's financial worth impact how quickly people adopt new technologies. Compared to fossil fuel-powered automobiles, these have lower service and maintenance expenses. According to the study and findings comparable to those in Zimm (2021), consumers are discouraged from purchasing EVs because of the initial high purchase price. This demonstrates that consumers are unaware of the potential savings that come with EVs' lower running expenses (Zimm, 2021). The lack of knowledge about EVs and their advantages may prevent more people from buying them (Wang et al., 2017). Innovators in the many-manufacturer EV market are constrained by a lack of understanding of potential future markets (Egn´er & Trosvik, 2018; Priessner et al., 2018). Additionally, electric vehicle designers and marketers must create and position their products to provoke favourable feelings (Rajper & Albrecht, 2020; Ziegler et al., 2022). Effective information dissemination would raise consumer awareness of the environment and drive them to adopt new behaviours.

4.8.2 *The private sector and partnerships*

The private sector constitutes a broad range of stakeholders who support the government in adopting EVs. The participants indicated that the private sector should develop partnerships to help reduce the cost of EVs. In addition, public-private partnerships were seen as one of the ways to make EVs affordable. The participants commented as follows:

There is no demand yet. Some products are not needed, but when people start sharing their value, demand can increase. The other stakeholders, such as Fidelity, who have specialized cars, can be introduced in manufacturing. To achieve a cheaper rate to charge, supplying parts and maintenance, the Department of Energy must invite more partners to resolve the pricing. **(EX1/ Senior Electrical Technologist)**

If you go and try to get the government, it's delayed because we rely too much on the government and Eskom. That's why we have load shedding right now. We will close the gaps much quicker if we engage the private sector. It will take a couple of years, but the private sector is more flexible. **(EX2/ Engineering Manager)**

I think engagement and collaboration with the motor industry and users will help. Information sharing and collaboration incentives can be used to entice investors. **(EX3/ Chief Executive Officer)**

We need to collaborate. The government must play a role, and the private sector must also participate for it to work. I think they can support the research organisations. Support people who are researching these technologies. And they also need to empower businesspeople with information like seminars and stuff to ensure people are aware of the technology. Because all these parties need to, they are involved in the process. The private sector manufactures these things. The government benefits from reduced emissions and the power we inject into the grid. Also, the end-user needs to be part of the conversation because they will purchase the product. **(EX4/ Senior Electrical Engineer)**

Partnerships between dealerships, charging infrastructure companies, and consumers are needed. We are engaged in the value chain in terms of charging AC and DC devices. We are engaging commercial stakeholders and educating them on managing these devices. **(EX3/ Chief Executive Officer)**

As a local government, we can support the EV industry by making spare capacity available wherever possible. The government might start promoting EV manufacturers; they have no choice. The ICE in South Africa brings in close to 13% of GDP. **(EX11/ Chief Engineer)**

So obviously, the stakeholders that should be involved include ESKOM, with the electricity generation, the municipality, and the electric vehicle manufacturers. They need to ensure their vehicles can allow for bi-directional charging and discharging. And obviously, we have the V2G aggregators, maybe the middle guys, who sell the electricity. I think we also need people like that. **(EX4/ Senior Electrical Engineer**

Prepare the energy grid for EV adoption, provide supporting regulation to drive EV adoption, and provide investment into the localisation of EV value chain elements to ensure a just economic transition and breakdown barriers to energy trading (Copy Cellular business model). **(EX12/ Production Engineering Manager)**

The study established that partnerships among EV and V2G stakeholders are important in adopting these technologies. The partnerships facilitate the technology's affordability and help address other impediments facing the industry, such as the lack of incentives and government policy for EVs. The findings show that partnerships help address the challenges associated with EV adoption, particularly pricing. Related studies (Zhang et al., 2021; Wang & Yongjian, 2018) state that public-private partnerships are important because they work well when the government is under much financial strain and needs to launch big initiatives. The stakeholders in electric car charging facilities have a relationship that suggests that the pricing for charging and the level of government support may impact the availability of charging stations (Hrelja et al., 2018; Yang et al., 2018).

4.9 Comparison of literature review and own findings

The literature review and the findings from the study are compared in Table 6 below:

Table 6: Comparison of literature review and findings

RQ #	Research Question	Prop	Proposition	Findings from own study
1	How can V2G adoption play a role in South Africa's energy transition?	1	V2G technology adoption positively influences South Africa's transition to zero-carbon energy.	V2G technology helps to address the current electricity shortages. V2G increases energy supply, resulting in less strain on the major electricity providers. South Africa has no capacity for V2G adoption as current electricity shortages may be worsened as more EVs feed draw more electricity from the grid.
2	Based on theory, what factors influence EV adoption in South Africa?	2	The MLP and diffusion of innovation theory are theoretical lenses that explain the adoption of V2G technology.	Relying on constructs from the MLP and diffusion of innovation theory, the study found that EV adoption is influenced by the following: • Usefulness of EVs • Ideal charging infrastructure • Government policies on EVs • Affordability of EVs • The capacity of Eskom grids. The findings showed that the diffusion rate of EV and V2G technology is slow due to unclear government policy, capacity challenges, lack of infrastructure for EVs and V2G and high costs.
		3	EV and V2G technology adoption can lead to a reduction in CO2 emissions.	EV and V2G result in the reduction of carbon emissions. While this is a possibility, the findings showed that South Africa is yet to achieve that success due to the slow rate of

				EV adoption and the challenges related to EV adoption.
		4.	A poor energy policy, lack of awareness, and undesirable economic and regulatory environments negatively affect the adoption of EVs and, thus, V2G technology in South Africa.	The findings showed that South Africa has no policy that allows for adding V2G into the Eskom grid, the EV and V2G technology tax regime is too high, and there are no incentives to promote the industry.
3			Different stakeholders in the V2G supply chain can play a role in promoting V2G in the country.	The findings indicate that government can introduce incentives towards EVs and V2G industry.
	What role can different stakeholders in the V2G supply chain play in promoting V2G in the country?	5	EV adoption accelerates the adoption of V2G.	The findings indicate that the current electricity challenges facing South Africa do not support the acceleration of V2G. The findings show that if the cost of EVs is reduced, V2G infrastructure is provided, and supportive policies are in place, the adoption of EVs may result in the adoption of V2G.
		6	Energy industry actors have strategies to adopt and promote EVs and V2G as part of their contribution towards zero-carbon energy.	Government can do awareness campaigns on EVs and V2G technology, and public-private partnerships can be useful platforms for government and private stakeholders to engage in EV and V2G technology.

4.10 Conclusion

The chapter presented the findings which emerged from the thematic analysis of interviews. The major issues revealed in the findings include the role of V2G technology in South Africa's energy transition. The findings show that V2G technology has the potential to provide cheap, alternative energy and supplement Eskom supplies. In addition, the findings showed the factors that influence the

adoption of EVs. The high EV cost and lack of government policy were identified, and affordability and usefulness were the major drivers. Lastly, the role of government and stakeholders in driving the adoption of V2G showed that the government and private sector are key players.

CHAPTER 5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

The chapter presents conclusions and recommendations based on the findings presented in the previous chapter. Firstly, conclusions for each of the research questions are presented. The conclusions provide insight into whether the research questions have been addressed. Further, a consistency table is presented to establish if the research findings have responded to research questions and initial propositions, showing the link between the research question, proposition, and findings. Informed by the findings, the chapter provides recommendations for energy planners, energy policymakers and energy professionals. The chapter closes with suggestions for future research.

5.2 Conclusions regarding research question 1

How can V2G adoption play a role in South Africa's energy transition?

The study established that V2G technology could be critical in South Africa's energy transition. With South Africa facing serious electricity shortages, the study envisaged V2G to provide alternative energy sources that could take off the burden from Eskom, the biggest electricity provider in South Africa. The findings also showed that V2G adoption increases power supply. With current electricity shortages in South Africa, V2G has been regarded as a potential game-changer by providing individuals, households, and organisations to add electricity into the grid, resulting in less strain on electricity providers. Although reviewed literature suggests that V2G adoption has the potential to ease electricity challenges, the study indicated that the situation in South Africa is different in that the technology may further strain the current electricity challenges facing the country as EVs first

need electricity before generating into the grid. Study findings suggest that the private and public sectors should collaborate to invest in the EV infrastructure to mitigate this challenge. As indicated in Chapter 1, South Africa has committed to taking measures to respond to the global need for decarbonisation. The findings of the study suggest that the adoption of V2G technology could potentially help in the reduction of carbon emissions.

5.3 Conclusions regarding research question 2

Based on theory, what factors influence EV adoption in South Africa?

The findings regarding this research question were informed by the Multi-level Perspective theory and Diffusion of Innovation theory, which indicates the factors influencing technology adoption. The factors that emerged from the study include the economic benefits of EVs, the usefulness of EVs, ideal charging infrastructure, policies relating to EVs, affordability, the capacity of electricity grids to accommodate EVs and the rate of adoption of EVs based on the opportunities and constraints. Firstly, the findings revealed that the economic benefits of EVs influence people to adopt the technology. Although there are economic benefits for the country and individuals, the literature indicates (Aghajan-Eshkevari et al., 2022) that the findings reveal that people do not see the economic benefits of EVs as they are too expensive for the reach of many.

Secondly, as the MLP model indicates, perceived usefulness is a key determinant for adopting technology. The study's findings revealed that EVs could help solve transport challenges by making public transport cheap. EVs can provide domestic energy needs for households and are pollution-free. The EV infrastructure is related to ease of use. The findings indicated inadequate EV infrastructure in South Africa, thus delaying EV adoption. Key infrastructural challenges include a lack of EV metering systems and charging facilities. The Eskom grid was not designed with EV technology; thus, it needs expansion and modernisation. Lastly, the study’s findings revealed that government policy on EVs was

inconsistent with reality. There is no policy on how V2G can be linked with the national grid. In addition, the government's high tax demands on EVs were found to discourage current and potential players in the industry. All the factors mentioned above for EV adoption influence the rate of adoption of V2G technology. The findings showed that the rate of EV adoption is currently slow due to the high cost of purchasing EVs, the lack of capacity to accommodate EVs and poor EV infrastructure.

5.4 Conclusions regarding research question 3

What role can different stakeholders in the V2G value chain play in promoting the technology in the country?

The role of government was identified as central towards adopting EVs and V2G technologies in South Africa. The findings revealed that the government introduced incentives to support stakeholders in the EV industry. The introduction of incentives would reduce the cost of production and result in a low cost of purchasing EVs. In addition, the study established that the government could use awareness campaigns to promote knowledge and adoption of EVs. The need for awareness campaigns was crucial as most people in South Africa did not know about EVs and V2G, their advantages and how they could be implemented.

Contrary to the literature which indicates the role of government in EV adoption (Noel et al., 2019), the study's findings showed that the South African government failed to fulfil its mandate in giving direction and supporting EV adoption. Lastly, the findings revealed that public-private partnerships are essential for EV adoption. When the government and private stakeholders in the EV industry engage, the costs related to doing business would be reduced, resulting in EVs becoming affordable. In addition, public-private partnerships allow for engagement between government and stakeholders on challenges faced by the industry and ways to address them.

Table 7 below illustrates how the study is consistent and coherent with the previously stated research questions and their respective propositions.

Table 7: Consistency table: research questions, conclusions, and contribution to knowledge

RQ #	Research Question	Literature-based proposition	Conclusion based on own research	Key differences between initial propositions and findings
1	How can V2G adoption play a role in South Africa's energy transition?	V2G technology adoption positively influences South Africa's transition to zero-carbon energy.	V2G technology helps to address the current electricity shortages. V2G increases energy supply, resulting in less strain on the major electricity providers. South Africa has no capacity for V2G adoption as current electricity shortages may be worsened as more EVs feed draw more electricity from the grid.	Although V2G technology helps to address the current electricity shortages, South Africa has no capacity for V2G adoption. Current electricity shortages may worsen as more EVs feed and draw more electricity from the grid.

RQ #	Research Question	Literature-based proposition	Conclusion based on own research	Key differences between initial propositions and findings
2	Based on theory, what factors influence EV adoption in South Africa?	The MLP and diffusion of innovation theory are theoretical lenses that explain the adoption of V2G technology.	The study found that EV adoption is influenced by the following: • Usefulness of EVs • Ideal charging infrastructure • Government policies on EVs • Affordability of EVs • The capacity of Eskom grids. The findings showed that the diffusion rate of EV and V2G technology is slow due to unclear government policy, capacity challenges, lack of charging infrastructure for EVs and V2G and high costs.	MLP emphasizes the importance of interaction between key stakeholders, but the findings show limited engagement between the government and stakeholders. The necessary conditions for the diffusion of EV and V2G technology are absent in the South African context. The conditions are ideal charging infrastructure, government policies that support EV adoption, EV affordability, and Eskom's electricity generation capacity to integrate V2G.

RQ #	Research Question	Literature-based proposition	Conclusion based on own research	Key differences between initial propositions and findings
		EV and V2G technology adoption will lead to a reduction in CO2 emissions.	EV and V2G result in the reduction of carbon emissions. While this is a possibility, the findings showed that South Africa is yet to achieve that success due to the slow rate of EV adoption and the challenges related to EV adoption.	EV and V2G can lead to a reduction in CO2, but the findings show that with the slow pace of diffusion on EV and V2G technology, South Africa had not achieved CO2 reduction by using EVs and V2G.
		A poor energy policy, lack of awareness, and undesirable economic and regulatory environments negatively affect the adoption of EVs and, thus, V2G technology in South Africa.	The findings showed that South Africa has no policy that allows for adding V2G into the Eskom grid, the EV and V2G technology tax regime is too high, and there are no incentives to promote the industry.	The literature provided cases from other developing countries. The findings from the study revealed that the South African context faces related challenges.
	What role can different stakeholders in the V2G supply chain play		The findings indicate that government can introduce incentives towards EVs and V2G industry.	

