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Assessing the Adoption of Green Hydrogen in South Africa

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ABSTRACT

South Africa is grappling with an energy crisis due to the depletion of fossil fuels deteriorating infrastructure and governmental challenges; aggravated by the increasing electricity demand and inadequate capacity to meet supply requirements. Green hydrogen can potentially assist with the alleviation of the energy crisis. This study assessed the potential for South Africa to manufacture and utilise green hydrogen as an alternative energy source focusing on the opportunities and the challenges. Data was collected through interviews with subject matter experts using thematic analysis. The study provided key insights on the adoption of green hydrogen in South Africa with government playing a pivotal role in unlocking the adoption of hydrogen in South Africa. The findings also indicated that South Africa has abundant land availability and renewable energy resources to produce green hydrogen. However, there are significant challenges with regards to technology, infrastructure, and legislative structures that limit the manufacture of green hydrogen. The study repeatedly addressed the capital and production costs of green hydrogen.

KEYWORDS

Green hydrogen, Electrolyser, South Africa, Renewable Energy, Desalination

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CHAPTER 1. INTRODUCTION

1.1 Statement of Purpose

This qualitative study, utilised thematic analysis, assessed the adoption of green hydrogen in a South African context.

1.2 Background of the Study

Coal has been the main source of power in South Africa for well over a hundred years. Approximately ninety percent of the electrical energy in South Africa is generated from coal sources (Qu, 2022). South Africa is one of the major producers of coal in Africa (Joshua & Alola, 2020). Although coal plays a crucial role in enabling electricity production and powering industrial processes; coal contributes to pollution, creating health hazards and environmental challenges (Nkambule & Blignaut, 2017). Coal is a complex organic matrix of hydrogen, nitrogen, sulphur, and other constituents. When burned, it emits greenhouse gases such as carbon dioxide and nitrogen oxides. The energy subdivision accounts for 80% of the greenhouse gases emitted in South Africa (NPC, 2018).

One of the reasons contributing to South Africa's energy crisis is due to finite coal stock and is currently experiencing electricity power cuts due to Eskom (the state-owned, essentially, the sole supplier of electricity) being unable to meet the energy demands (Mabunda, Munyaradzi, & Mudzanani, 2023). Due to the depletion of fossil fuels and the associated extreme carbon dioxide being released, renewable energy has been on the agenda for some time (Imasiku, Farirai, & Olwoch, 2021). Green hydrogen is one the possible alternatives that one can use as less carbon-intensive feedstock for energy (Qu, 2022). Green hydrogen produced in South Africa can solve the country's energy demand and provide a cash injection to the economy while providing jobs that will elevate living standards (Abouseada & Hatem, 2022). South Africa and Namibia have expressed keen interest in green hydrogen production (Hamukoshi, Mama, Shimanda, & Shafudah, 2022).

Green hydrogen can be generated via water electrolysis utilizing energy from sustainable resources such as solar, wind, and hydro. There are no carbon dioxide discharges from the manufacture of green hydrogen, it can be categorized as a green product (Azadnia, McDaid, Andwari, & Hosseini, 2023). The use of hydrogen can be classified into dualistic clusters. The first group is that hydrogen can be employed as an input material for industrial purposes, specifically in industries that consume large volumes of energy. The second category that hydrogen can be utilized for is as a carrier of energy enabling energy transition (G. Kakoulaki, 2021).

South Africa has the ideal conditions for solar and wind energy (Ayodele, 2019). The Industrial Development Corporation has developed a green hydrogen commercialization strategy (GHCS). The GHCS stipulates that South Africa can be a forerunner of green hydrogen manufacture (IDC, 2023). This will form part of the economic stimulation that is required in South Africa.

1.3 Research Problem

South Africa is facing critical energy challenges as the carbon-intensive resources are dwindling, except for the remote Waterberg area, and poses serious environmental challenges (Spalding-Fecher, Williams, & van Horen, 2000). Green hydrogen can be an alternative energy source for South Africa due to its plentiful opportunities for renewable energy resources. Green hydrogen can potentially address the energy crisis that South Africa faces as well as possibly produce economic stimulation for the country (Abouseada & Hatem, 2022). In addition to green hydrogen assisting with the energy crisis, the consumption of green hydrogen will decrease the amount of carbon emissions (Nnabuife, et al., 2023). However, there are challenges/barriers that the adoption of green hydrogen faces, including policy updates technological maturity, and infrastructure requirements (World Bank, 2020).

Sub-problem 1:

Technological challenges for producing green hydrogen in South Africa.

Sub-problem 2:

Key infrastructural barriers concerning storage and distribution of green hydrogen.

Sub-problem 3:

Lack of regulations and policies that prohibit the promotion of green hydrogen.

Sub-problem 4:

The identification of key areas of opportunities to increase the adoption of green hydrogen in South Africa

The study aimed to answer the following research questions:

Main Question: What are the challenges/barriers and opportunities of adopting green hydrogen in South Africa?

1. What are the technological challenges for producing green hydrogen in South Africa?
2. What are the infrastructural barriers relating to the storage and distribution of green hydrogen?
3. How does the lack of regulations and policies inhibit the promotion of green hydrogen?
4. From the identified challenges/barriers, what opportunities can be suggested to accelerate the adoption of green or sustainable hydrogen in South Africa?

1.4 Research Objectives

The objectives of the study include assessing the challenges that South Africa faces with the adoption of green hydrogen while providing an in-depth understanding of the opportunities. The objectives are stated below:

1. Identify global trends utilised for the adoption of green hydrogen.

2. Assess the technological challenges associated with generating green hydrogen.

3. Identify the key infrastructural barriers to the storage and distribution of green hydrogen.
4. Identify regulations and policies that promote the expansion and use of sustainable or green hydrogen and identify gaps in the policy.
5. From the challenges/barriers identified, recommend opportunities to accelerate the adoption of green hydrogen.

1.5 Rationale

According to Abouseada and Hatem (2022), green hydrogen has the potential to address the energy crisis, decrease greenhouse gas emissions, and stimulate economic growth in South Africa. The scope created a framework for completing research and producing insights that can be used for decision-making and investment opportunities to ensure for sustainable outlook for South Africa.

1.6 Delimitations of the Study

The scope of the study was limited to the production and use of green hydrogen in the South African context. The study focused on technology, policies, and infrastructural challenges and opportunities. This study focused on energy created by wind and solar sources. This study fixated on electrolysis pathways utilising wind and solar energy. Hence, energy generated from biomass was excluded. The focus was on the green hydrogen used in the chemicals and steelmaking industry. The usage of hydrogen in the transport industry will be excluded. The socio-economics aspects of the adoption of green hydrogen such job opportunities and upliftment aspects were excluded from this study.

1.7 Definition of Terms

Electrolyser is an equipment that is employed to separate water into hydrogen and oxygen (IRENA, 2022).

1.8 Assumptions

The assumptions are listed below:

1. Participants, chosen for the research, has the expertise and insight to respond to the questions.

2. It was assumed that the scope of this study will adequately address the research problem.

CHAPTER 2. LITERATURE REVIEW AND THEORETICAL FRAMEWORK

2.1 Introduction

Chapter Two reviewed existing literature on green hydrogen adoption in South Africa, drawing on journal articles, books, and reputable websites to provide a comprehensive analysis. The chapter is structured according to the answering the following research objectives:

1. Identify global trends utilised for the adoption of green hydrogen.

2. Identify regulations and policies that promote the expansion and use of sustainable or green hydrogen and identify gaps in the policy.

