Strategic Analysis of Nuclear Energy for Industrial Resilience in South Africa

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KEYWORDS

Resilience, Baseload Energy, Sustainability, Energy Security, Just Energy Mix

ABSTRACT

This study investigates the strategic role that nuclear energy can play in solving South Africa's perpetual energy problems and strengthening industrial resilience. Confronted with increased energy costs, load shedding, and aging coal-fired power infrastructure, the manufacturing sector needs reliable baseload energy to stabilise operations, sustain economic growth, and support environmental sustainability. Using both a theoretical framework of Critical Systems Heuristics, the results of a comparative analysis involving South Korea's highly successful nuclear program, the potential of nuclear energy for its contribution to a low-carbon, dependable source to diversify South Africa's energy mix is reviewed. Data collection was through interviews with experts and policy document reviews, focusing on opportunities, barriers, and strategic implications.

These findings point to nuclear energy's potential in reducing power outages, carbon emissions, increasing job creation, and driving innovation in technology. Yet, it faces critical challenges: public scepticism, regulatory hurdles, and financial constraints. Drawing on international best practices and adopting open and inclusive approaches, South Africa can overcome these obstacles and place nuclear energy at the heart of its energy strategy to meet national development objectives and contribute towards global sustainability.

KEYWORDS

Industrial Resilience, Baseload Energy, Sustainability, Energy Security, Just Energy Mix, Nuclear Energy, Decarbonisation, Strategic Analysis, Load shedding.

DECLARATION

I, **Zamazizi Princess Dlamini,** 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 Business Administration at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in this university or any other university.

Name: **Zamazizi Princess Dlamini** Signature: 

Signed at Hartbeespoort on the **27th** day of **February** 2025

DEDICATION

To my parents, my mother **Nokuthula Dlamini,** late father **Mphuthumi Dlamini**, I am sure you are proud of me where you are.

My siblings; **Nonkululeko, Jabulani, Nontuthuzo** and **Siyabonga (late)**, thank you for your unwavering support.

My two beautiful daughters; **Lerato** and **Nwabisa**, your understanding and swift adjustment.

I would not have made it this far without your love and support.

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CHAPTER 1 INTRODUCTION

1.1 Background

This qualitative study assesses the strategic implications of nuclear energy for enhancing the industrial resilience of South Africa's energy sector.

South Africa's energy crisis, which began in 2007 with rolling blackouts, has worsened over time, disrupting lives and weakening the economy (Walsh, 2020). A key contributor is the aging and poorly maintained coal-fired infrastructure, which affects reliability and performance (Nhleko., 2019). According to the New Development Bank, most of the challenges in the energy sector stem from infrastructure issues and inadequate maintenance, which hinder operational efficiency (Evaluation, 2024).

Coal currently dominates South Africa's energy mix, providing nearly 80%, followed by renewables (10.5%), nuclear (5.5%), and imported sources (4%) (Mirzania et al., 2023; Steenkamp, 2022). This heavy reliance on coal has made South Africa the twelfth largest emitter of greenhouse gases globally (Steenkamp, 2022).

Nuclear energy, by contrast, is a low-carbon, reliable baseload source that can support sustainable economic development (Addo et al., 2023). It helps mitigate climate change by avoiding the release of an estimated 1.2 to 2.4 gigatonnes of CO_2 annually (Remus, 2018). Because nuclear power generation is weather-independent and does not emit CO_2 during operation, it plays a critical role in achieving global Sustainable Development Goals, including affordable energy, clean water, economic growth, and industrial innovation ((IAEA), 2021).

Energy reliability is essential for economic growth and industrial productivity (Jian Xu, 2022). Load shedding has had a measurable impact: the South African Reserve Bank reduced its 2023 GDP forecast from 1% to 0.3% (Moobi, 2023). A

2022 Stats SA report showed a 4.7% drop in manufacturing output compared to the previous year, with energy supply disruptions cited as a primary cause ((Statssa), 2023). High energy prices between 2017 and 2021 led to lower production volumes, profit margins, and even plant closures (Beata Milewska, 2023). Power outages and escalating costs also disrupted supply chains, leading to delays, longer lead times, and increased costs for alternative logistics (Zhao, 2023). Job security was further undermined as manufacturers struggled to maintain stable operations (Statssa, 2022).

Despite its benefits, nuclear energy faces criticism regarding its affordability and public acceptance. While nuclear plants have high upfront construction costs, they benefit from low operational expenses and inexpensive fuel, such as uranium (Lombaard, 2016). Research suggests that nuclear energy helps lower overall electricity prices (Nkosi, 2021). However, proposals such as the Thyspunt nuclear site raise concerns about potential economic and environmental impacts on local industries like fishing (Nkosi, 2021).

Negative public perceptions of nuclear energy persist, largely due to historical incidents like Three Mile Island, Chernobyl, and Fukushima. Nevertheless, modern advancements—particularly in small modular reactors (SMRs)—have focused on safety, incorporating passive systems and low-pressure designs that function with minimal external intervention ((IAEA), 2023).

1.2 Context of the Study

In the developing countries manufacturing industry plays an important role in job creation however since 2008 there has been a decrease in outputs, job losses and market share loses (Fortunato, 2022). This is the same period that South Africa started experiencing load shedding and electricity price hikes leading to industries having to procure generators in order to remain operational (Fortunato, 2022). In the recent business tech news article, Sasol is planning to cut natural gas supply by 2026, this is part of their decarbonisation strategy. This poses a

great threat to the manufacturing industry which can lead to further job losses (BussinessTech, 2024). The delays in the publication of the Integrated Resource Plan (IRP) caused further strains and it is understood that the South African regulatory bodies have stringent constraints on licencing requirements, procurement processes, environmental requirements, etc.(Renaud,2020).

1.3 Problem Statement

South Africa faces energy security and economic challenges that are significantly harming its industry owing to delays in installing new capacity and poor performance of its current coal-fired power plants (Eyewitness News, 2022 March 25). The lower energy availability factor has an influence on the coal fleet decommissioning timeframe established in the 2019 Integrated Resource Plan (DMRE, 2019).

A balanced mix of gas, coal, nuclear, renewable energy, hydropower, and other energy sources may improve energy security and affordability, making the development of a sustainable (SDG 7) energy portfolio of crucial importance for the country (Ibrahim, 2023).

Nuclear energy is a potential solution to the current energy challenges by providing a dependable, low-carbon baseload source of energy that requires fewer materials and occupies less area (IAEA, 2021). By introducing a nuclear baseload, it will minimise the energy storage capacity required in a zero-carbon system as compared to a system based entirely on renewables (Cárdenas, 2023).

South Africa's energy mix does include nuclear energy however the strategic implication of this integration is underexplored. There is lack of comprehensive research that thoroughly examines how nuclear energy may assist in addressing current energy challenges, encourage economic growth, and advance global sustainability objectives within South Africa's unique socioeconomic and political environment.

1.4 Research Questions

1.4.1 Primary Questions

What are the strategic implications of integrating nuclear energy into South Africa's energy sector to enhance its industrial resilience?

1.5.1.1 Sub Questions

1.5.1.1 Sources of Motivation

Why is nuclear energy considered a strategic option for enhancing the industrial resilience of South Africa's energy sector?

1.5.1.2 Sources of Control

Who should hold decision-making authority and control over nuclear energy integration in South Africa?

1.5.1.3 Sources of Knowledge

What knowledge and expertise are needed to ensure the sustainability of nuclear energy, and who are the key contributors to providing this knowledge?

1.5.4 Sources of Legitimacy

How is the adoption of nuclear energy justified ethically, socially, and economically?

1.5 Justification of the Study

This case study aims to inform and support the efforts of policymakers, industry stakeholders, environmental advocates, and the academic community in advancing South Africa's energy security, economic growth, and sustainability goals. It will do this by providing a thorough analysis of the strategic implications of nuclear energy for enhancing the industrial resilience of the country's energy sector. In doing so, it will address the interests and needs of a variety of stakeholders.

South Africa's reliance on coal for electricity generation and its vulnerability to supply disruptions provide serious obstacles to the country's pursuit of energy security (Anekwe, 2024). Nuclear power can diversify the energy mix and increase energy security by lowering reliance on imported fuels and lowering the risk associated with erratic international energy markets (EIA, 2022). The government is committed to joining global initiatives to reduce greenhouse gas emissions and transition to a more sustainable energy system in order to slow down the effects of climate change (Department of treasury (SA),2010) (The Presidency (SA), 2023). Nuclear power may support business growth and innovation while assisting in the achievement of these sustainability goals because it is a low-carbon energy source. Nuclear energy investment has the ability to advance technical advancement, generate new employment opportunities, and propel South Africa's economy (DMRE,2019). In addition to encouraging economic innovation and growth, nuclear energy has the potential to generate skilled jobs in a number of industries, including manufacturing, construction, engineering, and research.

1.6 Delimitations of the Study

The Strategic Analysis of Nuclear Energy for Industrial Resilience in South Africa will focus on nuclear energy's potential to assist industrial resilience, notably in the manufacturing sector. The study acknowledges that nuclear energy has an

influence on the environment, but it will focus on its industrial resilience rather than doing extensive environmental studies, comprehensive awareness of the current legislative and governmental framework for nuclear energy development in South Africa, including its possibilities and constraints.

The Critical Systems Heuristics (CSH) framework provided a clear conceptual boundary for the strategic analysis of nuclear energy for industrial resilience in South Africa. By applying CSH's four sources; motivation, control, knowledge, and legitimacy, the analysis was able to systematically explore and define the boundaries of the system under consideration. Motivation focused on clarifying the purpose of integrating nuclear energy, identifying the intended beneficiaries, and evaluating whether the strategic objectives aligned with broader socio-economic goals. The control dimension helped pinpoint key decision-makers, assess the distribution of power among stakeholders, and determine how resources were managed to influence the strategic direction. Through knowledge, the framework emphasized the sources of expertise and evidence used to inform decisions, ensuring that the analysis incorporated a balanced and credible knowledge base. Finally, legitimacy guided the assessment of ethical considerations, the transparency of decision-making processes, and the extent to which public interests and societal values were reflected in the strategic approach.