RQ #	Research Question	Literature-based proposition	Conclusion based on own research	Key differences between initial propositions and findings
	in promoting V2G in the country?			
		EV adoption accelerates the adoption of V2G.	The findings indicate that the current electricity challenges facing South Africa do not support the acceleration of V2G. The findings show that if the cost of EVs is reduced, V2G infrastructure is provided, and supportive policies are in place, the adoption of EVs may result in the adoption of V2G.	Unlike the proposition, which assumes that EV adoption accelerates the adoption of V2G, the findings show that despite the availability of V2G, the adoption rate has been slow. Electricity challenges negate the adoption of V2G.
		Energy industry actors have strategies in place to adopt and promote EVs and V2G as part of their contribution towards zero-carbon energy	Government can do awareness campaigns on EVs and V2G technology, and public-private partnerships can be useful platforms for government and private stakeholders to engage in EV and V2G technology.	The literature indicated that both primary and secondary actors work together to ensure the success of EV adoption. The study's findings showed that the secondary actors are not working together; thus, no engagement would result in developing policy and reducing the purposing price for EVs.

5.5 Recommendations

The study's findings have indicated the current challenges limiting the adoption of EVs and V2G technology in South Africa. In order to address these limitations, the study proposes the following recommendations:

5.5.1 *Recommendations for energy planners*

Based on the findings from the literature review as well as from the primary research, the study makes the following recommendations for energy planners:

- ***Run awareness campaigns to change consumer perceptions of electric vehicles.***

Although energy planning is the primary responsibility of government organizations, it can also be carried out by energy companies and stakeholders through an integrated approach. This method considers the availability of energy sources and the contribution of energy efficiency to lower demand. Therefore, energy planning can be conducted with input from various stakeholders from government organizations, municipal utilities, academia, and other interest groups, and population growth should always be considered. The study recommends that for South Africa to address the technological barriers that impede the diffusion of EVs in the automotive market, there is a need for awareness campaigns to change consumer perceptions of electric vehicles. Energy planners can design EV awareness programmes targeting social media, traditional media, road shows, and learning institutions.

- ***Invest in more EV charging points***

The study indicates that inadequate charging stations prevent consumers from purchasing EVs. In order to address this challenge, the study recommends that energy planners develop a framework for the introduction of charging points in convenient areas such as on major roads, at major filling stations across the country and in workplaces. The existence of this infrastructure at these key

locations would improve user satisfaction with this new technology (Moeletsi, 2021). Government energy planners should take the initiative and get more involved in South Africa's network expansion of charging stations.

5.5.2 *Recommendations for policymakers*

The following recommendations are directed to policymakers in the energy industry:

- ***Government intervention in the pricing of EVs***

One of the impediments to adopting EV and V2G technology in South Africa is the high cost of purchasing these technologies. The study recommends that the government develop policies to bridge this price gap, such as introducing lucrative incentives for new EV purchases (Figenbaum, 2017). Incentives for reducing purchase prices are the most effective in adopting EVs and increasing market share (Moeletsi, 2021).

- ***V2G Pilot projects***

In the near term, both the public and private sectors can take a more active role in developing V2G in South Africa by initiating pilot projects on their fleets or in private consumers (both with their benefits) and targeting user types with information and experience campaigns.

- ***Introduce incentives for EV industry players***

Another policy intervention that can lead to a reduction in the EV purchase price is the introduction of fixed amount tax rebates. This makes EVs more affordable and indicates that governments are also committed to the cause of combating climate change (Raza & Lin, 2020).

5.5.3 *Recommendations for energy professionals*

- ***Allow energy professionals to lead EV and V2G adoption processes***

Energy professionals know EVs and V2G technologies. The government and energy entities should take advantage of these professionals and put them at the forefront of awareness campaigns on EVs and V2G technologies. These energy professionals can act as EV and V2G ambassadors in their neighbourhoods and on social media platforms. In addition, they can be incorporated to lead official awareness campaigns through road shows, traditional media, social media, and workshops.

5.6 Suggestions for further research

The following are suggestions for further research:

- Part of the study's findings indicated that the government has no clear EV policy. The study did not dwell on the policy gaps to fully understand the role of EV policy in adopting EVs and the subsequent use of V2G. To that end, future research may focus on developing a framework for adopting EV and V2G technology. This framework may provide insights to policymakers on what the EV policy should consider.
- This research only focused on energy experts within the electricity and automotive industries. However, both the transportation and electricity sectors can benefit from V2G technology, which makes it appealing to advocates. As such, exploring the views of experts from the oil, gas, and transportation sectors about V2G technology would be worthwhile.

- Additionally, EV owners in South Africa can be researched to determine if and under what conditions they would be willing to participate in electricity trading with the national utility.

REFERENCES

Abito, J. M., & Salant, Y. (2018). The effect of product misperception on economic outcomes: Evidence from the extended warranty market. *The Review of Economic Studies*, *86*(6), 2285–2318. https://doi.org/10.1093/restud/rdy045

Acocella, I. (2012). The focus groups in social research: advantages and disadvantages. *Quality & Quantity*, *46*(1), 1125-1136.

Adams, W. C. (2015). *Conducting semi-structured interviews.* Handbook of Practical Program Evaluation. Wiley Online Library. Accessible on: https://doi.org/10.1002/9781119171386.ch19

Adhabi, E. A., & Anozie, C. B. (2017). Literature review for the type of interview in qualitative research. *International Journal of Education*, *9*(3), 86. https://doi.org/10.5296/ije.v9i3.11483

Adhikari, M., Ghimire, L. P., Kim, Y., Aryal, P., & Khadka, S. B. (2020). Identification and analysis of barriers against electric vehicle use. *Sustainability*, *12*(12), 4850. https://doi.org/10.3390/su12124850

Aghajan-Eshkevari, S., Azad, S., Nazari-Heris, M., Ameli, M. T., & Asadi, S. (2022). Charging and discharging of electric vehicles in power systems: An updated and detailed review of methods, control structures, objectives, and optimization methodologies. *Sustainability*, *14*(4), 2137. https://doi.org/10.3390/su14042137

Ahmad, S., Wasim, S., Irfan, S., Gogoi, S., Srivastava, A., & Farheen, Z. (2019). Qualitative v/s quantitative research-A summarized review. *Journal of Evidence-Based Medicine and Healthcare*, *6*(43), 2828–2832. https://doi.org/10.18410/jebmh/2019/587

Al-Ghussain, L., Darwish Ahmad, A., Abubaker, A. M., & Hassan, M. A. (2022). Techno-economic feasibility of thermal storage systems for the transition to 100% renewable grids. *Renewable Energy*, *189*(1), 800–812. https://doi.org/10.1016/j.renene.2022.03.054

Alchemer. (2021, May 21). *What is SPSS, and how does it benefit survey data analysis?* Alchemer. Retrieved May 1, 2022, from https://www.surveygizmo.com/resources/blog/what-is-spss/

Alotaibi, M. A., & Eltamaly, A. M. (2022). Upgrading conventional power system for accommodating electric vehicle through demand side management and V2G concepts. *Energies*, *15*(18), 6541. https://doi.org/10.3390/en15186541

Amin, A. Z. (2018, November 26). *Renewables are the key to a climate-safe world*. International Renewable Energy Agency. Retrieved May 1, 2022, from https://www.irena.org/newsroom/articles/2018/Nov/Renewables-are-the-key-to-a-climate-safe-world

Ampah, J. D., Afrane, S., Agyekum, E. B., Adun, H., Yusuf, A. A., & Bamisile, O. (2022). Electric vehicles development in Sub-Saharan Africa: Performance assessment of standalone renewable energy systems for hydrogen refuelling and electricity charging stations (HRECS). *Journal of Cleaner Production*, *376*, 134238. https://doi.org/10.1016/j.jclepro.2022.134238

Archsmith, J., Heyes, A., & Saberian, S. (2018). Air quality and error quantity: Pollution and performance in a high-skilled, quality-focused occupation. *Journal of the Association of Environmental and Resource Economists*, *5*(4), 827–863. https://doi.org/10.1086/698728

Archsmith, J., Kendall, A., & Rapson, D. (2015). From cradle to junkyard: Assessing the life cycle greenhouse gas benefits of electric vehicles. *Research in Transportation Economics*, *52*(1), 72–90. https://doi.org/10.1016/j.retrec.2015.10.007

Barkenbus, J. N. (2020). Prospects for electric vehicles. *Sustainability*, *12*(14), 5813. https://doi.org/10.3390/su12145813

Bauer, G., Hsu, C. W., & Lutsey, N. (2021, November 24). *When might lower-income drivers benefit from electric vehicles? Quantifying the economic equity implications of electric vehicle adoption*. International Council on Clean Transportation. Retrieved May 1, 2021, from https://theicct.org/publication/when-might-lower-income-drivers-benefit-from-electric-vehicles-quantifying-the-economic-equity-implications-of-electric-vehicle-adoption/

Baumgartner, N., Kellerer, F., Ruppert, M., Hirsch, S., Mang, S., & Fichtner, W. (2022). Does experience matter? Assessing user motivations to accept a vehicle-to-grid charging tariff. *Transportation Research Part D: Transport and Environment*, *113*(1), 103528. https://doi.org/10.1016/j.trd.2022.103528

Bessa, R. J., & Matos, M. A. (2010). The role of an aggregator agent for EV in the electricity market. *7th Mediterranean Conference and Exhibition on Power Generation, Transmission, Distribution and Energy Conversion (MedPower 2010)*. https://doi.org/10.1049/cp.2010.0866

Bhattacherjee, A. (2012). *Social Science Research: Principles, methods, and practices*. New York: Creative Commons Attribution.

Bibak, B., & Tekiner-Mogulkoc, H. (2021). Influences of vehicle-to-grid (V2G) on power grid: An analysis by considering associated stochastic parameters explicitly. *Sustainable Energy, Grids and Networks*, *26*(1), 100429. https://doi.org/10.1016/j.segan.2020.100429

Bibak, B., & Tekiner-Moğulkoç, H. (2021). A comprehensive analysis of vehicle-to-grid (V2G) systems and scholarly literature on the application of such systems. *Renewable Energy Focus*, *36*(1), 1–20. https://doi.org/10.1016/j.ref.2020.10.001

Bilali, H. E. (2018). Transition heuristic frameworks in research on agro-food sustainability transitions. *Environment, Development and Sustainability*, *22*(3), 1693–1728. https://doi.org/10.1007/s10668-018-0290-0

Bilali, H. E. (2019). The multi-level perspective in research on sustainability transitions in agriculture and food systems: A systematic review. *Agriculture*, *9*(4), 74-82. https://doi.org/10.3390/agriculture9040074

Birt, L., Scott, S., Cavers, D., Campbell, C., & Walter, F. (2016). Member checking: A tool to enhance trustworthiness or merely a nod to validation? *Qualitative Health Research*, *26*(13), 1802–1811. https://doi.org/10.1177/1049732316654870

Bishop, J. D. K., Axon, C. J., Bonilla, D., Tran, M., Banister, D., & McCulloch, M. D. (2013). Evaluating the impact of V2G services on the degradation of batteries in PHEV and EV. *Applied Energy*, *111*(1), 206–218. https://doi.org/10.1016/j.apenergy.2013.04.094

Bloomberg New Energy Finance. (2020). *Electric vehicle outlook 2020*. Retrieved October 1, 2022, from https://about.bnef.com/electric-vehicle-outlook-2020/

Boddy, C. R. (2016). Sample size for qualitative research. *Qualitative Market Research: An International Journal*, *19*(4), 426–432. https://doi.org/10.1108/qmr-06-2016-0053

Bokopane, L., Kanzumba, K., & Vermaak, H. (2019). Is the South African electrical infrastructure ready for electric vehicles? *2019 Open Innovations (OI)*. https://doi.org/10.1109/oi.2019.8908171

Bolderston, A. (2012). Conducting a research interview. *Journal of Medical Imaging and Radiation Sciences*, *43*(1), 66–76. https://doi.org/10.1016/j.jmir.2011.12.002

Bompard, E., Ciocia, A., Grosso, D., Huang, T., Spertino, F., Jafari, M., & Botterud, A. (2022). Assessing the role of fluctuating renewables in energy transition: Methodologies and tools. *Applied Energy*, *314*(1), 118968. https://doi.org/10.1016/j.apenergy.2022.118968

Bonges, H. A., & Lusk, A. C. (2016). Addressing Electric Vehicle (EV) sales and range anxiety through parking layout, policy and regulation. *Transportation Research Part A: Policy and Practice*, *83*(1), 63–73. https://doi.org/10.1016/j.tra.2015.09.011

Boumaiza, A., Abba, S., Mohand, N., & Sanfilippo, A. (2018). Modelling the impact of innovation diffusion on solar PV adoption in city neighbourhoods. *International Journal of Renewable Energy Research*, *8*(3). https://doi.org/10.20508/ijrer.v8i3.7999.g7484

Braun, V., & Clarke, V. (2019). Reflecting on reflexive thematic analysis. *Qualitative Research in Sport, Exercise and Health*, *11*(4), 589–597. https://doi.org/10.1080/2159676x.2019.1628806

British Petroleum. (2020). *Statistical review of world energy 2020*. Retrieved July 1, 2022, from https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2020-full-report.pdf.