3. Assess the technological challenges associated with generating green hydrogen.

4. Identify the key infrastructural barriers to the storage and distribution of green hydrogen.

The information presented in this chapter serves as the foundation for answering the research questions.

2.2 Global Trends for Adopting Green Hydrogen

2.2.1 Global Trends on Green Hydrogen Adoption

To date, Japan, Germany, South Korea, Australia, the United States, and the United Arab Emirates are the forerunners in producing green hydrogen (Pancheko, et al., 2022). In terms of the trends observed the following factors are critical to the success of green hydrogen production: economies of scale are required to ensure cost-effectiveness, policy support is needed, technological innovation and investments are driving factors promoting the production of green hydrogen (Agyekum, et al., 2022). These countries are successful with the

implementation of green hydrogen due to the fact that they have strong national strategies that was supported by government funding. These countries leveraged abundant renewable energy to produce hydrogen in a cost effective manner. Additionally, these countries also invested in infrastructure, global partnerships and innovation to scale production and drive adoption (IRENA, 2022).

As seen in Figure 1, over sixty strategies have been developed throughout the world. These strategies highlight the necessity of green hydrogen and the infrastructure required to support it. European Union has progressive green hydrogen strategies concentrating on increasing production via the “Green Deal”. Australia’s strategy is focused on utilising renewable energy resources. Africa, Asia, Latin America, and the Caribbean could produce and export green hydrogen, but high production and infrastructure costs are major obstacles (Bank, 2020). Despite Africa’s potential to produce green hydrogen, skills development is required to enable the green hydrogen capacity (Rendezvous, 2022).



Figure 1

Hydrogen strategies per country

Source (IRENA, 2022)

2.2.2 Proposition one

Green hydrogen is still in its initial stages in most countries; however, South Africa has the potential to be part of the leading countries producing hydrogen.

2.3 Technological Feasibility

The technological assessment includes the renewable energy resources, electrolysers, water, and land that are required to enable the manufacture of green hydrogen.

2.3.1 Renewable Energy and Electrolysers

Renewable energy and water electrolysers are the two important components to produce green hydrogen. An electrolyser breaks water into the natural elements of hydrogen and oxygen utilising electricity (Nasser, Megahed, & Hassan, 2022). The International Renewable Energy Agency proposes that the price of producing sustainable hydrogen may decline by fifty percent due to the decreasing costs of electrolysers and renewables; efficiency, and economies of scale will improve (Baral & Sebo, 2024). Electrolysers can be scaled to different grid sizes and the required configurations (Cozzolino & Bella, 2024). This is to allow for upscaling of production.

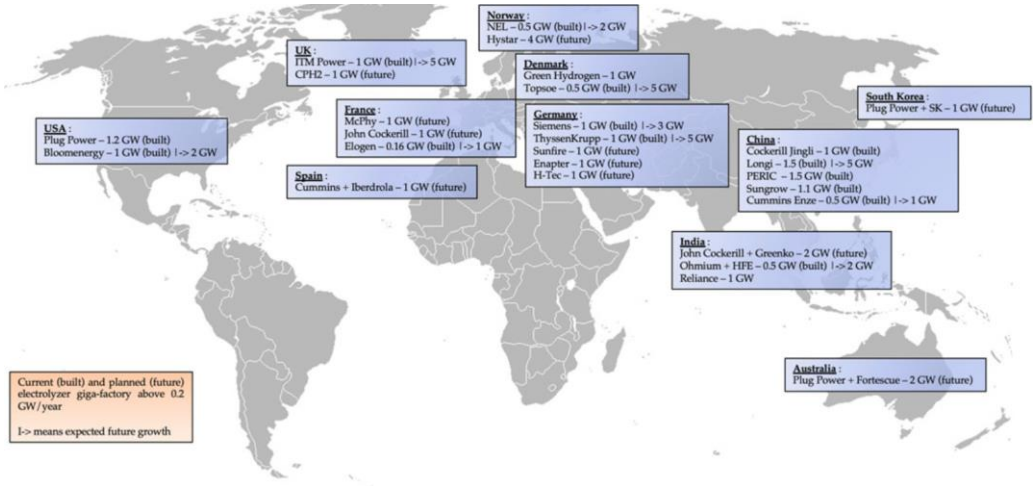


Figure 2

Current and planned electrolyser production

Source (Cozzolino & Bella, 2024)

As seen in the figure above, South Africa does not manufacture electrolysers. This will result in South Africa importing electrolysers, or a company opening up an electrolyser factory.

Table 1

Green Hydrogen Potential.

No.	Region	Estimated energy capacity, Exajoule (EJ)	Percentage value
1	Sub-Saharan Africa	2715	28.6
2	Middle East and North Africa	2023	21.3
3	North America	1314	13.8
4	Oceania (Australia)	1272	13.4
5	South America	1114	11.7
6	Rest of Asia	684	7.2
7	Northeast Asia	212	2.23
9	Europe	88	0.92
10	Southeast Asia	64	0.67

Source (Zainal, et al., 2024)

From Table 1 above, Sub-Saharan Africa possesses the highest capability to manufacture green hydrogen due to the availability of natural resources.

2.3.2 Water and Land Availability

Water is an essential input into the process of hydrogen production as large quantities are required for the electrolysis process. Due to South Africa being a water-scarce nation, desalination systems would be required which can be capital intensive, and acquiring the relevant technologies may be problematic (Beswick, Oliveira, & Yan, 2021).

Furthermore, large areas of land are required to install solar and wind panels to obtain renewable energy. South Africa also has just over one million km^2 and only nine percent is deemed as protected. This is low in contrast to other countries that have hydrogen-producing potential and decreases the trade-offs with sustainability aspirations (Thomann, et al., 2022).

Green hydrogen can also allow for investments in desalination plants which in turn can assist rural communities with their water scarcity issues (Burck, et al., 2023).

2.3.3 Proposition two

Electrolysers, the desalination process, and the reliance on wind and solar panels pose significant challenges to green hydrogen production, primarily due to high costs.

2.4 Infrastructure barriers

The storage capacity and distribution of green hydrogen are critical factors for its successful adoption in South Africa.

2.4.1 Storage and Distribution

Depending on the usage of green hydrogen it may be stored in either solid, liquid, or gaseous state (Maka & Mehmood, 2024). The issue with the storage of hydrogen is its low density, cryogenic tanks are required for storage. Storage of hydrogen can either be underground or on the surface, the main considerations with storage are safety and efficiency (Abe, Popoola, & Ajenifuja, 2019).

Road transportation is a favourable option for delivering green hydrogen to end-users (Rambhujun, et al., 2020). Using existing infrastructure such as gas pipelines would lower the transportation cost of hydrogen (IRENA, 2022). Driving global markets for green hydrogen will enable economies of scale and this can decrease overall expenses (Sadiq, et al., 2023).

2.4.2 Proposition three

South Africa can repurpose existing infrastructure for green hydrogen utilisation.