By establishing these boundaries, CSH enabled a holistic and reflective analysis that not only identified technical and economic factors but also integrated social, ethical, and governance dimensions. This boundary critique was essential in avoiding narrow or biased perspectives, allowing the analysis to remain open to diverse viewpoints and adaptive to emerging insights. The CSH approach ensured that the strategic analysis maintained a balanced perspective, highlighting not only the potential benefits of nuclear energy but also the risks, limitations, and broader implications for industrial resilience and societal well-being in South Africa.

1.7 Operational Definitions

1.7.1 Resilience:

The ability of a system to absorb disruptions while keeping unaltered relationships between its components and parameters (Pudel, et al., 2022), it is the essence of sustainability as it provides ability for the system to recover from disorders (Cheng, 2023) and mostly addressed in three forms ecological, engineering, and adaptive.

1.7.2 Just Energy Transition:

A state in which all groups may maintain a respectable standard of living, have access to reasonably priced, secure, and sustainable energy, can take part in the decision-making process regarding energy, and have the freedom to make adjustments (Sun, 2023).

Making the shift to a low-carbon economy from carbon-intensive activities to one that acknowledges the social and economic ramifications is known as the "net zero" transition ((PWC), 2023).

1.7.3 Baseload Energy:

The smallest quantity of electricity required by an electrical grid to supply the continuous demand for power over a 24-hour period (Gawell,2015). Baseload power sources are essential to an effective electric grid since they are anticipated to run constantly at a steady rate (Stian and Magnus, 2025)

1.7.4 Load shedding:

Strategy used by an energy utility to reduce demand for electricity generation (Municipaliy, 2023), it is to prevent collapse of power system as the system

becomes unbalanced as a result of insufficient power and power stations (ECOFLOW, 2023).

1.7.5 Decarbonisation:

Push to reduce greenhouse gas emissions to safeguard human prosperity and existence on the globe, as well as to adapt to changing climate systems (Municipaliy, 2023). It is also defined achievement of net zero CO_2 emission by 2050 by using mitigation measures and/or through the balance of surplus emissions (Alamoush, 2023).

1.8 Dissertation Structure

Chapter 1 (Introduction): This chapter outlines the research problems, purpose, importance and objectives of the study.

Chapter 2 (Literature Review): This chapter outlines South Africa's nuclear energy deployment, industrial resilience and energy sector challenges. Literature reviews based on research papers, policy documents and theoretical frameworks, focusing on nuclear energy's potential to alleviate energy challenges, increase economic growth and contribute to global sustainability.

Chapter 3 (Methodology): This chapter details the research methodology, including data collection, sample methods and processing procedures.

Chapter 4 (Findings and Data Analysis): This chapter presents findings based on data collection and the methodology used.

Chapter 5 (Discussions, Conclusions and Recommendations): Research findings are discussed in relation to the purpose of the study, literature and theoretical

frameworks. Key findings are summarised, and recommendations are made based on the findings

CHAPTER 2. LITERATURE REVIEW AND THEORETICAL FRAMEWORK

2.1 Introduction

To conduct a thorough examination of nuclear energy's potential to alleviate South Africa's energy concerns and foster industrial resilience, this part reviews the relevant literature. In addition to highlighting safety precautions and technological breakthroughs, strategies and ideas for obtaining "clean" nuclear energy are discussed, with an emphasis on how it may reduce carbon emissions, ensure energy security and contribute to sustainable development goals. To address industrial resilience in the context of nuclear energy adoption, strategic analysis frameworks such as critical systems heuristics is provided. This framework will provide techniques for doing systems analysis.

2.2 Impact of Energy Challenges on Industrial Resilience

Climate change and global warming have become significant and pressing issues in the twenty-first century ((UENP), 2019). The increased production of harmful gases because of human activity has resulted in significant environmental pollution, posing serious global environmental challenges (Ma, 2023). Environmental policies have gained significant traction in recent decades, becoming prominent focal points in the strategic agendas of governments and international authorities to combat climate change (Ma, 2023).
The urgent need for sustainable and environmentally friendly power sources has emerged as a top priority within the global policymaking framework, driven by the severe consequences of excessive reliance on fossil fuels, resulting in the emission of carbon emissions and the imminent depletion of natural resources (Ma, 2023).
The World Bank claims that because developing nations are less equipped to control fluctuations in energy prices, they bear the brunt of the burden, which in

some cases results in energy rationing and worsening poverty. Developing nation's energy-related problems have had a substantial impact on their industrial development (DMRE, 2022). South Africa, for example, has a sophisticated energy network but struggles with capacity issues and aging infrastructure. Rolling blackouts, brought on by a lack of energy, have hampered local business expansion and economic development ((DMRE), 2022). South Africa faces difficulties in striking a balance between energy security and economic imperatives, according to a 2022 CSIR engineering news article, they further imply that these difficulties are exacerbated by the coal fleet's subpar performance and delays in implementing new capacity additions (Engineering News, 2022). Future growth depends on filling in infrastructure gaps, boosting sustainable practices and diversifying energy sources.

2.3 Nuclear Energy in the Energy Transition

Nuclear power accounts for 11% of the world's power generation, making it a significant technology in the mix of energy sources (Malischek, 2016). The fact that nuclear power generates electricity almost entirely carbon-free is one of its main advantages. As a result, it is believed that nuclear power is essential to reducing climate change (Malischek, 2016). France's long-standing policy centred on energy security made it one of the world leaders in the adoption of nuclear energy, with nuclear power accounting for roughly 70% of its electricity generation ((WNA), 2024). Due to the extremely low cost of generation, France is also the world's largest net exporter of energy ((WNA), 2024). France decided to adopt nuclear and between 1975 and 1990 has boosted its local energy supply to lessen its dependency on imports, which subjected to price shocks similar to that seen during the oil crisis. Currently, 52 nuclear reactors are in operation in France (EIA., 2023).

Prior to the Fukushima accident in 2011, Japan derived a large portion of its electricity from nuclear energy, with 57 nuclear reactors producing about 30% of the country's total electricity (JEPIC, 2023). The 2011 nuclear accident

significantly affected Japan's electricity market with nuclear energy being replaced with fossil fuels (Statista, 2023). The two main sources of electricity production are coal and natural gas. Japan is reliant on imports because it does not have any internal fossil fuel reserves. Household electricity rates went up quickly after the catastrophe because of increased use of fossil fuels (Statista, 2023). Japan presently seeks to replace fossil fuels with nuclear and renewable energy to become less dependent on imports of fossil fuels, as well as to lower greenhouse gas emissions and electricity power costs (Statista, 2023).

Since the 1980s, hydropower and nuclear power have accounted for 41% and 29% of total electricity generation in Sweden, respectively (Statssa, 2023). Wind power, on the other hand, has increased its contribution to the grid over the last decade, accounting for 17% and solar for 1% (Agency S. E., 2023). Sweden is a global leader in decarbonisation and uses clean energy sources ((Statssa), 2023). Swedish energy policies are designed to enhance environmental sustainability, competitiveness and supply reliability (Swedish Energy Agency, 2023). Sweden, like South Africa, consumes the most energy in the industrial sector, which accounts for 39% of total consumption compared to 40% in South Africa (IAEA, 2022).

2.4 Theoretical Underpinnings for Strategic Analysis

The key theory informing this study is Critical Systems Heuristics (CSH), which provides a structured approach to evaluating complex systems and identifying potential improvements. The study draws insights from Strategic Management Theory, particularly regarding resource allocation, competitive advantage, and long-term sustainability in the energy sector. The theoretical underpinnings do not only support the research methodology but also ensure that proposed strategies are robust, evidence-based, and aligned with both local and international best practices in nuclear energy deployment.

2.4.1 Critical Systems Heuristics

Critical systems heuristics is a methodology by Werner Ulrich providing a framework for reflective practice based on practical philosophy and systems thinking (Ulrich, 2005). It aims at determining what is relevant, who should assist to determine it and how to handle conflicting views among relevant stakeholders by offering a checklist of twelve boundary questions of what is currently in place and what is ought to be in place (Jensen, 2023).

The first component of Critical Systems Heuristics is the notion of "boundary critique." This concept emphasises the importance of critically examining the boundaries that define a system, as these boundaries can often be subjective and reflect the values and perspectives of those involved. By questioning the underlying assumptions and biases that shape these boundaries, researchers and decision-makers can gain a deeper understanding of the system and its potentially hidden implications.

The second component is the concept of "is" and "ought" questions. This distinction highlights the difference between descriptive questions that seek to understand the current state of a system and normative questions that explore what the system should be. By addressing both types of questions, Critical Systems Heuristics encourages a holistic approach that considers not only the factual aspects of a system but also the ethical and moral considerations that should guide its design and implementation.

The third component of the framework is the notion of "reference systems". Critical Systems Heuristics suggests that in order to fully understand a system, it is necessary to consider alternative reference systems that may provide different perspectives and insights. By exploring these alternative viewpoints, researchers can challenge their own assumptions and biases, leading to a more nuanced and informed understanding of the system.

The final component of Critical Systems Heuristics is the use of "critical heuristics." These heuristics, or guiding principles, serve as a framework for critically analysing a system and its underlying assumptions.

Sources of influence	Boundary questions	
Sources of motivation	Beneficiary	1. Who ought to be/is the intended beneficiary of the system?
	Purpose	2. What ought to be/is the purpose of the system?
	Measure of improvement	3. What ought to be/is the system's measure of success?
Sources of control	Decision maker	4. Who ought to be/is in control of the conditions of success of the system?
	Resources	5. What conditions of success ought to be/are under the control of the system?
	Decision environment	6. What conditions of success ought to be/are outside the control of the decision maker?
Sources of knowledge	Expert	7. Who ought to be/is providing relevant knowledge and skills for the system?
	Expertise	8. What ought to be/are relevant new knowledge and skills for the system?
	Guarantor	9. What ought to be/are regarded as assurances of successful implementation?
Sources of legitimacy	Witness	10. Who ought to be/ is representing the interests of those negatively affected by but not involved with the system?
	Emancipation	11. What ought to be/are the opportunities for the interests of those negatively affected to have expression and freedom from the worldview of the system?
	Worldview	12. What space ought to be/is available for reconciling differing worldviews regarding the system among those involved and affected?