Broadbent, G. H., Metternicht, G. I., & Wiedmann, T. O. (2021). Increasing electric vehicle uptake by updating public policies to shift attitudes and perceptions: Case study of New Zealand. *Energies*, *14*(10), 2920. https://doi.org/10.3390/en14102920

Broto, V. C. (2017). Energy landscapes and urban trajectories towards sustainability. *Energy Policy*, *108*(1), 755–764. https://doi.org/10.1016/j.enpol.2017.01.009

Brown, A., Lommele, S., Schayowitz, A., & Klotz, E. (2021, May). *Electric vehicle charging infrastructure trends from the alternative fueling station locator: Third Quarter 2020.* Retrieved March 24, 2022, from https://www.nrel.gov/docs/fy21osti/79536.pdf

Brown, M. A., & Soni, A. (2019). Expert perceptions of enhancing grid resilience with electric vehicles in the United States. *Energy Research & Social Science*, *57*(1), 101241. https://doi.org/10.1016/j.erss.2019.101241

Brückmann, G., Willibald, F., & Blanco, V. (2021). Battery electric vehicle adoption in regions without strong policies. *Transportation Research Part D: Transport and Environment*, *90*(1), 102615. https://doi.org/10.1016/j.trd.2020.102615

Busetto, L., Wick, W., & Gumbinger, C. (2020). How to use and assess qualitative research methods. *Neurological Research and Practice*, *2*(1). https://doi.org/10.1186/s42466-020-00059-z

Butt, O., Zulqarnain, M., & Butt, T. (2021). Recent advancement in smart grid technology: Future prospects in the electrical power network. *Ain Shams Engineering Journal*, *12*(1), 687–695. https://doi.org/10.1016/j.asej.2020.05.004

Bürer, M. J., de Lapparent, M., Capezzali, M., & Carpita, M. (2021). Governance drivers and barriers for business model transformation in the energy sector. *Swiss Energy Governance, 12*(2),195–243. https://doi.org/10.1007/978-3-030-80787-0_10

Calitz, J. R. (2019). *The impact of battery electric vehicles on the least cost electricity portfolio for South Africa* [Thesis, University of Pretoria] https://repository.up.ac.za/handle/2263/71042

Candra, C. S. (2022). Evaluation of barriers to electric vehicle adoption in Indonesia through Grey Ordinal Priority Approach. *International Journal of Grey Systems*, *2*(1), 38–56. https://doi.org/10.52812/ijgs.46

Carmichael, T., & Cunningham, N. (2017). Theoretical data collection and data analysis with gerunds in a constructivist grounded theory study. *The Electronic Journal of*

Business Research Methods, *15*(2), 59–73. https://doi.org/https://academic-publishing.org/index.php/ejbrm/article/view/1357

Carminati, L. (2018). Generalizability in qualitative research: A tale of two traditions. *Qualitative Health Research*, *28*(13), 2094–2101. https://doi.org/10.1177/1049732318788379

Casteel, A., & Bridier, N. (2021). Describing populations and samples in doctoral student research. *International Journal of Doctoral Studies*, *16*(1), 339–362. https://doi.org/10.28945/4766

Centre for Environmental Rights. (2021, May 4). SA's revised climate plans are not ambitious enough. Retrieved August 11, 2021, from https://cer.org.za/news/sas-revised-climate-plans-are-not-ambitious-enough

Chen, C., de Rubens, G. Z., Noel, L., Kester, J., & Sovacool, B. K. (2020). Assessing the socio-demographic, technical, economic and behavioural factors of Nordic electric vehicle adoption and the influence of vehicle-to-grid preferences. *Renewable and Sustainable Energy Reviews*, *121*(1), 109692. https://doi.org/10.1016/j.rser.2019.109692

Cherp, A., Vinichenko, V., Jewell, J., Brutschin, E., & Sovacool, B. (2018). Integrating techno-economic, socio-technical and political perspectives on national energy transitions: A meta-theoretical framework. *Energy Research & Social Science*, *37*(1), 175–190. https://doi.org/10.1016/j.erss.2017.09.015

Chersich, M. F., & Wright, C. Y. (2019). Climate change adaptation in South Africa: A case study on the role of the health sector. *Globalization and Health*, *15*(1). https://doi.org/10.1186/s12992-019-0466-x

Chigwada, J. P. (2021). Management and maintenance of research data by researchers in Zimbabwe. *Global Knowledge, Memory and Communication, 71*(4), 193-207. https://doi.org/10.1108/gkmc-06-2020-0079

Chigwada, J., Chiparausha, B., & Kasiroori, J. (2017). Research data management in research institutions in Zimbabwe. *Data Science Journal*, *16*(1), 31. https://doi.org/10.5334/dsj-2017-031

Child, M., Nordling, A., & Breyer, C. (2018). The impacts of high V2G participation in a 100% renewable åland energy system. *Energies*, *11*(9), 2206. https://doi.org/10.3390/en11092206

Chivanga, S. Y., & Monyai, P. B. (2021). Back to basics: Qualitative research methodology for beginners. *Journal of Critical Reviews*, *8*(2), 1–7.

Clark, W. C., & Harley, A. G. (2020). An integrative framework for sustainability science. *Sustainability Science: A Guide for Researchers*. Open Publishing: PubPub. https://doi.org/10.21428/f8d85a02.d9dbc249

Cornell, R. P. (2017). *The environmental benefits of electric vehicles as a function of renewable energy* [Thesis, Havard University]. https://dash.harvard.edu/handle/1/33826493

Creswell, J. W. (2013). *Research design: Qualitative, quantitative, and mixed methods approaches*. London: SAGE.

Crick, J. M. (2020). Qualitative research in marketing: What can academics do better? *Journal of Strategic Marketing*, *29*(5), 390–429. https://doi.org/10.1080/0965254x.2020.1743738

Dane, A. (2014). *The potential of electric vehicles to contribute to South Africa's greenhouse gas emissions targets and other developmental objectives: How appropriate is the investment in electric vehicles as a NAMA?* Cape Town: University of Cape Town http://hdl.handle.net/11427/17148

Das, P. P., Bachchan, A. A., & Chaudhary, V. (2020). The effectiveness of smart grids V2G and integration of renewable energy sources. *Electric Vehicles, 14*(1) 231–245. https://doi.org/10.1007/978-981-15-9251-5_14

Davis, G. A., & Tilton, J. E. (2005). The resource curse. *Natural Resources Forum*, *29*(3), 233–242. https://doi.org/10.1111/j.1477-8947.2005.00133.x

Dawadi, S., Shrestha, S., & Giri, R. A. (2021). Mixed-methods research: A discussion on its types, challenges, and criticisms. *Journal of Practical Studies in Education*, *2*(2), 25–36. https://doi.org/10.46809/jpse.v2i2.20

Dearing, J. W., & Cox, J. G. (2018). Diffusion of innovations theory, principles, and practice. *Health Affairs*, *37*(2), 183–190. https://doi.org/10.1377/hlthaff.2017.1104

DeJonckheere, M., & Vaughn, L. M. (2019). Semistructured interviewing in primary care research: A balance of relationship and rigour. *Family Medicine and Community Health*, *7*(2), 1-8. https://doi.org/10.1136/fmch-2018-000057

Department of Forestry, Fisheries, and the Environment. (2021, March 30). South Africa's updated draft Nationally Determined Contribution (NDC) launched. Retrieved October 11, 2021, from https://www.dffe.gov.za/mediarelease/creecy_indc2021draftlaunch_climatechangecop26

Department of Mineral Resources & Energy. (2019). *Integrated Resource Plan 2019*. Retrieved November 11, 2021, from https://www.energy.gov.za/IRP/2019/IRP-2019.pdf.

Department of Mineral Resources & Energy. (2019). *The South African energy sector report 2019*. Retrieved October 11, 2021, from http://www.energy.gov.za/files/media/explained/2021-South-African-Energy-Sector-Report.pdf.

Department of Trade, Industry & Competition. (2021). *South African new energy vehicle."* Retrieved June 14, 2022, from https://www.tips.org.za/images/TIPS-BM_South_African_New_Energy_Vehicle_Research_Report_December_2021.pdf

Department of Trade, Industry & Competition. (2021). *The South African road to production of electric vehicles (The roadmap): "Delivering for the people, for the planet and for our prosperity."* Retrieved September 4, 2021, from http://www.thedtic.gov.za/wp-content/uploads/EV_Green_Paper.pdf.

Department of Transport. (2018). *Green transport strategy for South Africa: (2018-2050)*. Retrieved October 11, 2021, from https://www.transport.gov.za/documents/11623/89294/Green_Transport_Strategy_2018_2050_onlineversion.pdf.

Di Natale, L., Funk, L., Rüdisüli, M., Svetozarevic, B., Pareschi, G., Heer, P., & Sansavini, G. (2021). The potential of vehicle-to-grid to support the energy transition: A case study on Switzerland. *Energies*, *14*(16), 4812. https://doi.org/10.3390/en14164812

Dioha, M. O., Duan, L., Ruggles, T. H., Bellocchi, S., & Caldeira, K. (2022). Exploring the role of electric vehicles in Africa's energy transition: A Nigerian case study. *iScience*, *25*(3), 715-717. https://doi.org/10.1016/j.isci.2022.103926

Douglas, J. W., Raudla, R., & Hartley, R. E. (2015). Shifting constellations of actors and their influence on policy diffusion: A study of the diffusion of drug courts. *Policy Studies Journal*, *43*(4), 484–511. https://doi.org/10.1111/psj.12113

Egbue, O., & Long, S. (2012). Barriers to widespread adoption of electric vehicles: An analysis of consumer attitudes and perceptions. *Energy Policy*, *48*(1), 717–729. https://doi.org/10.1016/j.enpol.2012.06.009

Egnér, F., & Trosvik, L. (2018). Electric vehicle adoption in Sweden and the impact of local policy instruments. *Energy Policy*, *121*(1), 584–596. https://doi.org/10.1016/j.enpol.2018.06.040

Englberger, S., Gamra, K., Tepe, B., Schreiber, M., Jossen, A., & Hesse, H. (2021). Electric vehicle multi-use: Optimizing multiple value streams using mobile storage systems in a vehicle-to-grid context. *Applied Energy*, *304*, 117862. https://doi.org/10.1016/j.apenergy.2021.117862

Environmental Protection Agency. (2020, October 18). Electric vehicle myths. Retrieved June 11, 2021, from https://www.epa.gov/greenvehicles/electric-vehicle-myths

Eskom. (2021). *Integrated report:* Retrieved March 31, 2021, from https://www.eskom.co.za/wp-content/uploads/2021/02/Eskom_2019_integrated_report.pdf.

Eskom. (2022). *Medium-term system adequacy outlook 2023-2027*. Retrieved October 11, 2021, from https://www.eskom.co.za/wp-content/uploads/2022/10/Medium-Term-System-Adequacy-Outlook-2023-2027.pdf.

Farooq, M. B., & de Villiers, C. (2017). Telephonic qualitative research interviews: When to consider them and how to do them. *Meditari Accountancy Research*, *25*(2), 291–316. https://doi.org/10.1108/medar-10-2016-0083

Finkelman, R. B., Wolfe, A., & Hendryx, M. S. (2021). The future environmental and health impacts of coal. *Energy Geoscience*, *2*(2), 99–112. https://doi.org/10.1016/j.engeos.2020.11.001

Finkelman, R. B., Wolfe, A., & Hendryx, M. S. (2021). The future environmental and health impacts of coal. *Energy Geoscience*, *2*(2), 99–112. https://doi.org/10.1016/j.engeos.2020.11.001

Foley, G., & Timonen, V. (2015). Using grounded theory method to capture and analyze health care experiences. *Health Services Research*, *50*(4), 1195–1210. https://doi.org/10.1111/1475-6773.12275

Ford, R., & Hardy, J. (2020). Are we seeing clearly? The need for aligned vision and supporting strategies to deliver net-zero electricity systems. *Energy Policy*, *147*(1), 111902. https://doi.org/10.1016/j.enpol.2020.111902

Forrest, K. E., Tarroja, B., Zhang, L., Shaffer, B., & Samuelsen, S. (2016). Charging a renewable future: The impact of electric vehicle charging intelligence on energy storage requirements to meet renewable portfolio standards. *Journal of Power Sources*, *336*(1), 63–74. https://doi.org/10.1016/j.jpowsour.2016.10.048

Fulari, S. C., & van de Kaa, G. (2021). Overcoming bottlenecks for realizing a vehicle-to-grid infrastructure in Europe through standardization. *Electronics*, *10*(5), 582. https://doi.org/10.3390/electronics10050582

Geels, F. W. (2002). Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study. *Research Policy*, *31*(8-9), 1257–1274. https://doi.org/10.1016/s0048-7333(02)00062-8

Geels, F. W. (2010). Ontologies, socio-technical transitions (to sustainability), and the multi-level perspective. *Research Policy*, *39*(4), 495–510. https://doi.org/10.1016/j.respol.2010.01.022

Geels, F. W. (2011). The multi-level perspective on sustainability transitions: Responses to seven criticisms. *Environmental Innovation and Societal Transitions*, *1*(1), 24–40. https://doi.org/10.1016/j.eist.2011.02.002

Geels, F. W. (2012). A socio-technical analysis of low-carbon transitions: Introducing the multi-level perspective into transport studies. *Journal of Transport Geography*, *24*, 471–482. https://doi.org/10.1016/j.jtrangeo.2012.01.021

Gentles, S., Charles, C., Ploeg, J., & McKibbon, K. A. (2015). Sampling in qualitative research: Insights from an overview of the methods literature. *The Qualitative Report*. https://doi.org/10.46743/2160-3715/2015.2373

Gerring, J. (2011). *The case study: What it is and what it does*. London: Oxford Handbooks Online. https://doi.org/10.1093/oxfordhb/9780199604456.013.0051

Geske, J., & Schumann, D. (2018). Willing to participate in vehicle-to-grid (V2G)? Why not! *Energy Policy*, *120*(1), 392–401. https://doi.org/10.1016/j.enpol.2018.05.004

Ghazouani, A., Xia, W., Jebli, M. B., & Shahzad, U. (2020). Exploring the role of carbon taxation policies on CO2 emissions: Contextual evidence from tax implementation and non-implementation European countries. *Sustainability*, *12*(20), 8680. https://doi.org/10.3390/su12208680

Ghosh, A. (2020). Possibilities and challenges for the inclusion of the electric vehicle (EV) to reduce the carbon footprint in the transport sector: A review. *Energies*, *13*(10), 2602. https://doi.org/10.3390/en13102602

Goel, S., Sharma, R., & Rathore, A. K. (2021). A review on barrier and challenges of electric vehicles in India and vehicle to grid optimisation. *Transportation Engineering*, *4*(1), 100057. https://doi.org/10.1016/j.treng.2021.100057

Grin, J., Rotmans, J., & Schot, J. (2010). *Transitions to sustainable development: New directions in the study of long-term transformative change* (1st ed.). New York: Routledge.