2.5 Regulations and Policies Development

2.5.1 South Africa's Policy on Green Hydrogen Development

South Africa has embarked on just transition strategies that recognize the influence that energy transition has on workers, communities, and livelihoods of South Africans (Presidency, 2022). Developing the export industry is critical to creating the regional market and hastening the switch to green hydrogen. Policy documents state that locking in global markets justifies the investments in locally (DTIC, 2022).

Extensive consultation between the private companies and local government resulted in the development of a roadmap for initiatives that will accelerate the green hydrogen agenda (DSI, 2021). The main project is the Platinum Valley corridor which connects multiple provinces. This initiative connects the mining industry to the port, incorporating the mobility, industrial, and building corporations. Other projects include producing aviation fuel for global markets,

international green ammonia and hydrogen ventures as well as carbon capture alternatives (DSI, 2021).

The Green Hydrogen Commercialization Strategy has listed over thirty active initiatives. These initiatives vary in stages consisting of concept design, feasibility demonstration (DTIC, 2022). This strategy is aimed at attracting private sector players such as Sasol, Anglo-American, Toyota, Linde, Impala Platinum, Engie and Arcelor Mittal Steel (Gevaert et al., 2023).

2.5.2 Proposition four

South Africa's policy development is well established, however; it lacks incentivising stakeholders to either produce or utilise green hydrogen.

2.6 Sustainability Framework

The term Triple Bottom Line devised by Elkington (1977) has become the adopted approach for most companies. This model serves as a strategic lever for companies to transition into the sustainability pillars of sustainable development, environmental concerns, social justice, and economic advantages (Elkington . J., 1998). The most favourable model to articulate sustainability is the Venn diagram (Figure 3), also known as the nested spheres model. Sustainability is illustrated where all three aspects of the Triple Bottom Line intersect (Sandhu, McKenzie, & Harris, 2014).

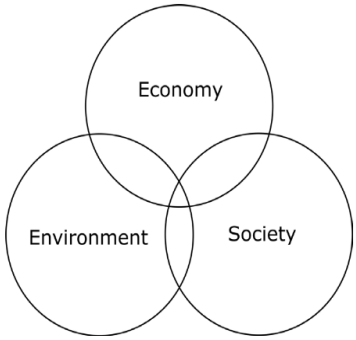


Figure 3

Triple Bottom Line

Source (Sandhu, McKenzie, & Harris, 2014)

The economic aspect focuses on the amount of value that the company creates however it goes beyond that to include economic and operational impact on society. Economic sustainability is a critical aspect since the economic crisis in 2008 affected financial stability. Initial investment in green hydrogen infrastructure is significantly higher but the long-term economic benefits and increased energy security. The social aspect, people, includes the welfare of both the employees and the community and addressing social injustices. This increases the Corporate Social Responsibility initiatives. The adoption of green hydrogen has positive social impacts such as new job opportunities as the manufacture of green hydrogen can assist with the economic development in the communities where it is implemented. The environmental aspect, referred to as the “planet”, reflects the company’s plans to minimise its ecological footprint. This aspect is considered to be the most important for scholars because everything else is dependent on the Earth’s resources (Sheth, Sethia, & Srinivas, 2011). Green hydrogen production offers substantial environmental benefits for all stakeholders in the value chain.

The Triple Bottom Line framework provides a comprehensive approach to assessing sustainability initiatives and organisations can evaluate the holistic impact of green hydrogen and make knowledgeable decisions.

2.7 CONCLUSION OF LITERATURE REVIEW

Chapter 2, the literature review has studied the aspects of opportunities and challenges of adopting green hydrogen technologies in South Africa.

Proposition one

Green hydrogen is still in its infancy stage in most countries; however, South Africa has the potential to be part of the leading countries producing hydrogen.

This proposition addressed objective one.

Proposition two

Electrolysers, the desalination process, and the reliance on wind and solar panels pose significant challenges to green hydrogen production, primarily due to high costs.

This proposition addressed objective two.

Proposition three

South Africa can repurpose existing infrastructure for green hydrogen utilisation.

This proposition addressed objective three.

Proposition four

South Africa’s policy development is well established, however; it lacks incentivising stakeholders to either produce or utilise green hydrogen.

This proposition addressed objective four.

CHAPTER 3. RESEARCH METHODOLOGY

3.1 Research Approach

Due to the nature of the research objective of determining what are the challenges and opportunities of South Africa adopting green hydrogen, the research approach lends itself towards a qualitative approach (Creswell & Creswell, 2009). The use of dense descriptions of the subjects, experiences, and views; as well as an interpretation of the subjects' actions was used to obtain insights into the green hydrogen opportunities and challenges (Denzin, 1989). Due to the nature of the challenges and opportunities of green hydrogen, the qualitative approach was utilised to gain a deeper understanding of the study (Chalhoub-Deville & Deville, 2008).

3.2 Research Design

Research design was the blueprint for developing the research process. This research employed an exploratory research design approach (Leavy, 2017). Data was obtained via interviews. However, there are some disadvantages of the qualitative approach. The disadvantages of this design are subject to researcher bias and skewing the interpretation of information (Miles, Huberman, & Saldana, 2014). Another limitation was the dismissal of contextual sensitivities and to zone in on both experiences and meanings (Silverman, 2010).

3.3 Data Collection Methods

One-on-one interviews were used as tools to collect data about the participants' views, knowledge, and experiences about a specific topic (Lambert & Loiselle, 2007). The semi-structured approach was employed. This allowed for the information to be collected in an organized and thorough manner (Oflazoglu, 2017). Open-ended questions were used. The interviews were completed via an electronic channel such as Microsoft Teams or Zoom, depending on the participant's preference.

3.4 Population and Sample

The population and sample strategies are described in the following two sections.

3.4.1 Population

It's critical to select the correct participants because it will impact the findings of the study (Wrona & Gunnesch, 2016). South Africa has been selected for this research because of its green hydrogen ambitions that are intended to alleviate the country's energy and economic crisis (Abouseada & Hatem, 2022). The population included potential green hydrogen producers, consumers, and electrolyser manufacturers. From the literature review petrochemical, mining, steel manufacturing, and electrolysers manufacturers' were identified as the private sector players (Gevaert et al., 2023).

3.4.2 Sample and Sampling Method

Non-probabilistic sampling worked well as the researcher required information from participants who has experience and expertise in the green hydrogen space and provided insight into the challenges and opportunities (Saunders, Lewis, & Thornhill, 2019). The purposive sampling was applied to individuals who work on projects that are related to the manufacture, utilisation of green hydrogen, and the manufacture of electrolysers. The sample size of this research consisted of fifteen individuals in senior management roles. The sample comprised of participants with whom the researcher has previously worked, as well as those recruited through referrals.

3.5 The Research Instrument

The questionnaire used for this research can be found in Appendix A with the consent letter to the participant in Appendix B. The questionnaire developed was guided by both the research objectives and the literature review.

3.6 Procedure for Data Collection

The researcher approached the participants directly.