Figure 1: The boundary categories and questions of CSH (Adapted from Ulrich 1996, p. 44)

Moreover, utilising the critical systems heuristics approach, which aimed at considering the social and ethical consequences of implementing the complex system, can provide valuable insights into strategic considerations surrounding the implementation of the nuclear energy in South Africa. This approach can be effectively used to present the stakeholders, their concerns, the prospective social effects of Nuclear energy program and thus direct the advancement and usage of this technology in compliance with the indications of sustainable growth and welfare of the South African public (Greyvenstein et.al, 2008) (Uhunamure, et al., 2021).

2.5 Summary

Chapter 2 provides a comprehensive review of the literature and theoretical frameworks needed to evaluate nuclear energy's role in addressing South Africa's energy challenges and fostering industrial resilience. The chapter highlights the critical impact of energy crises on industrial development, emphasising the urgent need for sustainable, reliable and low-carbon energy sources like nuclear power.

Key global examples, including France, Japan and Sweden, demonstrate the diverse applications of nuclear energy in achieving energy security, economic growth and environmental sustainability. These case studies underline the importance of strategic planning, stakeholder engagement and policy alignment in integrating nuclear power effectively.

Critical Systems Heuristics is introduced as essential tools to guide the decision-making process. These framework focus on shaping the desired future, fostering stakeholder inclusion, and addressing ethical and social dimensions in implementing nuclear energy projects.

This chapter sets the foundation for understanding nuclear energy's potential to transform South Africa's energy sector and industrial resilience, forming the basis for further strategic analysis.

CHAPTER 3. RESEARCH METHODOLOGY

3.1 Overview

The section gives a description of research methodology in terms of research approach, design, data collection methods, population and sample, research instrument, data analysis strategies and ethical considerations for the strategic analysis of nuclear energy for industrial resilience in South Africa that was used.

3.2 Research Approach.

In this study South Korea was used as our global community as it has faced challenges similar to those experienced by South Africa, such as energy security concerns, the need for industrial resilience (Platte, 2022), aging infrastructure, and high energy costs and have successfully integrated nuclear power into its national energy mix (Hong, 2014). A qualitative method that included critical systems heuristics then integrating this methodology resulted in a more rigorous and comprehensive strategic analysis of nuclear energy for South Africa's industrial resilience. Stakeholder engagement (nuclear industry experts) (IAEA, 2001), internal assessment (Phadermrod, 2016) and external environmental assessment (Song, 2017), resulting in a comprehensive understanding of the opportunities, challenges and strategic imperatives for enhancing industrial resilience through nuclear energy deployment in South Africa.

3.3 Research Design

The design of the case study included existing studies on nuclear energy, industrial resilience and relevant policy documents for both in South Africa and

South Korea. They provide access to a variety of viewpoints, evidence-based insights, and practical recommendations drawn from scholarly literature and current research (positivist). Interviews with industry experts who offered insightful expertise (interpretivist) were conducted; nevertheless, their opinions and recommendations may have been influenced by conflicts of interest or biases.

3.4 Population and Sample

Data was collected by means of existing case studies which were source through scholarly research documents and journals, interviewing the nuclear industry experts. Experts across the industry were approached in their personal capacity which will include areas in safety, regulatory, waste management, academics, communications and government. They were sent email request to participate in the study which were accompanied by a consent form with the details of the study.

3.4.1 Population

The study was qualitative general where thirteen experts were interviewed, and existing studies and policies were reviewed for commonalities.

3.4.2 Sample and Sampling Method

The study used purposive sampling; the sample were experts across the nuclear industry who were approached in their personal capacity, in these areas; safety, regulatory, waste management, academics, communications and government. It will included international expert's views as they were be able to answer all questions, who are strong in their areas of expertise, giving us a total of thirteen interviews.

3.5 The Research Instrument.

This study relied on expert interviews in the nuclear industry (due to the limitation of study period and research not being a full theses), existing studies and policy documents. Critical systems heuristics analysis method was used; guiding the research questions in Chapter 4 and assisted in making informed recommendations.

3.6 Procedure for Data Collection

Existing studies related to nuclear energy and industrial resilience including policies were analysed. Experts in the nuclear industry were approached in their personal capacity which will include areas in safety, regulatory, waste management, academics and communications. They were sent email requests to participate in the study which will be accompanied by consent form with the details of the study.

3.7 Data Analysis Strategies and Interpretation

Expert interviews were transcribed, key themes and topics highlighted and compared to other experts' responses and also with the case studies for commonalities. Thematic analysis (Braun, 2006) based on predefined themes related to nuclear energy, industrial resilience and strategic priorities were be identified from expert interviews, policy documents and industry reports. Comparative analysis on experiences and outcomes of South Korea's nuclear energy program.

3.8 Possible Limitations and Challenges of the Study

Some of the limitations to this study was the availability of data as there are few studies in this area; public perceptions as the is little awareness which is resulting in lack of acceptance of the technology regulatory policies which are stringent.

3.9 Quality Assurance

Table1: Quality Assurance

Qualitative	
Transferability	The findings can be used in another similar set up eg. Researching for other forms of energy or applying it to other fields such as medicine.
Dependability	The study can produce similar results if done in the same manner.
Credibility	Independent expert will be asked to review the information.
Confirmability	Data analysis will be done as described in the methodology.

3.10 Ethical Considerations

Risk levels were minimal, the study involved literature review and expert interviews. Experts were approached on individual capacity, consent form detailing the aim of the study, researcher's conduct and confidentiality requirements.

3.11 Summary

This chapter presented the research approach, design, data collection methodology, research population and sample, research instrument and data collection, data analysis strategies and interpretations, quality assurance and ethical considerations. The study was to investigate the strategic role that nuclear energy can play in solving South Africa's perpetual energy problems and strengthening industrial resilience. The next chapter will present the study's findings as guided by the research methodology.

CHAPTER 4. Findings and Data Analysis

4.1 Introduction

The purpose of this study was to explore the role of nuclear energy in enhancing industrial resilience in South Africa. By investigating how nuclear energy can contribute to economic stability, energy security and environmental sustainability. The study aimed to provide a strategic analysis to guide decision-making for stakeholders in South Africa's energy and industrial sectors. The analysis is rooted in Critical Systems Heuristics (CSH), a methodological framework that examines the normative ethical, and practical dimensions of complex systems.

To address this purpose, the study was guided by the following four research questions derived from CSH:

1. What are the sources of motivation and purpose? This examines the values, goals and justification underlying nuclear energy's role in industrial resilience.
2. What are the sources of control and resources? This question investigates the mechanisms, institutions and resources that enable or constrain the implementation of nuclear energy strategies.
3. What are the sources of expertise and assurance? This addresses the knowledge, evidence and criteria used to validate and evaluate nuclear energy's impact on industrial resilience.
4. What are sources of legitimacy? This question identifies the actors who define the purpose, resources, and constraints of the nuclear energy system.

The findings and analysis are presented using deductive thematic analysis (Braun, 2006), a method in which the themes are pre-determined based on the

guiding framework in this case, CSH. This approach ensures that the analysis remains tightly aligned with the research questions and theory.

Figure 2: Figure showing how data was analysed

Familiarisation with data: Semi-structured interviews with nuclear sector stakeholders, energy experts, policymakers, and industrial leaders were transcribed verbatim. Policy documents, strategic plans, industry reports, and regulatory frameworks were carefully examined to extract relevant information.

Coding Phase: The coding phase involved systematically labelling segments of the data according to the established themes. were developed based on the pre-established themes, ensuring a focused and objective analysis. Relevant excerpts from interviews and documents were assigned to the appropriate codes.

Create Themes: The data was organised into broader themes that captured the essence of the findings.

Review Themes: The review phase involved evaluating the identified themes for consistency, relevance, and clarity. The review process helped to validate the thematic framework, ensuring that it was both comprehensive and focused.

Define Themes: Once the themes were reviewed, each was defined clearly to capture its specific contribution to the research

Write Thematic Analysis: The final step involved compiling the thematic analysis into a structured report. The analysis was presented according to the defined themes.

The choice of deductive thematic analysis ensures a structured approach that provides clarity and depth in understanding the interplay between nuclear energy and industrial resilience. By grounding the thematic analysis in CSH, the study maintains a critical and systemic perspective, enabling the findings to address not only practical considerations but also normative and ethical dimensions.

4.2 Analysis of Results

The interviews were conducted to gain qualitative insights from industry experts, policymakers, engineers and academics on nuclear energy's strategic role, regulatory hurdles and operational challenges within South Africa's unique context.

4.2.1 *Experts' Profile*

Below is the table of experts' profiles across the nuclear technology field;

Respondent #	Profile
1	Chief Scientist, works at the Research Institution with 22 years' experience in; Nuclear Licensing, Reactor Operations, Nuclear Waste Management, Modelling and Project Management

2	Chief Physicist works in Energy Operations with 24 years' experience in; Nuclear Safety, Nuclear Power Generation, Modelling, Reactor Physics and Nuclear Forensic
3	Nuclear Waste Advisor works at the International Atomic Energy Agency with 20 years' experience in; Nuclear Licensing, Nuclear Waste Management, Nuclear Safety, Leadership and Project Management
4	Radioactive Materials Specialist works at the International Atomic Energy Agency with 13 years in; Nuclear Waste Management, Radioactive Chemicals, Leadership, Nuclear Safeguards and Project Management
5	Independent Consultant with 27 years in; Modelling, Nuclear Licensing, Leadership, Reactor Operations and Project Management
6	Nuclear Security Officer (International Missions) works at the International Atomic Energy Agency with 25 years' experience in; Nuclear Regulatory, Nuclear Law, Reactor Technology, Nuclear Safety, Nuclear Security, Nuclear Waste Management, Nuclear power Generation, Nuclear Emergency Preparedness and Nuclear Safeguards
7	Chief Director works for National Government with 19 years' experience in; Nuclear, Waste Management, Nuclear Licensing, Nuclear Safety, Nuclear, Emergency Preparedness, Nuclear Policies and Legislations and Board Member
8	Director works for National Government with 23 years' experience in; Modelling, Renewable Energy, Nuclear Power Generation, Nuclear Law and Policies and Board Member
9	Scientist works at the Research Institution with 12 years' experience in; Science Communication and Education, Nuclear Chemistry Research
10	Education Specialist works at the Research Institution with 20 years' experience in; Research Physicist, Science Communication and Education
11	Lecturer works at the Academic Institution with 12 years' experience in; Industrial Physics, Nuclear Safety, Nuclear Reactor Technology and Beamline Physics
12	Manager at the Research Institution with 16 years' experience in; Nuclear Emergency Preparedness, Nuclear Safety, Nuclear Waste Management and Medical Radiation
13	Senior Researcher works at the Research Institution with 18 years' experience in; Reactor Theory, X-Ray Computed Tomography and Nuclear Physics

Justification of 13 experts

Initially, it was planned for fifteen experts to be interviewed as the industry is not huge in South Africa. However, one was able to do thirteen interviews which is two experts less.