Gschwendtner, C., Sinsel, S. R., & Stephan, A. (2021). Vehicle-to-X (V2X) implementation: An overview of predominate trial configurations and technical, social and regulatory challenges. *Renewable and Sustainable Energy Reviews*, *145*(1), 110977. https://doi.org/10.1016/j.rser.2021.110977

Gunawan, I., Redi, A. A., Santosa, A. A., Maghfiroh, M. F., Pandyaswargo, A. H., & Kurniawan, A. C. (2022). Determinants of customer intentions to use electric vehicle in Indonesia: An integrated model analysis. *Sustainability*, *14*(4), 1972. https://doi.org/10.3390/su14041972

Guo, D., & Zhou, C. (2016). Potential performance analysis and future trend prediction of electric vehicle with V2G/V2H/V2B capability. *AIMS Energy*, *4*(2), 331–346. https://doi.org/10.3934/energy.2016.2.331

Habich-Sobiegalla, S., Kostka, G., & Anzinger, N. (2018). Electric vehicle purchase intentions of Chinese, Russian and Brazilian citizens: An international comparative study. *Journal of Cleaner Production*, *205*(1), 188–200. https://doi.org/10.1016/j.jclepro.2018.08.318

Habla, W., Huwe, V., & Kesternich, M. (2020). Beyond monetary barriers to electric vehicle adoption: Evidence from observed usage of private and shared cars. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3625452

Hammarberg, K., Kirkman, M., & de Lacey, S. (2016). Qualitative research methods: When to use them and how to judge them. *Human Reproduction*, *31*(3), 498–501. https://doi.org/10.1093/humrep/dev334

Harrison, G., & Thiel, C. (2017). An exploratory policy analysis of electric vehicle sales competition and sensitivity to infrastructure in Europe. *Technological Forecasting and Social Change*, *114*(1), 165–178. https://doi.org/10.1016/j.techfore.2016.08.007

Hashim, M. S., Yong, J. Y., Ramachandaramurthy, V. K., Tan, K. M., Mansor, M., & Tariq, M. (2021). Priority-based vehicle-to-grid scheduling for minimization of power grid load variance. *Journal of Energy Storage*, *39*(1), 102607. https://doi.org/10.1016/j.est.2021.102607

Hatt, K., Wilson, B., & Butt, P. (2020, October 1). *Benefits and barriers to electric vehicle (EV) adoption in the city of Guelph*. Guelph: University of Guelph. https://atrium.lib.uoguelph.ca/xmlui/handle/10214/21415

Higueras-Castillo, E., Guillén, A., Herrera, L.J., & Liébana-Cabanillas, F. (2020). Adoption of electric vehicles: Which factors are really important? *International Journal of Sustainable Transportation*, *15*(10), 799–813. https://doi.org/10.1080/15568318.2020.1818330

Hu, C. X., & Li, T. R. (2020). Analysis of emission reduction benefits of electric vehicles. *IOP Conference Series: Earth and Environmental Science*, *581*(1), 012001. https://doi.org/10.1088/1755-1315/581/1/012001

Høj, J., Juhl, L., & Lindegaard, S. (2018). V2G—an economic game-changer in E-mobility? *World Electric Vehicle Journal*, *9*(3), 35. https://doi.org/10.3390/wevj9030035

International Energy Agency. (2020). *Global EV outlook 2020: Entering the decade of electric drive?* Retrieved October 11, 2021, from https://www.iea.org/reports/global-ev-outlook-2020

International Energy Agency. (2021). *Global EV outlook 2021: Accelerating ambitions despite the pandemic*. Retrieved October 12, 2021, from https://www.iea.org/reports/global-ev-outlook-2021

International Energy Agency. (2021). *Net zero by 2050: A roadmap for the global energy sector*. Retrieved October 11, 2021, from https//www.iea.org/reports/net-zero-by-2050

International Renewables Energy Agency. (2019). *Innovation Outlook: Smart charging for electric vehicles*. Retrieved October 11, 2021, from https//www.irena.org/publications/Innovation-Outlook-Smart-Charging

International Renewables Energy Agency. (2020, June 8). Energy transition outlook. Retrieved April 17, 2021, from https://www.irena.org/Energy-Transition/Outlook

Iyamu, H. O., Anda, M., & Ho, G. (2022). Exploring the multi-level perspective in municipal solid waste management transition. *Habitat International*, *129*(1), 102664. https://doi.org/10.1016/j.habitatint.2022.102664

Jamshed, S. (2014). Qualitative research method-interviewing and observation. *Journal of Basic and Clinical Pharmacy*, *5*(4), 87. https://doi.org/10.4103/0976-0105.141942

Jezard, A. (2017, October 16). *Fossil fuels will still dominate energy in 20 years despite green power rising*. WEF. Retrieved June 12, 2021, from https://www.weforum.org/agenda/2017/10/fossil-fuels-will-dominate-energy-in-2040/

Jochem, P., Babrowski, S., & Fichtner, W. (2015). Assessing CO 2 emissions of electric vehicles in Germany in 2030. *Transportation Research Part A: Policy and Practice*, *78*(1), 68–83. https://doi.org/10.1016/j.tra.2015.05.007

Johansson, P., Vendel, M., & Nuur, C. (2020). Integrating distributed energy resources in electricity distribution systems: An explorative study of challenges facing DSOS in Sweden. *Utilities Policy*, *67*(2), 101117. https://doi.org/10.1016/j.jup.2020.101117

Johnson, J. L., Adkins, D., & Chauvin, S. (2019). A review of the quality indicators of rigor in qualitative research. *American Journal of Pharmaceutical Education*, *84*(1), 7120. https://doi.org/10.5688/ajpe7120

Jones, L., Lucas-Healey, K., Sturmberg, B., Temby, H., & Islam, M. (2021). *The A to Z of V2G. A comprehensive analysis of vehicle-to-grid technology worldwide*. Perth: Australian Renewable Energy Agency. https://arena.gov.au/assets/2021/01/revs-the-a-to-z-of-v2g.pdf.

Kannangara, M., Bensebaa, F., & Vasudev, M. (2021). An adaptable life cycle greenhouse gas emissions assessment framework for electric, hybrid, fuel cell and conventional vehicles: Effect of electricity mix, mileage, battery capacity and battery chemistry in the context of Canada. *Journal of Cleaner Production*, *317*(1), 128394. https://doi.org/10.1016/j.jclepro.2021.128394

Kempton, W., Tomic, J., & Letendre, S. (2001). *Vehicle-to-grid power: Battery, hybrid, and fuel cell vehicles as resources for distributed electric power in California*. Clifornia: University of California.

Kempton, W., & Kubo, T. (2000). Electric-drive vehicles for peak power in Japan. *Energy Policy*, *28*(1), 9–18. https://doi.org/10.1016/s0301-4215(99)00078-6

Kempton, W., & Tomić, J. (2005). Vehicle-to-grid power implementation: From stabilizing the grid to supporting large-scale renewable energy. *Journal of Power Sources*, *144*(1), 280–294. https://doi.org/10.1016/j.jpowsour.2004.12.022

Kempton, W., Tomic, J., Letendre, S., Brooks, A., & Lipman, T. (2002, June 24). *Vehicle-to-grid power: Battery, hybrid, and fuel cell vehicles as resources for distributed electric power in California*. University of California. Retrieved April 30, 2021, from https://escholarship.org/uc/item/0qp6s4mb

Khan, S. A., Kadir, K. M., Mahmood, K. S., Alam, I. I., Kamal, A., & Bashir, M. A. (2019). Technical investigation on V2G, S2V, and V2I for next-generation smart city planning. *Journal of Electronic Science and Technology*, *17*(4), 300–316. https://doi.org/10.1016/j.jnlest.2020.100010

Kiger, M. E., & Varpio, L. (2020). Thematic analysis of qualitative data: Amee Guide no. 131. *Medical Teacher*, *42*(8), 846–854. https://doi.org/10.1080/0142159x.2020.1755030

Kim, H., Kim, D. W., & Kim, M. K. (2022). Economics of charging infrastructure for electric vehicles in Korea. *Energy Policy*, *164*(1), 112875. https://doi.org/10.1016/j.enpol.2022.112875

Kivunja, C., & Kuyini, A. B. (2017). Understanding and applying research paradigms in educational contexts. *International Journal of Higher Education*, *6*(5), 26. https://doi.org/10.5430/ijhe.v6n5p26

Klitkou, A., Bolwig, S., Hansen, T., & Wessberg, N. (2015). The role of lock-in mechanisms in transition processes: The case of energy for road transport. *Environmental Innovation and Societal Transitions*, *16*(1), 22–37. https://doi.org/10.1016/j.eist.2015.07.005

Koch, S. (2015). Assessment of revenue potentials of ancillary service provision by flexible unit portfolios. *Energy Storage for Smart Grids, 1*(1), 35–66. https://doi.org/10.1016/b978-0-12-410491-4.00002-6

Kongklaew, C., Phoungthong, K., Prabpayak, C., Chowdhury, M. S., Khan, I., Yuangyai, N., Yuangyai, C., & Techato, K. (2021). Barriers to electric vehicle adoption in Thailand. *Sustainability*, *13*(22), 12839. https://doi.org/10.3390/su132212839

Krishna, G. (2021). Understanding and identifying barriers to electric vehicle adoption through thematic analysis. *Transportation Research Interdisciplinary Perspectives*, *10*(1), 100364. https://doi.org/10.1016/j.trip.2021.100364

Krouwel, M., Jolly, K., & Greenfield, S. (2019). Comparing Skype (video calling) and in-person qualitative interview modes in a study of people with irritable bowel syndrome – an exploratory comparative analysis. *BMC Medical Research Methodology*, *19*(1), 1-7. https://doi.org/10.1186/s12874-019-0867-9

Krueger, H., Fletcher, D., & Cruden, A. (2021). Vehicle-to-grid (V2G) as line-side energy storage for support of DC-powered electric railway systems. *Journal of Rail Transport Planning & Management*, *19*(1), 100263. https://doi.org/10.1016/j.jrtpm.2021.100263

Kumar, R. (2019). *Research methodology: A step-by-step guide for beginners*. London: SAGE.

Kumar, R. R., & Alok, K. (2020). Adoption of electric vehicle: A literature review and prospects for sustainability. *Journal of Cleaner Production*, *253*(1), 119911. https://doi.org/10.1016/j.jclepro.2019.119911

Lachman, D. A. (2013). A survey and review of approaches to study transitions. *Energy Policy*, *58*(1), 269–276. https://doi.org/10.1016/j.enpol.2013.03.013

Laffont, P., Waygood, E. O., & Patterson, Z. (2022). How many electric vehicles are needed to reach CO2 emissions goals? A case study from Montreal, Canada. *Sustainability*, *14*(3), 1441. https://doi.org/10.3390/su14031441

Langbroek, J. H. M., Franklin, J. P., & Susilo, Y. O. (2016). The effect of policy incentives on electric vehicle adoption. *Energy Policy*, *94*(1), 94–103. https://doi.org/10.1016/j.enpol.2016.03.050

Lawan, S. M., & Abidin, W. A. W. Z. (2020). A review of hybrid renewable energy systems based on wind and solar energy: Modelling, design and optimization. Retrieved October 9, 2021, from https://doi.org/10.5772/intechopen.85838

Ledna, C., Muratori, M., Brooker, A., Wood, E., & Greene, D. (2022). How to support EV adoption: Tradeoffs between charging infrastructure investments and vehicle subsidies in California. *Energy Policy*, *165*(1), 112931. https://doi.org/10.1016/j.enpol.2022.112931

Leung, L. (2015). Validity, reliability, and generalizability in qualitative research. *Journal of Family Medicine and Primary Care*, *4*(3), 324. https://doi.org/10.4103/2249-4863.161306

Li, T., Tao, S., He, K., Lu, M., Xie, B., Yang, B., & Sun, Y. (2021). V2G multi-objective dispatching optimization strategy based on user behaviour model. *Frontiers in Energy Research*, *9*(1), 23-31. https://doi.org/10.3389/fenrg.2021.739527

Li, W., Long, R., Chen, H., Chen, F., Zheng, X., & Yang, M. (2019). Effect of policy incentives on the uptake of electric vehicles in China. *Sustainability*, *11*(12), 3323. https://doi.org/10.3390/su11123323

Liu, Y., Zheng, R., & Yuan, J. (2020). The economics of peaking power resources in China: Screening curve analysis and policy implications. *Resources, Conservation and Recycling*, *158*(1), 104826. https://doi.org/10.1016/j.resconrec.2020.104826

Lopes, J. A., Soares, F. J., & Almeida, P. M. (2011). Integration of electric vehicles in the electric power system. *Proceedings of the IEEE*, *99*(1), 168–183. https://doi.org/10.1109/jproc.2010.2066250

Lopez-Behar, D., Tran, M., Froese, T., Mayaud, J. R., Herrera, O. E., & Merida, W. (2019). Charging infrastructure for electric vehicles in multi-unit residential buildings: Mapping feedbacks and policy recommendations. *Energy Policy*, *126*(1), 444–451. https://doi.org/10.1016/j.enpol.2018.10.030

Lu, Y., Khan, Z. A., Alvarez-Alvarado, M. S., Zhang, Y., Huang, Z., & Imran, M. (2020). A critical review of sustainable energy policies for the promotion of renewable energy sources. *Sustainability*, *12*(12), 5078. https://doi.org/10.3390/su12125078

Lukey, P. (2020). *The South African national climate change response policy – an evidence-based policy-making case study*. Pretoria: Department of Forestry, Fishery and the Environment https://www.dffe.gov.za/sites/default/files/reports/nccrp_nationalclimatechange_responsepolicy_casestudy.pdf.