3.7 Data Analysis Strategies and Interpretation

Thematic content analysis was utilised to analyse the data from the interviews. The thematic content analysis included identifying, analysing, and interpreting patterns from the data (Braun & Clarke, 2019). This process involved transcribing and understanding the data, and then selecting the phrases or quotations. The second step selected the keywords. The third step contained the data coding process. The fourth step was whereby themes were developed. Thereafter, the conceptualisation was completed by interpreting themes, keywords phrases, and codes. The final step was to develop a conceptual model**,** of the challenges and opportunities of South Africa adopting green hydrogen (Naeem et al, 2023).

3.8 Possible Limitations and Challenges of the Study

The restrictions of this study were confined to stakeholders identified in the literature review. There could be potentially other role players in the green hydrogen space that have not publicly mentioned their intentions. This could have impacted the findings. Participant bias can occur due the limited exposure,

knowledge, and experience. There may have been unintentional researcher bias. There were also constraints on the time and the participant's availability.

3.9 Quality Assurance

3.9.1 Transferability

Transferability can be achieved utilising a rich description of the data collected (Morse, 2015). Future researchers can apply this study to other perspectives in the green hydrogen space.

3.9.2 Credibility

Data was triangulated by using the literature review and the interviews to ensure that credibility was maintained (Cypress, 2017). The participants are senior leaders and subject matter experts.

3.9.3 Dependability

Dependability was maintained by guaranteeing that the research was well-documented and logical (Shenton, 2004). The data collected can be traceable; if this research was replicated employing the same participants, and methods, the outcomes would be consistent.

3.10 Ethical Considerations

The relevant documentation was presented to the Ethics Committee for consent. Appendix B has the consent form that states the informed, voluntary consent before the interview can take place. The participants' responses are kept private and secure. Pseudonyms were utilised to anonymise data, store the transcripts and recordings. The recordings are stored and handled securely to prevent

unauthorised access. The interviews were conducted in a manner that respected the participant's rights, dignity, and autonomy.

CHAPTER 4. ANALYSIS OF RESULTS

4.1 Introduction

This chapter demonstrated the qualitative findings that are required for achieving the research objectives. A total of eleven face-to-face and online interviews were concluded with various subject matter experts who are involved in the green hydrogen domain. The interviewees are from major petrochemical, steelmaking industries and consultants involved with green hydrogen development. The study utilised a non-probability sampling technique.

The completing interviews aimed to collate information that was intended to provide insights into the following research questions below:

Main Question: What are the challenges/barriers and opportunities of adopting green hydrogen in South Africa?

1. What are the technological challenges for producing green hydrogen in South Africa?
2. What are the infrastructural barriers relating to the storage and distribution of green hydrogen?
3. How does the lack of regulations and policies inhibit the promotion of green hydrogen?
4. From the identified challenges, what opportunities can be suggested to accelerate the adoption of green hydrogen in South Africa?

This chapter consists of the following sections:

Section A: Outlined the participants' general information such as their gender, job designation, and years of experience within the industry.

Section B: Displayed the outcomes of the study that are organised according to themes.

4.2 Section A: Description of the Interviews

This investigation utilised a non-probability sampling method since the researcher did not have access to the entire population. A total of eleven structured interviews with subject matter experts and senior management within the green hydrogen domain was completed.

Table 2

General information about the participants

Participant	**Current position**	**Years of experience**	**Gender**
P1	Engineering Manager	21	Male
P2	Senior Process Engineer	20	Female
P3	Head of Low Carbon Solutions	26	Male
P4	General Manager	13	Male
P5	Chief Executive Officer	36	Male
P6	Senior Mechanical Engineer	13	Male
P7	Senior Business Development Specialist	18	Female

P8	Vice President Hydrogen Technical	32	Male
P9	Project Manager for Alternate Energy	19	Male
P10	Head of Policy, Stakeholder & communications management for Green Hydrogen Projects	17	Male
P11	Senior Programme Manager Sustainability	19	Male

The interviews were performed with the applicable permissions granted by the Ethics Committee and the participants themselves. The code of ethics was adhered to in all interviews.

The interviews were conducted until there were no further insights gained and saturation point was achieved.

The participants were identified via the researcher's network and some referrals. All participants are based in South Africa.

4.3 The Coding Process

Thematic analysis was utilised as the technique to code the transcribed data from the interviews to determine themes and patterns. The process of identifying, analysing, and reporting the data patterns serves as the basis for the thematic analysis. This was the basis of qualitative analysis. The process involved the researcher becoming immersed in the data and then identifying themes. The first part of the process was to understand the data, complete initial coding and

develop the codebook and review, recode, and reclassification of the data to determine the themes.

During the literature review codes were created, while others were determined during the coding development. When subsequent interview data was coded and the codes did not change the content of the codebook, data saturation was achieved. Each question from the questionnaire was ranked according to the number of themes identified with rankings listed in descending order.

4.4 Section B: Presentation of the Findings

The findings of the study was categorised according to the sub-questions relating to the research questions.

4.4.1 What are the Technological Challenges for Producing Green Hydrogen in South Africa?

This question aimed to explore the technological challenges that producers may face in the manufacturing of green hydrogen.

4.4.1.1 Electrolysers

The themes that were discovered from the interviewee's responses relate to the cost and sourcing of electrolysers, sustainable energy requirements, economies of scale, and maturity of the technology.

Table 3

Themes identified for the electrolyser challenges

Rank	Theme	Frequency
1	Cost and Sourcing of Electrolysers	24
2	Sustainable Energy Requirements	17
3	Economies of Scale	10
4	Maturity of Technology	8

4.4.1.1.1 Cost and Sourcing of Electrolysers

The interviewees acknowledged that the electrolysers pose an issue for the manufacture of sustainable hydrogen. The responses indicated that the cost of the electrolysers is high and that sourcing the electrolysers is an issue because it needs to be imported. The interviewees' quotes are depicted in the table below.

Table 4

Participant responses for cost and sourcing of electrolysers

Participant	Description of code
P1	“Technology perspective, it is the electrolysers. So can we say it's the solar panels and it is the electrolysers that would require a capital cost.”
P2	“The major one, is the cost and sourcing of the technology because we do not have manufacturers within South Africa or Africa. So, everything is sourced from the global platform, which adds schedule pressure as well to this logistics, which is another factor.”
P2	“The major challenge for producing green hydrogen now is costing and access to technology. “
P3	“We're not manufacturing any electrolysers locally. At the moment these are imported, and it is a little bit tricky, but it is not something we cannot overcome.”
P6	“If you have to compare greenhouse to coal, it remains expensive to produce.”
P8	“So, a lot of the manufacturers will be quite willing to set up shop in the country where there's a demand.”
P9	“So, one of the major stumbling blocks is you need a green energy source as well and the actual technology used for greenhouse production is quite a high consumer of energy. It questions the viability of most green hydrogen projects. It ultimately comes down to the financial aspect proving to be one of the major challenges at the moment.”

4.4.1.1.2 Sustainable Energy Requirements

To produce green hydrogen, sustainable energy is required to operate the electrolysers. The participants indicated that large quantities of sustainable energy are required. Sizable volumes of solar panels would be essential and capital costs would be needed for the purchase of these panels.