The decision to engage thirteen experts for the study on the strategic analysis of nuclear energy for industrial resilience in South Africa is grounded in both methodological and practical considerations. Diverse perspectives are essential, as the scope of nuclear energy and its implications for industrial resilience span multiple domains, including energy policy, engineering, economics, environmental science and societal impact (Ateba & Prinsloo, 2019).

By interviewing thirteen experts from diverse fields such as government, academia, industry and environmental organisations, the study ensures a comprehensive understanding of the challenges and opportunities in the adoption of nuclear energy (Adebayo et.al, 2023).

Qualitative research often aims to reach a saturation point, where additional interviews no longer yield new insights. Thirteen interviews are a practical number to achieve this balance, ensuring depth and breadth of information while avoiding redundancy (Montmasson-Clair & Ryan, 2014). The study also incorporates insights from international best practices (e.g., South Korea, France and Sweden), allowing for comparisons between local challenges and global benchmarks, and ensuring strategies are both contextually relevant and globally informed.

4.2.2 Experts Responses

Experts from diverse fields including nuclear engineering, environmental science, policy-making, and socio-economic development were engaged to provide insights across these four dimensions of Critical Systems Heuristics. The responses were collected through semi-structured interviews, enabling a deep exploration of each expert's perspective while maintaining the flexibility to probe emerging themes.

Structure of Expert Responses

The presentation of expert responses aligned with the CSH framework, organised as follows:

4.2.2.1 Sources of Motivation: Insights into the intended purpose of nuclear energy for industrial resilience and who stands to benefit from this strategic direction.

4.2.2.2 Sources of Control: Perspectives on the key decision-makers, governance structures, and the influence of political and economic power dynamics.

4.2.2.3 Sources of Knowledge: Contributions regarding the scientific, technical, and experiential knowledge informing the strategic analysis.

4.2.2.4 Sources of Legitimation: Reflections on the ethical considerations, societal values, and normative criteria shaping the strategic vision for nuclear energy in South Africa.

By structuring the expert responses through the lens of CSH, this analysis aims to provide a balanced and critically reflective assessment of nuclear energy's potential to contribute to industrial resilience, highlighting both opportunities and challenges within the South African context.

4.2.2.1 Sources of Motivation

Introduction to Sources of Motivation

This section addresses three aspects of sources of motivation which are beneficiary, purpose, and measures of improvement. The beneficiary aspect focuses on identifying the key stakeholders who stand to gain from enhanced industrial resilience. The purpose aspect emphasises the strategic intent behind

leveraging nuclear energy. The measures of improvement outlines the specific metrics and benchmarks used to assess progress.

Sources of Motivation	Experts Responds
Beneficiary: Q1: Who is currently benefiting from nuclear energy?	#1: “The current beneficiaries of nuclear energy include the government, the national electricity utility Eskom, and the broader economy. The Koeberg Nuclear Power Station, operated by Eskom, contributes approximately 1860 MW of electricity to the South African grid, which is the lowest electricity cost in the country.” #2 “As the nuclear energy in SA is the cheapest in all the Eskom grid, the whole country is benefeting from the low cost of nuclear.” #3: “The City of Cape Town, households, and businesses benefit from nuclear energy through a reliable electricity supply, supported by Koeberg Nuclear Power Plant. Koeberg itself employs over 1,000 people and creates over 500 indirect contributing to local job creation and economic stability.”
Q2: Who is expected to benefit from increased nuclear energy capacity into South Africa's industrial sector?	#1: “Increased nuclear energy capacity has the potential to benefit many sectors in South Africa's industrial economy, notably energy-intensive and skills-enabling industries. Key sectors include automotive manufacturing, metals, machinery, mining, cement, chemicals, and agro-processing, all of which are foundational to South Africa’s economy. For instance, the automotive industry alone contributes about 4.3% to the national GDP, while mining which employs half a million people contributes around 8% to GDP. Expanding nuclear energy would strengthen these industries by providing them with stable, low-cost energy to support their operations and facilitate growth.” #2: “Society and industry relieved from massive blackouts or loadshedding. Provision of baseload electricty protected from fluctuation of supply. Increased pruductivity from small, intermediate to industrial scale activities in manufacturing, processing, providing goods and services sectors. Employment creation and poverty eradication enabling small to big economic players equittable roles in industry. Social security and secure market growth leading to national security across all socio-econoimc lifestyle.” #3: “The beneficiaries will be in in the member of the public that uses electricity on a day-to-day basis in the sense that the electricity. Nuclear energy is climate resilient, do not pollute the environment, and can maintain the economic growth and stability of the country. So, the beneficiaries of this source of

	energy likely to be every member of the public, in the sense that electricity is used by all of us.”
Purpose: Q1: What purpose is nuclear energy currently serving in South Africa?	#1: “Nuclear energy in South Africa serves as a baseload power source, providing a continuous and stable supply of electricity that meets the country's energy demands and sustains economic growth. Koeberg Nuclear Power Plant, which supplies approximately 5% of the national grid, is a key asset in this regard. Nuclear power’s reliability and cost-effectiveness make it essential for South Africa, especially as coal plants are retired.” #2: “Energy Supply: Nuclear energy contributes to the stable supply of electricity in South Africa. The Koeberg Nuclear Power Station, the only nuclear power plant in the country, provides a significant portion of the country's electricity, helping to meet the increasing energy demands.” #3: “Electricity generation from the Koeberg nuclear power plant and radiopharmaceuticals and researcher, that which is done in the Safari1 research reactor.
Q2: Why would the South African energy sector want to use nuclear energy in order to improve industrial resilience?	#1: “Nuclear energy offers several benefits, including energy security, environmental sustainability, economic development, technological advancement, and resilience to external shocks. It is a reliable and consistent power source, meeting the energy needs of the industrial sector. South Africa's nuclear power plant operation and research capabilities contribute to its global leadership in nuclear technology. Diversifying its energy sources reduces vulnerability to global energy market fluctuations and external economic shocks, ensuring industrial stability and growth. This aligns with South Africa's broader objectives of environmental stewardship and sustainability. Furthermore, South Africa's nuclear energy sector can further enhance its technological advancement and global leadership.” #2: “For sustainable development. Building more nuclear power plants would not only strengthen our baseload and give South Africans a reliable energy source but would bring in job creation which would contribute to the economy of the country where the main contention regarding adding nuclear energy to the baseload has been.” #3: “it is reliable energy source. It is also a clean energy in the context of climate change. A number of countries have been requested to reduce on their carbon emissions, so South African will benefit a lot. By slowly moving away from high carbon intensity energy production like your coal-fired power plants.”
Measures of improvement:	#1: “Koeberg NPP, been voted the best NPP in the world over the years. Taking in to considerations its safety records, lowest cost electricity, most availability factor.”

Q1: What is currently being used as measure of success with the nuclear industry?	#2: “Nuclear provides sustainable energy or electricity, it also creates highly skilled jobs (engineering, nuclear engineering, electrical engineers, mechanical, including scientists, physicists). It is one of the cheapest energy source, thereby bringing a lot of revenue into the system, for instance Koeberg it has paid itself off more than 20 years ago and currently as we speak, it is almost like a cash cow because it is pumping money into the economy. It is a long term technology, hence it is even being extended to another 20 years, so it can last for 60 years.” #3: “It is issues like jobs; how many jobs that you create? Direct, indirect and induced? It's things like the contribution to the economy, both local as well as internationally. It is things like carbon dioxide emissions that you are able to defer and you know things like on the medical front, the revenue that Necsa generates was mentioned to be about R2.6 billion Rand, bulk that is coming from international sales.”
Q2: How would success look like for the industry in the context of deploying nuclear energy to industrial sector?	#1: “Success in this context would mean reliable, cost-effective, and sustainable energy for industries, reducing dependence on fossil fuels and making South Africa’s industrial sector more resilient to energy fluctuations. High-capacity nuclear power could provide consistent and uninterrupted energy, which is crucial for industries that require stable power, like manufacturing and mining. Furthermore, expanding nuclear in industrial settings would create new jobs in the nuclear sector and increase energy security for South Africa. It would also mean less environmental impact compared to coal and oil-based energy sources, enhancing South Africa’s commitment to a greener industrial landscape.” #2: “if you use the metrics that, you'd have to look at am I am I dropping this year’s emissions or how much is O_2 emissions? Economic development in terms of the revenue generation and contribution to the GDP. The operations at the different entities they differ, primarily in the medical sphere, they will have a more of a mandate around producing MSc’s and PhDs for intellectual property as well as generating foreign revenue, whereas at Eskom it's about the unit kWh unit of electricity that is generated and how much it costs and with Koeberg being the lowest on grid electricity generated at the moment at R0.44 per kWh, that would be a measure of success. If you can sustain that going to the future.” #3: “Placement of skilled young professionals in the right areas industry development.”

The responses share a common theme centred around the economic and societal benefits of nuclear energy in South Africa through Koeberg Nuclear

Power Plant which is ensuring affordable, stable electricity while supporting economic growth and job creation. From the enhanced industrial resilience, industries, communities, and the broader economy stands to gain.

Currently nuclear energy's role in South Africa's serves as baseload energy in the Western Cape and additional role of nuclear technology is in research and radiopharmacy. Nuclear energy serves as the driver of sustainable development, economic growth and energy security, it is a low carbon alternative therefore supporting initiatives in reducing carbon emission and aligns with global climate change policies.