Lund, H., & Kempton, W. (2008). Integration of renewable energy into the transport and electricity sectors through V2G. *Energy Policy*, *36*(9), 3578–3587. https://doi.org/10.1016/j.enpol.2008.06.007

Maguire, M., & Delahunt, B. (2017). *Doing a thematic analysis: A practical, step-by-step guide for learning and teaching scholars.2018*. All Ireland Journal of Higher Education. Retrieved June 2, 2022, from https://ojs.aishe.org/index.php/aishe-j/article/view/335

Mashhoodi, B., & van der Blij, N. (2020). Drivers' range anxiety and cost of new EV chargers in Amsterdam: A scenario-based optimization approach. *Annals of GIS*, *27*(1), 87–98. https://doi.org/10.1080/19475683.2020.1848921

Mastoi, M. S., Zhuang, S., Munir, H. M., Haris, M., Hassan, M., Usman, M., Bukhari, S. S., & Ro, J.-S. (2022). An in-depth analysis of electric vehicle charging station infrastructure, policy implications, and future trends. *Energy Reports*, *8*(1), 11504–11529. https://doi.org/10.1016/j.egyr.2022.09.011

Mayring, P. (2014). Qualitative content analysis: Theoretical background and procedures. *Advances in Mathematics Education, 38*(1), 365–380. https://doi.org/10.1007/978-94-017-9181-6_13

McLaren, J., Miller, J., O'Shaughnessy, E., & Shapiro, E. (2016). *Emissions associated with electric vehicle charging: Impact of electricity generation mix, charging infrastructure availability, and vehicle type*. National Renewable Energy Laboratory. Retrieved February 14, 2021, from https://www.nrel.gov/docs/fy16osti/64852.pdf

Milev, G., Hastings, A., & Al-Habaibeh, A. (2021). The environmental and financial implications of expanding the use of electric cars - A case study of Scotland. *Energy and Built Environment*, *2*(2), 204–213. https://doi.org/10.1016/j.enbenv.2020.07.005

Mkhize, P., Mtsweni, E. S., & Buthelezi, P. (2016). Diffusion of innovations approach to the evaluation of learning management system usage in an open distance learning institution. *The International Review of Research in Open and Distributed Learning*, *17*(3), 295-312. https://doi.org/10.19173/irrodl.v17i3.2191

Mkhize, S., & Dorrell, D. G. (2019). *Practical limitations of vehicle-to-grid (V2G) infrastructure*. 2019 IEEE International Conference on Industrial Technology (ICIT). https://doi.org/10.1109/ICIT.2019.8754965

Mohammad, A., Zamora, R., & Lie, T. T. (2020). Integration of electric vehicles in the distribution network: A review of PV-based electric vehicle modelling. *Energies*, *13*(17), 4541. https://doi.org/10.3390/en13174541

Moleko, N., & Swilling, M. (2020). *New wine into wineskins. An alternative economic strategy for South Africa's reconstruction*. Cape Town: University of Stellenbosch. Retrieved October 1, 2021, from https://www.usb.ac.za/usb_reports/new-wine-into-new-wine-skins-an-alternative-economic-strategy-for-south-africas-economic-reconstruction/

Montmassin-Clair, G., Dane, A., & Moshikaro, L. (2020). *Harnessing electric vehicles for industrial development in South Africa*. Retrieved October 1, 2021, from https://www.tips.org.za/research-archive/sustainable-growth/green-economy/item/3876-harnessing-electric-vehicles-for-industrial-development-in-south-africa

Moon, K., Brewer, T. D., Januchowski-Hartley, S. R., Adams, V. M., & Blackman, D. A. (2016). A guideline to improve qualitative social science publishing in ecology and conservation journals. *Ecology and Society*, *21*(3). https://doi.org/10.5751/es-08663-210317

Morse, J. M., Barrett, M., Mayan, M., Olson, K., & Spiers, J. (2002). Verification strategies for establishing reliability and validity in qualitative research. *International Journal of Qualitative Methods*, *1*(2), 13–22. https://doi.org/10.1177/160940690200100202

Murugan, M., & Marisamynathan, S. (2022). Elucidating the Indian customer requirements for electric vehicle adoption: An integrated analytical hierarchy process – quality function deployment approach. *Case Studies on Transport Policy*, *10*(2), 1045–1057. https://doi.org/10.1016/j.cstp.2022.03.017

Mwasilu, F., Justo, J. J., Kim, E. K., Do, T. D., & Jung, J. W. (2014). Electric vehicles and smart grid interaction: A review on vehicle to grid and renewable energy sources integration. *Renewable and Sustainable Energy Reviews*, *34*(1), 501–516. https://doi.org/10.1016/j.rser.2014.03.031

Müller, J. M. (2019). Comparing technology acceptance for autonomous vehicles, battery electric vehicles, and car sharing—a study across Europe, China, and North America. *Sustainability*, *11*(16), 4333. https://doi.org/10.3390/su11164333

Newbery, D. (2018). Shifting demand and supply over time and space to manage intermittent generation: The economics of electrical storage. *Energy Policy*, *113*(1), 711–720. https://doi.org/10.1016/j.enpol.2017.11.044

Niesten, E., & Alkemade, F. (2016). How is value created and captured in smart grids? A review of the literature and an analysis of pilot projects. *Renewable and Sustainable Energy Reviews*, *53*(1), 629–638. https://doi.org/10.1016/j.rser.2015.08.069

Noble, H., & Smith, J. (2015). Issues of validity and reliability in qualitative research. *Evidence-Based Nursing*, *18*(2), 34–35. https://doi.org/10.1136/eb-2015-102054

Noel, L., Rubens, G. Z., Kester, J., & Sovacool, B. K. (2019). *Vehicle-to-Grid: A sociotechnical transition beyond electric mobility*. New York: Palgrave Macmillan.

Nowell, L. S., Norris, J. M., White, D. E., & Moules, N. J. (2017). Thematic analysis: Striving to meet the trustworthiness criteria. *International Journal of Qualitative Methods*, *16*(1), 160940691773384. https://doi.org/10.1177/1609406917733847

Nunes, P., & Brito, M. C. (2017). Displacing natural gas with electric vehicles for grid stabilization. *Energy*, *141*(1), 87–96. https://doi.org/10.1016/j.energy.2017.09.064

Nuvve Corp. (2021, July 5). *Nuvve expands vehicle-to-grid footprint to help electrify school buses*. Retrieved October 1, 2021, from https://nuvve.com/nuvve-expands-vehicle-to-grid-footprint-to-help-electrify-school-buses/

Nykvist, B., & Nilsson, M. (2015). Rapidly falling costs of battery packs for electric vehicles. *Nature Climate Change*, *5*(4), 329–332. https://doi.org/10.1038/nclimate2564

Nyumba, T. O., Wilson, K., Derrick, C. J., & Mukherjee, N. (2018). The use of focus group discussion methodology: Insights from two decades of application in conservation. *Methods in Ecology and Evolution*, *9*(1), 20–32. https://doi.org/10.1111/2041-210x.12860

Ockwell, D., Byrne, R., Hansen, U. E., Haselip, J., & Nygaard, I. (2018). The uptake and diffusion of solar power in Africa: Socio-cultural and political insights on a rapidly emerging socio-technical transition. *Energy Research & Social Science*, *44*(1), 122–129. https://doi.org/10.1016/j.erss.2018.04.033

Olsson, L. (2019). The role of electric vehicles in reducing climate impact: Swedish public debate 2010–2018. *The International Journal of Climate Change: Impacts and Responses*, *11*(3), 1–13. https://doi.org/10.18848/1835-7156/cgp/v11i03/1-13

ÓhAiseadha, C., Quinn, G., Connolly, R., Connolly, M., & Soon, W. (2020). Energy and climate policy—an evaluation of global climate change expenditure 2011–2018. *Energies*, *13*(18), 4839. https://doi.org/10.3390/en13184839

Palinkas, L. A., Horwitz, S. M., Green, C. A., Wisdom, J. P., Duan, N., & Hoagwood, K. (2013). Purposeful sampling for qualitative data collection and analysis in mixed method implementation research. *Administration and Policy in Mental Health and Mental Health Services Research*, *42*(5), 533–544. https://doi.org/10.1007/s10488-013-0528-y

Pasaoglu, G., Fiorello, D., Martino, A., Zani, L., Zubaryeva, A., & Thiel, C. (2014). Travel patterns and the potential use of electric cars – results from a direct survey in six European countries. *Technological Forecasting and Social Change*, *87*(1), 51–59. https://doi.org/10.1016/j.techfore.2013.10.018

Pastor-Fernández, C., Yu, T. F., Widanage, W. D., & Marco, J. (2019). Critical review of non-invasive diagnosis techniques for quantification of degradation modes in lithium-ion batteries. *Renewable and Sustainable Energy Reviews*, *109*(1), 138–159. https://doi.org/10.1016/j.rser.2019.03.060

Patwardhan, A., Azevedo, I., Foran, T., Patankar, M., Rao, A., Raven, R., Samaras, C., Smith, A., Verbong , G., & Walawalkar, R. (2012). *Transitions in energy systems*. Energy Assess. Retrieved October 1, 2021, from https://previous.iiasa.ac.at/web/home/research/Flagship-Projects/Global-Energy-Assessment/GEA_Chapter16_transitions_hires.pdf

Pavlenko, N., Slowik, P., & Lutsey, N. (2021, November 24). *When does electrifying shared mobility make economic sense?* Retrieved November 21, 2022, from https://theicct.org/publication/when-does-electrifying-shared-mobility-make-economic-sense/

Peters, D. R., Schnell, J. L., Kinney, P. L., Naik, V., & Horton, D. E. (2020). Public health and climate benefits and trade-offs of U.S. vehicle electrification. *GeoHealth*, *4*(10), 1-16. https://doi.org/10.1029/2020gh000275

Pérez, M. E., Scholten, D., & Stegen, K. S. (2019). The multi-speed energy transition in Europe: Opportunities and challenges for EU energy security. *Energy Strategy Reviews*, *26*(1), 100415. https://doi.org/10.1016/j.esr.2019.100415

Priessner, A., Sposato, R., & Hampl, N. (2018). Predictors of electric vehicle adoption: An analysis of potential electric vehicle drivers in Austria. *Energy Policy*, *122*(1), 701–714. https://doi.org/10.1016/j.enpol.2018.07.058

Ragland, C. J., Feldpausch-Parker, A., Peterson, T. R., Stephens, J., & Wilson, E. (2011). Socio-political dimensions of CCS deployment through the lens of social network analysis. *Energy Procedia*, *4*(1), 6210–6217. https://doi.org/10.1016/j.egypro.2011.02.633

Rahi, S. (2017). Research design and methods: A systematic review of research paradigms, sampling issues and instruments development. *International Journal*

of Economics & Management Sciences, *6*(2), 1-5. https://doi.org/10.4172/2162-6359.1000403

Rajper, S. Z., & Albrecht, J. (2020). Prospects of electric vehicles in the developing countries: A literature review. *Sustainability*, *12*(5), 1906. https://doi.org/10.3390/su12051906

Rangarajan, S., Sunddararaj, S. P., Sudhakar, A. V. V., Shiva, C. K., Subramaniam, U., Collins, E. R., & Senjyu, T. (2022). Lithium-ion batteries—the crux of electric vehicles with opportunities and challenges. *Clean Technologies*, *4*(4), 908–930. https://doi.org/10.3390/cleantechnol4040056

Ravi, S. S., & Aziz, M. (2022). Utilization of electric vehicles for vehicle-to-grid services: Progress and perspectives. *Energies*, *15*(2), 589-600. https://doi.org/10.3390/en15020589

Ravitch, S. M., & Carl, N. M. (2016). *Qualitative research bridging the conceptual, theoretical, and Methodological*. London: SAGE.