Table 5

Participant responses for sustainable energy

Participant	**Description of code**
P1	“The major challenges are the electricity demand for those electrolysers, but that's sort of magnitude as well if you want to produce high-quality stream.”
P3	“The key thing that we have seen seeing is the fact that you have to have exceptional renewable electricity. For these things to work on an hourly basis.”
P3	“So, the problem in South Africa is we don't have good enough for renewable electricity and it sounds counterintuitive because we've got so much sun and when but it's just not good enough to compete with the rest of the world.”
P4	“The energy required to produce green hydrogen and where do you get that energy from looking at cradle to grave.”
P5	“Solar will only work if the sun is shining. The wind only works when the wind is blowing. You are going to have a

	finite number of resources like natural gas, and you have to look at some other alternative water.”
P11	“The country is not necessarily geared up to be able to supply large amounts of electricity that we need, so that introduces more costs.”

4.4.1.1.3 Economies of Scale

The interviewees noted that due to the investment costs required for the setting up of the facility, it is better to have a large-scale operation to obtain the economies of scale benefit in terms of the costs.

Table 6

Participant responses for economies of scale

Participant	**Description of code**
P1	“Technology perspective, it's the electrolysers. The major challenges are the electricity demand for those electrolysers.”
P2	“So, it is pointless going smaller, right? Because it is expensive. You would rather go slightly bigger with your green hydrogen facility to obtain the benefit of it.”
P3	“If my renewable electricity is good, my capacity effect is good; I'll make more electricity, and electricity from the 100 MW of installed renewable electricity. More hydrogen, so it drives down my unit cost of my hydrogen.”

4.4.1.1.4 Maturity of the Technology

The interviewees indicated that South Africa lacked the technology and maturity to make green hydrogen. However, it is an aspect that can be solved via partnerships if the demand is large enough for technology companies to set up shop in South Africa. This is tabulated in Table 7 overleaf:

Table 7

Participant responses for maturity of technology

Participant	**Description of code**
P2	“So, the fact that we need to access technology that is not something that is licensed within the country and we need to get technology that's licensed external to the country.”
P3	“We're not manufacturing any electrolysis locally. If the market was large enough, one could partner with an electrolyser supplier to set up factories away. Manufacturing facilities in the country, but the demand is too small for these companies to warrant them to come and install the manufacturing capabilities. Now these are imported, and it is a bit tricky, but it's not something we cannot overcome.”
P8	“The technology should improve as and the cost should come down, through optimization of technology.”
P6	“So, the problem is the technology is still not mature and is expensive.”

P7	“I think maybe we need to sort of maybe invest in our own research and development or even at some point start looking at our commercial production of electrolysers and then maybe we have then you have that technical expertise in the country.”

4.4.2.1 Desalination Process

From the analysis of the desalination process, the cost of desalination, location of the facility, and disposal of the waste/brine water were highlighted as themes.

Table 8

Themes identified for the desalination process

Rank	**Theme**	**Frequency**
1	Cost of desalination	10
2	Location of facility	9
3	Disposal of waste/brine water	7

4.4.2.1.1 Cost of Desalination

As indicated by the participants the cost of the process is expensive. The capital costs are high. It is also a process that consumes large volumes of energy that will need to be from a renewable source to maintain the green concept.

Table 9

Participant responses for cost of the desalination process

Participant	Description of code
P1	“It is usually quite expensive. So, you need capital expenditure.”
P2	“All of this requires energy, making it energy intensive. This raises the question of where that energy will come from, which means additional renewable infrastructure is needed to supply the desalinated water.”
P2	“It's double the price and, on that side, as compared to if you have to do it on the eastern side of the country, but it's our capacity factors are higher on the Western northern side or north, the western side of the country. That is the reason why it's so expensive.”
P4	“The investment of a desalinization plant is not cheap. The initial outlay of cash would be extremely expensive. the payback may not be as lucrative as other investments or opportunities.”

4.4.2.1.2 Location of facility

The participants indicated that the location of the desalination process needs to be close to the coast and the hydrogen facility. This reduces the logistics costs.

Table 10

Participant responses for the location of the facility

Participant	Description of code
P1	“But it must be close to the coast. Your solar plan needs to be somewhere close by. Everything needs to be around there.”
P2	“Because this desalinization now is linked to your green hydrogen facility. You would want to build your green hydrogen facility in an area where you get high-capacity factors for your renewable energy.”
P6	“There was a day when Cape Town had so many water issues. We are talking about day zero, day zero, and so on. Yes, Cape Town is in a strategic position, we have the sea, sun, and wind in all this. Somehow, we as a country have not taken advantage of such.”
P8	“So, to your location is important, you have to be on the coast.”

4.4.2.1.3 Disposal of Waste/Brine Water

Another theme that was highlighted during the interviews, was the disposal of brine water that has been processed. This water is highly concentrated with salt and is at a higher temperature than the seawater.

Table 11

Participant responses for disposal of brine/wastewater

Participant	Description of code
P1	"One of the bigger things is you produce a brine waste with desalinization. So how do you dispose of that? It is easier with the desalination at the sea because you got a place to put it."
P3	“But the one thing that will have to be considered is the brine and the potential reintroduction of the brine back into the ocean. This impacts the biodiversity in the specific area where we are reintroducing the brine, but it doesn't mean that it cannot be done, it might have to be done a couple of kilometres or a fair distance back into the ocean and the other coast, which contributes to the cost, you know processing the brine and doing something else with it.”
P6	“The thing with using water is that they got environmental impacts, disposal of salty water waste. How will it impact marine life?”
P10	“You've got an issue with brine, which is the byproduct, and therefore you need a brine management strategy. There are different ways of managing it. So, you have got to you if you can use the salt for something else, you are in a good you are in good shape.”

4.4.2 What are the Infrastructural Challenges Relating to the Storage and Distribution of Green Hydrogen?

This question was aimed at understanding the supply and distribution of green hydrogen. For South Africa to adopt green hydrogen, the entire value chain needs to be studied.

The themes identified were the cost of storage and distribution, safety considerations, and pipeline utilisation.

Table 12

Themes identified for the infrastructural challenges

Rank	Theme	Frequency
1	Pipeline utilisation	17
2	Costing of storage and distribution	12
3	Safety considerations	10

4.4.2.1.4 Pipeline Utilisation

Pipelines can be utilised for the distribution of green hydrogen. However, some modifications and extensions of the current pipelines would be required.

Table 13

Participant responses for pipeline utilisation

Participant	Description of code
P2	“For distribution of green hydrogen, the best way will be via pipeline.”
P5	“Currently we transport gases in South Africa and energy via our pipelines. So, I presume we would be able to do that with green hydrogen with some modifications on the math scale and some configurations would be required.”

P7	“So, for example, if I think about it, if I'm a producer of green hydrogen and I want to export it, would it make sense then to have a green hydrogen pipeline.”
P10	"Hydrogen molecules are smaller. They get into the pipeline material, and they make it brittle. So, in some cases, you need to upgrade pipelines but there is the opportunity for South Africa to build new pipelines.”
P11	“I believe that you can repurpose it. They would need to be some checks when it comes to the materials of construction.”