The economic, job creation and sustainability of nuclear energy demonstrated by Koeberg's operational excellence and cost effectiveness, highly skilled professionals plus direct and indirect jobs, long operational lifespan by Safari 1, lastly research and medical benefits are current measures of improvements. Nuclear energy cost (R0.44 per kWh). Success will be measured by reduction in carbon emissions, GDP contributions and foreign revenue. Various contributions for different sectors; electricity generation, intellectual property and education.

4.2.2.2 Sources of Control

Introduction to Sources of Control

This section addresses the three aspects of the sources of control: decision makers, resources, and decision environment. The decision makers aspect refers to the key stakeholders, including government bodies, industry leaders, and regulatory authorities, whose choices influence the direction of nuclear energy initiatives. The resources aspect highlights the financial, technological, and human capital required to implement and sustain nuclear energy projects effectively. The decision environment aspect examines the external and internal factors, such as regulatory frameworks, market dynamics, and socio-political conditions, that shape decision-making processes.

Sources of Control	Experts Responds
Decision makers: Q1: Who are the main decision makers or stakeholders in South Africa who are establishing nuclear energy policies and strategies?	#1: “To a large extent it is the government, then you have your Parliament and civil society NGOs every company has got a bit of autonomy in terms of what it can set up and support. The level of autonomy in the organisations that are taking part in the industry themselves, but they usually follow the government's stated strategy and policy. We’ve got a number of those that are regulating the industry at the moment.” #2: “The primary decision-makers in South Africa’s nuclear energy policy include government bodies, Eskom, the National Nuclear Regulator (NNR), and the Nuclear Energy Corporation of South Africa (Necsa), private businesses and civil organizations influence nuclear energy policy.” #3:” The Minister of Electricity and Energy, National Energy Regulator of South Africa (Nersa), and Cabinet are key players in South Africa's nuclear energy policy-making process. The Minister of Electricity and Energy is responsible for formulating and implementing nuclear energy policies, while Nersa regulates the energy sector and ensures industry compliance. The cabinet has approved a phased decision-making approach for the new-build nuclear program, demonstrating their involvement in high-level policy decisions. Public engagement is crucial in shaping nuclear energy policies, and Eskom, South Africa's leading energy provider, is involved in operational and technical aspects of nuclear power.”
Q2: With regards to applying nuclear energy to the industrial sector for industrial resilience; who will be the main decision makers or stakeholders involved in establishing strategies and policies?	#1: “For industrial nuclear applications, key stakeholders would include industry representatives, governmental bodies, and nuclear operators like Eskom and Necsa. Regulatory oversight from the National Nuclear Regulator (NNR) will ensure safe deployment, while industries using high-capacity energy will need to be involved in strategy discussions to align energy supply with demand. Partnerships with private sector companies, particularly those interested in SMRs for remote or off-grid applications, will also be essential. The voices of labour unions, environmental NGOs, and the public will play a role in shaping policies, ensuring that industrial nuclear projects are aligned with community and environmental standards.” #2: “The national nuclear regulator and also the boards and CEO's of the state owned entities currently operating reactors such as Necsa and Eskom. The non-governmental organizations, mostly consisting of environmental groups and generally citizens who live around a currently operated facilities who seem to be more conscious and knowledgeable about nuclear than the average population.” #3: “The Department of Electricity and Energy is the primary decision maker in in in terms of establishing a direction for a nuclear energy and the policies and the strategies. The regulatory body and other environment entities, such as a Department of Environmental affairs are also a stakeholders that have an impact in deciding when energy

	policies and strategies. Organizations such as Necsa and Eskom also have a saying the drafting of policies and strategies and one other important stakeholder is the public.”
Resources: Q1: What resources are currently available in the country; financial, technology infrastructure, human capital?	#1: “SA is previliage as the country have a long history of operating NPP, therefore the human capital is available. The eletricity grid form the key infrstructure needed to expand the nuclear power. The financing options also not behind due to SA s banking capabilities.” #2:” The South African government plans to invest R943.8 billion in public infrastructure over the next three years, with the World Bank supporting various financial operations. The country has a strong foundation in digital technology, which is crucial for resource mobilization and development. The government has identified 12 infrastructure projects for preparation in the 2024/25 financial year, with the value of planned investment projects increasing sharply due to sustained electricity supply and easing logistical constraints. Human capital is a significant driver of productivity, with around 40% determined by it, and the education system is supported by industry-focused curricula.” #3: “South Africa have a strong manufacturing base which will be able to support in the manufacturing of equipment and support systems that does not require high technical manufacturing capability. In terms of human capital, South Africa has been operating Safari 1 for approximately 60 years and the cubic units for approximately 40 years, so there is available nuclear skill in the country, however, this, in my opinion not sufficient as a lot of people in the nuclear industry have have immigrated a lot. With the establishment of the nuclear engineering and Nuclear sciences, the departments at universities, some effort is being made to develop nuclear skills at the moment.”
Q2: Considering expansion of nuclear energy; what additional resources will the country require?	#1: “Financing models from banks. Everything else is in place, the universities and TVET colleges are ready to produce skills needed.” #2: “I think finance is our biggest challenge that we will need and I think somehow we might have to find some favourable financial models to be able to finance that. And also depending on what we do, we might have to buy the technology. We are at the stage that we don't possess the technology currently in the country to be able to move with the expansion of nuclear energy. For us to be able to buy that technology, we will need the money to do that.” #3: “I feel that the country needs to allocate a designated budget just for nuclear, new build as a long term plan. The country will need to develop more high-tech manufacturing capabilities. Companies will need to obtain accreditation to manufacturer to manufacture nuclear grade quality material. More technical people need to be trained specifically for the nuclear industry.”

Decision environment: Q1: What factors are currently causing stagnation for adoption or expansion of nuclear energy in the country? (Political, Economy, Social, Technology, Environmental)	#1: “I would say political definitely, if politicians can step back a bit and allow people, that has got experience and they know how in nuclear to be decision makers, it will help a great deal. Socially as well, people are not yet comfortable a, but I think again it has got to do with education that people need to be educated so that they can be liberated from their fear of the unknown because most of the things are caused by fear of the unknown and economically. So I would say financial, but in terms of the economy, it will actually boost our economy.” #2: “There's a lot of factors that that are causing stagnation. I think the most important fact is probably around legal the legal aspects of things, because you need to tick all the boxes with regards to compliance, to the procedures that are available, whether it's through the acts that have been promulgated by Parliament; the Electricity Regulation Amendment Act; the National Environmental Management Act, which allows for us to come through with the environmental impact assessment that needs to be done; PMFA, which public Finance Management Act. So these acts, you know, adherence to them is very important that and that's before you can actually start doing any procurement and when you're doing procurement. There are others from the Department of Trade, Industry and Competition. So I think the legal aspect is the most important one. And then your social one is probably second, second most important because touch. On the social licence that you need to receive before you can operate these facilities, and that's something that, you know, there's an attitude of saying not in my backyard type of an attitude. So you've got to navigate that you've got to navigate that very well. In order to get the approval that you need and then technology point of view, there's an emergence of small modular reactors. But in South Africa, none of them have been licensed globally. I think about two designs have been licensed. Then of course, you got the economic factor is important because how you structure that deal is is what will make it a reality or make it to fail. As I mentioned, the environmental aspect is very, very important because it touches to touches on issues of how you will handle the waste. How will you will handle accidents, how you will ensure that no member of the public is exposed to.” #3: “Political factors, such as a lack of strong support for nuclear energy, are significant barriers. The emphasis on renewable energy, primarily supported by external funding for the Just Energy Transition (JET) project, diverts focus and resources away from nuclear. Misinformation about nuclear energy being “unsafe” or “unclean” adds to social resistance, even though nuclear energy is one of the cleanest and most reliable baseload energy sources available. Historically, nuclear energy has been associated with events like Hiroshima, Three Mile Island, Chernobyl, and Fukushima, which has led to public distrust. However, these incidents are not indicative of modern nuclear technology, which has evolved significantly with increased safety standards. Political and economic interests in renewable energy, particularly among those invested in IPPs, further complicate the

	narrative around nuclear, pushing an agenda that prioritizes renewables even though they are more costly and inconsistent.”
Q2: With the aim of adoption of nuclear energy for industrial resilience, how can these factors be addressed?	#1: “You have to address legal, of course. The only thing we can call for is adherence. There is case law that shows you know how you've gone wrong. You can turn that into a positive by developing strategies that address the case law issues that have been raised. So that's all I can say on legal on environmental, you will never receive a license without proving your case. You know the steps that are required to your to your studies, you know, on time, prepare for them on time and make sure the studies are available when they are needed and they are done with quality companies and companies that know what they are doing and you know. You not found wanting from an environmental point of view and then from a technology point of view, you know, I would advise we use mature technology. Rather than first of a kind type of technology that that's very much important. And then on economy, They are innovative types of ideas to own the nuclear power plants these days, including the public, private and Partnership Public private partnership with different stakeholders. As long as your policies allow for that, you can be able to gain some equity from different players and then be able to make the project a reality. But the most important day is how you build your business case around that. On social you have to engage public participations is very important.” #2: “To overcome misinformation, the nuclear industry must amplify its voice by educating the public about the safety, efficiency, and environmental benefits of nuclear energy. Communication specialists can help simplify complex nuclear concepts for the average citizen, making nuclear more accessible and dispelling myths. Additionally, NGOs that influence energy policy should disclose their funding sources, as many are funded by organizations invested in competing technologies. Strengthening public awareness through transparent discussions can reduce the influence of these vested interests and foster a more balanced perspective on nuclear energy.” #3: “Through transparency and forming solid structures that will be bound by long term contractual agreements where each new government would have to uphold.”

In terms of decision making, the government plays an important role in shaping nuclear energy policies whereas the regulatory bodies ensure safety and compliance while civil society contribute to discussions through public participation.

South Africa has a foundation of skilled workforce a result of long operational history, developed electricity grid, however additional skilled personnel need to be trained and developed. Financing is identified as the major barrier; the country may need to explore favourable financial models to support nuclear expansion, a significant capital investment will be required to obtain technology and infrastructure development.