Raza, M. Y., & Lin, B. (2020). Decoupling and mitigation potential analysis of CO2 emissions from Pakistan's transport sector. *Science of The Total Environment*, *730*(1), 139000. https://doi.org/10.1016/j.scitotenv.2020.139000

Rezvani, Z., Jansson, J., & Bodin, J. (2015). Advances in consumer electric vehicle adoption research: A review and research agenda. *Transportation Research Part D: Transport and Environment*, *34*(1), 122–136. https://doi.org/10.1016/j.trd.2014.10.010

Ritchie, H., Roser, M., & Rosado, P. (2020, November 28). *Fossil fuels*. Our World in Data. Retrieved April 28, 2022, from https://ourworldindata.org/fossil-fuels#citation

Roberts, K. B. (2016). *Vehicle-to-grid: UD-developed V2G technology launches in Denmark*. Retrieved July 3, 2021, from https://www.udel.edu/udaily/2016/august/vehicle-to-grid-denmark/

Rodgers, B. L., & Cowles, K. V. (1993). The qualitative research audit trail: A complex collection of documentation. *Research in Nursing & Health*, *16*(3), 219–226. https://doi.org/10.1002/nur.4770160309

Roff, A., Steyn, G., Renaud, C., Brand, R., & Burton, J. (2020). *A vital ambition: Determining the cost of additional CO2 emission mitigation in the South African electricity system.* Retrieved July 3, 2021, from https://www.meridianeconomics.co.za/wp-ontent/uploads/2020/07/Ambition.pdf

Rokadiya, S., & Yang, Z. (2019, April 24). *Overview of global zero-emission vehicle mandate programs*. International Council on Clean Transportation. Retrieved July 30, 2021, from https://theicct.org/publication/overview-of-global-zero-emission-vehicle-mandate-programs/

Roller, M. R., & Lavrakas, P. J. (2015). *Applied Qualitative Research Design: A total quality framework approach*. The Guilford Press.

Rudestam, K. E., & Newton, R. R. (2015). *Surviving your dissertation: A comprehensive guide to content and process*. London: SAGE.

Rüdisüli, M., Bach, C., Bauer, C., Beloin-Saint-Pierre, D., Elber, U., Georges, G., Limpach, R., Pareschi, G., Kannan, R., & Teske, S. L. (2022). Prospective life-cycle assessment of greenhouse gas emissions of electricity-based mobility options. *Applied Energy*, *306*(1), 118065. https://doi.org/10.1016/j.apenergy.2021.118065

Saldaña Johnny. (2021). *The coding manual for qualitative researchers*. London: SAGE.

Salkind, N. J. (2010). *Encyclopedia of research design*. London: SAGE.

Sanguesa, J. A., Torres-Sanz, V., Garrido, P., Martinez, F. J., & Marquez-Barja, J. M. (2021). A review on electric vehicles: Technologies and challenges. *Smart Cities*, *4*(1), 372–404. https://doi.org/10.3390/smartcities4010022

Sarparandeh, M. H., & Ehsan, M. (2017). Pricing of vehicle-to-grid services in a microgrid by Nash bargaining theory. *Mathematical Problems in Engineering*, *2017*(1), 1–11. https://doi.org/10.1155/2017/1840140

Saunders, M., Lewis, P., & Thornhill, A. (2007). *Research methods for business students* (4th ed.). London: Pearson Education Limited.

Shakeel, U. (2022). Electric Vehicle Development in Pakistan: Predicting consumer purchase intention. *Cleaner and Responsible Consumption*, *5*(1), 100065. https://doi.org/10.1016/j.clrc.2022.100065

Shenton, A. K. (2004). Strategies for ensuring trustworthiness in qualitative research projects. *Education for Information*, *22*(2), 63–75. https://doi.org/10.3233/efi-2004-22201

Sierzchula, W., Bakker, S., Maat, K., & van Wee, B. (2014). The influence of financial incentives and other socio-economic factors on electric vehicle adoption. *Energy Policy*, *68*(1), 183–194. https://doi.org/10.1016/j.enpol.2014.01.043

Silverman, D. (2010). *Doing qualitative research: A practical approach*. New York: SAGE.

Skouras, T., Gkonis, P., Ilias, C., Trakadas, P., Tsampasis, E., & Zahariadis, T. (2019). Electrical vehicles: Current state of the art, future challenges, and perspectives. *Clean Technologies*, *2*(1), 1–16. https://doi.org/10.3390/cleantechnol2010001

Smith, K., Wood, E., Pesaran, A., & Neubauer, J. (2015). *Identifying and overcoming critical barriers to widespread2 second use of PEV batteries*. Retrieved May 1, 2022, from https://www.nrel.gov/docs/fy15osti/63332.pdf

Sovacool, B. K., & Hirsh, R. F. (2009). Beyond batteries: An examination of the benefits and barriers to plug-in hybrid electric vehicles (PHVEs) and a vehicle-to-grid (V2G) transition. *Energy Policy*, *37*(3), 1095–1103. https://doi.org/10.1016/j.enpol.2008.10.005

Sovacool, B. K., Axsen, J., & Kempton, W. (2017). The future promise of vehicle-to-grid (V2G) integration: A sociotechnical review and research agenda. *Annual Review of Environment and Resources*, *42*(1), 377–406. https://doi.org/10.1146/annurev-environ-030117-020220

Sovacool, B. K., Kester, J., Noel, L., & Zarazua de Rubens, G. (2020). Actors, business models, and innovation activity systems for vehicle-to-grid (V2G) technology: A comprehensive review. *Renewable and Sustainable Energy Reviews*, *131*(1), 109963. https://doi.org/10.1016/j.rser.2020.109963

Sovacool, B. K., Noel, L., Axsen, J., & Kempton, W. (2018). The neglected social dimensions to a vehicle-to-grid (V2G) transition: A critical and systematic review. *Environmental Research Letters*, *13*(1), 013001. https://doi.org/10.1088/1748-9326/aa9c6d

Stiles, J. (2020). Strategic niche management in transition pathways: Telework advocacy as groundwork for an incremental transformation. *Environmental Innovation and Societal Transitions*, *34*(1), 139–150. https://doi.org/10.1016/j.eist.2019.12.001

Sun, M., Shao, C., Zhuge, C., Wang, P., Yang, X., & Wang, S. (2021). Exploring the potential of rental electric vehicles for vehicle-to-grid: A data-driven approach. *Resources, Conservation and Recycling*, *175*(1), 105841. https://doi.org/10.1016/j.resconrec.2021.105841

Sutton, J., & Austin, Z. (2015). Qualitative research: Data collection, analysis, and management. *The Canadian Journal of Hospital Pharmacy*, *68*(3). https://doi.org/10.4212/cjhp.v68i3.1456

Taherdoost, H. (2018). Development of an adoption model to assess user acceptance of E-service technology: E-service technology acceptance model. *Behaviour & Information Technology*, *37*(2), 173–197. https://doi.org/10.1080/0144929x.2018.1427793

Talantsev, A. (2017). Who gains and who loses in the shift to electric vehicles: Impact assessment through multi-criteria multi-stakeholder analysis. *Procedia Environmental Sciences*, *37*(1), 257–268. https://doi.org/10.1016/j.proenv.2017.03.057

Taliotis, C., Fylaktos, N., Partasides, G., Gardumi, F., Sridharan, V., Karmellos, M., & Papanicolas, C. N. (2020). The effect of electric vehicle deployment on renewable electricity generation in an isolated grid system: the case study of

Cyprus. Frontiers in Energy Research, 8(1), 205-212. https://doi.org/10.3389/fenrg.2020.00205

Tappen, R. M. (2011). *Advanced nursing research: From theory to practice*. Burlington: Jones & Bartlett Learning.

Tenny, S., Brannan, J. M., & Brannan, G. D. (2021). *Qualitative study*. Tampa: StatPearls Publishing.

Tepe, B., Figgener, J., Englberger, S., Sauer, D. U., Jossen, A., & Hesse, H. (2022). Optimal pool composition of commercial electric vehicles in V2G fleet operation of various electricity markets. *Applied Energy*, *308*(1), 118351. https://doi.org/10.1016/j.apenergy.2021.118351

Teter, J., Tattini, J., & Petropoulos, A. (2020). *Tracking transport 2020*. International Energy Agency. https://www.iea.org/reports/tracking-transport-2020.

Tobin, G. A., & Begley, C. M. (2004). Methodological rigour within a qualitative framework. *Journal of Advanced Nursing*, *48*(4), 388–396. https://doi.org/10.1111/j.1365-2648.2004.03207.x

Tongwane, M. I., & Moeletsi, M. E. (2021). Status of electric vehicles in South Africa and their carbon mitigation potential. *Scientific African*, *14*(1), 1-12. https://doi.org/10.1016/j.sciaf.2021.e00999

Tran, M., Banister, D., Bishop, J. D. K., & McCulloch, M. D. (2013). Simulating early adoption of alternative fuel vehicles for sustainability. *Technological Forecasting and Social Change*, *80*(5), 865–875. https://doi.org/10.1016/j.techfore.2012.09.009

Triviño-Cabrera, A., Aguado, J. A., & Torre, S. de. (2019). Joint routing and scheduling for electric vehicles in smart grids with V2G. *Energy*, *175*(1), 113–122. https://doi.org/10.1016/j.energy.2019.02.184

Tunçel, N. (2022). Intention to purchase electric vehicles: Evidence from an emerging market. *Research in Transportation Business & Management*, *43*(1), 1-10. https://doi.org/10.1016/j.rtbm.2021.100764

Turton, H., & Moura, F. (2008). Vehicle-to-grid systems for sustainable development: An integrated energy analysis. *Technological Forecasting and Social Change*, *75*(8), 1091–1108. https://doi.org/10.1016/j.techfore.2007.11.013

Uddin, K., Dubarry, M., & Glick, M. B. (2018). The viability of vehicle-to-grid operations from a battery technology and policy perspective. *Energy Policy*, *113*(1), 342–347. https://doi.org/10.1016/j.enpol.2017.11.015

Ummel, D., & Achille, M. (2016). How not to let secrets out when conducting qualitative research with dyads. *Qualitative Health Research*, *26*(6), 807–815. https://doi.org/10.1177/1049732315627427

Un-Noor, F., Padmanaban, S., Mihet-Popa, L., Mollah, M., & Hossain, E. (2017). A comprehensive study of key electric vehicle (EV) components, technologies, challenges, impacts, and future direction of development. *Energies*, *10*(8), 1217. https://doi.org/10.3390/en10081217

uYilo. (2021, August). *Electric vehicle smart grid ecosystem*. Retrieved October 1, 2021, from https://www.uyilo.org.za/facilities-services/smart-grid-ecosystem/

Vaismoradi, M., Turunen, H., & Bondas, T. (2013). Content analysis and thematic analysis: Implications for conducting a qualitative descriptive study. *Nursing & Health Sciences*, *15*(3), 398–405. https://doi.org/10.1111/nhs.12048

Van Heuveln, K., Ghotge, R., Annema, J. A., van Bergen, E., van Wee, B., & Pesch, U. (2021). Factors influencing consumer acceptance of vehicle-to-grid by electric vehicle drivers in the Netherlands. *Travel Behaviour and Society*, 24, 34–45. https://doi.org/10.1016/j.tbs.2020.12.008

Van Welie, M. J., & Romijn, H. A. (2018). NGOs fostering transitions towards sustainable urban sanitation in low-income countries: Insights from Transition Management and Development Studies. *Environmental Science & Policy*, *84*(1), 250–260. https://doi.org/10.1016/j.envsci.2017.08.011

Vasileiou, K., Barnett, J., Thorpe, S., & Young, T. (2018). Characterising and justifying sample size sufficiency in interview-based studies: Systematic analysis of qualitative health research over a 15-year period. *BMC Medical Research Methodology*, *18*(1), 12-21. https://doi.org/10.1186/s12874-018-0594-7

Wang, C., Xu, J., Yang, L., Xu, Y., Zhang, X., Bai, C., Kang, J., Ran, P., Shen, H., Wen, F., Huang, K., Yao, W., Sun, T., Shan, G., Yang, T., Lin, Y., Wu, S., Zhu, J., Wang, R., … He, J. (2018). Prevalence and risk factors of chronic obstructive pulmonary disease in China (the China Pulmonary Health [CPH] study): A national cross-sectional study. *The Lancet*, *391*(10131), 1706–1717. https://doi.org/10.1016/s0140-6736(18)30841-9

Wang, H., & Sun, B. (2021). Diffusion mechanism of leading technology in the new energy industry based on the Bass Model. *Frontiers in Energy Research*, *9*(1), 1-10. https://doi.org/10.3389/fenrg.2021.586787

Wang, M., & Craig, M. T. (2021). The value of vehicle-to-grid in a decarbonizing California grid. *Journal of Power Sources*, *513*(1), 230472. https://doi.org/10.1016/j.jpowsour.2021.230472

Wang, N., Tang, L., & Pan, H. (2018). Analysis of public acceptance of electric vehicles: An empirical study in Shanghai. *Technological Forecasting and Social Change*, *126*(1), 284–291. https://doi.org/10.1016/j.techfore.2017.09.011

Wei, H., Zhang, Y., Wang, Y., Hua, W., Jing, R., & Zhou, Y. (2022). Planning integrated energy systems coupling V2G as flexible storage. *Energy*, *239*(1), 122215. https://doi.org/10.1016/j.energy.2021.122215

Wellings, J., Greenwood, D., & Coles, S. R. (2021). Understanding the future impacts of electric vehicles—an analysis of multiple factors that influence the market. *Vehicles*, *3*(4), 851–871. https://doi.org/10.3390/vehicles3040051

Whitehead, J., Smit, R., & Washington, S. (2018). Where are we heading with electric vehicles? *Air Quality & Climate Change*, *52*(3), 18–27.