4.4.2.1.5 Costing of Storage and Distribution

The cost of storing and distributing green hydrogen is expensive and a high capital outlay is required. This theme was very evident in the responses detailed in Table 14 below:

Table 14

Participant responses for cost of storage and distribution

Participant	**Description of code**
P1	“You'll also need some form of initial investment and the operation costs because keeping it pressurized at such a high pressure is also expensive.”
P2	“High-pressure liquefaction of hydrogen is an option if you are considering very, very large quantities of hydrogen, that is an option to consider, but it is a costly option.”

P3	“You will also need an initial investment, along with operational costs, as maintaining such high pressure is expensive.”

4.4.2.1.6 Safety Considerations

The interviewees highlighted the safety concerns concerning storing and transporting green hydrogen. The incorrect storing and transportation of green hydrogen can cause damage to property and endanger lives.

Table 15

Participant responses for safety considerations

Participant	**Description of code**
P1	“A dangerous exercise, as with most energy requirements.”
P6	“You don't want leaks, and we also know that hydrogen is highly flammable.”
P4	“Green hydrogen is it's similar to nuclear, it can explode, can blow up, can cause a lot of damage, and put the brakes on the technology itself.”
P9	“It's your typical type of storage requirement, such as safety systems and control systems.”

4.4.3 What can the South African Government do to Promote the Adoption of Clean Hydrogen?

This question intended to understand what the South African government can do to pave the way for the manufacture and use of sustainable hydrogen. The following themes were identified:

Table 16

Themes identified for the promotion of green hydrogen

Rank	**Theme**	**Frequency**
1	Policy and regulation	7
2	Maintain and upgrade infrastructure	7
3	Obtain investments	6

4.4.3.1 Policy and regulation

To promote the green hydrogen agenda, support will be required from the government. From the interviewees, policy, and regulation needs to change. It was suggested that incentives be given to industries for decarbonization.

Table 17

Participant responses for policy and regulation

Participant	Description of code
P3	“They're going to have to provide some sort of incentive for industry to decarbonize at the moment.”
P4	“I think policy and energy surplus at low cost to enable the processing of it.”
P6	“Well, the government needs to subsidize companies involved with this technology.”
P11	“The biggest thing that the South African government can do is to be able to land incentives from the off takers for green hydrogen."

4.4.3.2 Maintain and Upgrade Infrastructure

The interviewees noted that in order for South Africa to promote the green hydrogen agenda, the government can ensure that the infrastructure in the country is maintained to facilitate the manufacture, storage, and distribution of green hydrogen.

Table 18

Participant responses for maintaining and upgrading infrastructure

Participant	Description of code
P2	“What the government can also do is to make sure that their infrastructure and their companies that are responsible for managing infrastructure in the country should be up to scratch.”
P7	“We're looking at what volumes are we transporting and where are we transporting those volumes. So, does it make sense to do physical pipelines? Because this is a long-term agreement of you? Or does it make sense to use tankers? Do we have the capacity and the capabilities to make sure that these products can be evacuated continuously? Government can assist with infrastructure requirements.”
P5	“You might have to invest in upgrading the road. You want to have alternatives if something goes wrong.”

4.4.3.3 Obtain Investments

The cost of making, storing, and supplying green hydrogen is expensive. South Africa would require assistance from investors for funding and partnerships.

Table 19

Participant responses for obtaining investments

Participant	Description of codes
P2	“The thing is that what the government can do is make our processes more attractive for external investors into the country since it is expensive. As I said, we need a lot of investment into the country, a lot of partnerships, etcetera, but that comes with certain processes that should be easy for our external investors to be able to invest in these projects.”
P8	“South African government and industry should work together to end with overseas partners to unlock the first large export project and I think that will be the catalyst for them starting to look at domestic use in terms of energy as fuel.”
P9	They could prompt partnerships with the government instead of waiting for them to come up with something like the Triple P Program (public-private-partnerships) on their own.
P10	“There's a mixture of monies that are thrown in there and the European export credit agencies are playing quite a major role.”
P11	“In Southern Africa, there will be a need for external funding to be brought into the region in order to bridge the gap.”

CHAPTER 5. DISCUSSION OF RESULTS

5.1 Introduction

The analysis of the interviews was presented in chapter four. The findings of the investigation are presented in line with the research asks and relative to the literature study conducted in chapter two. Based on the findings from the interviews that were directed by the ten questions, the themes that emanated from the interviews are represented in Table 20 and the themes were organised in line with the research questions shown below:

Main Question: What are the challenges/barriers and opportunities of adopting green hydrogen in South Africa?

1. What are the technological challenges for producing green hydrogen in South Africa?
2. What are the infrastructural challenges relating to the storage and distribution of green hydrogen?
3. How does the lack of regulations and policies inhibit the promotion of green hydrogen?
4. From the identified challenges, what opportunities can be taken to accelerate the adoption of green hydrogen in South Africa?

Table 20

Themes from the interviews

Research question	Number of themes	Themes
1. What are the technological challenges for producing green hydrogen in South Africa?	4	Cost and sourcing of electrolysers, sustainable energy requirements,

(electrolysers)		economies of scale, and maturity of technology
2. What are the technological challenges for producing green hydrogen in South Africa? (desalination process)	3	Cost of desalination, location of the facility, and disposal of the waste/brine water
3. What are the infrastructural challenges relating to the storage and distribution of green hydrogen?	3	Cost of the storage and distribution, safety considerations, and pipeline utilisation
4. How does the lack of regulations and policies inhibit the promotion of green hydrogen?	3	Policy and regulation Maintain and upgrade infrastructure and obtain investments
5. From the identified challenges, what opportunities can be taken to accelerate the adoption of green hydrogen in South Africa?		

5.2 Discussion of Findings for Research Question One: What are the Technological Challenges for Producing Green Hydrogen in South Africa?

Technology is a key enabler to producing green hydrogen. Therefore, this research question was aimed at understanding the technological challenges. The technological challenges for producing green hydrogen have been categorised into challenges of electrolysers deployment and the desalination process. The challenges and opportunities are identified in Table 20.

5.2.1 Cost and Sourcing of Electrolysers

From the interviews, high capital costs would be required for the electrolysers and the solar panels. Electrolysers are manufactured internationally, and this would require some effort to source them, especially in terms of logistics. If the demand is large enough, this challenge can be overcome by electrolyser manufacturers setting up facilities in South Africa.

Electrolysers and renewable energy are the major concerns about technology (Nasser, Megahed, & Hassan, 2022). South Africa does not produce electrolysers. The findings from the interviewees and the literature study are aligned.

5.2.2 Sustainable Energy Requirements

Sustainable energy is required for the functioning of the electrolysers and the desalination process. The question of the amount of sun and wind energy, in South Africa, has been interrogated.

The literature study states that Sub–Saharan Africa has sufficient renewable energy resources to support the renewable energy adoption (Zainal, et al., 2024). More studies are required to gain insight into South Africa's capacity to produce the required renewable energy. Energy storage systems will be required such as batteries however this will add to the costs of green hydrogen.

5.2.3 Economies of Scale

The interviewees mentioned that a high volume of renewable energy is required and in addition, larger volumes of produced, will result in cheaper unit costs of hydrogen produced.

Findings from the literature study iterate that the cost of electrolysers and renewables could decline resulting in cheaper costs of hydrogen (Baral & Sebo, 2024). The electrolysers can be scaled according to grid and production requirements (Cozzolino & Bella, 2024).