Some of the barriers are financial and political support of nuclear energy, a call made that professionals are allowed space in decision making. Public perceptions are also another identified barrier because of misinformation, environmental impacts and waste management are also serious concern to the public. These can be addressed through adherence to legal frameworks and compliance, transparency, public engagement and a sound financial model.

4.2.2.3 Sources of Knowledge

Introduction to Sources of Knowledge

This section addresses the three aspects of the sources of knowledge: expertise, expert, and guarantor. The expertise aspect refers to the specialised knowledge and technical skills required to assess and implement nuclear energy solutions effectively. The expert aspect highlights the role of individuals and institutions with deep experience and proven track records in nuclear technology, energy policy, and industrial strategy. The guarantor aspect involves entities that provide validation, oversight, and assurance of the quality and reliability of the knowledge applied.

Sources of Knowledge	Experts Responds
Expertise: Q1: What areas of expertise or specialised knowledge do we as the country possess when it	#1: “South Africa has a wealth of nuclear expertise, developed over decades of operation with both nuclear power plants (NPPs) and the SAFARI-1 research reactor. Our skilled workforce includes specialists in nuclear engineering, reactor operations, safety and regulatory compliance, and nuclear fuel cycle technology. These professionals have contributed to projects globally, including in the

comes to nuclear technology?	UAE's Barakah NPP, and work in leading international organizations like the IAEA, Rosatom, EDF, and X-Energy. Necsa (Nuclear Energy Corporation of South Africa) plays a crucial role in advancing nuclear capabilities within the country, particularly in nuclear research, medical isotope production, and fuel manufacturing." #2: "We have qualified nuclear professionals with technical skills that are needed when it comes to nuclear technology from construction, education, scientific and engineering specialised knowledge and project management." #3: "We have a lot of good nuclear engineers, nuclear scientists, chemists, oncologists, operators, project managers, project planners, project schedulers, artisans. You know, we some of our people have been poached a lot in the last number of years, but we still keep on training more skills out with regards to that."
Q2: What areas of expertise or specialised knowledge would be required for the South African energy sector if it adopts nuclear energy for industrial sector?	#1: "Experts in the nuclear science and engineering disciplines, economics and financial knowledge around financing models for long-term projects like this, energy policy makers, research, construction, and professional communicators." #2: "**Nuclear Engineering and Reactor Physics:** Safe reactor design and neutron management for energy generation. Safety and Regulatory Compliance: Radiation protection, emergency response, and regulatory knowledge. Environmental Science and Sustainability: Nuclear's environmental impact, waste management, and sustainable practices. Supply Chain and Project Management: Materials management, construction oversight, and quality control. Electrical and Mechanical Engineering: Efficient turbines and robust control systems for nuclear facilities. Nuclear Fuel Cycle and Chemistry: Fuel processing and reprocessing knowledge. Policy, Economics, and Public Engagement: Development of policies, economic analysis, and public outreach. R&D: Continuous technological advancements and reactor design innovations. Training and Development: Building nuclear-specific skills through training programs. South Africa's existing expertise, supplemented by targeted education and training, will enable the country to develop a capable workforce and a resilient industrial sector powered by nuclear energy." #3: "The country it will need to train more people and create more institutions of learning solutions. There are more international students that are trained rather than local, this must be looked at. Manufacturing opportunities need to be created. Industries that will support that will support the expansion. All areas of engineering they need to be supported and established. They need to be supported so that the when the expansion starts, it will be easy to support the expansion. By investing now in education, in establishing industries that will have positive spin offs in terms of establishing communism in in

	terms of creating a jobs. **T**he government policies need to be looked into."
Expert: Q1: What part does an expert play in providing information and contributing to talks, choices, and policy-making processes concerning nuclear energy projects?	#1: "An expert is off course able to provide accurate information in how the technology works, its benefits and current technological advancements and setbacks. As much as experts are well versed on a subject can speak on it at a higher level, most do not do the best job when it comes to conveying the message to the everyday person. Either experts need to be trained how to "dumb a subject" down for the average joe or we need trained communication specialist though to be able to be able to convey the message to the average Joe so they grapple with what nuclear energy is about." #2: "Their skills, insights and ability to unpack and simplify complex themes, and being accountable for the information they share and their roles in the nuclear projects. I also think making use of the platforms and spaces they are in, and the opportunities that are there to continuously communicate their thoughts and share their expertise." #3: "An expert plays a very critical role in this, and it's also a question of them being given the platform to share that information. As a policymaker myself, I undertake research, I formulate policy, I analyse policy options, and I communicate this with stakeholders. So this is a very critical point."
Q2: What ethical obligation does the expert have in terms of giving unbiased, evidence-based insights and recommendations to decision makers?	#1: "Experts have a strong ethical duty to provide truthful, evidence-based insights without bias. Unfortunately, in today's world of unregulated social media, people can claim expertise without verification, often spreading half-truths and misinformation. We see this in the promotion of certain renewable energy agendas, where some "experts" are financially backed by vested interests and share selective information. Nuclear professionals, by contrast, are generally committed to ethical standards, as demonstrated by the recent statement from the regulator on Koeberg's long-term operation. Maintaining ethical integrity in public messaging should be a requirement across the industry to ensure that society receives well-rounded, factual information about energy choices." #2: "It is important for the expert to be transparent and unbiased in giving their insights in order to not be misleading and avoid conflict of interest. Confidentiality is also an ethical obligation." #3:" It is important for the expert to be objective to avoid conflict of interest, those are important and to act with the necessary control and stay within the ambit of the law. I think that's what is expected of the of the of the expert from ethical point of view."
Guarantor: Q1: In your opinion, who should be the guarantor of	#1: "Everyone deserves a voice, but science and engineering should be the foundation for decisions on technology deployment. Evidence-based, peer-reviewed research should guide choices, not personal or political agendas. While political and business interests

choices about nuclear energy deployment?	often have the influence to shape public opinion, scientists and engineers have a responsibility to consider not only technical design but also the social and environmental impacts. This broader perspective should inform the final decision to ensure it aligns with both ethical standards and the well-being of society." #2: "National governments set the policy framework and provide financial and regulatory support for nuclear energy projects, making high-level decisions about the strategic direction of development. Independent regulatory bodies, like the Nuclear Regulatory Commission (NRC) in the US, ensure compliance with safety standards and environmental regulations. International organizations like the International Atomic Energy Agency (IAEA) provide guidelines, safety standards, and technical assistance to member states, promoting international cooperation and sharing best practices. Public and stakeholder engagement is crucial for the acceptance and successful deployment of nuclear energy, addressing concerns and building trust in the sector." #3: "The stakeholders/government"
Q2: What criteria can be used for legitimacy?	#1: "Legitimacy should be grounded in evidence-based, peer-reviewed science, as well as an understanding of the technology's socio-economic impact. Only by evaluating both technical data and societal effects can we ensure that the chosen energy solution is sustainable and truly beneficial." #2: "Do all the public consultations that are obligated by law" #3: "Public involvement. Stakeholder engagement"

South Africa boasts decades of nuclear experience, with a pool of skilled professionals spanning various nuclear-related fields. However, the country faces a persistent challenge of talent migration, as many experts seek opportunities abroad. While there is a wealth of specialized expertise, continued investment in industries that support nuclear energy expansion is critical to retaining talent and strengthening local capacity.

A key opportunity lies in enhancing communication skills among nuclear experts, enabling them to convey complex technical information clearly and accurately to the public and non-experts. Maintaining accountability, truthfulness, transparency, and objectivity is essential, particularly in combating misinformation and avoiding conflicts of interest.

Establishing legitimacy in nuclear energy policy hinges on evidence-based decision-making and robust public engagement. Policies must be rooted in scientific evidence while incorporating public consultations and stakeholder participation to foster trust and transparency. Key stakeholders include the government, which is responsible for setting policies, providing financial support, and guiding strategic direction; regulatory bodies that ensure safety and compliance; and the public, whose involvement is crucial for building trust and ensuring that nuclear initiatives align with societal needs and expectations. This holistic approach can strengthen South Africa's nuclear energy strategy, balancing expertise, governance, and public confidence.

4.2.2.5 Sources of Legitimacy

Introduction to Sources of Legitimacy

This section addresses the three aspects of the sources of legitimacy: emancipation, witnesses, and worldviews. The emancipation aspect focuses on promoting inclusivity and empowering marginalised voices. The witnesses aspect involves engaging credible observers, such as independent experts, regulatory bodies, and civil society organisations, to validate the transparency, fairness, and impact of strategic decisions. The worldviews aspect considers the diverse cultural, ethical, and philosophical perspectives that influence public perception and acceptance of nuclear energy as a solution for industrial resilience.

Sources of Ligitimacy	Experts Responds
Emancipation: Q1: Through conversations and choices pertaining to nuclear energy, how are the stakeholders including experts, policymakers, and	#1: “Through consultative, engagements, consultations, over and above obligated by law. Give everyone a voice.” #2: “Through conversation; there are platforms for them to share their knowledge and to share their expertise and to help guide government in in making that decision in South Africa, nuclear operates under