Windrim, C., & Higgins, M. F. (2022). Trans-vaginal ultrasound simulation: An exploratory qualitative research study focused on the end-user's perception of learning. *European Journal of Obstetrics & Gynecology and Reproductive Biology*, *270*(1), 201–205. https://doi.org/10.1016/j.ejogrb.2022.01.015

Woo, J. R., Choi, H., & Ahn, J. (2017). Well-to-wheel analysis of greenhouse gas emissions for electric vehicles based on electricity generation mix: A global perspective. *Transportation Research Part D: Transport and Environment*, *51*(1), 340–350. https://doi.org/10.1016/j.trd.2017.01.005

Woodside, J. M., Augustine, F. K., & Giberson, W. (2017). *Blockchain technology adoption status and strategies*. Retrieved December 12, 2022, from https://scholarworks.lib.csusb.edu/jitim/vol26/iss2/4

Wright, J. G., & Calitz, J. R. (2020). *Setting up for the 2020s: Addressing South Africa's electricity crises and getting ready for the next decade*. Retrieved October 1, 2021, from CSIR. https://researchspace.csir.co.za/dspace/handle/10204/1128

Wu, W., & Lin, B. (2021). Benefits of electric vehicles integrating into power grid. *Energy*, *224*(1), 120108. https://doi.org/10.1016/j.energy.2021.120108

Yang, E., Hua, Y., & Diciccio, T. (2018). Diffusion of innovation in sustainable building practices and the role of stakeholders. *Journal of Green Building*, *13*(4), 91–102. https://doi.org/10.3992/1943-4618.13.4.91

Yasmeen, R., Tao, R., Jie, W., Padda, I. U., & Shah, W. U. (2022). The repercussions of business cycles on renewable & non-renewable energy consumption structure: Evidence from OECD countries. *Renewable Energy*, *190*(1), 572–583. https://doi.org/10.1016/j.renene.2022.03.138

Yıldız, İ. (2018). Fossil fuels. *Comprehensive Energy Systems*, *1*(5), 521–567. https://doi.org/10.1016/b978-0-12-809597-3.00111-5

Yilmaz, M., & Krein, P. T. (2013). Review of the impact of vehicle-to-grid technologies on distribution systems and utility interfaces. *IEEE Transactions on Power Electronics*, *28*(12), 5673–5689. https://doi.org/10.1109/tpel.2012.2227500

Zagrajek, K., Paska, J., Sosnowski, Ł., Gobosz, K., & Wróblewski, K. (2021). Framework for the introduction of vehicle-to-grid technology into the Polish electricity market. *Energies*, *14*(12), 3673. https://doi.org/10.3390/en14123673

Zhang, C., Greenblatt, J. B., MacDougall, P., Saxena, S., & Jayam Prabhakar, A. (2020). Quantifying the benefits of electric vehicles on the future electricity grid in the Midwestern United States. *Applied Energy*, *270*(3), 115174. https://doi.org/10.1016/j.apenergy.2020.115174

Zhang, H., Tian, M., Zhang, C., Wang, B., & Wang, D. (2021). A systematic solution to quantify economic values of vehicle grid integration. *Energy*, *232*(1), 121006. https://doi.org/10.1016/j.energy.2021.121006

Zhang, R., & Hanaoka, T. (2021). Deployment of electric vehicles in China to meet the carbon neutral target by 2060: Provincial disparities in energy systems, CO2 emissions, and cost-effectiveness. *Resources, Conservation and Recycling*, *170*(1), 105622. https://doi.org/10.1016/j.resconrec.2021.105622

Zhang, X., Xie, J., Rao, R., & Liang, Y. (2014). Policy incentives for the adoption of electric vehicles across countries. *Sustainability*, *6*(11), 8056–8078. https://doi.org/10.3390/su6118056

Zhou, C., Xiang, Y., Huang, Y., Wei, X., Liu, Y., & Liu, J. (2020). Economic analysis of auxiliary service by V2G: City comparison cases. *Energy Reports*, *6*(2020), 509–514. https://doi.org/10.1016/j.egyr.2020.11.205

Ziegler, D., & Abdelkafi, N. (2022). Business models for electric vehicles: Literature review and key insights. *Journal of Cleaner Production*, *330*(1) 129803. https://doi.org/10.1016/j.jclepro.2021.129803

Zimm, C. (2021). Improving the understanding of electric vehicle technology and policy diffusion across countries. *Transport Policy*, *105*(1), 54–66. https://doi.org/10.1016/j.tranpol.2020.12.012

Zohrabi, M. (2013). Mixed method research: Instruments, validity, reliability and reporting findings. *Theory and Practice in Language Studies*, *3*(2). https://doi.org/10.4304/tpls.3.2.254-262

APPENDICES

APPENDIX A: ESKOMS' EAF TRAJECTORIES & ACTUALS
APPENDIX B: GLOBAL V2G PROJECTS IN DEVELOPMENT
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APPENDIX A: ESKOMS' EAF TRAJECTORIES & ACTUALS



Source: (Eskom, 2022)

APPENDIX B: GLOBAL V2G PROJECTS IN DEVELOPMENT

Project Location	Name	Value traded	Lead Organisation
Australia	Realising Electric Vehicle Services (REVs)	Frequency control	Evo Energy
United Kingdom	Project Sciurus	Energy market price management, Distribution congestion management	OVO Energy
United States (Canada)	ChargeForward	Energy market price management	BMW
Japan	Denso Project	Home energy management	Denso
Australia	100 MW Challenge	Distribution congestion management	Western Power
Denmark	Parker Project	Frequency Control	DTU
United States	JUMPSmartMaui	Renewable energy Integration	Mitsubishi Research Institute
Australia	Smart Charge QLD	Distribution congestion management	Energex

United States	University of California V2G Project	Grid Balancing	University of California, San Diego

Source: Adapted from Jones et al. (2021)

APPENDIX C: INTERVIEW GUIDE

Interview Number	Section	Sub-section (Research Questions)	Interview Questions	Participant Responses
8	**(A)** **Demographics**		Gender	
			Age	
			Qualifications	
			Work Experience	
	(B) **Research Question 1**	**How can V2G adoption play a role in South Africa's energy transition?**	How do you see emerging technologies (such as EVs & V2G technology) playing a role in the South African energy sector?	
			Based on your experience, will the use of V2G technology benefit the ordinary South African? If so, may you explain how?	
			In your view, how can V2G technology adoption address the current electricity challenges in South Africa?	
			Do you think V2G technology could help South Africa overcome the current energy crisis by supporting its energy transition?	
			What do you think is the biggest barrier to V2G technology adoption?	
	(C) **Research Question 2**	**Based on theory, what factors are influencing the adoption of EV adoption in South Africa?**	What are your thoughts on the rate or pace of diffusion/adoption of EVs in South Africa?	
			What do you think the government and other stakeholders in the energy industry can do to promote the diffusion of EVs?	
			Apart from the environmental benefits of EVs, which other benefits do you think are there for stakeholders and ordinary South African	

			citizens that can stimulate the diffusion of the technology?	
			What are your thoughts on government or industry-run awareness campaigns designed to inform individuals, fleets, and car dealerships about the benefits of EVs?	
			Do you think the deployment of EVs in South Africa could support its decarbonization strategy?	
	(D) **Research Question 3**	**What role can different stakeholders in the V2G value chain play in promoting V2G in the country?**	Who do you think are the stakeholders that should be involved in the V2G technology adoption?	
			Are you engaging with any stakeholders in the V2G value chain? If so, what are you doing to promote V2G technology adoption?	
			What are your thoughts on government or industry-run awareness campaigns designed to inform individuals, fleets, and car dealerships about the benefits of V2G technology while also addressing the perceived risks, such as range anxiety or battery degradation?	
			Do you think the current national electricity rules obstruct grid services that will likely be provided by distributed resources such as V2G technology? Please, elaborate.	
			What do you think the best ways would be to speed up the adoption of EVs and V2G technology?	

APPENDIX D: PARTICIPANT INFORMATION SHEET

Project Title	*Vehicle-To-Grid Technology in South Africa's Energy Transition*
Ethics Clearance Reference	**WBS/EL2410574/385**
Supervisor	*Dr Fanny Saruchera*

Dear Sir/Madam,

My name is Thelma Ramutla. I am a master's student at the University of the Witwatersrand's Energy Leadership program. As part of my research, I am investigating how Vehicle-to-Grid (V2G) technology could play a role in South Africa's energy transition. My findings may assist energy planners, policymakers, energy professionals, and other energy sector actors in developing and implement better strategies for this technology.

Because of your knowledge, skills and experience as an expert working in an energy-related sector in the country, I am inviting you to participate in my study and allow me to interview you for approximately one hour. The meeting will take place virtually or at a convenient location for you, and where interruptions will not be a problem. It will be a confidential interview since I will not record your name or organisation. Any information shared will be kept in a locked cupboard in my locked office. If it is electronic, on a double password-protected document on my computer and not shared with anyone else. I will use a code to represent your participation in the documents, my final research report, and any articles resulting from the findings.

I also request that you allow me to audio record the interview so that I do not miss anything you tell me and so I capture the interview accurately. The recordings will be destroyed once I have completed my research and publications. Your participation is voluntary, and you can decline to answer any specific questions or withdraw at any time without any negative consequences. You will not receive any benefits from participating, and I do not anticipate that there will be any negative consequences. Please use the information below to contact my supervisor or me regarding the study. If you would like a summary of the findings, I will gladly supply it to you. However, I will need your contact information.

Many thanks for considering my request for your valuable input.

Yours sincerely,

Researcher: Thelma Ramutla

thelmaramutla@yahoo.com, 0781027078

Supervisor: Dr Fanny Saruchera,

fanny.saruchera@wits.ac.za, 011 717 3787

APPENDIX E: PARTICIPANT CONSENT FORM

Research title: Vehicle-To-Grid Technology in South Africa's Energy Transition

Researcher: Thelma Ramutla

I, ……., agree to participate in the research project named above. The study has been explained to me, and I understand what my participation will involve.

Please circle the relevant options below.

I agree that my participation will remain confidential	YES	NO
I agree that I am volunteering to participate in this project and can withdraw at any time without repercussion	YES	NO
I agree that the researcher may use anonymized quotes from my interview in the research report & publications	YES	NO
I agree that the interview may be audio recorded	YES	NO
I agree that I will not be remunerated for participating in the study	YES	NO

Signature: ……..…

Name (optional) ……

Date ……

APPENDIX F: TRANSCRIBED DATA & DATA CODING FORM

Research question 1: How can V2G adoption play a role in South Africa's energy transition?

Participant	Code number	Transcript	Initial code	Theme
1	**1**	*It looks like a drop in the ocean, but it will assist a lot in public sector vehicles and hospitals. When these vehicles are idling in the night, they can assist in lighting and security at night.*	*Alternative source of electricity at night*	Alternative power supply
3	**2**	*Connecting to the grid and charging your home reduces the load on the national grid. There will be*	*Alternative power supply through connecting to the grid and charging homes*	Alternative power supply

		less load shedding.		
4	**3**	*This will definitely help in terms of making sure that we have enough supply of electricity for the country*	Alternative power source to fill the gap	Alternative power supply
4	**4**	*It gives a variety of options. Let us say, in my house, I use this V2G. This means I will be reducing the bill for Eskom electricity.*	More power options	Alternative power supply
8	**5**	*It can also relieve the stress on the utility grid because then you need to consider other energy sources like renewable*	*EVs and V2Gs technology can also relieve the stress on the utility grid*	Alternative power supply

		energy sources mostly that is how you see the EVs and V2Gs technology playing a role in the energy sector		
10	**6**	*The fact that you are using your vehicle for household (working from home) power when there is no power could be a new door opening to the country.*	V2G can be used when there is load shedding	Alternative power supply
11	**7**	*I see EVs helping in terms of grid stabilization and transport if it's properly rolled out.*	Grid stabilisation	Alternative power supply

12	**8**	*It will drive the shift in energy mix towards renewables*	**Alternative energy sources**	Alternative power supply

Total codes: 8

Theme: Alternative power supply

Participant	Code number	Transcript	Initial code	Theme
Participant 1	9	*We need an energy mix that is reliable at all times – seasons – day and night.*	Electricity availability all the time	Increasing power supply
4	10	*You know because we have shortage in terms of power, if we have so many devices injecting back into the grid it means we will increase the supply*	*Many energy sources increase the supply*	Increasing power supply

5	11	*It could stabilize the grid more than we think*	More energy sources stabilize grid	Increasing power supply
6	12	*One of the things that is causing people to adopt this is the security of the supply problems we have at the moment. Now an EV can solve that problem almost immediately*	Reliable energy supply	Increasing power supply
6	13	*The generation capacity at that level is double the capacity at the 275KV level. And then when you come down with the distribution network to 11KV to 400 Volt. In other words that final transformer,*	Increase in electricity generation and supply	Increasing power supply

		the capacity doubles again.		
7	14	*At the moment we have load-shedding. The strain if reduced there will be very few load-shedding*	More energy and less strain	Increasing power supply
8	15	*This will help to mitigate the current electricity challenge in South Africa because there will be less strain on the grid*	More energy sources stabilize grid	Increasing power supply
9	16	*It can benefit in terms of energy access. Currently we are at 80 percent in terms of access*	Enhanced energy sources	Increasing power supply

Total codes: 8

Theme: Increasing power supply

Research question 2: Based on theory, what factors are influencing the adoption of EV adoption in South Africa?