For South Africa to be one of the first movers of green hydrogen, the cost factor and the economies of scale need to be balanced.

5.2.4 Maturity of Technology

The interviewees highlighted that the technology is still in its early stages and that the costs of the technology are expected to decrease over time. The interviewees suggested that South Africa invest in research and development to manufacture the electrolysers in the country to drive down the costs. This can bring much-needed economic stimulation to South Africa. This alternative has the potential to provide more economic benefits than importing the equipment (Cozzolino & Bella, 2024).

5.2.5 Cost of Desalination

The participants reiterated that a large capital outlay is required for constructing a desalination plant. The plant would also require large amounts of renewable energy to operate. This will add to the energy requirements that are needed for the electrolysers. The western side of the country is a more viable choice as it has more wind and solar energy.

5.2.6 Location of Facility

The participants stressed that the coastline (source of water), the desalination facility, the renewable power sources, and the hydrogen plant need to be in proximity to one another. The western side has ideal conditions for all factors.

The literature study showed that communities can benefit from desalination of water (Burck et al, 2023). However additional reverse osmosis will be required. There is a possibility of obtaining government funding to assist with providing potable water to communities.

5.2.7 Disposal of Brine/Wastewater

The disposal of brine or water that has been processed after the desalination process poses a major environmental concern. The location of the facility needs to be close to the coastline to re-introduce the brine water back into the sea. If the sodium chloride can be extracted from the brine water and re-used for another process, that would be an ideal scenario. Therefore, an integrated value chain needs to be investigated.

5.3 Discussion of Findings for Research Question Two: What are the Infrastructural Challenges Relating to the Storage and Distribution of Green Hydrogen?

5.3.1 Costing of Storage and Distribution

The initial costs for erecting the tanks are required. The tanks need to be operated under high pressure and this is also expensive. The literature review indicates that cryogenic tanks are required (Abe, Popoola, & Ajenifuja, 2019).

5.3.2 Safety Considerations

The interviewees stressed the importance of storing and distributing hydrogen safely. This is in line with the literature survey that states safety is the main concern when storing hydrogen (Abe, Popoola, & Ajenifuja, 2019).

5.3.3 Pipeline Utilisation

There is a network of pipelines in South Africa that can be modified to assist with the distribution of green hydrogen. However, this network needs to be extended and upgraded across the country to support the application of sustainable hydrogen. The literature states that using existing pipelines can lower transportation costs (IRENA, 2022).

5.4 Discussion of Findings for Research Question Three: What Opportunities can be Taken to Accelerate the Adoption of Green Hydrogen in South Africa?

5.4.1 Policy and Regulation

The participants indicated that the South African government can offer incentives for companies to decarbonise. Now, there is not enough drive for companies to decarbonise. The theme of costs has been reiterated throughout the study. The energy crisis is a serious issue that South Africa faces. Government can assist with developing policies to ensure renewable energy generation and subsidise these initiatives. This will lessen the burden on the electricity grid and help with carbon emissions. Working towards obtaining partnerships with technology companies, can assist with technological challenges. Providing lucrative options, such as offering tax concessions, for technology companies to set up manufacturing capabilities in South Africa.

5.4.2 Maintain and Upgrade Infrastructure

From the analysis of the interviews, the participants noted that the government needs to ensure that infrastructure within the country is developed and maintained. Storage tanks, pipelines well, and rail infrastructure need to be expanded especially in the western part of the country.

5.4.3 Obtaining Investments

South Africa needs to obtain funding to assist with the green hydrogen agenda. External investments are required. Partnerships need to be developed. South Africa can be an exporter of green hydrogen and can be one of the key role players.

5.5 What are the Challenges and Opportunities of Adopting Green Hydrogen in South Africa?

The following diagram is a representation of the findings.

<table>
<tr><th colspan="4">Challenges</th></tr>
<tr><td colspan="4">Technological</td></tr>
<tr><td rowspan="2">Electrolysers</td><td>Cost & Sourcing</td><td>Maturity of technology</td><td rowspan="2">Sustainable energy requirements</td></tr>
<tr><td>Economies of scale</td></tr>
<tr><td rowspan="2">Desalination</td><td>Cost</td><td rowspan="2">Disposal of waste</td></tr>
<tr><td>Location of facility</td></tr>
<tr><td colspan="4">Storage and Distribution</td></tr>
<tr><td>Cost</td><td>Safety considerations</td><td colspan="2">Pipeline Utilisation</td></tr>
<tr><td colspan="4">Opportunities</td></tr>
<tr><td colspan="2">Policy and regulation</td><td colspan="2">Maintain and upgrade infrastructure</td></tr>
<tr><td colspan="2">Obtain investments</td><td colspan="2">Create additional water supply</td></tr>
<tr><td colspan="4">Export green hydrogen</td></tr>
</table>

Figure 4

Diagrammatic summary of findings

Author's own source

South Africa has great potential to produce and utilise green hydrogen however there are serious challenges South Africa faces. Based on the literature study and the assessment of the interviews; the challenges and opportunities focus on technology, infrastructure, and South Africa's regulatory landscape.

The technological challenges are focused on electrolysis and the desalination process (Beswick, Oliveira, & Yan, 2021). The high cost of capital and the challenges with sourcing electrolysers make it difficult for South Africa to produce large volumes of green hydrogen. Green hydrogen necessitates large quantities of sustainable energy to power the electrolysers (Nasser, Megahed, & Hassan, 2022). South Africa is abundant with renewable energy, and depending on the volumes, obtaining sufficient renewable energy may pose a challenge. Batteries may be considered for storage, but this is expensive.

Producing green hydrogen in large quantities can drive down costs, especially in the infancy stages (Baral & Sebo, 2024). For South Africa to be a player in the hydrogen industry, the export market needs to be considered (DTIC, 2022). The storage and distribution infrastructure would also require significant investments, especially with the use of cryogenic tanks (Abe, Popoola, & Ajenifuja, 2019). There are safety challenges that need to be factored in the storage and movement of green hydrogen.

Regardless of the challenges, there are opportunities that can advance the adoption of green hydrogen in South Africa. The South African government can incentivise organisations to decarbonise as well as offer subsidies for renewable energy and hybrid manufacturing technologies. Partnering with international companies is one of the mechanisms for building technological capacity in South Africa (Agyekum, Nutakor, Agwa, & Kamel, 2022). The desalination process can undergo reverse osmosis to provide potable water to communities.

The development and expansion of the infrastructure are required for South Africa to be one of the first movers of green hydrogen. Expansion of tanks for storage, pipelines, and networks is needed for the distribution and storing of green hydrogen. The infrastructure investments should be strategically aligned to the green hydrogen plants to ensure that the supply chain is optimised. South Africa needs to obtain partnerships with global companies and obtain funding or grants from organisations that promote the green hydrogen agenda.

CHAPTER 6. CONCLUSION

6.1 Introduction

This chapter summarised the findings of the research, highlighting conclusions that are aligned with the research objectives. It also provided the recommendations for future studies and offers actionable insights for stakeholders who would be interested in advancing the green hydrogen agenda. The limitations of the study are included in this chapter.

6.2 Summary of Key Findings

The main research question that was guiding the study was:

Main Question: What are the challenges/barriers and opportunities of adopting green hydrogen in South Africa?