members of the community empowered or liberated?	government and also the choices that are being made are largely being overseen by the involvement of government..”
Q2: In what ways can the energy industry foster inclusion, transparency, and social justice through collaborative problem-solving techniques, information sharing and emancipatory action?	#1: “Inclusion and transparency can be fostered by openly sharing data on the performance and impact of various energy sources. For example, the industry can collaborate with communities to weigh the pros and cons of different technologies, clearly explaining why certain shifts are taking place in the global energy landscape. Stakeholders should be informed of both the benefits and potential downsides of each energy source, allowing them to be part of a decision-making process that reflects shared goals and values.” #2: “The first point would be to create the platforms for information sharing. Whether it is, I know in the nuclear space there is there are platforms like public safety information forums but those are happening quarterly and they are called for by the MNR act. Similar could be also adopted across the wider industry and not just nuclear. And then those platforms are also used to transparently share information, so they are shared by independent parties and they involve the operators to bring in the necessary information and share with the public. And that platform is attended by a number of stakeholders from the sector of social justice and others and then the collaborative. Problem solving techniques are something that have to be deliberate on how things are being undertaken because you know the impact on whether the social license continue to exist or whether it is challenged and not able to be in effect anymore and that plant maybe is called on to shut down because it did not obtain a social license. The part of US information sharing is part and parcel of the transparency.”
Witnesses: Q1: With regards to loadshedding, aging infrastructure, and high energy costs impacting the industrial sector, how do you see your position as an observer of the potential and problems confronting the South African energy sector?	#1: “Most of our coal infrastructure is outdated, with a large portion expected to be decommissioned by 2030. Ideally, we should already be advancing replacement infrastructure that ensures consistent baseload generation, as renewables alone cannot fulfil this need due to resource and cost demands. Load shedding, which began around 2007, resulted from leadership and management failures, particularly neglecting maintenance of coal plants.” #2: “We need the Just Energy Transition in order to balance both social and environmental concerns by localizing energy production instead of keeping it private where only the elite get to have a say. Amidst all the problems and issues, there are opportunities for transformation and productivity through adding nuclear energy in the energy mix thereby leading to an inclusive policy reform.”
Q2: How do you perceive systemic dynamics and complexity in the energy sector impacting decision-	#1: “The integration of nuclear energy into the energy mix involves complex interactions with other energy sources, including renewables and fossil fuels. Technological advancements, regulatory frameworks, and public perception are all critical factors that influence the decision-

making processes surrounding the deployment of nuclear energy?	making process. Technological advancements can alter the economic viability and strategic importance of nuclear energy, while regulatory frameworks, including safety standards and environmental regulations, can impact the cost and feasibility of nuclear projects. Public engagement and trust are also critical factors, and effective communication and engagement strategies are necessary to address these concerns. Economic viability and environmental sustainability are also key considerations, and risk management and safety are crucial. Decision-makers must develop robust safety protocols and risk management strategies to mitigate these risks." #2: "The integration of nuclear energy into the energy mix involves complex interactions with other energy sources, including renewables and fossil fuels. Technological advancements, regulatory frameworks, and public perception are all critical factors that influence the decision-making process. Technological advancements can alter the economic viability and strategic importance of nuclear energy, while regulatory frameworks, including safety standards and environmental regulations, can impact the cost and feasibility of nuclear projects. Public engagement and trust are also critical factors, and effective communication and engagement strategies are necessary to address these concerns. Economic viability and environmental sustainability are also key considerations, and risk management and safety are crucial. Decision-makers must develop robust safety protocols and risk management strategies to mitigate these risks."
Worldviews: Q1: What underlying beliefs, attitudes, and views affect your perception of nuclear energy's role in alleviating energy concerns, boosting economic growth and contributing to global sustainability in South Africa?	#1: "Technological advancements, particularly in nuclear energy, can significantly address energy challenges. The belief is that nuclear power can contribute to reducing greenhouse gas emissions and combating climate change, as it is a low-carbon energy source that complements renewable sources. Nuclear energy can also stimulate economic growth by providing a stable and reliable energy supply, creating jobs and stimulating economic activity. Energy security is vital for national development, as nuclear energy can diversify the energy mix and reduce dependence on imported fuels. Effective risk management and safety protocols are essential for the deployment of nuclear energy. Public engagement and transparency are crucial for successful deployment of nuclear energy. Global cooperation is essential for addressing energy and sustainability challenges, as international collaboration can facilitate the transfer of nuclear technology and provide financial support. Finally, the strong commitment to environmental protection, stating that nuclear energy can contribute to environmental conservation by reducing dependence on fossil fuels." #2: "My perspective on nuclear energy is not driven by beliefs or attitudes but by the technology's proven benefits. There is a misconception that South Africa lacks nuclear expertise, that nuclear waste is unmanageable, and that nuclear is too costly and time-consuming. In reality, the nuclear industry is highly responsible, with strict protocols for waste management and secure disposal. While nuclear does require substantial initial capital and 5–10 years for construction, these facilities are long-term investments, typically operating for 60 years, with potential extensions up to 80 or even 100 years as stated by Director General of the IAEA Rafael Grossi. Operating costs are low because uranium is an affordable fuel, and

	price stability since the 1980s supports its cost-effectiveness. Research from countries like France has shown that nuclear energy is the most reliable, clean, and economically viable option. Countries closest to their net-zero targets generally rely on a combination of nuclear and hydroelectric power, highlighting nuclear's essential role in sustainable energy." #3: "The fact that it has become a political ploy for some time now forgetting the basic needs of the average South African. The role of nuclear energy is to address energy concerns and meet the demand while contributing to economic growth and sustainability. A lot more information needs to be shared in a transparent manner and there has to be accountability from all parties involved. The country needs clean energy and that means decarbonisation which contributes to reducing global warming."
Q2: How do you reconcile potentially opposing or competing worldviews among stakeholders, and what tactics do you use to encourage mutual understanding, respect, and collaboration in decision-making processes?	#1: "Reconciling differing views requires open communication and respect for evidence-based science. I encourage dialogues that respect each stakeholder's concerns, offering clear, factual explanations to counter myths or biases. By presenting nuclear energy's economic and environmental advantages transparently, we can build mutual respect and ensure that all parties feel heard and understood in the decision-making process." #2: "Building long-term relationships by fostering trust and prioritizing mutual understanding and having everyone understand what their roles are which would lead to collaborative decision-making. South African needs to exploit its potential by making use of its talent and expertise (collaborative effort across industries) and openly addressing challenges and collectively finding solutions." #3: "Facilitating dialogue among stakeholders, promoting empathy and active listening, and providing accurate information about nuclear energy. Educational workshops and seminars play a role in enhancing stakeholders' understanding of nuclear energy and its role in addressing energy challenges. The use of multi-stakeholder platforms, which involve diverse stakeholders from government officials, industry representatives, environmental groups, and local communities. Consensus-building techniques are employed to reach decisions that are acceptable to all parties. Conflict resolution techniques, such as mediation and negotiation, which focus on the underlying interests and needs of stakeholders. Open communication is maintained to build trust and accountability. Regular updates on the progress of nuclear energy projects and any changes in plans or policies are provided to keep stakeholders informed. Cultural competence and adaptation, recognizing and respecting cultural differences among stakeholders. This involves tailoring nuclear energy projects to meet the specific needs and concerns of local communities, incorporating local knowledge and practices into project design and implementation."

Open and honest discussions with the public are crucial for building trust and addressing concerns about nuclear energy in South Africa. Experts emphasise that nuclear energy policies should prioritise transparency, shared governance, and equitable distribution of benefits. Engaging with the public through diverse platforms fosters an environment of inclusiveness and openness, which is vital for aligning nuclear initiatives with societal expectations. South Africa's energy strategy must balance reliability, sustainability, and social equity by investing in both nuclear and renewable energy sources while addressing existing policy and infrastructure gaps.

A balanced approach to nuclear energy integration involves evaluating technological advancements, economic viability, safety, and public trust. Nuclear energy should be viewed as a practical and essential component of the country's energy transition, contributing to energy security, sustainability, and economic growth not merely as a political issue. Improving public understanding, ensuring accountability, and establishing clear policies are critical to supporting nuclear deployment for long-term economic and environmental benefits. Experts advocate for stakeholder engagement, consensus building, and conflict resolution to navigate policy and implementation challenges. Transparent communication, inclusive decision-making, and education combined with cultural sensitivity and mediation techniques can effectively address resistance and facilitate successful nuclear energy integration.

4.3 Summary

The aim of the study was to explore the strategic role of nuclear energy in addressing South Africa's energy challenges and enhancing industrial resilience, guided by the research questions “What are the strategic implications of integrating nuclear energy into South Africa's energy sector to enhance its industrial resilience?”

The findings highlight the need for a dependable baseload energy source to mitigate rolling blackouts and stabilise industrial operations. Nuclear energy was identified as a low-carbon alternative that can contribute to economic growth, job creation and technological innovation. Key barriers include public scepticism stemming from safety concerns, regulatory delays and financial constraints.

The study also emphasised the need for strategic alignment between government policy, industry practices, and public engagement to overcome barriers and build a robust, resilient industrial sector. The findings support a balanced approach that integrates nuclear energy with broader energy transition goals, contributing to South Africa’s economic and environmental objectives.

CHAPTER 5. Discussion

5.1 Overview

This strategic analysis of nuclear energy for industrial resilience in South Africa provides a comprehensive review of the research conducted. The study involved expert interviews and critical systems heuristics. The primary aim has been to assess how nuclear energy can enhance industrial stability. The research question guiding this study was: What are the strategic implications of integrating nuclear energy into South Africa's energy sector to enhance its industrial resilience?

5.2 Summary of Findings

Nuclear energy was identified as a reliable baseload power source, offering consistent electricity supply that can stabilise industrial operations. Experts emphasised its capacity to mitigate the effects of loadshedding, a critical issue hampering South Africa's manufacturing sector. Furthermore, nuclear energy's potential to stimulate economic growth was evident in its ability to create jobs, attract foreign investment and foster local technological innovation. On the environmental front, nuclear energy was highlighted as a low-carbon solution capable of reducing South Africa's heavy dependence on coal, aligning with global decarbonisation goals. These findings underscore nuclear energy's potential to fulfill the study's objectives, providing a comprehensive solution to the country's multifaceted energy crisis.

The findings corroborate existing literature on nuclear energy's role in energy transitions, industrial resilience and sustainability. Literature consistently identifies nuclear energy as a dependable source of baseload power (Malischek, 2016) (Steenkamp, 2022), describe nuclear power's ability to provide weather-independent, continuous energy, making it ideal for stabilising industrial activities. Similarly, the findings confirm that nuclear energy can address South Africa's

loadshedding crisis, providing a stable energy supply essential for energy-intensive sectors like mining and manufacturing.

Studies emphasise nuclear energy's economic benefits, including job creation, lower electricity costs and technological advancement (Addo et.al, 2023) (Nkosi, 2021). The findings align with this perspective, revealing that nuclear energy can bolster local economies by creating skilled jobs in construction, operation and maintenance. Moreover, public-private partnerships and technology transfer opportunities were identified as pathways for leveraging foreign investment and building local capacity.

The role of nuclear energy in decarbonisation is well-documented in the literature (Pravalie, 2018) (IAEA, 2021). By producing minimal greenhouse gas emissions during operation, nuclear energy contributes to a cleaner energy mix. The findings reinforce this, positioning nuclear energy as a critical component in reducing South Africa's coal dependency and achieving its carbon reduction targets.