Participant	Code number	Transcript	Initial code	Theme
4	17	*if we invest in V2G it means our economy will grow in terms of that.*	V2G boosts the economy	Economic benefits
6	18	*We do not have enough electricity for the grid but in places like Vern Ros that used to be an industrial place, businesses have left. There is a lot of grid infrastructure we could use for charging vehicles such as trucks.*	Trucks can be charged to enhance business	Economic benefits
11	19	*Electric public transport will benefit them in*	Lower transport costs	Economic benefits

		terms of reducing the taxi transport.	for electric transport	
13	20	*Obviously if the EVs come in the demand for petrol is lowered and price will go down. There will be more investment in the energy sector*	Reduced fuel costs	Economic benefits

Codes: 4

Theme: Economic benefits

Participant	Code number	Transcript	Initial code	Theme
6	21	*Evs can provide cheaper and efficient transport even in poor communities.*	*cheaper and efficient transport*	Usefulness of Evs

6	22	*What is valued highly is the ability to plug the vehicle to the house. The vehicle can supply energy to the house when there was an outage.*	*It can provide electricity to the house*	Usefulness of Evs
7	23	*You can use your EV to charge appliances at home*	*EV can charge appliances*	Usefulness of Evs
8	24	*If done properly it will stabilize the grid. Allowing vehicles to charge and recharge dynamically*	*vehicles can charge and recharge*	Usefulness of Evs

Number of codes: 4

Theme: Usefulness of EVs

Participant	Code number	Transcript	Initial code	Theme
2	25	*The metering is not ready – municipality will not know how much power they have given to you. The* users can claim they are the ones providing it.	No metering system	Ideal charging infrastructure
5	26	*The question is do we have the infrastructure to bring them in? If SA is serious the gap will be closed. In terms of electricity generation capacity that is where we are*	No charging infrastructure	Ideal charging infrastructure

		lacking in terms of charging		
7	27	*Even now the grid cannot accommodate South Africa at the moment so if we add more EVs today in the mix then obviously we are going to strain the grid*	*grid cannot accommodate V2G*	Ideal charging infrastructure

Number of codes 3

Theme: Ideal charging infrastructure

Participant	Code number	Transcript	Initial code	Theme
2	28	*There is some serious investment on the grid. You need to protect the grid. That is*	*No generation capacity*	Electricity generation capacity

		the most important thing. Unfortunately, we do not have enough capacity.		
7	29	*If we look at infrastructure right now, EVs will put a strain on the grid*	Existing infrastructure has no capacity for V2G	Electricity generation capacity
10	30	*We don't have electricity generation capacity but now you have a vehicle that charges*	*No generation capacity*	Electricity generation capacity
12	31	*We need to review the current electricity capacity to establish whether the grid will be able to absorb or maintain what the EVs will require.*	*No generation capacity*	Electricity generation capacity

Total codes: 4

Theme: Electricity generation capacity

Participant	Code number	Transcript	Initial code	Theme
2	32	*Ideally it should be helpful in reducing carbon emissions and other environmental effects.*	*reducing carbon emission*	Reduction of carbon emissions
2	33	*Clean technology will change the energy profile. It plays a big role*	*Clean technology*	Reduction of carbon emissions
3	34	*You won't have emissions and it does not need any petrol attendants. If we*	Less emissions	Reduction of carbon emissions

		have less vehicles polluting, then we can reduce pollution.		
4	35	*As a clean solution this would definitely work. Definitely because the more we feedback it means the more we depend less on the coal power.*	Clean energy	Reduction of carbon emissions
6	36	*There is a cleaner, more sustainable future for transport.*	Clean energy	Reduction of carbon emissions
7	37	*The department of transport mentioned that, and they are actually contributing more*	*green-house gas solutions*	Reduction of carbon emissions

		green-house gas solutions.		
8	38	*If you think about the transport sector where everything is electrified, then we are going to cut on the greenhouse gas emissions*	Clean energy	Reduction of carbon emissions
10	39	*V2G reduces potential stress on the environment.*	Clean energy	Reduction of carbon emissions

Total codes: 8

Theme: Reduction of carbon emissions

Participant	Code number	Transcript	Initial code	Theme
1	40	*the government doesn't allow us*	Government restrictions	Policies relating to EVs

		to feed into the grid.		
2	41	*We need to do away with monopoly.*	Monopoly	Policies relating to EVs
3	42	*National electricity rules obstruct grid services*	Government interference	Policies relating to EVs
6	43	*The government is also very slow in some respect because we still have very high import tax on EVs*	Higher tax on Evs	Policies relating to EVs
9	44	*You need assurance in terms of regulation and guaranteed returns. Because of load shedding investors are sceptical. Security of supply is questionable.*	Government restrictions	Policies relating to EVs

10	45	*Government is the stumbling block. All the vehicles are imports yet there is not government intervention in terms of price point.*	Lack of government support	Policies relating to EVs

Total number of codes: 6

Theme: Policies relating to EVs

Participant	Code number	Transcript	Initial code	Theme
1	46	*The Evs operate at a charge at a specific km – it can limit people who want to travel- it can be*	Expensive	Affordability

		hard for poor communities.		
2	47	*It is not cost effective because currently it is not based on supply versus demand.*	Expensive	Affordability
3	48	*The cars are quite expensive. To synchronize you will be looking only at household not the nation as a whole. I can't say it will help the problem but maybe at residential level.*	Evs are expensive	Affordability
4	49	*It could be the price that is maybe the other issue and also I do not think the benefit is*	Evs are expensive	Affordability

		emphasized to the public.		
5	50	*It is generally high-end market. It is going to take time for industry to produce EV components*	*high-end market-expensive*	Affordability
6	51	*I think the price of the electric vehicle needs to come down significantly before we can assume much movement there.*	*the price of the electric vehicle needs to come down*	Affordability
8	52	*They are expensive because even the cheapest EV right now is going for between 500 000 and 600 000 there*	Evs are expensive	Affordability

7	53	*At the moment everything is just expensive.*	Evs are expensive	Affordability
10	54	*At the moment you know everything is so expensive.*	Evs are expensive	Affordability

Total number of codes: 9

Theme: Affordability

Research question 3: What role can different stakeholders in the V2G value chain play in promoting V2G in the country?

Participant	Code number	Transcript	Initial code	Theme
1	55	*The government owns a high number of vehicles, so they are capacitated to do campaigns*	Awareness campaigns	Role of government

		and support other manufacturers.		
2	56	*Government should introduce incentives for EVs as they are too expensive and look luxurious.*	Incentives	Role of government
4	57	*They need to support in terms of charging, every petrol station should have at least one charging system so that if you buy the car, you will have support*	Provision of charging infrastructure	Role of government
8	58	*So obviously the government needs to be involved in the policy making.*	*Policy making.*	Role of government
5	59	*They can create incentive*	Incentives	Role of government

		programs for local manufacture. We rely on imports regards to components of EVs.		
7	60	*Government incentives will go a long way. In some states they give subsides if you want to buy the car.*	Incentives and subsidies	Role of government
12	61	*It is too early but we are supporting the introduction of key value chain items and monitoring signals and start-up businesses activity to make the move at the right time.*	Supporting EV businesses	Role of government

Total number of codes: 7

Theme: Role of government

Rate of adoption of EVs

Participant	Code number	Transcript	Initial code	Theme
1	62	*On the rate of adoption, firstly I will say the EVs are expensive, and SA is a very unequal society. A high majority cannot afford. It is slow because it is seen as a luxury.*	Slow adoption	Rate of adoption of EVs
2	63	*Whether it's Tesla or Hyundai? They are taking too long. It took the government more than 15*	Slow adoption	Rate of adoption of EVs

		years to create the grid		
3	64	*The affordability is my concern. I think that is my number one concern. It is those with high level skills that will be able to stay*	Slow adoption due to high costs	Rate of adoption of EVs
4	65	*It`s slow. I do not even think we are anywhere with this technology in South Africa because we don`t even have hear about this thing anywhere.*	Slow adoption	Rate of adoption of EVs
6	66	*You know this whole issue of ESKOM is unreliable because if it was reasonably reliable I do not*	Slow due to Eskom unreliability	Rate of adoption of EVs

		think you`d have a problem to charge an EV		
12	67	*The demand is exceeding supply without a supportive structure in place to off-set the price premium to consumers*	Slow because they are expensive	Rate of adoption of EVs
13	68	*They are taking too long. It took the government more than 15 years to create the grid.*	Government delay	Rate of adoption of EVs
6	69	*Maybe the other barrier is the slowness of municipal distributors to adopt new technology.*	*low to adopt new technology.*	Rate of adoption of EVs
8	70	*The uptake of these EVs is*	*Slow uptake*	Rate of adoption of EVs

		quite slow so, we need a lot of these EVs so that the V2G technology can be used.		
3	71	*. I cannot ignore the local context. We just import and assemble which lessens job security. It is scary; one has to think about it, our economy will not hold it.*	Slow because they are expensive	Rate of adoption of EVs
4	72	*You know if we were somewhere with it, we would be, if you ask any ordinary citizen about this thing, they probably don`t even know what you are talking about.*	Slow due to lack of awareness	Rate of adoption of EVs

Total codes: 10

Theme: Rate of adoption of EVs

Participant	Code number	Transcript	Initial code	Theme
1	73	*We need shows on Tv. It has to involve a lot of people- the government can impose the platinum angle*	Awareness campaigns	Awareness campaigns by government
2	74	*We need to give guarantees that this thing can last you ten years but apparently it is not happening. Campaigns are not fully promoting.*	Market the EV products	Awareness campaigns by government
3	75	*There should be work on better awareness. They*	Awareness campaigns	Awareness campaigns by government

		are not promoting.		
4	76	*We need things like webinars. I am saying webinars because they are educational so at least we can educate people while they are there in the webinar*	Awareness campaigns	Awareness campaigns by government
5	77	*We just need awareness- people talking about it, actually using them.*	Awareness campaigns	Awareness campaigns by government
7	78	*The awareness still needs a boost. Student can also share the knowledge.*	Awareness campaigns	Awareness campaigns by government
8	79	*Our organization is also part of that government*	Awareness campaigns	Awareness campaigns by government

		initiative to raise awareness		
9	80	*Stakeholders can take advantage of social media to raise EV awareness.*	Awareness campaigns	Awareness campaigns by government

Total number of codes: 8

Theme: Awareness campaigns by government

Participant	Code number	Transcript	Initial code	Theme
1	81	*Some products are not needed but when people start sharing its value demand can increase.*	Collaboration	Private sector and partnerships
2	82	*If we engage the private sector, we will close the*	Private-public partnerships	Private sector and partnerships

		gaps much quicker.		
3	83	*I think engagement and collaboration with the motor industry and users will help. Information sharing and collaboration can be used to entice investors.*	Collaboration	Private sector and partnerships
4	84	*We need to collaborate. The government needs to play a role the private sector needs to also play a role for it to work*	Collaboration	Private sector and partnerships
5	85	*Partnerships between dealerships, charging infrastructure, companies and*	Collaboration	Private sector and partnerships

		consumers are needed		
6	86	*The government might start promoting the manufacturers of EVs,*	Collaboration	Private sector and partnerships
8	87	*So obviously the stakeholders that should be involved is obviously the ESKOM, with the generation, so the ESKOM guys, and also the municipality,*	Collaboration	Private sector and partnerships
11	88	*We are engaging in the value chain in terms of charging, AC and DC devices.*	Collaboration	Private sector and partnerships
13	89	*If we engage the private sector, we will close the*	Private-public partnerships	

		gaps much quicker.		Private sector and partnerships
12	90	*Prepare the energy grid for EV adoption, provide supporting regulation to drive adoption of EV, provide investment into localisation of EV value chain elements to ensure a just economic transition*	Private-public partnerships	

APPENDIX G: ETHICS CLEARANCE FORM

Graduate School of Business Administration
University of the Witwatersrand, Johannesburg

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

Ethics Clearance Certificate

Ethics protocol number: WBS/EL2410574/385
This certificate is only valid with a legitimate ethics protocol number and signed by the Researcher (below).

Project title	Vehicle-to-grid technology in South Africa's energy transition
Investigator / Researcher	Ms Machwene Thelma Ramutla
Nature of Project	MM (Energy Leadership)
Decision of the Committee	Approved, provided stakeholders and participants are guaranteed confidentialty.
Issue Date of Certificate	2022-06-01
Expiry date	Date of submission of the project / research report
Chairperson	Prof Anthony Stacey ☎ +27 11 717 3587 +27 82 880 4531 anthony.stacey@wits.ac.za

Declaration by Researcher

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

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

Signature

02 June 2022
Date:

APPENDIX H: LANGUAGE-EDITING CONFIRMATION

LANGUAGE-EDITING CONFIRMATION

To whom it may concern:

This memo serves to confirm that the manuscript/research project detailed below has been language-edited and/or proof-read.

Regards,

M. Sine *(Ed.)*
Contact: +27639364636
sarchcot@gmail.com

****

Title:

VEHICLE-TO-GRID TECHNOLOGY IN SOUTH AFRICA'S ENERGY TRANSITION

Author:

Machwene Thelma Ramutla

Issued on:

05/02/2023

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The editors (proofreaders) detach themselves from the accuracy of the manuscript contents nor the objectives of the author. While all possible efforts have been made to ensure the text as edited is readable and grammatically correct, the author had the option to accept or reject suggestions and trackable changes made to the document before submission.

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