South Africa is well-positioned to be a global player in the production of green hydrogen due to its wind and solar energy resources and abundant land availability. However, there are significant challenges that exist within the three significant areas: technological, infrastructural, and regulatory frameworks.

From a technological perspective, the high costs of the electrolysers and desalination plant setups, coupled with the difficulty of acquiring electrolysers represent significant barriers (Beswick, Oliveira, & Yan, 2021). While South Africa has an ample supply of renewable energy, ensuring a reliable supply of energy to power these systems is a complex process.

There is an opportunity to scale up production to drive lower costs as demonstrated by global trends (Baral & Sebo, 2024). Government incentives such as subsidies can provide the assistance that is required for green hydrogen adoption. Partnerships with electrolyser manufacturers can address the technological gaps (Agyekum, Nutakor, Agwa, & Kamel, 2022). Upgrading of infrastructure such as storage tanks, pipelines, and the transportation network will be critical to ensure efficient storage and distribution of green hydrogen.

The findings emphasize that funding and strategic collaborations are essential for South Africa to emerge as a forerunner in the international green hydrogen economy (DTIC, 2022). The research aligns with existing literature, reinforcing the identified challenges and opportunities both through theoretical and empirical insights.

6.3 Recommendations for Future Studies

The following recommendations can be investigated for future studies:

6.3.1. Economic model for determining the balance between costs and the quantity of hydrogen produced.

A study to be initiated that can investigate exploring the balance between hydrogen produced and costs, and how these costs may be reduced in time.

6.3.2. Renewable energy supply generation

Studies can look at exploring sustainable and efficient methods of producing energy. Energy storage solutions can also be investigated.

6.3.3. Policy and Regulatory Frameworks

By comparing hydrogen strategies in more advanced countries, the insights gained can be used as inputs to shape the regulatory framework that South Africa needs.

6.3.4. Partnerships and funding models

The research can study ways of attracting partnerships or obtaining funds or grants for green hydrogen projects.

6.3.5. Technological Challenges

The feasibility of the existing pipelines, addressing the desalination shortfalls and advantages, and local manufacturing of electrolysers to enable local production can further be investigated to provide deeper insights into resolving the challenges.

6.3.6. Pilot Study

A pilot study is recommended to assess challenges and opportunities before scaling up, as the technology could support South Africa’s energy transition and security.

6.4 Limitations of research

The study as highlighted in Chapter Three, has certain limitations. There could have been role-players that are advanced in their green hydrogen strategy but have not indicated their intentions publicly and they were not part of the sample size. The participants in this study consisted of various stakeholders in different leadership and expertise domains, the participants may have depicted potential bias in their responses.

Table 21:Consistency table: research questions, propositions, data collection and data analysis

RQ #		State Research Question or Objective	Proposition #	State Proposition or Hypothesis	Data collection detail	Data analysis method
1		Determine the global trends for adopting green hydrogen	1	Green hydrogen is still its infancy stage in most countries however South Africa has the potential to be part of the leading countries producing hydrogen.	Literature review	Thematic analysis
2		Assess the technology feasibility of producing green hydrogen	2	Electrolysers, the desalination process, wind and solar panels are the major challenges to producing green hydrogen due costs.	Interview guide questions 1, 2, 3, 4	Thematic analysis

RQ #		State Research Question or Objective	Proposition #	State Proposition or Hypothesis	Data collection detail	Data analysis method
4		Assess the regulations and policies governing the production and use of green hydrogen in South Africa	4	South Africa's policy development is well established, however; it lacks incentivising stakeholders to either produce or utilise green hydrogen.	Interview guide questions 7, 8, 9	Thematic analysis

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APPENDIX A: CONSENT FORM



Cheryl Ramballie

Wits Business School

2 Saint Davids Place

Parktown

2193

Email address: 721116@students.wits.ac.za.

Cell number: 063 699 4151

4 April 2024

Dear Sir/Madam

Subject: Consent to join in a research to Assess the adoption of green hydrogen in South Africa

Introduction and Study Description:

My name is Cheryl Ramballie and student at Witwatersrand Business University completing my degree in Masters Business Administration. I am conducting research on assessing the adoption of green hydrogen in South Africa. The objective of this investigation is to assess the opportunities and challenges that South Africa experiences

with the adoption of green hydrogen while providing actionable understandings into these issues. The research required collection of data via interviews to gain understanding on the opportunities and challenges in South Africa adopting green hydrogen.

Voluntary Participation:

Participation in this study is completely voluntary. You at liberty to decline participation or withdraw from the study at any given time.

Informed Consent:

Before deciding to partake in the research, you need to have an understanding of the study which includes your right as a participant, knowledge of how your data will be utilized and who will have authority to access it.

Confidentiality and Anonymity:

All data that will be gathered during this research will be kept private. Pseudonyms will be utilised to anonymise data, store the transcripts and recordings. The recordings will be stored and handled securely to prevent unauthorised access.

Data Collection and Usage:

The expected duration of the interview is approximately an hour. The interview will be recorded. The recordings will be utilised exclusively for research purposes. Direct quotations transpiring from the interview may be employed in the study. Information from the interview will be transcribed and analysed which will be documented into report. All information used in the report will be anonymised. Processing of individual information will conform to the Protection of Personal Information Act (POPIA).

Risks and Benefits:

There are no expected consequences involved in joining in this study. The advantages of participating in research include contributing and obtaining insights into South Africa adopting green hydrogen.

Right to Withdraw:

You can at any time, withdraw from the research study, without having to provide a reason. Your decision not to participate will be without any consequences.

Contact Information:

If you have any inquiries, please contact me or my supervisor, Doctor Horne.

Sincerely,

Cheryl Ramballie

[Signature]

4 April

Supervisor: Doctor Renee Horne

Email: Renee.Horne@wits.ac.za

Cell number : 079 576 8754

[Date]

[Doctor Horn's signature]

By signing the form, you accept that you have examined and recognized the information given in this letter and voluntarily agree to partake in this study.

[Participants Name]

[Date]

[Participant 's Signature]

APPENDIX B: QUESTIONNAIRE

Interview guide

Section A

Questions

1. What is your current role in the company?
2. How many years of experience do you have in the industry?

Section B

Questions

Questions to be asked	**Research Questions**
1. In your experience, what are the major challenges with regards to producing green hydrogen from technology perspective?	2
2. Why do you think these challenges, that were mentioned in above question, are the major challenges?	2
3. How do you propose that South Africa navigate through these technological challenges?	2, 4
4. From your knowledge, what are the barriers to desalinating water in South Africa?	3
5. According to you, what infrastructure is required for the storage green hydrogen to enable to use of green hydrogen in SA?	3

6. What infrastructure is required for the distribution of green hydrogen?	3
7. Do you think that the current infrastructure can be repurposed for the use of green hydrogen?	3, 4
8. From your perspective, what can the government do to promote the adoption of green hydrogen in South Africa?	1
9. What do you think are the other issues South Africa faces with regards to the adoption of green hydrogen?	4
10. What do you think companies can do to promote the green hydrogen agenda?	4

Thank you for your time and contribution, this is the end of the interview. Do you have any questions that you want to ask?