The challenges surrounding nuclear energy, particularly public scepticism and regulatory hurdles, are consistent with literature. Studies by (Andries Lodewikus Lombaard, 2016) and (Marsh, 2021) highlight safety concerns and waste management as key obstacles. The findings echo these concerns, emphasizing the need for transparent communication, robust regulatory frameworks and advanced waste management solutions to address public apprehension and foster acceptance.

South Korea's success in integrating nuclear power into its energy mix through stable policies, technological localisation and public-private partnerships (Sanghyun Hong, 2014) (Uhunamure, et al., 2021) was frequently cited as a model for South Africa. The findings confirm that adopting similar strategies could help South Africa overcome financial, regulatory and social challenges.

The findings bridge the study's purpose, existing literature and theoretical frameworks by demonstrating nuclear energy's strategic role in addressing South

Africa’s challenges. They validate the literature’s emphasis on nuclear energy’s reliability, economic benefits and environmental advantages while aligning with theoretical approaches that advocate collaborative, iterative and ethical strategies.

CHAPTER 6. Conclusions of the Study

The findings provide a compelling case for nuclear energy as a cornerstone of South Africa's energy strategy, aligning with the study's purpose, corroborating existing literature and leveraging theoretical frameworks. Nuclear energy's potential to stabilise energy supply, drive economic growth and reduce carbon emissions positions it as a viable solution to South Africa's energy challenges. However, addressing barriers such as public perception, regulatory delays and financial constraints is critical for success.

The study highlights that nuclear energy can address South Africa's energy security challenges by providing a consistent and weather-independent power supply essential for industrial operations. This capacity to mitigate disruptions such as loadshedding, positions nuclear energy as a cornerstone for enhancing industrial resilience. Furthermore, nuclear energy offers long-term economic benefits through job creation, technological innovation and investment opportunities. By integrating nuclear into its energy mix, South Africa can also make significant strides in decarbonisation, reducing its reliance on coal and contributing to global climate commitments.

However, the adoption of nuclear energy is not without challenges. Public concerns over safety and waste management, coupled with high upfront costs and stringent regulatory requirements, pose significant obstacles.

6.1 Recommendations

To ensure the sustainability and strategic impact of nuclear energy on industrial resilience in South Africa, a multi-faceted approach involving policy, practice, and managerial interventions is required. This section outlines key recommendations across these domains to support the effective integration of nuclear energy into the national industrial landscape.

Policy Recommendations

A robust policy framework is critical to establishing a stable and conducive environment for nuclear energy development. Firstly, the South African government should develop a clear and comprehensive nuclear energy policy that aligns with broader national energy and industrial strategies. This policy must provide regulatory certainty, encourage long-term investments, and outline safety and environmental standards in line with international best practices.

To attract investment into the nuclear sector, policy instruments such as tax incentives, subsidies, and public-private partnership models should be introduced. Additionally, regulatory frameworks need to be strengthened to enhance safety and compliance. This includes rigorous environmental assessments, transparent licensing processes, and alignment with global nuclear safety standards. Furthermore, promoting research and Innovation is essential. Government funding and collaboration with academic and research institutions can drive innovations in advanced nuclear technologies, waste management solutions, and sustainability practices.

Practice Recommendations

On a practical level, adopting advanced nuclear technologies such as small modular reactors (SMRs) and next-generation nuclear systems can offer improved efficiency, safety, and scalability. These technologies can also facilitate the integration of nuclear energy into both large-scale industrial operations and smaller, localized energy grids.

Capacity building is another crucial aspect. Establishing training programs for engineers, technicians, and policymakers will ensure that South Africa develops a skilled workforce capable of managing nuclear technologies and maintaining high safety standards. Additionally, fostering international collaboration with global nuclear agencies and countries like South Korea can help South Africa adopt best practices and technological advancements in the nuclear sector.

Public awareness campaigns are also important to address misconceptions and educate communities about the benefits, safety measures, and long-term sustainability of nuclear energy. Transparent communication can enhance public support and reduce resistance to nuclear projects.

Managerial Recommendations

Effective managerial strategies are needed to translate policy and practice into measurable outcomes. Strategic leadership and governance structures should be established to oversee nuclear energy projects, ensuring alignment with national objectives of industrial resilience. This involves setting up dedicated project management teams with clear mandates and accountability frameworks.

Risk management is a critical component of managerial practice in the nuclear sector. Developing robust frameworks to identify, assess, and mitigate risks—ranging from safety concerns to regulatory changes—will enhance project stability and public trust. Additionally, resource optimization through efficient project management practices can improve budget control, resource allocation, and project timelines.

Performance monitoring is essential for measuring the impact of nuclear energy initiatives on industrial resilience. Establishing key performance indicators (KPIs) will provide valuable insights into project effectiveness, enabling continuous improvement and strategic adjustments where necessary.

6.2 Limitations of the Study and Future Research

The study offers critical insights into the potential of nuclear power to enhance the nation's industrial stability and sustainability. However, this study is not without its limitations, which need to be acknowledged to provide a balanced understanding of the findings and their applicability.

Limitations of the Study

One of the primary limitations of this study lies in data availability and reliability. The research relied heavily on expert interviews and publicly available data sources to formulate its conclusions. While these methods provided valuable insights, they also introduced potential biases and gaps in information. Some data related to nuclear energy infrastructure, regulatory frameworks, and safety protocols may be proprietary or classified, limiting the depth of the analysis. Moreover, the use of qualitative data from expert interviews, although enriching, may be influenced by subjective interpretations and individual biases. This subjectivity, while offering nuanced perspectives, may not fully represent the broader industry sentiment or public opinion.

Future Research

Building on the findings and limitations of this study, one promising direction would be to conduct a comparative analysis of nuclear energy against other energy sources, including renewable (e.g., solar, wind) and non-renewable (e.g., coal, natural gas) options. This analysis could provide a more holistic perspective on which energy mix offers the most stability, sustainability, and cost-effectiveness for industrial applications.

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APPENDICES

APPENDIX A: Participant Invitation Letter

Dear Prof./Dr./Mr/Ms

Research Topic: Strategic Analysis of Nuclear energy for industrial resilience in South Africa

My name is Zamazizi Dlamini, I am a Masters in Business Administration (MBA) student in the faculty of Commerce, Law and Management (CLM) at the University of the Witwatersrand, Johannesburg. My supervisor is Prof. Nixon Ochara.

You are invited to participate in a research study that will investigate the strategic implications of nuclear energy for improving the industrial resilience of South Africa's energy sector. This study aims to address current energy sector challenges, such as load shedding, aging infrastructure, and high energy costs, with a particular emphasis on their impact on the manufacturing industry. The study's research methodology will be guided by theoretical frameworks such as interactive planning and critical system heuristics. Expert interviews, existing studies, and policies will be used to gather information on the potential of nuclear energy to address energy issues, stimulate economic growth, and contribute to global sustainability.

If you agree to participate in this study, you will be asked to take part in an expert interview. The interview will be conducted in person, over the phone, or via video conferencing, depending on your preference. During the interview, you will be asked to share your thoughts, experiences, and perspectives on the strategic implications of nuclear energy for the South African energy industry. The interview is expected to last about 60 minutes.

Your participation in this study is entirely voluntary, and all information gathered will be kept confidential. Your identity will be kept anonymous in any reports or publications resulting from this research. Only the researcher and authorised personnel will have access to the collected data, which will be securely stored in accordance with data protection regulations.

Participation in this study could contribute to a better understanding of the

potential benefits and challenges associated with nuclear energy adoption in South Africa.

If you have any questions during or afterwards about this research study, feel free to contact me or my supervisor on the details listed below. If you have any concerns or complaints about the ethical procedures of this research study, you are welcome to contact the University Human Research Ethics Committee (Non-Medical), telephone +27(0) 11 717 1408, email hrecnon-medical@wits.ac.za.

Yours sincerely,

Zamazizi Dlamini

Researcher:

Zamazizi Dlamini, 0616084T@students.wits.ac.za, +27 76 738 5083

Supervisor:

Prof Nixon Ochara, Nixon.Ochara@wits.ac.za

Appendix B: Participant Consent Form

Consent Form,

Title of project: Strategic Analysis of Nuclear Energy for Industrial Resilience in South Africa

Name of researcher: Zamazizi Princess Dlamini

I, ……., agree to participate in this research project.

I agree to the following:

(Please circle the relevant options below)

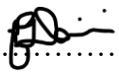
The research study was explained to me. I understand what this study is about.	YES	NO
I understand that I can volunteer to take part in the study	YES	NO
I agree that the interview/focus group/other activity may be audio recorded	YES	NO

I agree that direct quotations from my interview/focus group/other activity may be used by the researcher in their research report/ manuscript/book chapter	YES	NO
I agree that my participation will remain anonymous (my name or other identifying data will not be used by the researcher in their research report/manuscript/book chapter)	YES	NO
I agree that other researchers may use the information I provide in my interview/focus group/other activity (depending on their own ethics clearance being obtained) but my name and any personal information will not be used or passed on	YES	NO

…… (signature)

…… (name of participant)

…… (date)


…… (signature)

ZP Dlamini …… (name of researcher/person seeking consent)

…… (date)

Appendix C: Ethics Clearance Certificate

Graduate School of Business Administration
University of the Witwatersrand, Johannesburg

Wits Business School

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

Ethics Clearance Certificate

Ethics protocol number: WBS/BA0616084T/393
This certificate is only valid with a legitimate ethics protocol number and signed by the Researcher (below).

Project title	Strategic analysis of nuclear energy for industrial resilience in South Africa
Investigator / Researcher	Ms Zamazizi Dlamini
Nature of Project	MBA (Research Article)
Decision of the Committee	Approved, provided stakeholders and participants are guaranteed confidentialty.
Issue Date of Certificate	23/07/2024
Expiry date	Date of submission of the project / research report
Chairperson	Ms Ayanda Magida ☎ +27 11 717 3953 ✉ ayanda.magida@wits.ac.za

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Declaration by Researcher

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

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

Signature

25/07/2024
Date: