Establishing a collaborative supply chain framework for advancing renewable energy development through industrial clusters in South Africa.

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ABSTRACT

Background: Industrial clusters in South Africa were established since 2007, focusing initially on the wine, textile, and automobile sectors to promote international collaborations and boost the global presence of South African products. These partnerships aimed to enhance the competitiveness, productivity, and trade performance of key sectors in the South African economy. With the global emphasis on reducing carbon emissions, industrial clusters are now seen as a means to accelerate decarbonisation efforts within the energy sector.

Problem statement: The energy transition journey has not been gaining traction due to conflicting business goals in industrial areas. From a supply chain perspective, there is a need to investigate which elements of the supply chain network can be ring-fenced in order to ensure there is collaborative benefit for organisation's operating in the industrial clusters.

Purpose: This study aims to establish a framework for guiding and encouraging collaborative supply chain networks within industrial clusters, with a focus on supporting renewable energy development in South Africa. It aims to assess various elements of supply chain network design and identify common collaboration aspects among organisations in an industrial region to expedite the decarbonisation process through renewable energy solutions.

Design, methodology and approach: The study aims to gather qualitative data by distributing a comprehensive questionnaire to professionals in industrial regions across South Africa. Respondents will be sourced through networks such as word of mouth, acquaintances, LinkedIn, and other energy sector professional networks. At least 30 responses are expected, with the link shared with 60 potential respondents to account for invalid responses or non-responses. Data will be analysed using content analysis to identify patterns and trends.

Findings: South African organisations struggle with collaboration challenges, which include inefficiencies, poor cost reduction strategies, and inadequate talent development. Key enablers include improved resource management and talent development. Technological and communication issues, bureaucratic barriers, and unsupportive policies hinder progress in renewable energy projects. Enhancing collaboration can leverage shared knowledge, improve problem-solving, and strengthen supply chain resilience amongst cluster partners. Streamlined processes, better logistics, and robust policies are essential for faster decision-making and infrastructure development, can support the success of renewable energy projects.

Key words: Decarbonisation, renewable wind energy, industrial clusters, supply chain, collaboration, industrial cluster partnerships

DECLARATION

I, **SELOGADI RACHEL MOSEHLE**, declare that this research report is my own work except as indicated in the references and acknowledgements. It is submitted in partial fulfilment of the requirements for the degree of Master of Management in **ENERGY LEADERSHIP** at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in this or any other university.

Name: **Selogadi Mosehle** Signature:

Signed at Sandton, South Africa.

On the **27th day of February 2025**.

DEDICATION

Firstly, I dedicate this qualification to my daughter, Pholosho. Thank you for giving me the strength and courage to do more and be more in life! You have added so much colour to my life, and I appreciate you so much my Angel!

I dedicate this research to my parents – Mr and Mrs Mosehle. Your collective faith and support have been the cornerstone of this journey. Thank you for being my pillars of strength and for helping me turn my aspirations into reality. I’m truly blessed by your hopes and prayers upon my life; may they continue to manifest in your honour.

This research report is also dedicated to all individuals and organisations tirelessly working towards a just transition of our energy sector. Your unwavering commitment to achieving a fair and equitable shift to sustainable practices inspires us all. Thank you for your relentless pursuit of a future where prosperity and sustainability go hand in hand, and for championing the cause of a just and inclusive society. Through all your hard work, may Africa’s energy poverty be eradicated indefinitely.

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Disclaimer: This research report was constructed with the assistance of AI language and referencing tools, including Grammarly, Microsoft Word Editor, Copilot, and Mendeley. These tools have significantly enhanced the efficiency and accuracy of my work by providing language support, such as paraphrasing, rephrasing, and ensuring proper citations. The support and contribution of these tools to the quality and coherence of this report has been instrumental. However, the underlying ideas and arguments presented are the result of my own attributes. The insights, interpretations, and final presentation are a true reflection of my understanding and perspective on the topic.

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LIST OF ACRONYMS

CBAM - Carbon Border Adjustment Mechanism

CO_2 – Carbon di oxide

COP - Conference of the Parties

CSIR - Council for Scientific & Industrial Research

DMRE – Department of Mineral Resources & Energy

DTI – Department of Trade and Industry

EU - European Union

GHG - Green-house gas

GHCS - Green Hydrogen Commercialisation Strategy

GHP - Green Hydrogen Panel

GW – Gigawatt

HSR – Hydrogen Society Roadmap

IPG - International Partners Group

JET - Just Energy Transition

JETIP – Just Energy Transition Investment Plan

JETP – Just Energy Transition Plan

KPI - Key performance indicator

L2C - Learning to Compete

NDP - National Development Plan

NPO - Non-profit organisations

OEM - Original equipment manufacturers

R&D - Research and development

RE – Renewable Energy

SAREM – South African Renewable Energy Masterplan

SC – Supply Chain

SMMEs – Small, Medium, and Micro Enterprises

UN - United Nations

USD – United States Dollar

WEF – World Economic Forum

ZAR - South African Rand

CHAPTER 1: INTRODUCTION

1.1. Purpose of the study

This study aimed to establish a framework that would guide and encourage collaborative supply chain networks within industrial clusters with key partners that were looking to support various decarbonisation initiatives across South Africa. The study set out to assess the various elements of supply chain networks and identify common aspects that organisations in a specific region could collaborate on, to help fast track the decarbonisation of that region. In determining these common elements, partners in the regional clusters could share insights to address opportunities and challenges more effectively through a collaborative approach than individually.

Climate change had become a global phenomenon. Over the past few years, there had been a global effort championed by the World Economic Forum (WEF, 2024), for various countries to find quicker solutions to reducing their carbon emissions. This had also led to the adoption of industrial clusters to try and progress the adoption of various technologies to help reduce the carbon footprint, with a specific focus and due respect to the local context of each geography and market (WEF, 2024). The South African government had adopted and promoted the creation of new industrial clusters to accelerate decarbonisation goals and to influence different policies that would inform how the transition was progressed. This had led to the establishment of an energy-focused industrial cluster, with more industrial companies, local communities, and non-profit organisations pulling together to find quicker ways to reduce their carbon emissions through collaborative efforts. With the global drive to reduce carbon emissions and tracing back to the country’s reliance on fossil fuel, this study would explore establishing a supply chain framework that was focused on advancing renewable energy development through industrial clusters within South Africa.

1.2. Context of the study

South Africa was amongst the top 15 largest greenhouse gas (GHG) emitters globally (McSweeney and Timperley 2018), and the largest in Africa, of carbon dioxide (CO_2) emissions due to the country's historical reliance on coal for energy production. As a developing country, energy produced from coal was the heartline of South Africa's economic activity, making coal a crucial player in ensuring the minimum amount of electric power needed by the country was available (Kabeyi and Olanrewaju, 2021). This raised concerns on whether low-carbon energy sources could play a critical role in ensuring sustainable electricity supply to industrial consumers (Kabeyi and Olanrewaju, 2021). South Africa made international obligations to contribute towards addressing climate change impacts by instituting dramatic reductions in greenhouse gas (GHG) emissions through the adoption of cleaner technologies. To achieve this, the change needed to be undertaken mostly by existing industrial companies with large carbon emission footprints (WEF, 2024). New climate change policy tools such as the European Union's (EU) Carbon Border Adjustment Mechanism (CBAM) policy tool aimed to reduce GHG footprints within EU states as well as prevent carbon "leakage" through importation of goods produced in jurisdictions with lower carbon tax frameworks (ECA, 2023). CBAM imposed a carbon border tax on imported carbon-intensive products to ensure a level playing field between EU manufacturers and importers (ECA, 2023). While CBAM was essential for achieving the EU's climate objectives, it had significant implications for countries like South Africa, whose exports were at risk (ECA, 2023).

Furthermore, South Africa had recognised the need to take deliberate actions to address the over-reliance on fossil-fuel emissions in the energy mix (NCP, 2023). In June 2021, Minister Ebrahim Patel announced the establishment of the Green Hydrogen Panel (GHP) tasked with drafting the Green Hydrogen Commercialization Strategy (GHCS), which was intended to build on the Hydrogen Society Roadmap (HSR) and produce a commercial and industrialisation green hydrogen country masterplan. The GHCS was approved by Cabinet in October 2023. As part of GHCS work, specific "lighthouse" green hydrogen projects and initiatives that should be supported as part of the strategy were identified. The Medium-term Strategic Framework 2014-2019 identified opportunities in the green economy, the ocean economy, as well as research and technology development, as emerging clusters that various organisations could partner on (DPME, 2024). The medium-term strategic framework 2014-2019 proposed a green economy cluster and had progressed this cluster notion into regionally focused industrial clusters. Industrial clusters were defined as geographical areas where groups of manufacturing industries (representing either a single or multiple industries) were co-located. When industries have similar ambitions, such as decarbonisation technology pathways being adopted, the co-location would provide prospects to address opportunities and challenges more effectively through working together than individually (Porter, 2020). This included enabling economies of scale, sharing risk and resources, aggregation, and leveraging complexities (Porter, 2020).

The formation of an industrial cluster identified collaboration as a key enabler to its success (ECA, 2023). Furthermore, an energy industrial cluster is focused on decarbonising the industrial region by fostering a partnership amongst key stakeholders that operated or lived in that region. This, therefore, necessitated the need to understand how industrial clusters could serve as vehicles to fast-track the country's decarbonisation goals. In doing so, the study delved deeper into unpacking renewable energy as a decarbonisation energy solution, and what the supply chain for such a cluster would look like. Following this trail, the findings allowed for the establishment of a collaborative supply chain, with the understanding of what challenges the partnering organisations were faced with, and a determination of what benefits could be extrapolated from such a strategy. While literature offered a basic explanation of what a supply chain was, the processes that were involved in the production, purchase, and delivery of products, from manufacturers to end users (Forrest, 2024), remained complex if applied to multiple organisations with differing policies and cultures (ECA, 2023). Managing these activities could be clustered into a network that was perceived to be complex and forever evolving. However, in an article, Forrest (2024) expanded further on the supply chain network term, stating that location intelligence played a critical role in designing a supply chain network (Forrest, 2024). The modelling of a supply chain network was aimed at understanding the cost and time linked to ensuring goods were brought to market, which was enabled by resources and location. According to Forrest (2024), location positioned an important factor in the success of a supply chain, and in support of ECA (2023), it could be deduced that industrial clusters might inform the viability of determining (i) how and where renewable energy raw materials would be stored, (ii) when and how the renewable energy materials would reach their final destination (i.e., the consumer) in a more coordinated and collaborative manner (ECA, 2023).

1.3. Problem Statement

With the world faced with climate change challenges, securing clean energy sources had been top of mind. South Africa was not excluded from this endeavour with an added risk to powering economic development. The country's overarching National Development Plan (NDP) 2030 advocated for increased investment in an energy sector that was both economically inclusive and environmentally sustainable (NCP, 2024). The NDP identified, as a priority, the production of sufficient energy to ensure availability, accessibility and affordability while reducing the carbon intensity of the economy.

Thus far, decarbonisation efforts in South Africa had not taken off at a large scale, due to multiple factors that threatened sustainable economic development (Baxi, 2024). These factors included lack of investment; market structure; innovation and technology; and infrastructure and capacity challenges, to name a few (Baxi, 2024). Baxi (2024) further described these challenges to have affected both the readiness and capacity of markets to embrace cleaner energy (Baxi, 2024). Despite this, obstacles persisted for small businesses and their underdeveloped supply chains, limiting their access to opportunities in the low carbon energy sector (Baxi, 2024). While supply chains may have differed for each partner within the industrial cluster, this paper sought to understand the key elements of a supply chain network design, that might determine a best-fit structure to guide future developments of partnerships in other regions across South Africa.

In line with South Africa's draft renewable energy masterplan (SAREM, 2023) strategies to support the Just Transition, industrial collaboration would play a key role in realising the objectives of the masterplan. Alongside the topic of collaboration within industrial clusters, supply chain activities had a direct impact on driving economic activity (SAREM, 2023). In order to create a scalable, well-functioning, and viable low-carbon economy, it was believed that coordinated and integrated efforts from all key value chain role players such as global original equipment manufacturers (OEMs) and suppliers, customers, supporting industries, enabling policy & regulatory environment, and funding would have to pull together and show commitment to this path (Deloitte,

2021) (Hmouda, Orzes, & Sauer, 2023). In this study, it was appreciated that for this type of partnership to prove successful, a reliable supply chain design must exist. While the various partners might rely on their own internal resources to deliver decarbonisation initiatives, a central focus that leveraged each partner’s strength was key (ECA, 2023). At the core of such partnerships was the movement of materials and equipment that would ensure that the partners leveraged economies of scale and prioritisation of resources, joint supplier development initiatives, and industry skills (Spekman et al., 1998). Supply chains were generally designed to be competitive and resilient (Baxi, 2024), but in this case study, the need was for industrial sectors to collaborate on specific supply chain network elements that would allow supply chains to re-imagine their competitiveness, be more transparent, and be driven towards achieving a common cause – decarbonisation goals of the region they operated in. The challenge in this respect was designing a model that highlighted common supply chain interests that the industry partners could work from, to leverage skills and resources from each other to ensure a seamless supply chain network that advocated a win-win solution for the regional cluster partnership. With the collaboration of the industry partners, a centralised and region-specific supply chain network design could serve as a framework that enabled successful, sustainable, and accelerated decarbonisation of various regions.

1.4. Research objectives

The study's objectives were formulated based on the problem statement. The primary objective of the study was to establish a collaborative supply chain framework for advancing renewable energy development through industrial clusters; it was prudent to explore aspects that might influence the framework. The study explored the following:

- Identified the activities that signified the existence of industrial cluster partnerships.
- Identified the anticipated benefits for establishing a collaborative supply chain.
- Identified the challenges associated with establishing a collaborative supply chain within an industrial cluster, which might hinder the efficiency and effectiveness of the cluster’s supply chain.

- Highlighted key supply chain elements that would enable successful, sustainable, and accelerated adoption of renewable energy through industrial clusters.

1.5. Significance of the study

Industrial clusters are not a new phenomenon to the country. Some of the literature on industrial clusters suggested that such partnerships had been in existence for several years and were introduced to developing countries based on specific sectors that were on an economic growth path in the countries in question (Nadvi and Schmitz, 1994). This phenomenon was introduced to sectors such as textiles, wine, food, and automobile (Nadvi and Schmitz, 1994). Partners within the clusters were selected based on the country's economic growth drivers and were grouped according to the sector they were classified under (i.e., in the automobile industry, only car manufacturers and retailers in a region would form part of that cluster) (Nadvi and Schmitz, 1994). With the world focused on climate change, the efforts that countries were undertaking to realise their JET plans have since introduced energy as a sector of interest (ECA, 2023).

In a study on the Saldanha development zone pre-feasibility analysis, it was reported that there was a global demonstration that clusters ensured sustainable competitive advantage, and that specific actions and interventions could improve this strength (Demacon, 2009). The report further explained the objectives of such clusters and what they aimed to achieve, particularly for the progression of renewable energy (Demacon, 2009). Therefore, in determining a collaborative supply chain network design, it was imperative to understand the context as to why the clusters were established and what benefits the framework would introduce to the region in question.

The nationwide implementation of decarbonisation initiatives had slowed down due to the barriers faced by various institutions (Rudgard, 2023), as listed below:

a) Evolving market due to cost competitiveness of green products versus fossil alternatives.

b) Lack of green finance and funding opportunities to assist in reducing the cost of capital.
c) Maturity and acceptance of the application technology (e.g., high expectations for renewable energy, electrolysis, electricity & hydrogen storage costs to keep reducing, but also high uncertainty on size & timing of reductions and technology winners).
d) Insufficient supporting policy and regulatory uncertainty.
e) Resource and skills constraints.

These abovementioned barriers impacted the design of the cluster's supply chain. While there were no formal solutions proposed to the above barriers, workaround strategies still needed to be deployed to ensure the work progressed (Rudgard, 2023). Developing a framework to guide the design of a supply chain network using a collaborative approach might have unlocked small-scale benefits that were aimed at realising decarbonisation goals of concentrated regions (through wind energy) while fast-tracking economic advancement through the collaboration of industrial cluster partners.

1.6. Delimitations of the study

The study focused on aspects that would guide the establishment of a collaborative supply chain network that could advance the development of renewable energy in an industrial cluster. The objective was to have a framework that would provide a tool for stakeholders to optimise efficiency, reduce costs, enhance flexibility, and improve overall performance across the renewable energy supply chain in an industrial cluster. The stakeholders of the industrial cluster who collaborated on a collaborative supply chain included entities such as manufacturers, suppliers, distributors, and retailers, working together closely to achieve common goals. While there were more stakeholders that formed part of an industrial cluster, such as non-profit organisations (NPOs), residents, and government offices, this study only considered responses from individuals employed by entities that played a direct role in the supply chain network of renewable energy development initiatives and were directly impacted by the supply chain design to ensure that the renewable energy initiatives were mapped out.

The collection of data might have excluded some experts in the above-mentioned fields due to anticipated challenges around the technology platforms used (in place of in-person interviews), loadshedding uncertainties, and disputes on non-disclosure agreement clauses. The limitations of the research study were anticipated factors that could impact the study's reliability, including the following:

- Availability of respondents
- Willingness of respondents
- Understanding and experience of industrial cluster initiatives that were focused on various low carbon energy solutions.

1.7. Definition of terms

Table 1: Definition of terms *(Source: Author's own)*

	Term	**Definition**
a.	Supply Chain network design	The process of building and modelling a supply chain to better understand the costs and time associated with bringing goods to market with the resources and locations available (Forrest, 2024).
b.	Collaboration	a cooperative strategy of supply chain partners with a common goal of serving customers through integrated solutions for lowering cost and increasing revenue (Simatupang et al. 2004).
c.	Just Energy Transition (JET)	Refers to the phasing out fossil fuels to sustainable options, in a fair manner, that prioritises a people-centric approach (Halsey et al., 2019).
d.	Industrial Clusters	These are industry organisations that are concentrated geographically, normally within a region that constitutes a metropolitan area, labour market shed, or other functional economic units (Bergman & Feser, 2020).
e.	Supply chain collaboration	Has been known as a cooperative strategy when one or more companies or business units work together to create mutual benefits (Spekman et al., 1998).

f.	Decarbonisation	Refers to the reduction of carbon dioxide emissions using low carbon energy sources, achieving a lower output of greenhouse gasses into the atmosphere (TWI, 2024).
g.	Low Carbon Energy	Energy generated from low-carbon sources such as wind, solar, hydro, and nuclear power is better for the planet as it releases less carbon into the atmosphere (Moses, 2020).
h.	Renewable Energy	Technology advancement and deployment in the low carbon energy value chain to support just transition, through wind, solar, geothermal, or hydro as natural sources of energy (Zepf, 2020).
i.	Localisation	A concept of co-creating low carbon energy manufacturing capabilities and export infrastructure while also advancing the local market through incubation in localised areas (DSBD, 2019).

1.8. Assumptions

This study included assumptions, as certain factors were beyond the control of the research scope. These were listed as follows:

- The sample consisted of various experts in the energy sector, including some experts from the regional cluster partnership.
- The sample profiled renewable energy developers and manufacturers, including renewable energy and supply chain professionals, who were all potential players in industrial clusters.
- Participants of the study understood the questions and answered honestly and without any bias.

1.9. Structure of the report

- Chapter 1 provided an overview of the study, explaining its purpose and background. It outlined the research problem and objectives, defined key terms, and concluded with a discussion of the assumptions and limitations of the study.
- Chapter 2 offers a theoretical overview of relevant literature, elaborating on key concepts such as collaboration, supply chain network design, renewable energy, industrial clusters, and localisation.
- Chapter 3 describes the research methodology, covering the research design, population, data collection methods, research instruments, and the validity and reliability of the data. It also discusses data analysis, and the techniques used for analysis.
- Chapter 4 provides a summary of the results and findings, documenting and reporting participant responses in accordance with the objectives set out in Chapter 1.
- Chapter 5 observes and discusses the data collected, while integrating the literature from Chapter 2 with the study's findings.
- In Chapter 6, the study is summarised and concludes with detailed recommendations for future research.

CHAPTER 2: LITERATURE REVIEW

2.1. Introduction

The purpose of this section was to gain an understanding of contemporary literature relevant to this study. The study considered what the "just" transition to a low carbon economy would entail, the benefits of a scalable low carbon economy through renewable energy, the history and benefits associated with clusters alongside the risks that threatened industrial cluster partnerships. The chapter then set out to understand the capabilities and attributes of supply chains, while delving into the barriers that compromised collaborative supply chains. In closing the chapter, the benefits of collaborating on a supply chain design within industrial clusters were reviewed.

2.2. Transitioning to a Low Carbon Economy

While transitioning to a low carbon economy was characterised by being "just," this compelled the transition to be approached with great caution and presented a fair opportunity to all who were involved and impacted by the transition. The World Economic Forum (WEF) described "just transition" as "a shift to more sustainable economies whereby workers and communities did not bear an inordinate cost or burden" (WEF, 2023). Cherp, Vinichenko, Jewell, Brutschin, and Sovacool (2018) asserted that national energy transitions were predominantly defined by policies governing the energy sector, energy production, and the necessary technological advancements to facilitate the transition. These aspects shaped the understanding of energy transitions from political, techno-economic, and socio-technical viewpoints. This was how Just Energy Transition Partnerships (JETP) began to play a pivotal role in just energy transition discussions due to the transition risks that they would address. At the United Nations Climate Conference (COP 26) in 2021, South Africa launched the JETP, a first-ever, internationally applauded decarbonisation programme (Vanheukelom, 2023). The JETP was made up of several countries (United Kingdom, the United States, France, Germany, and the European Union) that committed a substantial amount of concessional climate finance (Vanheukelom, 2023).

A report by Suharsono and Maulidia (2023) described JETPs as a financing mechanism agreed between a group of industrialised countries and a developing country, designed to fund a transition of the coal-dependent developing nation away from fossil fuel production and consumption toward low-carbon energy while addressing the social consequences involved (Suharsono & Maulidia, 2023). As a country that relied heavily on fossil fuels in the industrial sector, South Africa was one of the developing countries that entered into such an agreement (Suharsono & Maulidia, 2023). The study outlined that funding provided under the JETP included grants, loans, and investments, and, as of March 2023, the donor group included the International Partners Group (IPG) and the Glasgow Financial Alliance for Net Zero Working Group (Suharsono & Maulidia, 2023). The report further argued that ensuring JETP programs could deliver a just energy transition as well as infrastructure investment was a significant challenge (Suharsono & Maulidia, 2023; Halsey, Overy, Schubert, Appies, McDaid, & Kruyshaar, 2019). While the design process of the South African JETP was highly criticised for its lack of inclusivity (Suharsono & Maulidia, 2023), it was important that with the establishment of industrial clusters, the relationship between industry and the communities they operated in be strengthened and prioritised. Suharsono & Maulidia's report found that prior to the publication of the Just Energy Transition Investment Plan (JET IP) in November 2022, the participating policy drafting groups that worked on the investment plan did not consult the public with their findings nor did they have representation in the affected fence line communities (Suharsono & Maulidia, 2023). This was an important aspect that had to be met in order to fulfil the "just" aspect of the energy transition and ensure a balance between tackling clean energy issues and delivering a socially just transition.

Suharsono & Maulidia's 2023 report further highlighted the investment needs for the energy sector, as there was a close relation between what was produced, transmitted, and ultimately distributed, with projections spanning from 2023 to 2027 (See figure 1). Through the figure, it was noted that renewable energy technologies required the most investment, alongside the upgrading of the transmission grid and storage. These projections came against the backdrop of an announcement that International Partners Group (IPG)—which comprised the governments of the United Kingdom, the United States, France, Germany, and the European Union—had committed to fund South Africa's just transition plans to meet the commitments made at the UN Climate Conferences over the years. However, figure 1 indicated that the value required by South Africa to meet the electricity needs of the country was beyond the USD 8.5bn that had been promised by the IPG. Although the adoption of renewable energy had been on an incline, it was nearly impossible to advance transition goals in a developing country quickly enough without the necessary investment support, and this was the dilemma in which the South African government found itself.

National electricity sector's infrastructure investment needs	ZAR billion
Coal plant decommissioning	4.1
Transmission	131.8
Distribution	13.8
New solar PV	233.2
New wind	241.7
New batteries	23.1
TOTAL	**1,480 (98.7)**

Figure 1: South Africa national electricity sector's infrastructure investment needs, 2023–2027. (*Source: The Presidency, Republic of South Africa, 2022.)*

The South African government did not have adequate funds to realise the electricity needs of the country. A projected R812m was forecasted as the treasury budget plan for infrastructure development in 2022, which included upgrades to Energy (R125m), Digital (no clear figure as cost is embedded into different sectors), Transport and logistics (R312m) infrastructure upgrades, closely linked to job creation and progressing critical projects (Treasury.gov, 2022). The establishment of industrial clusters aimed to fast-track just transition ambitions by calling for support from all industrial experts, small, medium, and micro enterprises (SMMEs), communities, and government institutions to pull together to find solutions for the immediate areas they operated in. It should, therefore, be noted that to transition to a low carbon economy, attention had to be given to just transition initiatives in both coal-producing and coal-reliant regions such as Mpumalanga, Limpopo, and the Vaal regions. Decarbonising the highest carbon-emitting regions in the country could support and fast-track climate change obligations. It should be noted that the stakeholders that needed to be engaged for decision-making, over and above industrial companies, included direct and indirect employees of the overall coal value chain, local communities because they were the most socially impacted by such transitions (i.e., job impact, health impact, environmental impact, etc.). Suharsono & Maulidia (2023) highlighted a key lesson from the experience that an inclusive mechanism with fence-line communities had to be developed to ensure that the communities were consulted first before deciding on the investment plans and to ensure that the investment plan took into consideration the needs and challenges faced by the immediate communities (Suharsono & Maulidia, 2023). This was what would drive the social justice element in South Africa's "just transition" because that was what set JETP apart from the previous financing cooperation (Suharsono & Maulidia, 2023).

2.2.1 Benefits of a scalable low carbon economy

During the 2024 State of the Nation Address (SONA), the South African President Cyril Ramaphosa highlighted that energy security was at the helm of driving South Africa's economic growth and transformation (The Presidency - SONA, 2024). The national government highlighted its ongoing commitment to the country's Just Transition and bringing an end to the energy crisis. Driving a low carbon economy was said to unlock growth opportunities for the country. Low carbon technologies included mechanics like wind turbines, solar panels, biomass systems, and carbon capture equipment. With the identification of renewable energy set to produce less pollution than traditional energy from fossil fuels, renewable energy would play a vital role in the transition to a low carbon economy.

For the context of this paper, Renewable Energy was defined as the technology advancement and deployment in the low carbon energy value chain to support just transition through wind, solar, biomass, or hydro (Zepf, 2020). Some of the data represented in literature indicated that the potential of renewable energy was region-dependent, and this would most likely determine the technology type. When choosing renewable energy technology, the resource of that technology had to be profiled to determine adequate supply and volumes of production. For example, for solar technology, solar farms needed to be in regions that enjoyed high weather temperatures for good solar profiles. Although most South African provinces might still enjoy the privilege of hot weather conditions, the reliability and consistency of sunlight varied per province. Another example was wind technology, which concerned establishing wind farms in provinces that had high wind profiles, including but not limited to the Northern Cape, Eastern Cape, Western Cape, and some inland areas.

Therefore, when industrial clusters were set up, the regions needed to determine which renewable technology would best serve their decarbonisation initiatives and develop a roadmap on how to achieve these ambitions.
Since industrial clusters were made up of different industries with common decarbonisation goals, there needed to be an appreciation of the most suitable renewable energy technology that could be used, in accordance with how much capacity the electricity transmission grid (operated by Eskom) could capacitate for that region (PCC, 2023).

As illustrated in Figure 2, the energy structure for renewable energy had shown a steady increase in production capacity, indicating the highest increase recorded in 2016/2017 (Cowling, 2024), at a time when Eskom was facing amplified operational challenges at the power generating stations. In 2023, the CSIR reported that the total system demand was similar to that of 2021 but less than the pre-lockdown demand levels of 2019 (CSIR, 2023). The report further stated that with coal still dominating the South African energy mix (by 74% provision), the contribution of renewable energy technologies had indicated an increase in 2022 to a total of 6.2 GW installed capacity and contributed 7.3% of the total energy mix (CSIR, 2023). Although the demand for renewable technology had been on a slow and steady increase, it was envisaged that renewable energy production could change the outlook on energy for industry and ensure that decarbonisation goals were realised (CSIR, 2023).

Following an analysis by the PCC (2023), it was reported that South Africa required between 6 GW and 8 GW of renewable energy generation capacity to be rolled out every year (PCC, 2023). Other studies advised that renewable energy would introduce the following benefits (The Presidency – SONA, 2024):

i) *unlock cheaper prices for electricity users,*
ii) *provide dependable electricity,*
iii) *create jobs, and*
iv) *enable industries to remain globally competitive.*

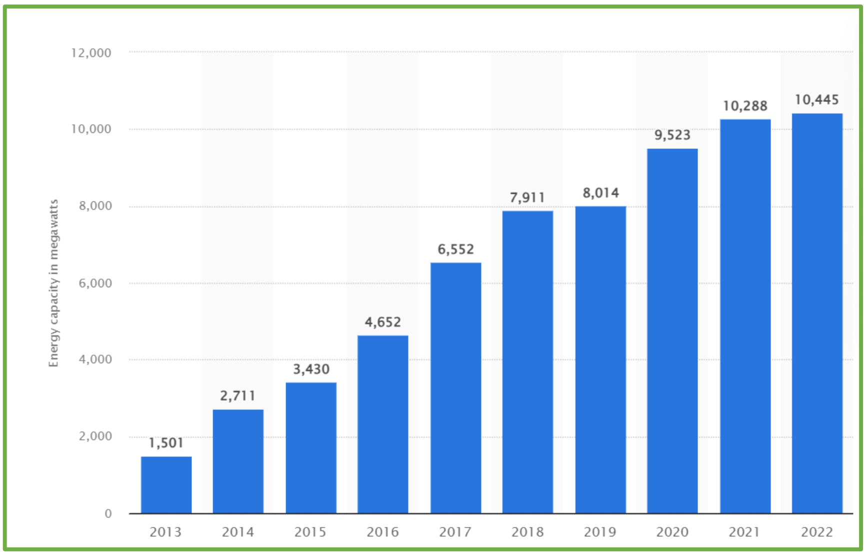


Figure 2: Total renewable energy capacity in South Africa from 2013 to 2022(in megawatts). *Source : https://www.statista.com/statistics/1218109/south-africa-total-renewable-energy-capacity/*

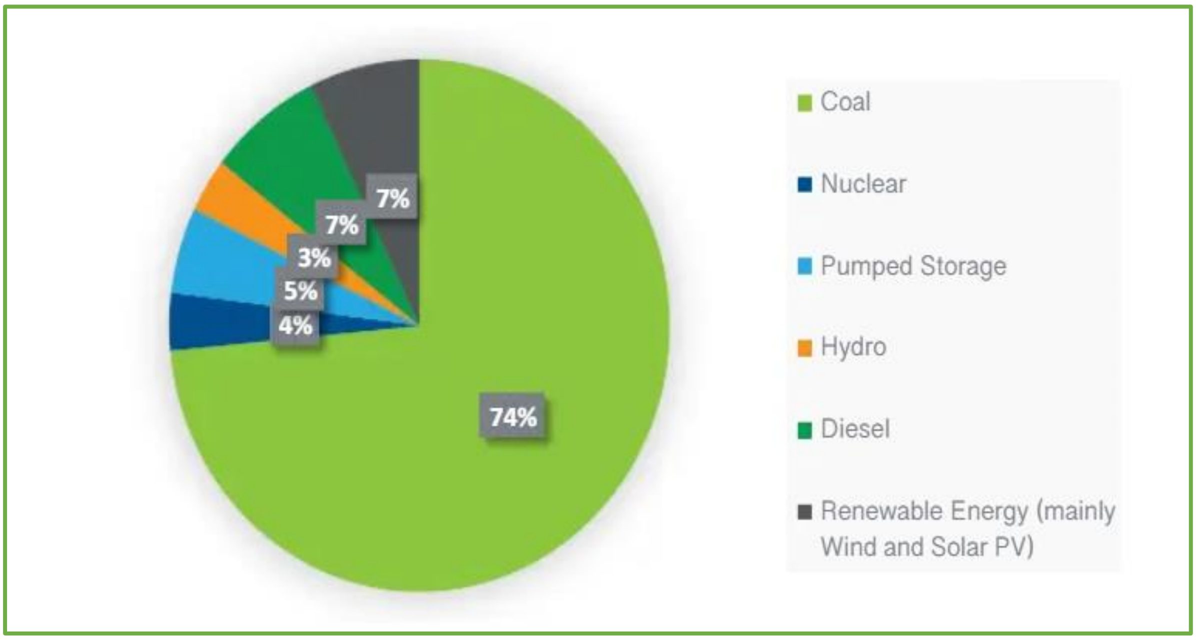


Figure 3: South African Electricity Mix. *(Source: DMRE, 2019)*

2.2.2 Risks associated with transitioning to renewable energy

According to PCC (2024), the transition to renewable energy became more urgent given that some industries in South Africa were significantly impacted by the country's power supply shortfalls. Furthermore, South Africa's power grid infrastructure was inadequate, and if it was not expanded and strengthened, it posed a risk to the rollout of renewables at scale (PCC, 2024). While the CSIR was tasked to continue monitoring the fuel-saving and security-of-supply benefits of renewable energy, there were still risks and constraints that were not linked to grid capacity, which should be considered (CSIR, 2023). The European Union (EU) low carbon roadmap identified:

(i) **The risk to competitiveness** was associated with increasing carbon reduction costs that could have forced EU companies to relocate to other countries with weaker carbon controls, thus leaving the EU's economy vulnerable. The mitigation proposed for this risk was to reduce carbon emissions at a comparable rate, particularly for carbon-intensive industries (Harrison, 2014).

(ii) **Investment risks** denoted that the transition to a low-carbon economy required large upfront capital investments, revealing that consumers and the private sector would not be willing to make such investments (Harrison, 2014).

While the identified risks were not unique to the EU and other developed countries, for developing countries such as South Africa, a more concerted effort should have been applied. In a separate study, Romero stated that it was important that renewable energy was viewed as a long-term investment as opposed to a quick fix solution to the country's energy crisis (Romero, 2010). This low carbon solution was meant to also introduce a diversified energy mix and address environmental challenges and should therefore have been complemented with supporting funds for research and development (R&D) (Romero, 2010). These two studies narrowed down South Africa's risks to be those of infrastructure investment, affordability, and local competitiveness (Harrison, 2014; Romero, 2010). To understand and manage these risks, a localised mindset should have been applied. An understanding of which regions were carbon-intensive and which industries were in these regions would have furthermore dictated the kind of renewable technology available in the said regions. For example, if the focus had to be regional and an area such as the Vaal was selected, there needed to be an understanding of just how carbon-intensive the region was and what the renewable energy technology profiles would prove to be more sustainable and deliver successful prospects of decarbonising the region, i.e., did the region have adequate water supply to consider Hydro technologies or was the region better suited to explore solar technologies. Harrison (2014) further advised that some of the synergies, such as the cross-sectoral opportunities, might have arisen from innovation, or the increased demand for products might have arisen in one sector (e.g., lightweight plastics) from greenhouse gas reductions in other economic sectors such as transport (Harrison, 2014). Therefore, being region-focused could have enabled the understanding of who the industries were in that area, what their energy needs were, and what their supply chains currently looked like (Harrison, 2014). This cluster approach provided an opportunity to design best-fit solutions that addressed area-specific challenges (PCC, 2024).

The understanding of such risks led to the introduction of Just Energy Transition Partnerships (JETPs). PCC's own analysis indicated that South Africa required between 6 GW and 8 GW of renewable energy generation capacity to be rolled out every year. While placing a concerted effort on understanding the risks of transitioning to a low carbon economy, it was noted that there were not enough details on an analysis regarding regional impacts and the competitiveness of firms that undertook to lead the transition as expected by the government. This gave rise to resistance by energy-intensive and high carbon-emitting areas such as Mpumalanga. The impact on employment and economic output had to be carefully socialised and solutions determined through a collaborative lens. Harrison's report (Harrison, 2014) highlighted that the EU had gone through similar challenges and good practice was evident in that the messaging was holistic in its approach, addressing all key audiences with targeted messages on a wide range of synergies and trade-offs. The lesson from Harrison's report was that a stakeholder-led approach could help de-risk initiatives that aimed at reducing a region's carbon footprint, and the opportunity to build collaboration between different stakeholders should not be lost (Harrison, 2014).

2.3. Background on industrial clusters

Porter (1998) described clusters as “geographic concentrations of interconnected companies, specialised suppliers, service providers, firms in related industries, and associated institutions in particular fields that competed but also cooperated” (Porter, 1998). In a later version, he updated his definition to read: “regional concentrations of related industries” (Porter, 2020). This updated version of the definition by Porter highlighted the inclusion of government agencies and other institutions that provided education, information, research, and technical support to a regional economy (Porter, 2020). In the case of South Africa, agencies such as The Industrial Development Corporation of South Africa (IDC), CSIR, and local government were considered in cluster partnerships. The World Economic Forum recognised the IDC as a “self-financing national development finance institution whose primary objectives were to contribute to the generation of balanced, sustainable economic growth in Africa and to the economic empowerment of South Africans, thereby promoting the economic prosperity of all citizens. It achieved this by promoting entrepreneurship through the building of competitive industries and enterprises based on sound business principles” (WEF, 2024).

Eitan, Rosen, Herman, and Fishhendler (2020) emphasised that the business sector has the capacity to equip vulnerable communities and workers impacted by the energy transition with the necessary skills, facilitating their employment as fence-line service providers to upcoming opportunities (Eitan et al., 2020). Therefore, it could be said that industrial clusters were a network of economic relationships that created a competitive advantage for related firms in a particular region that enjoyed their service offering and products (PCC, 2024). According to literature from DTI and DTC (2018), various efforts to promote cluster development had resulted in initiatives such as the Cluster Development Programme (CDP) within the Department of Trade and Industry being established (DTI and DTC, 2018). Consequently, industrial clusters were positioned as networks of interconnected companies and supporting organisations that enhanced the competitiveness of firms in a specific region. WEF (2024) motivated that an industrial cluster’s focus on shared resources, expertise, and collaboration could fast-track decarbonisation initiatives and improve overall performance in the energy sector (WEF, 2024).

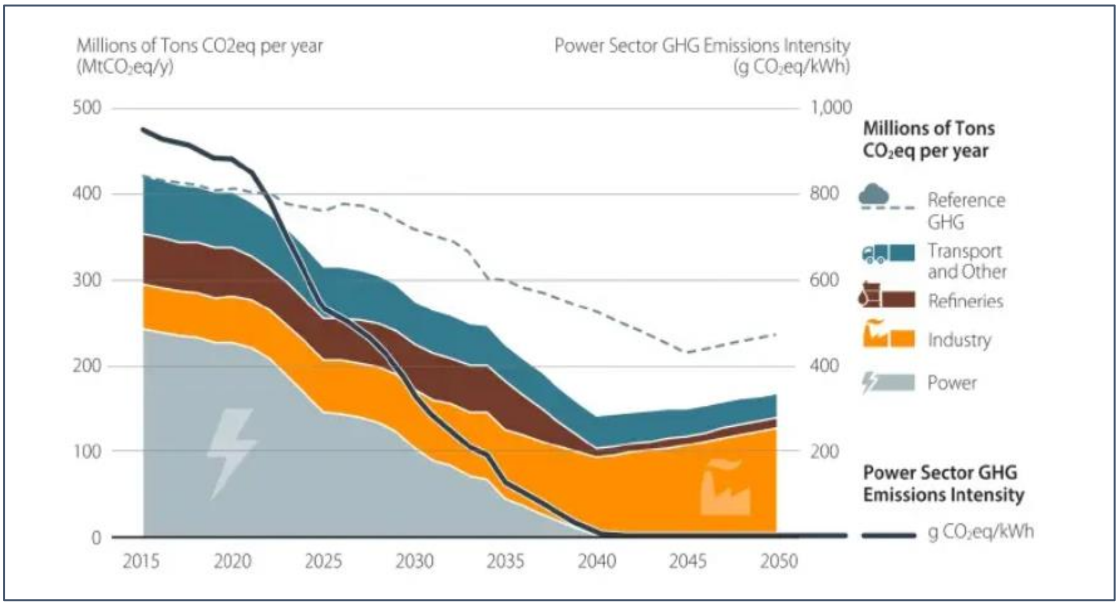


Figure 4: Sectoral Emissions in the least cost, Paris Agreement Compatible Pathway. Source: Burton, Marquard and McCall, 2019.

Industrial clusters in South Africa have a history that was traced back to the early to mid-20th century (Viviers, Pisa, and Rossouw, 2015). The establishment of industrial clusters was influenced by factors such as economic development, resource availability, and government policies (Viviers et al., 2015). One notable early cluster was the automotive industry in Port Elizabeth, which began developing in the 1920s. However, the concept of industrial clusters as a deliberate economic strategy gained more attention in the latter part of the 20th century (Viviers et al., 2015). In the 1990s, with the end of apartheid and the subsequent economic reforms, South Africa started to focus on industrial development and competitiveness. According to Viviers et al. (2015), efforts were made to identify and promote specific regions for the concentration of industries, leading to the establishment and growth of various industrial clusters across the country (Viviers et al., 2015).

The establishment of industrial clusters continued into the 21st century as South Africa sought to enhance economic diversification and global competitiveness (Viviers et al., 2015). Therefore, clusters were not only limited to the energy industry; more industries such as agriculture, food, and automobile industries benefited from the formation of industrial clusters. The uptake of industrial clusters in the energy sector was propelled by the energy crisis the country faced, alongside global climate change objectives.

As discovered in a research paper by Mtati (2017), the cluster development programme had promoted industrialisation, sustainable economic growth, and job creation in South Africa through cluster development and industrial parks (Department of Trade and Industry, n.d.; Mtati, 2017). The cluster-based approach started with the industries and assets that were already present in the region, and regional stakeholders pursued initiatives to make those industries better (Porter, 2020).

2.3.1. Benefits of Industrial Cluster Partnerships

To unpack the benefits of industrial cluster partnerships, Porter (2020) explained that an approach for creating new clusters in a region was a strategy to improve overall business environment conditions. Porter (2020) asserted that this could be done by:

(i) upgrading skills, access to finance, and infrastructure,
(ii) streamlining government rules and regulations,
(iii) supporting local demand, and
(iv) being open to foreign investment and competition.

At the core of this approach was the objective to find solutions to common or related challenges within that cluster. Industry was localised in Gauteng, Western Cape, Mpumalanga, the Richards Bay-Durban-Pinetown area of KwaZulu-Natal, and the Port Elizabeth-Uitenhage area of Eastern Cape (DTI and DTC, 2018). These regions hosted several types of industries and had established an interlinked value chain in their various concentrated areas (DTI and DTC, 2018).

Some of the notable benefits introduced by industrial clusters were traced to a study by Professors Connell and Thorpe (2012), in which the deduction was that clusters had the ability to facilitate knowledge exchange and collaboration amongst companies, researchers, and stakeholders. This could lead to shared insights, best practices, and innovation, fostering technological advancements (Connell & Thorpe, 2012). In another study determined to unpack the benefits of industrial clusters, a series of quantitative studies on four different country cases (Vietnam, Cambodia, Ethiopia, and Tunisia) was conducted by Page (2015) through the Learning to Compete (L2C) project. The L2C study set out to determine the drivers of agglomeration in poor countries and the impacts of agglomeration on firm-level productivity (Page, 2015). It was found that concentrating sector-related businesses in a cluster could lead to economies of scale (Page, 2015). Shared infrastructure, resources, and services could result in cost savings for companies within the cluster, making them more competitive (Page, 2015). The proximity of these businesses within a cluster could streamline the supply chain and lead to improved logistics, reduced lead times, and better coordination among suppliers, manufacturers, and distributors in the energy sector. This could potentially minimise the price consumers would ultimately pay (Page, 2015). Industrial clusters were also found to attract a skilled workforce to the region, creating a talent pool with expertise in the sector. Connell and Thorpe (2012) emphasised that the concentration of skilled workers could contribute to a vibrant and innovative industry ecosystem (Connell & Thorpe, 2012).

Over the years, technology development to support cross-industry decarbonisation had advanced and allowed critical milestones, set forth by the Paris Agreement, regional policy drivers, and corporate sustainability goals to be realised (WEF, 2023). With industrial clusters receiving support at such a global level, local collaborations drove a common governance framework that guided and steered inclusive policy advocacy (WEF, 2023). Industrial clusters provided a platform for collective advocacy on policy issues affecting the energy sector (WEF, 2023). The combined influence of companies and other stakeholders within a community (i.e., region) could lead to more effective engagement with policymakers, helping shape regulations and incentives in a way that benefited the industry (WEF, 2023).

In a case study related to Silicon Valley, Porter (2020) continued to test his theory on the establishment of clusters. It was found that a well-developed concentration of related businesses prompted three (3) important activities: increased productivity (through specialised inputs, access to information, synergies, and access to public goods), more rapid innovation (through cooperative research and competitive striving), and new business formation (filling in niches and expanding the boundaries of the cluster map) (Porter, 2020). Brikinshaw (2000) further supported these findings with revelations that clusters that were leading centres for their industries would attract all the key players locally and internationally (Brikinshaw, 2000). Furthermore, Brikinshaw (2000) emphasised that “foreign-owned companies could enhance the leadership of the cluster and contribute to its upgrading” (Brikinshaw, 2000). Moloi and Mutambara

(2019), in their KwaZulu-Natal focused study, positioned an interesting view that the cluster of economies possessed shared activities such as technical knowledge; specialised labour pools; reduced costs of buying raw material and transportation (Moloi & Mutambara, 2019). The study proposed that industrial clusters should operate as formal and recognised entities by the government, for the sake of continuity and sustainability (Moloi & Mutambara, 2019). It was cited that if industrial clusters were formally set up, then they would endeavour to outline aspirations and objectives that would bind them together in order to achieve the desired goal for the regions they operated in, thus improving the carbon footprint, energy stability, and introducing social benefits to their fence-line communities (Moloi & Mutambara, 2019). Viviers et al. (2015) asserted that industrial clusters were vital for diverse national growth as firms specialised in their competitive advantage regions and outsourced less efficient tasks, boosting efficiency and productivity across the entire cluster, which ultimately led to increased competitiveness (Viviers et al., 2015).

In summary, the benefits associated with the various literature above, highlights the following:

- *Knowledge Exchange and Collaboration:* Clusters facilitated the exchange of knowledge and collaboration among companies, researchers, and stakeholders, leading to shared insights, best practices, and innovation (Connell & Thorpe, 2012).
- *Economies of Scale:* Concentrating sector-related businesses in a cluster led to shared infrastructure, resources, and services, resulting in cost savings and making companies more competitive (Page, 2015).
- *Improved Logistics and Coordination:* Proximity within a cluster streamlined the supply chain, improved logistics, reduced lead times, and enhanced coordination among suppliers, manufacturers, and distributors (Page, 2015).
- *Attraction of Skilled Workforce:* Clusters attracted a skilled workforce to the region, creating a talent pool with expertise in the sector, contributing to a vibrant and innovative industry ecosystem (Connell & Thorpe, 2012).
- *Enhanced Competitiveness:* Firms within clusters specialised in their competitive advantage regions and outsourced less efficient tasks, boosting

efficiency and productivity across the entire cluster, leading to increased competitiveness (Viviers et al., 2015).

- *Support for Renewable Energy and Decarbonisation:* Clusters received global support, driving local collaborations that guided inclusive policy advocacy and supported decarbonisation initiatives (WEF, 2023).
- *Effective Policy Advocacy:* The combined influence of companies and stakeholders within a cluster led to more effective engagement with policymakers, helping shape regulations and incentives to benefit the industry (WEF, 2023).
- *Promotion of Industrialisation and Economic Growth: Cluster* development programs promoted industrialisation, sustainable economic growth, and job creation through the establishment of industrial parks (Mtati, 2017).

2.3.2 Concerns related to Industrial Cluster Partnerships

(Newman, et al., 2016) gave an overview of the findings in some case study reviews conducted on the effect industrial clusters had on localisation and competition. Examples of industries that had similar companies innovating for the same purpose or goals were reviewed. It was found that where such organisations (within a cluster) differed or tended to fail was if the purpose/goals of the cluster were different for each partner. This was also prompted by their location. The location of such clusters played a role in the success of such initiatives as it prioritised and advanced the localisation needs and developments of a region (Newman, et al., 2016). Examining which organizations are in the same region could accelerate the identification of needs that organizations need to address or collaborate on.

The National Development Plan (NDP) highlighted the necessity of reducing reliance on fossil fuels to meet climate change targets while simultaneously achieving socio-economic objectives such as reducing inequality, poverty, and unemployment (PWC, 2021). The plan also underscored the significant role of the business community in driving the "Just Energy Transition" and ensuring job creation. Therefore, at the core of industrial clusters should be the creation of jobs and development of skills for the fence-line communities. Morris and Barnes (2007) further advised that the establishment of industrial clusters should not be initiated or driven by the government (Morris & Barnes, 2007). Instead, industrial businesses should have taken the lead so that the aspirations and objectives that bound them together would encourage them to achieve desired goals (Morris & Barnes, 2007).

In a book written by Wessner et al. (2003), it was discovered that industrial cluster partnerships were perceived to be fast aiding in times of crisis, especially when collaboration, immediate action, and innovative solutions were sought after with little time to spare. This was like the case of South Africa's energy sector. Wessner et al. (2003) outlined some of the benefits that industrial partnerships could extrapolate in specific regions. Similar to previous findings, Wessner et al. (2003) recognised that industrial cluster partnerships could be mutually beneficial to participants with a common goal in various industries. The success was enabled by the understanding and appreciation of the challenge at hand, e.g., high carbon emissions in a specific region. Some of the benefits were driven by a need to innovate. Drivers included lower costs and increased efficiency, but organisations still competed privately through individual product-related initiatives. Industrial cluster partnerships could fast-track the deployment and adoption of new technologies and remove the silo mentality between industries, communities, and agencies that were established in the same region, to fast-track the deployment of new technology solutions (Wessner et al., 2003).

In the context of this study, clusters were assumed to be crucial economic vehicles that would enable and facilitate the transition to a low carbon economy in the regions in which they were established. A diverse coalition of social, financial, and sustainability-focused stakeholders would ensure that all parties gain significant benefits, such as job creation, skills development for emerging technologies, socio-economic improvements, and progress in transitioning to a low-carbon economy, while also achieving financial profitability (Eitan et al., 2020). Pfanelo (2017) stated that a "…partnership emphasises direct, long-term association and encourages mutual planning and problem-solving efforts…" and further outlined barriers to partnerships as:

- *“Insufficient focus on the long term,*
- *Improper definition of cost and benefit,*
- *Over reliance on relations, conflicts on priority, and*
- *Underestimating the scale of change and turbulence surrounding partnering.”*

"In order to foster an inclusive and integrated industrial cluster partnership, the WEF (2023) advised that there should have been a centralised integration office that developed external workforce transformation and community education programs, while internally shaping agreements and IT infrastructure that supported key performance indicator (KPI) reporting, project management, and other collaboration needs (WEF, 2023).

2.4 Designing Collaborative Supply Chains

This section had a specific focus on the history of supply chain designs within different industries. There was a specific focus on challenges that could be anticipated when designing a supply chain for the purpose of transitioning to a low carbon economy within an industrial cluster, and the benefits that could be expected. According to Brown and Hendry (1998), “supply chains involved vertical relationships between firms engaging in commercial transactions for the exchange of goods and services, while industrial districts involved firms in local proximity, which might entail customer-supplier relationships but also might include various collaborative and sharing arrangements of a lateral kind” (Brown and Hendry, 1998). In other literature, Brown (2000) then went on to suggest that a supply chain could operate within a cluster, emphasising procurement and sales processes. The theory was rooted in regional development, which pointed out the importance of value creation by local suppliers. The cluster aimed to enhance its economic impact through the supply chain to effectively influence a geographic area (Brown, 2000).

Spain, Hernandez et al. (2006) cited in Ramírez et al. (2009) stated that the objectives of a supply chain were to produce the best product at the minimum possible cost. This could be considered true for all types of energy, but also the objectives within renewable energy were heading towards a more sustainable approach. Often, the non-renewable energy supply chains were taken as benchmarks for how to achieve things in the most efficient way (Hmouda, Orzes, & Sauer, 2023). For example, large transport vehicles were used to move raw materials to manufacturing plants and the finished products to retailers. This had, in recent times, proven to be the most efficient and reliable way to move goods. Plus, many companies such as BP or Shell, who now operated in the renewable energy sector, tried to integrate their successful low-cost/high-profit methods which were used in the fossil fuel sector (Hmouda, Orzes, & Sauer, 2023). By establishing collaborative supply chains, it was assumed that inter-enterprise relationships and enhanced information exchange would improve the quality of decision-making, reduce demand uncertainty, and, ultimately, improve supply chain performance (Ahmed & Ullah, 2021).

2.4.1 The Evolution of Supply Chains and Key Innovations

The global supply chain had seen enormous changes over the last 100 years. How goods were sourced, manufactured, and transported had been transformed. Since the 1900s, supply chains had evolved significantly, transitioning from local and manual processes to global, interconnected networks facilitated by technological advancements (BGT, 2019). Initially, supply chains were simple and localised, relying on manual labour and limited transportation options. The mid-20th century saw the emergence of mass production and the rise of multinational corporations, leading to more complex supply chains spanning multiple regions (BGT, 2019). With the advent of computers and the internet, supply chain management became more efficient, enabling real-time tracking, inventory management, and just-in-time production methods. By today, supply chains were highly sophisticated, leveraging technologies like artificial intelligence, big data analytics, and blockchain for enhanced transparency, efficiency, and resilience (BGT, 2019). Environmental and social considerations also played a significant role, driving sustainability initiatives and ethical sourcing practices. Supply chains had been progressing towards a more data-centric, network-based, and collaborative ecosystem, which generated tangible value and fostered growth for all involved stakeholders, therefore informing a model that could be adopted by industrial cluster partnerships.

2.4.2 Attributes of a Collaborative Supply Chain

Supply chains were designed with capabilities of predicting, preparing for, responding to, and recovering from any form of disruption, while maintaining operations at an acceptable cost and performance level (BGT, 2019). Pfanelo's (2017) study stated that the objective of supply chain collaboration should have been to create synergies for competitive advantage among supply chain partners through information sharing. Pfanelo (2017) further argued that once supply chains achieved collaboration, they had the potential to improve forecasting accuracy. This then labelled forecasting accuracy as a means of measuring the success of supply chain collaborations. Therefore, at the core of supply chain collaborations should have been a tool that would facilitate and enable information sharing amongst supply chain partners within an industrial cluster. Pfanelo's (2017) findings highlighted that "…lack of internal integration (organisational barrier) would have been a great obstacle for manufacturers to efficiently use demand and forecast information (operational barrier)" (Pfanelo, 2017).

BGT (2019) suggested that "…designing a resilient supply chain required a comprehensive approach that encompassed enhanced visibility and predictive analytics, agile operations, robust collaboration, strategic inventory management, and a dedication to sustainability" (BGT, 2019). This resilience was seen to be crucial for resolving immediate challenges that came from multiple needs (of cluster partners) and the long-term change and uncertainty that characterised decarbonisation (BGT, 2019). BGT (2019) described the decarbonisation change and uncertainty as "…climate change; nationalism, protectionism, conflict, and mounting geopolitical competition" (BGT, 2019). With these varying concepts in mind, it was said that the integration of information within an industrial cluster created visibility for all stakeholders, which awarded the supply chains of such clusters an opportunity to be more agile when responding to known and unknown factors during South Africa's transition to a low carbon economy. Both literatures led to the understanding and acknowledgment that the cornerstone of collaborative supply chains in times of uncertainty was Resilience (characterised by integration, visibility, and agility) (BGT, 2019; Pfanelo, 2017).

If Pfanelo (2017) and BGT (2019) were correct, a resilient supply chain for an industrial cluster should have displayed the ability to integrate information sharing systems of organisations within the cluster, allowed for the organisations to have visibility of data, behaviour, and market trends of supply chain data and activities, while actively responding to market challenges and risks with high tolerance and flexibility for change needs that might have arisen. According to O’Rourke (2014), to understand this better, there should have been a shared understanding and appreciation for how each organisation within the industrial cluster responded to consumer demands, product disruptions, commodity prices, currency fluctuation, and political risks effectively and efficiently (O'Rourke, 2014). The next sub-section delved deeper into the supply chain elements that could have potentially influenced which areas of a cluster’s supply chain the organisations could collaborate on to ensure the qualities of the supply chain were maintained.

2.4.3. An outlook on supply chain elements

BGT’s (2014) literature investigated the historical evolution of supply chains from the 1900s to date. It depicted that supply chain elements had evolved and advanced from serving local markets to cross-border markets or what is now known as global supply chains. By today, common elements within a 21st-century supply chain network for a typical business ran up to 10, depending on which industry the supply chain was in or the challenge the cluster was solving for (Axestrack, 2022). According to Axestrack (2022), the elements gave organisations a better understanding of how to meet and keep up with ever-changing customers’ needs (Axestrack, 2022). It was often challenging to determine which one was more important than the other, due to the different objectives that organisations tracked. However, through this study, the aim was to determine whether industrial organisations within a cluster could come to a common understanding and agree on elements that would best drive the adoption of renewable energy as part of the country’s “just transition” decarbonisation journey.

Larsen and Hansen’s (2020) research outlined that utilising shared resources and investment can significantly enhance coordination among stakeholders and encourage local sourcing, which helps reduce costs and streamline regulatory compliance. Their research emphasises the critical role of effective collaboration and transparent governance structures in achieving successful knowledge sharing and capacity building. These factors ultimately drive innovation and improve operational efficiency within the renewable energy sector.

Morash & Clinton (1998) suggested that the renewable energy supply chain elements differed based on the type of renewable technology being deployed. The elements could work together to ensure the effective deployment and operation of renewable energy systems. The transition to renewable energy requires a robust and well-integrated supply chain that supports the full lifecycle of energy systems - from initial resource evaluation to end-of-life management. As highlighted by Sageer and Ahmad (2025), effective grid integration and infrastructure planning are essential for operational success. Additionally, Wang, He, and Gao (2025) emphasize the importance of aligning supply chain processes with circular economy principles to enhance sustainability and resource efficiency. Table 2 presents a structured overview of common supply chain elements applied by various organisations in the renewable energy sector. These elements are critical for ensuring operational efficiency, technological integration, and long-term viability across diverse energy platforms. Each phase of the supply chain - from resource assessment to recycling - plays a strategic role in enabling the deployment and long-term viability of renewable energy infrastructure. The terminology used reflects current academic and industry practices, aligning with global trends in energy transition and circular economy principles.

Table 2: *Summary of common Supply Chain elements applied by various organisations for renewable energy. (Source: Various sources)*

Element		Outline
1.	**Site Feasibility and Resource Characterisation**	*This involves evaluating potential locations for renewable energy projects, such as wind farms or solar installations, to determine the availability and quality of the resource (Tiara et al., 2024).*
2.	**Component Manufacturing and Supply Sourcing**	*This involves the production of components like solar panels, wind turbines, and batteries used in renewable energy systems (Raygoza-Limón et al., 2025).*

3.	**Infrastructure and EPC (Engineering, Procurement, Construction)**	*This phase involves building and installing renewable energy infrastructure, including wind farms, solar arrays, and hydroelectric plants (Suyambu, 2025)*
4.	**Asset Management and Preventive Maintenance**	*Once renewable energy systems are operational, ongoing maintenance is required to ensure optimal performance and longevity (Nwankwo & Lele, 2024).*
5.	**Grid Interconnection and Smart Grid Integration**	*Renewable energy systems need to be integrated into existing power grids, requiring infrastructure upgrades and management systems to balance supply and demand (Sageer & Ahmad, 2025) (Wang, He, & Gao, 2025).*
6.	**Energy Transmission and Distribution Network Management**	*Energy generated from renewable sources needs to be transported from production sites to end-users, which involves distribution networks and infrastructure (Rahimi et al. 2025)*
7.	**End-of-Life Management & Circular Economy Practices**	*At the end of their life cycles, renewable energy components need to be recycled or disposed of properly to minimise environmental impact, e.g. recovering valuable minerals from decommissioned systems and reintroducing them into the supply chain (Alqahtani & Afy-Shararah, 2025).*

2.4.4. Exploring supply chain capabilities

While clusters were geographically and industrially concentrated, and exhibited a level of entrepreneurship, inter-firm cooperation, and learning and innovation processes that were not seen outside such locations (Porter, 1998; Marshall, 1920). A 'cluster-focused' approach to researching supply chain dynamics was also practitioner and policy-oriented, as regions and nations sought to develop clusters of industries as a means of promoting economic development and technological capability (Porter, 1998). In the energy sector, decarbonisation added to the objectives of establishing clusters. Understanding the structure and dynamics of supply chains in renewable energy industries necessitated an approach that looked at the entire production network of an industry. However, the highly complex and multi-tiered nature of modern supply chains made this a difficult task. Organisations that formed part of industrial clusters were different in nature and thus possessed different supply chain capabilities.

A supply chain was a network of facilities and distribution options that performed the functions of procurement of materials, transformation of these materials into intermediate and finished products, and the distribution of these finished products to the best customer (Brown & Hendry, 1998). It was made up of various players such as suppliers, manufacturers, producers, and stores, who tried to integrate and automate their operations based on their harmony and with the aim to improve both efficiency and effectiveness. Therefore, in determining the capabilities of a supply chain, it served the cluster stakeholders to understand the relationships that existed within the cluster to help determine the complexity of the relationship. According to insights from PWC (2021), mapping out a collaborative supply chain network and conducting a joint risk assessment could allow for ring-fenced economic opportunities in any industry (PWC, 2021).

Furthermore, Larsen and Hansen's (2020) research outlined that utilising shared resources and investment can significantly enhance coordination among stakeholders and encourage local sourcing, which helps reduce costs and streamline regulatory compliance (Larsen & Hansen, 2020). The research emphasises the critical role of effective collaboration and transparent governance structures in achieving successful knowledge sharing and capacity building (Larsen & Hansen, 2020). These factors ultimately drive innovation and improve operational efficiency within the renewable energy sector.

There have been efforts to introduce wind turbine manufacturers locally, including partnering efforts for skills training in South Africa, dating as far back as 2011(Eberhard; Kolker; & Leigland, 2020). Despite these significant efforts made by international material suppliers that are highly specialised and own some of the IP, to train and supervise local employees, the quality of critical products produced was not credible and thus prevented the international suppliers from guaranteeing performance standards (Eberhard et al, 2020). This situation highlights the challenges posed by high quality requirements and the limited capabilities within the supply base (Eberhard et al, 2020)

Whilst most organisations were driven by competition, it could be noted that fundamental trade-offs in supply chain design were between cost and quality

(O'Rourke, 2014). Any supply chain design should have endeavoured to deliver high-quality products and services to customers, with minimal operational and logistical costs. Certain trade-offs such as location, market, product, price, and storage could be used as a lever to minimise costs and optimise processes. The successful optimisation of a supply chain stemmed from understanding the various capabilities and trade-offs involved. While delivering quality products and services, companies also tried to minimise operational and logistical costs (O'Rourke, 2014). With the transition to a low carbon economy, the energy industry was shifting towards a collaborative supply chain that was not after being first-to-market or the title of best product, but the cluster was tasked to find concerted ways that would enable quick adoption to a low carbon economy. The cluster partners should have understood that the benefit of pulling together and collaborating on this technology was to assist their organisations in building consistent power supply for their businesses to operate optimally. Overall, a collaborative supply chain in an industrial cluster enabled companies to leverage collective strengths, resources, and expertise to enhance competitiveness, innovation, and sustainability. Below was a summary of capabilities that could serve such collaborative supply chains from various literature:

Table 3: *Summary of collaborative Supply Chain capabilities derived from various sources.*

No.	**Capability**	***Outline***
1.	Shared resources and infrastructure	*Collaborative supply chains within industrial clusters can leverage shared resources such as transportation networks, warehousing facilities, and utilities, reducing individual costs and environmental impacts (O'Rourke, 2014).*
2.	Information sharing and transparency	*Enhanced communication and data sharing among cluster members enable better demand forecasting, inventory management, and coordination of production schedules, leading to efficiency gains and reduced lead times (Pfanelo, 2017) (O'Rourke, 2014).*
3.	Joint innovation and R&D	*Collaboration fosters innovation through shared research and development initiatives, enabling cluster members to collectively develop new products, processes, and technologies, driving competitiveness and sustainability (Wessner, et al., 2003) (Alhaj, 2020).*

4.	Risk management and resilience	*By pooling resources and expertise, collaborative supply chains can better anticipate and mitigate risks such as disruptions in supply or demand, natural disasters, and regulatory changes, enhancing overall resilience (Axestrack, 2022). In a study abstract focused on understanding the correlation between supply chain risks and resilience, Brusseta, and Tellerb (2017) found that integration allows managers to identify and address key areas efficiently, thereby minimising risks to the timely and smooth flow of information while reducing coordination and transaction costs (Brusseta, & Tellerb, 2017).*
5.	Skills development and workforce collaboration	*Industrial clusters provide opportunities for workforce development and knowledge exchange through training programs, skill-sharing initiatives, and collaboration on talent recruitment and retention strategies (Porter, 2020) (Eitan, et al., 2020).*
6.	Collective sustainability initiatives:	*Collaborative supply chains in industrial clusters can work together to implement sustainability practices, such as reducing carbon emissions, minimising waste, and promoting responsible sourcing, contributing to the cluster's reputation and attractiveness to customers and investors (Alhaj, 2020).*

2.4.5. Supply Chain Network Design Challenges

In the WEF (2023) report on transitioning industrial clusters, it was highlighted that transitioning industrial clusters was centred around four strategic approach areas (WEF, 2023). These four areas, namely: Partnership, Policy, Financing, and Technology, needed to be embedded in goals of a common business model that would provide sustainability both economically and to the community (WEF, 2023). This recognition at a global level informed us that at a local or regional level, industrial cluster partnerships should have considered these elements with an integrated approach. The WEF (2023) report advised that industrial clusters should have established a central integration office that would focus on the 4 strategic areas to accomplish the objectives of the industrial cluster. Therefore, there needed to be an integrated understanding of the industrial cluster's supply chain and the challenges that could hinder the adoption of renewable energy.

Winkenbach (2024) highlighted how challenging it could be for industrial clusters to design a supply chain if it was not understood from the onset what supply chain challenges the organisations were facing individually, as this could deter the success of achieving the industrial cluster's goals. Winkenbach (2024) further advised that this level of awareness was critical because ultimately the supply chain design would signify a series of processes and technologies and represent a complex network of human interactions that needed to be coordinated with understanding (Winkenbach, 2024). While Winkenbach (2024) advocated for industrial cluster partners to focus on understanding their supply chains, Anderson, Müllern, and Danilovic (2022) suggested that the focus should have been set on business culture, business model, understanding of innovation, and the management of innovation to uphold the common ground for collaboration. It could be said that in an industrial cluster for renewable energy, where various organisations within the same region collaborated to decarbonise the region, the challenges of a collaborative supply chain could be seen as complex. This was assumed by various literature to be as listed below:

Table 4: *Summary of collaborative supply chain challenges derived from various sources.*

	Challenge	Outline
1.	Competition and Cooperation Balance	*Balancing competition with cooperation among companies within the cluster can be challenging. While collaboration can lead to efficiency gains and cost savings, companies may also compete for market share and innovation. Anderson et al, (2022) state that deliberate communication across stakeholders of the cluster should be encouraged. The study highlights that dialogue and intentional interaction between stakeholders of the cluster (regardless of rank), encourages mutual understanding and trust, thus maintaining a cooperate balance and transparency (Anderson et al, 2022).*
2.	Resource Sharing	*Coordinating the sharing of resources such as manufacturing facilities, transportation infrastructure, and skilled labour can be complex, especially when companies have different production schedules and priorities. Employing neutral actors such as researchers or establishing an integration office specifically for the*

		industrial cluster, can drive the partnership stakeholders to harmonise to achieve joint targets (Anderson et al, 2022). Furthermore, Moser., and Lowes. (2017) highlight the importance of allocating dedicated resources towards partnership initiatives. How time expectations, expertise and financial resource commitments will be allocated within the partnership should clarified and inform a governance framework that the partners will reference in times of conflict or not meeting agreed upon objectives (Moser., and Lowes. 2017).
4.	Supply Chain Integration	*Pfanelo (2017), further argues that another challenge is of* ***supply chain integration,*** *where the managerial capacity for combining resources and competencies from various supply chain partners and business units and directing all relevant parties towards an expanded resource base and competitive advantage is unclear (Pfanelo, 2017). Achieving consensus on standards can be difficult due to differing technological preferences and priorities of the cluster partners. Consequently, integrating various components and services from different cluster partners into a cohesive supply chain requires robust communication channels, information sharing platforms, and interoperable systems (Brusseta., and Tellerb, 2017).*
5.	Regulatory Compliance	*Meeting regulatory requirements related to renewable energy production, environmental standards, and worker safety across multiple companies within the cluster can be challenging and may require coordinated efforts and resources. Compliance with local, national, and international regulations can impose additional costs and administrative burdens on supply chain operations and create an opportunity for corruption (Anderson et al, 2022).*
6.	Risk Management	*Managing supply chain risks such as supply shortages, quality issues, and market fluctuations becomes more complex when multiple companies are involved. Developing risk mitigation strategies and contingency plans collaboratively is essential (Brusseta, & Tellerb, 2017).*
7.	Innovation Ecosystem	*Fostering an innovation ecosystem within the cluster to support research, development, and technology transfer requires collaboration among industry, academia, and government stakeholders (WEF, 2021). However, aligning interests and priorities among these stakeholders can be challenging.*
8.	Market Volatility	*Fluctuations in global commodity prices, geopolitical dynamics, exchange rates, or demand patterns can create uncertainty and risk for*

		businesses within the supply chain (Anderson et al, 2022), e.g., spot rates in shipping costs influenced by oil price.
9.	Sustainability Goals	*Ensuring that the collaborative supply chain aligns with sustainability goals, such as reducing carbon emissions and minimising environmental impact, requires a shared commitment to sustainability among cluster partners is highlighted as a crucial stage (Chauhan et al, 2022).*
10.	Business Model	*(Anderson et al, 2022) mentions that one of the barriers is the contemporary business model that is rooted in each organisation. A new model that bears no restrictions and allows for collaborative innovation as a group with a common goal can allow for a seamless and effective supply chain network.*
11.	Availability of Skills	*Shortages of skilled labour or a lack of specialised training programs tailored to the needs of the supply chain can impede productivity and innovation (Anderson et al, 2022).*

Literature acknowledged that addressing the supply chain challenges listed above would require collaboration among different stakeholder groups, government support on policy advocacy, investment in infrastructure and human capital, and strategic planning to promote growth and enhance the competitiveness and resilience of industrial clusters focused on renewable energy (Moser and Lowes, 2017; Pfanelo, 2017; O'Rourke, 2014; Anderson et al., 2022). Therefore, the challenges depicted here could inversely present themselves as opportunities (like those listed in section 2.4.4.), that enabled the supply chain to reach its full potential. This study further revealed that there was a positive relationship between the implementation rate of integration capabilities and the level of resilience in supply chains (Brusseta and Tellerb, 2017), which was consistent with the findings presented by Pfanelo (2017) and O'Rourke (2014).

2.4.6. Benefits of a collaborative supply chain for industrial clusters

Following some of the outlined challenges highlighted by Pfanelo (2017), it was understood that developing a supply chain network design framework would help the cluster decide on which supply chain nodes they would pursue and integrate for the cluster (Pfanelo, 2017). Pfanelo (2017) discussed two integration points to be considered upfront when collaborating on supply chain activities, namely:

(i) *Internal Integration – "which allowed for functions to strategically collaborate across various aspects that involved product design, procurement, production, sales, and distribution in order to meet customer requirements at a low total system cost."*
(ii) *External Integration – "which entailed a strategical collaboration between a focal firm and its suppliers in managing cross-firm business processes, including information sharing, strategic partnership, collaboration in planning, joint product development, and so forth."*

A joint determination on the purpose of collaboration guided the supply chain discussions on what aspects an industrial cluster should have collaborated on and guided the benefits that would have steered the direction of the partnership. The period for decarbonisation was much too limited to move forward without the benefit of lessons learned, still-developing insights, and success (as well as failure) stories from the global community. However, a few benefits from other industries could be deduced in literature, which might have been applicable to industrial clusters in the energy sector. BGT's (2014) study advised that in relation to supply chain data, companies had to know cost-related matters, and supply chain-disruption risks related to "extreme or unusual" weather events, resource shortages, commodity price spikes, and labour unrest. In his 2014 study, O'Rourke highlighted that companies were collectively starting to measure the global impacts of supply chain networks (both upstream and downstream), that affected their businesses, such as energy use, carbon emissions, water use, waste emissions, and land-use conversions across the full life cycle of products (O'Rourke, 2014). In a carbon-intensive area such as the Vaal Region or Mpumalanga, pulling together to innovate for sustainable solutions to adopt a low carbon economy became more compelling.

Newman, Page, Rand, Shimeles, and Tarp (2016) outlined competition as a benefit. This was because competition could be used as a lever to drive competition in collaborative supply chain activities as opposed to limiting it. The study further outlined that by enabling competition for a limited local market (i.e., only for the cluster) would lead to a weeding out of higher-cost producers, and survivors would experience an erosion of markups and ensure that profit margins were realised (Newman et al., 2016). Newman et al. (2016) asserted that "…organisational leaders should have advocated for full participation in forums where policy enablers, financing models, and technology use cases were explored and co-planning of infrastructure, supply chains, etc. took place...” (Newman et al., 2016). They argued that this did not limit competitive advantage but rather afforded local industrial supply chains exposure to how collaboration could de-risk investments for various stakeholders, while enabling the rollout of economic and social benefits (Newman et al., 2016). According to Pfanelo (2017), more benefits were identified for cross-industry stakeholders who had access to shared infrastructure, and saved resources and energy, resulting in environmental, economic, and social benefits because of collaborating on supply chain activities (Pfanelo, 2017).

Pfanelo (2017) found that improved supply chain performance contributed positively to the collaboration, integration, relationship commitment, and overall performance of SMEs manufacturing enterprises (Pfanelo, 2017). The study highlighted that the involvement of SMEs was believed to be key in empowering a local community if the aim was to deploy a particular focus on the marginalised segments and reducing poverty through support for entrepreneurship and providing income through employment (Pfanelo, 2017). Therefore, a conclusion could be drawn that the supply chain network design for an industrial cluster should have been designed with an objective to highlight and ring-fence local opportunities that the local community could leverage and benefit from. This would in essence inform the localisation plan for suppliers in the cluster. Literature by Larsen & Hansen (2020) found that supply chain partnerships were designed to leverage the strategic and operational capabilities of individual organisations to help them achieve significant ongoing benefits (Larsen & Hansen, 2020). Owing to this, their concerted effort to collaborate emphasised direct, long-term association and encouraged mutual planning and problem-solving efforts (Larsen & Hansen, 2020).

To secure the right talent at reasonable costs, renewable energy companies must revamp their key HR and recruitment strategies (Daume, P., Heineke, F., Janecke, N., Klärner, H., Krause, J., & Winter, R., 2022). Organisations can incorporate some effective practices from other industries but should also explore novel and unconventional methods to attract and retain employees (Daume et al., 2022).

The McKinsey report touches on several strategies that can help organisations succeed in the face of growing talent shortages:

Table 5: (Source, Author's own, using data from Daume et al., (2022), published by McKinsey & Company)

	Benefits realisation strategies	**Outline**
i)	Employer brand and recognition	*Companies could assess the perception amongst potential employees both locally and globally and focus on regional branding to attract specialised talent.*
ii)	Career Path Development	*Renewable-energy companies need to outline their plans for employee development, offering multiple tracks with various specialisations and including temporary relocation as an attractive career path.*
iii)	Long-term Incentive Programs	*Offering long-term incentives can attract ambitious and educated employees. These incentives provide a competitive edge, despite taking longer to realise due to development timelines.*
iv)	Early Career Recruitment Initiatives	*Addressing talent scarcity by targeting universities and vocational schools early in individuals' careers can help secure future talent and establish strong connections. Regional recruiting programs can replace relocated employees with local talent.*
v)	Mergers and Acquisitions for Talent	*This approach is particularly useful for securing specialised skills needed in the renewables industry, such as energy technicians and developers in emerging markets.*
vi)	Training Programs	*Employers can offer training programs with clear, long-term career paths to attract and retain technically skilled workers, particularly for temporary roles in constructing, operating, and maintaining new wind plants.*

According to the McKinsey report the above talent and skills development strategies can unlock other critical benefits such as better risk management, increased market responsiveness, and improved customer satisfaction, ultimately contributing to a more resilient and competitive supply chain (Daume et al., 2022).

2.5 Conclusion of Literature Review

At this juncture, the establishment of industrial clusters seemed to propose an achievable position by introducing aspects that different industrial stakeholders could collaborate on. Although it was unknown whether the benefits of a low carbon economy would exceed the initiative realisation costs, at the helm of discussion was the shared vision – to resolve the country's energy crisis and improve economic development. With renewable energy positioned as an ideal low carbon energy solution, it did not change the fact that this was a new industry altogether, compared to conventional energy sources such as coal. There was, however, still a gap in literature when it came to researching renewable energy supply chains, due to the lack of sufficient information and certainty regarding the transition to low carbon economies, thus making supply chain designs complex and difficult to optimise (Alhaj, 2020). The transition itself still required the correct policy signals, geopolitical harmony, and strengthened support for innovation and technology. Through literature, it was also understood that challenges surrounding industrial clusters had been attributed to their influence on economic activity. While collaborative industrial cluster partnerships had the potential to create market-based and sustainable responses to challenges in emerging markets (Moser & Lowes, 2017), a clear framework that outlined the supply chain network had to be developed. This framework could act as a guide to support industrial clusters within the energy sector and fast-track the development and adoption of renewable energy in that cluster.

In closing, Chapter 2 laid out a review of the literature by providing a background understanding of what establishing a low carbon economy enabled by renewable technology entailed. The study considered the history and benefits associated with industrial clusters alongside the risks that threatened industrial cluster partnerships. Industrial clusters and supply chains, while addressing distinct challenges, are increasingly recognized as complementary frameworks in advancing renewable energy systems. Industrial clusters are positioned to primarily focus on geographic concentration and collaboration among business organisations, by enabling shared infrastructure, innovation, and resource pooling to accelerate clean energy deployment (WEF, 2025).

In contrast, supply chains emphasize the coordinated flow of materials, information, and services across production and distribution stages to ensure efficiency and resilience (Ogunsuji, Amosu, Choubey, Abikoye, Kumar, & Umeorah, 2024). When integrated, these two concepts create synergistic ecosystems that enhance operational performance, reduce costs, and support circular economy practices. For instance, clustered firms can localize component manufacturing and recycling, thereby streamlining supply chain logistics and reducing environmental impact (Tolossa, Beshah, Kitaw, Mangano, & De Marco, 2013). This convergence not only strengthens regional industrial capabilities but may further contribute to global sustainability goals by fostering innovation and resilience in energy infrastructure.

The chapter then set out to understand the capabilities and attributes of supply chains, while delving into the barriers that compromised collaborative supply chains. In closing the chapter, the benefits of collaborating on a supply chain design within industrial clusters were reviewed.

Topic: Establishing a collaborative supply chain framework for advancing renewable energy development through industrial clusters

Table 6: Consistency table: research questions and propositions

RQ #	Objective	Prop / hyp #	State Proposition or Hypothesis
1	Outline the rationale that signifies the need for a collaborative supply chain within an industrial cluster.	1	• Limited availability of infrastructure to enable renewable energy development at a high rate. • Minimise the risk of supply chain disruptions. • Foster a learning culture within an ecosystem.
2	Identify the challenges associated with establishing a collaborative supply chain within an industrial cluster.	2	• Challenges of collaborative supply chains in industrial clusters include competition and cooperation balance, resource sharing, supply chain integration, regulatory compliance, risk management, availability of skills, market volatility, and an innovative ecosystem.
3	Identify anticipated benefits in establishing a collaborative supply chain.	3	• Identified benefits include competitiveness through shared strategic and operational capabilities, mutual planning and problem-solving efforts, knowledge sharing, reduced costs through economies of scale, improved market access, greater resilience to disruptions through risk sharing and diversification of suppliers.
4	What are the key supply chain elements that will enable successful, sustainable, and accelerated adoption of RE through industrial clusters.	4	• Identified elements include robust infrastructure for renewable energy production and distribution, material, and distribution assessments to enable sourcing plans and minimise supply chain disruptions, enhance skills and knowledge sharing between cluster partners, understanding of operation and maintenance requirements. • Technological innovation to improve the efficiency and reliability of renewable energy systems. • Recycling and Disposal of renewable energy components to ensure the environmental impact is kept to a minimum.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

This study was aimed at establishing a collaborative supply chain framework for advancing renewable energy development through industrial clusters. To address this objective, the study explored the background of industrial clusters and how these industrial clusters could serve as vehicles to fast track the development of renewable energy. The literature review outlined the need for decarbonisation and the transition to low carbon energy solutions, with renewable wind energy at the heart of the study. The literature further investigated the need for collaboration as a strategic lever in designing a supply chain network within an industrial cluster. This meant identifying the challenges and benefits of a collaborative supply chain and understanding which key supply chain elements are widely used in most network designs.

The intent of Chapter 3 was to bring attention to the research methodology by elaborating on the research approach, research design, data collection methods, population, sample, research instrument, procedure of data collection as well as data analysis and interpretation. The following research questions were instrumental in concluding this chapter:

- Determined the rationale that signifies the need for a collaborative supply chain within an industrial cluster.
- Identified the challenges associated with establishing a collaborative supply chain within an industrial cluster.
- Identified anticipated benefits in establishing a collaborative supply chain within an industrial cluster.
- Determined key supply chain elements that will enable successful, sustainable, and accelerated adoption of RE through industrial clusters.

3.2. Research Approach

There were different research methods that one could explore during the research process. Taherdoost (2022) described a research approach as a researcher’s philosophical stance that was based on different types of research that included application of the study, the objectives of the research, and information obtained (Taherdoost, 2022). These research types were commonly known as quantitative, qualitative, and mixed methods (Taherdoost, 2022).

The research approach for establishing a collaborative supply chain framework for advancing renewable energy development through industrial clusters followed the qualitative method (Hancock, Ockleford, & Windridge, 2009). Hancock et al. (2009) explained qualitative research as a means of providing a series of explanations for social phenomena (Hancock et al., 2009). Taherdoost (2022) went on to expand on this method by stating that it was aimed at collecting primary, first-hand, textual data and analysing it using specific interpretive methods (Taherdoost, 2022). The approach was appropriate for this study because it intentionally focused on the work experiences of the sampled participants and relied on this experience to determine common feedback that could be used to develop a standard framework that would serve as a guideline for organisations that wished to collaborate on supply chain activities. The research leveraged their experience and knowledge, aiming to design a collaborative framework that could be used as a template for supply chain experts within an industrial cluster with a similar objective. Furthermore, the qualitative approach was aimed at gathering new insights or potentially generating new theories, through a deliberate understanding and appreciation for various interpretations provided by the respondents, attributed to various events, deeds, and objects (Taherdoost, 2022). Anticipating the findings to the research problem was not the intention of this approach, other than obtaining information from explanations and data collection by engaging with respondents.

3.3. Research Design

In a journal by Panday & Panday (2015), it was found that research design was described as a framework that described the different research methods and techniques that would be used to conduct the study (Panday & Panday, 2015). The research design was interpreted to be an overall strategy for conducting a study. It was described as a framework that detailed how the research would be carried out, including the collection and analysis of data, in a manner that aimed to generalise the findings to ensure their reliability and validity (Panday & Panday, 2015). Research design was meant to provide a clear understanding of the research objectives and the desired outcomes.

Taherdoost (2022) explained that exploratory research was valuable, as it aided in uncovering new insights, ideas, and potential avenues that could be investigated further. It was aimed at investigating the research topic and announcing better understanding, especially if the area of research was new (Taherdoost, 2022). Panday & Panday (2015) highlighted that exploratory research ideally helped to unpack the research topic by identifying key variables that would facilitate the process of formulating the hypothesis (Panday & Panday, 2015).

The use of exploratory research in establishing a collaborative supply chain framework for advancing renewable energy development through industrial clusters was chosen because it would have provided an understanding of the complex dynamics that unfolded when developing renewable energy within industrial clusters and might have laid the groundwork for effective collaboration in the energy sector. Furthermore, this research exercise focused on understanding the subjective experiences of individuals by using experience surveys to solicit different segments of information and leverage the knowledge and experience of key potential stakeholders who might have participated in industrial cluster initiatives and understood the relevance of collaboration (Hancock, et al, 2009). In using experience surveys, the aim was to engage participants who might have formed part of an industrial cluster (regardless of the sector); had made significant inputs to supply chain activities or had worked on renewable energy technology, to foster an understanding and appreciation of the possibilities of these three (3) aspects pursuing a collaborative framework.

3.4. Data collection methods

Data collection when conducting a qualitative research study was concerned with the way data would be collected (Panday & Panday, 2015). It assumed that time and substantial effort was required to make the necessary arrangements for collection and to ensure adequate quality (Panday & Panday, 2015), which might have added to the disadvantages of this method. However, the researcher could make use of different tools during this process of collecting data, which included interviews, questionnaires, observations, or schedules (Panday & Panday, 2015), that allowed for flexibility in obtaining the best inputs from the respondents.

This study made use of a structured questionnaire which included a mix of pre-determined questions and supplementary answers for participants to choose from. The use of structured questions usually required simplified and themed questions to allow respondents to answer on their own without the researcher providing much clarification. This method required the questionnaire to be carefully curated to ensure no ambiguity or confusion was caused (Hancock, et al., 2009). The questionnaire made provision for free text answers to allow respondents to expand on their selections with detailed justifications.

3.5. Population and sampling

Population referred to the set or group of all the units on which the findings of the research were to be applied (Panday & Panday, 2015) and a sample was concerned with the individuals that took part in the study (Taherdoost, 2016). Therefore, the process of selecting a sample from a population was called sampling (Taherdoost, 2016). The other approach was to identify smaller populations that were not easily accessible through the snowballing technique. This technique would allow the initial participants to refer new participants to respond to the study (Taherdoost, 2016).

3.5.1 Population

The primary population set out to engage RE and SC professionals who had expert knowledge of these fields of study.

Table 7: Description of population type

Description of population type	Work Experience	Number to be sampled
Supply Chain employees	Min 2yrs	20
Renewable Energy employees	Min 2yrs	20
Individuals employed by industrial organisations	Min 1yr	20
Total		**60**

3.5.2 Sample and sampling method

The target sample for this study was selected using non-probability sampling and, in particular, purposive sampling where subjective judgement was used in the sample selection in preference to random selection (Omeihe, 2021).

The participants were selected based on the following criteria:

i. Individuals who work in the SC profession (min 2 years working experience)
ii. Individuals who work in the RE profession (min 2 years working experience)
iii. Individuals who work for organisations that operate in industrial areas and are directly involved in their company's industrial cluster initiatives (min 1 year working experience)

3.6 The research instrument

Castillo-Montoya (2016) defined a research instrument as a tool or technique used to collect data from participants in a study. Therefore, the research instrument that was used in this study to gather relevant information was a questionnaire. This instrument was advantageous because it could be administered remotely (Castillo-Montoya, 2016), therefore eliminating location restrictions for respondents. The questions were structured in a systematic and well-organised manner, with the intent to elicit information which would provide insight into the nature of the problem under study (Munir, 2017). The downfall of this method was that the respondents might have misunderstood the question, which could adversely affect the quality of the data. Therefore, the population selection had to be given careful consideration. The questionnaire was drafted in English, as this is the main communication medium in South Africa. Respondents received a cover letter that outlined the purpose of the research. Furthermore, it declared the indemnity rights of participants and outlined how the data collected would be used.

3.7 Procedure for data collection

- A message request was issued to individuals who worked in the renewable energy and supply chain profession, in organisations that were linked to the energy sector and understood the background of the country's energy crisis alongside the proposed solutions, to ensure eligibility.
- The message contained a brief request for participation, which required recipients to consent and participate in responding to a questionnaire encrypted in a link.
- Once recipients engaged with the message further by clicking on the link, the objectives of the research study as well as criteria of eligibility were highlighted.
- Individuals who work in the energy sector were eligible to participate, however, the participants had to understand the supply chain and renewable energy disciplines.

3.8 Data analysis and interpretation

The data in this study was analysed using the Content Analysis method, which involves examining and reporting on text data to identify patterns, themes, trends, or categories to understand underlying meanings and concepts (Hesse-Biber & Leavy, 2010). This qualitative data analysis approach enabled researchers to delve deeply into the findings and uncover complex meanings within the data (Surendran, 2024). The method was suitable as it covered various concepts related to the research questions. After data collection, it was essential to organise the raw data by converting it to text format using Microsoft Word and grouping it into relevant data sets. Each participant's transcript was assigned in the same format to ensure alignment, supported by a consistency table to maintain alignment with the research questions. The data was then coded using the Maxqda tool, with Surendran (2024) describing data coding as categorising and assigning properties to the data collected to help derive theories from relevant findings (Surendran, 2024). This coding process allowed the identification of patterns, providing in-depth insight and supporting informed decisions based on the research findings.

Following data preparation, a meticulous review was conducted, where each piece of data was read multiple times to grasp the overall content and assess completeness (Nowell, Norris, White, & Moules, 2017). The coding process involved analysing interview transcripts, identifying similarities, and developing descriptive codes to categorise the information. This reflective process enabled the identification of relevant text sections and the assignment of labels for indexing based on specific themes (Nowell et al., 2017). The study utilised Maxqda for organising and managing the data, coding, and comparing various codes. The next step was data validation, with Surendran (2024) emphasising the importance of frequent validation to ensure data accuracy and reliability (Surendran, 2024). Data validation could take various forms but should be conducted regularly throughout the study. Finally, the data was systematically presented in a report, highlighting the methods used for data collection, limitations, and suggestions for future research (Surendran, 2024). According to Surendran (2024), business intelligence relies on the synergy between analytics and reporting, where analytics uncovers valuable insights, and reporting communicates these findings to stakeholders (Surendran, 2024).

3.9 Limitations and challenges of the study

The study focused on aspects that would guide the establishment of a collaborative supply chain network, which could advance the development of renewable energy in an industrial cluster. The objective was to have a framework that would focus on providing a tool that stakeholders could use to optimise efficiency, reduce costs, enhance flexibility, and improve overall performance across the renewable energy supply chain in an industrial cluster. The stakeholders of the industrial cluster who were collaborating on a collaborative supply chain included entities such as manufacturers, suppliers, distributors, and retailers, working together closely to achieve common goals. While there were more stakeholders that formed part of an industrial cluster, such as NPOs, residents, and government offices, this study only focused on entities that played a direct role in the supply chain network and were directly impacted by how the supply chain design would be mapped out.

The collection of data might have excluded some experts in the above-mentioned fields due to anticipated challenges around the technology platforms used (in place of in-person interviews), loadshedding uncertainties, and disputes on non-disclosure agreement clauses.

The limitations of a research study are factors that may affect the study's reliability.

- **Availability of respondents –** Respondents were sensitised on the request for their participation and informally briefed. The respondents were also given 90 days to complete the questionnaire to allow them adequate time to respond.
- **Willingness of respondents –** This assumption relied on the respondent's acceptance of the questionnaire and the brief provided by the researcher. The confidentiality clause functioned as a mitigation to ensure the identity of respondents was kept anonymous.
- **Understanding and experience of industrial cluster initiatives –** The brief explanation provided at the start of the questionnaire outlined this and encouraged understanding of the topic and its application.

3.10 Trustworthiness

Trustworthiness in research methodology was used to determine whether the methods used to collect data provided an accurate measure of what was intended, including the accuracy of the findings (Korstjens & Moser, 2018). Daniel (2019) cited that it encompassed several dimensions that ensured the quality and integrity of the research process and outcomes, which were noted as the credibility, reliability, and validity of the research findings (Daniel, 2019).

3.10.1. Transferability

Transferability relates to the extent to which the findings of a study can be applied or generalised to other contexts or populations (Korstjens & Moser, 2018). The recruitment and selection of the sample is based on the knowledge and expertise that the participants are predicted to have. With respect to delimitations, the research has clearly defined its scope and provided context, suggesting that the knowledge gained will be applicable to similar situations and offer valuable insights (Daniel, 2019). However, should more delimitations be identified during the data collection process, they will be managed on a case-by-case method and added to the delimitations section of this proposal.

3.10.2 Dependability

Daniel (2019) described dependability as the consistency and stability of the research findings over time and across different researchers or settings. Dependability was achieved through transparency in data collection and analysis procedures, including documentation of research decisions, data coding processes, and analytical techniques, to enable replication and verification of the study findings (Daniel, 2019). The questionnaire was developed with a deep understanding of the literature. Before administering the questionnaire to the target participants, a pilot test was launched with a small sample of individuals who were similar to the target population (i.e., RE and SC professionals). This ensured that any ambiguities, inconsistencies, or technical issues with the questionnaire were identified early in the process and allowed for the questionnaire to be revised and improved upon.

3.10.3 Credibility

"Ensuring trustworthiness of the research study involved establishing credibility in the research findings and ensuring that the data collected accurately reflected the participants' perspectives and experiences (Daniel, 2019). According to Daniel (2019), this referred to the believability and accuracy of the research findings. It required the application of rigorous data collection and analysis methods. In this study, clear and diligent record keeping of participant responses and clarification queries was recorded. As part of analysing the data, similarities and differences were identified so that the various frames of reference were represented (Suri, 2011). The pilot test participants were asked for feedback and validation regarding their responses to the questionnaire. Some of the participants were asked to confirm, clarify, or provide additional insights on their responses. Other researchers were consulted, to avoid researcher bias.

3.10.4 Confirmability

Confirmability related to the objectivity and neutrality of the research findings, ensuring that they were not unduly influenced by the researchers' biases or preconceptions (Daniel, 2019). It was achieved through maintaining an audit trail of the research process, including documenting data sources, analytical procedures, and interpretations, to demonstrate the credibility and reliability of the findings (Daniel, 2019). Therefore, all correspondence with respondents, consent letters, and all relevant documentation were recorded. A consistency table was maintained to ensure that the research questions and hypothesis were aligned. Furthermore, participants were asked to sign a declaration which was included within the questionnaire design, to ensure that integrity was maintained. During the data collection phase, a professional distance from the research participants was maintained to minimise potential biases or influences on their responses (Daniel, 2019).

3.11 Ethical considerations

Mirza, Bellalem, and Mirza (2023) referred to ethical considerations as the principles and values that guided decisions related to the collection and analysis of data, as well as the sharing of findings (Mirza, Bellalem, & Mirza, 2023). According to Mazumdar (2022), this entailed respecting the participants (even if they were anonymous), providing surety over consent, and respecting the feedback received (Mazumdar, 2022). Mirza et al. (2023) further stated that keeping participants anonymous and preserving the privacy of data should have been a priority and handled with great effort (Mirza et al., 2023). Mirza et al. (2023) further highlighted the unintentional bias of the researcher during the translation or interpretation stage. While explaining the research to participants, the researcher could have posed a suggestive position without being aware of the act. This was expected, as they had engaged the research from different angles.

All participants of this research were treated with respect. The participants had the opportunity to review the consent form before undertaking to respond, to award them a chance to decide (at their own discretion) if they wished to participate. To ensure there was a clear and transparent relationship and interaction with all the participants during the distinct phases of the research, the data collection link (questionnaire) was shared widely through various social media platforms and the identity of the respondents was not known to the researcher when responses were furnished. Participants were reassured through a declaration process (which also served as consent), that their responses would be kept private and there would be nothing in the feedback received that exposed their identity. The anticipated level of anonymity ensured that the feedback received had no bias towards the findings at the stage of concluding the research. The participants were made aware that participating in this study would not be of personal benefit, and no compensation would be issued. During the data collection process, the researcher availed themselves to translate or clarify questions that the participants might have had. This might have created a bias position for the researcher, but research questions were designed in a manner that was believed to be clear and non-ambiguous, in an attempt to minimise the probability of the researcher influencing the answers that participants provided. Before any data was collected, this research followed the Wits Business School (WBS) ethical clearance process and obtained the necessary approval.

3.12 Consistency table

Table 8: Consistency table summarising the research questions, data collection details and data analysis methods.

RQ #	Objective	Prop / hyp #	Sub-Questions	State Proposition or Hypothesis	Data collection detail	Data analysis method
1	**Outline the rationale that justifies the need for a collaborative supply chain within an industrial cluster.**	1.1	Can a collaborative supply chain network design enhance the competitiveness of organisations that form part of industrial clusters?	(i) Limited availability of infrastructure to enable RE development at high rate. (ii) Minimise the risk of supply chain disruptions. (iii) Foster a learning culture within an ecosystem. (iv) Reduce costs. (v) Influence Policy and regulation Support sustainability goals. (vi) Talent and skills development / retention with a regional focus. Market access.	Structured Questionnaire	Content Analysis
		1.2	Select the three drivers that would warrant your organisation forming part of an industrial cluster partnership?			
		1.3	Which of the following drivers may enable further collaboration between cluster stakeholders?			
		1.4	Which of the following collaborative SC strategies are critical to decarbonisation of industrial clusters? *Select only three options*			
		1.5	Which of the following can influence the impact of a collaborative supply chain within industrial clusters? Select only three options:			
		1.6	Can organisations that form part of industrial cluster partnerships gain economic benefits from collaborating on supply chain network designs?			
		1.7	What are the potential economic benefits of implementing a collaborative supply chain within an industrial cluster?			
		1.8	Select three aspects of supply chains within industrial clusters that can be enhanced by collaboration?			
2	**Identify the challenges associated with establishing**	2.1	What barriers do you see in making a commitment to join the cluster?	(i) Challenges of collaborative supply chains in industrial clusters include competition and cooperation balance, resource sharing, supply chain integration, regulatory compliance, risk management, availability of skills, market	Structured Questionnaire	Content Analysis
		2.2	Which of the below can be classified as primary obstacles to initiating collaboration within the supply chain of an industrial cluster?			

	a collaborative supply chain within an industrial cluster.	2.3	Which of the following aspects can negatively affect the establishment of a collaborative supply chain within an industrial cluster? Select only 3:	volatility, and an innovative ecosystem.		
		2.4	What barriers do you see in organisations within an industrial cluster committing to a collaborative supply chain network design?			
3	**Identify anticipated benefits in establishing a collaborative supply chain.**	3.1	Select three benefits that are associated with a collaborative supply chain within an industrial cluster?	i. Identified benefits include competitiveness through shared strategic and operational capabilities, mutual planning and problem-solving efforts, knowledge sharing, reduced costs through economies of scale, improved market access, greater resilience to disruptions through risk sharing and diversification of suppliers.	Structured Questionnaire	Content Analysis
		3.2	Select three benefits that have direct impact on how collaborative supply chains may enhance inventory management and reduce excess inventory levels?			
		3.3	Which of the following benefits should be a priority when establishing a collaborative supply chain for RE?			
		3.4	In your experience, which benefits can be anticipated from establishing a collaborative supply chain? Select only three options:			
4	**What are the key supply chain elements that will enable successful, sustainable, and accelerated adoption of RE through industrial clusters.**	4.1	In line with your experience, what are the principal advantages that organisations hope to gain by integrating a collaborative supply chain strategy into an industrial cluster? Select only three options:	(i) Identified elements include robust infrastructure for renewable energy production and distribution, material, and distribution assessments to enable sourcing plans and minimise supply chain disruptions, enhance skills and knowledge sharing between cluster partners, understanding of operation and maintenance requirements. (ii) Technological innovation to improve the efficiency and reliability of renewable energy systems. (iii) Recycling and Disposal of RE components to ensure the environmental impact is kept to a minimum.	Structured Questionnaire	Content Analysis
		4.2	What are the supply chain design elements may impact the development of renewable energy within industrial clusters? Select only three options:			
		4.3	What are the supply chain design elements may impact the adoption of renewable energy within industrial clusters? Select only three options:			
		4.4	In your experience, which collaborative supply chain benefits might motivate industrial clusters to invest in the development of renewable energy as decarbonisation solution? Select only three options:			
		4.5	In your experience, which collaborative supply chain network design elements are believed to facilitate the accelerated adoption of renewable energy? Select only three options:			

CHAPTER 4. PRESENTATION OF FINDINGS

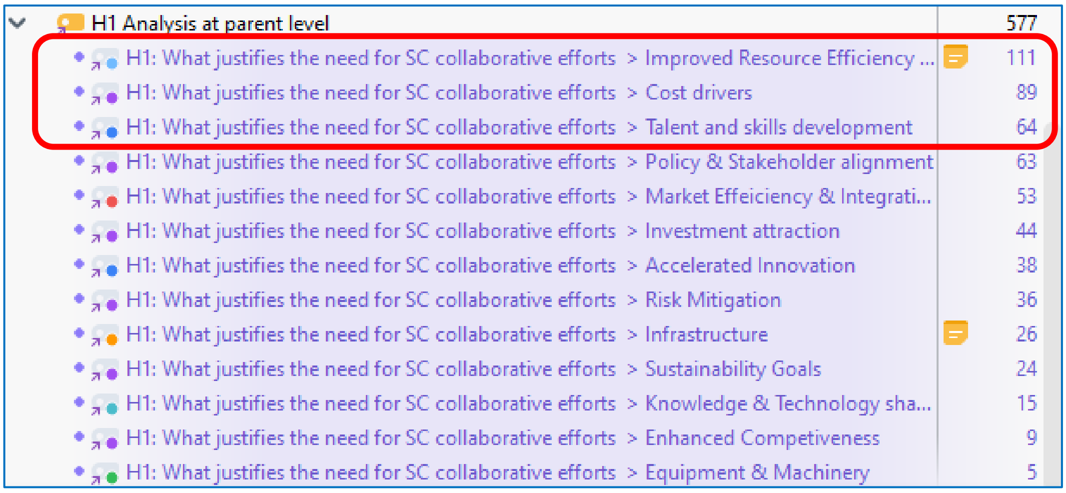
4.1 Introduction

This chapter outlines the findings of the study achieved from a structured questionnaire aimed at addressing the objectives identified in Chapter 1. The findings were gathered from 45 various participants stemming from the energy sector, who cut across various knowledge streams such as renewable energy engineering, supply chain, market and business development, regulations, legal and finance. The data was analysed using MAXQDA, a computer aided qualitative data analysis software program. The results submitted underwent a process of coding and code grouping into themes in alignment with addressing the objectives. Using the content analysis method, an interpretation-focused coding strategy was used. This strategy was used to highlight the relationships between various codes that co-occur or overlap, and to analyse the patterns or trends.

4.2 Results pertaining to Objective 1

Objective 1: Outline the rationale that justifies the need for a collaborative supply chain within an industrial cluster.

The objective was to explore and articulate factors that justify the need for a collaborative supply chain approach to advance the adoption of renewable (wind) energy within industrial clusters that are located inland. Participants were asked to review themes that are in line with collaborative practices that will lead to achieving shared goals. While selecting, the participants were asked to elaborate and justify their answers, to capture a detailed understanding of whether collaborating on these practices would be an ideal approach to advancing renewable energy development. In this section, we will focus on unpacking the top three (3) themes, as they received overwhelming feedback from 73% of participants.



H1 Analysis at parent level	577
H1: What justifies the need for SC collaborative efforts > Improved Resource Efficiency ...	111
H1: What justifies the need for SC collaborative efforts > Cost drivers	89
H1: What justifies the need for SC collaborative efforts > Talent and skills development	64
H1: What justifies the need for SC collaborative efforts > Policy & Stakeholder alignment	63
H1: What justifies the need for SC collaborative efforts > Market Effeiciency & Integrati...	53
H1: What justifies the need for SC collaborative efforts > Investment attraction	44
H1: What justifies the need for SC collaborative efforts > Accelerated Innovation	38
H1: What justifies the need for SC collaborative efforts > Risk Mitigation	36
H1: What justifies the need for SC collaborative efforts > Infrastructure	26
H1: What justifies the need for SC collaborative efforts > Sustainability Goals	24
H1: What justifies the need for SC collaborative efforts > Knowledge & Technology sha...	15
H1: What justifies the need for SC collaborative efforts > Enhanced Competiveness	9
H1: What justifies the need for SC collaborative efforts > Equipment & Machinery	5

Figure 5: A summary table of the themes and their ranking as per responses for Objective 1. *(Source: Maxqda project as created by Author)*

Seventy-three percent (73%) of the participants in this study provided perspectives on key aspects that justify the need for a collaborative supply chain approach to advance the adoption of renewable wind energy within inland industrial clusters were aligned. All participants acknowledged that collaboration of various organisations within an industrial cluster and with different service offerings could fast track the adoption of renewable energy. However, there was a consensus that specific elements of the supply chain network would need to be reviewed with significant focus. There was also a general understanding of the fact that all elements of the supply chain play an important role and would need to be investigated accordingly, but as a starting base for collaboration amongst key stakeholders, three (3) aspects were outlined as top preference.

4.2.1. Improved Resource Efficiency

This theme had a particular focus on the efficiency of resources such as raw materials, components, logistics (transportation), roads, equipment, and land. It explores the theory of how shared resources can minimise waste and optimise utilisation. It is also focused on reducing redundancies and costs of these resources through collective planning and coordination. Thirty-seven (37) of the forty-five (45) participants expressed the need for improved resource efficiency and how this rationale will ensure that supply chain collaboration succeeds. Participants highlighted multiple supply chain aspects that are currently failing within the renewable energy (particularly wind) sector, alongside the history of challenges that supply chains face globally. One participant highlighted how the location of wind farms can impact the reliability of its supply chain and the efficiency of energy security.

"Wind farms are large in size - located in remote sites, they are not independent and not yet able to supply reliable and efficient energy securely." (Participant 15)

Regarding the impact of location on resource efficiency, other participants outline the challenge that setting up wind farm projects in inland areas would create, such as long delivery lead times and distance between the project sites versus the ports for material / component imports. This in turn highlights the importance of feasibility studies that research the location aspect, with a link to how the location will influence resource (land, labour and materials) availability.

"Inland provinces are remotely located from Ports which could lead to long lead times in delivery of equipment." (Participant 24)

"If wrong location or feasibility studies fail then there may be issues with resource availability that should be ensuring production". (Participant 25)

The topic of land as a resource seems to have sparked major concerns, as this is closely linked to policy and regulation issues relating to land ownership and licensing requirements which rest with the supply chain discipline under market research investigations.

"Landlocked inland areas become difficult to access due to the size of the infrastructure required for wind energy projects." (Participant 23)

"If wrong location or feasibility studies fail then there may be issues with resource availability that should be ensuring production." (Participant 25)

"Inland sites may suffer from logistics constraints relating to route access for transportation of large components such as Towers and Turbine blades." (Participant 29)

There were 37 respondents that agreed with the improved efficiency element, and 17 of these participants expressed concerns over the logistics network and readiness if the South African road and transport landscape.

“Logistics networks for land-based wind turbine components are increasingly strained due to the increasing size of components, such as blades. Technology evolution, including increasingly larger wind turbine components, drives the need for facility upgrades and retooling and compounds difficult transportation hurdles. Shortages of rare earth magnets and fundamental commodity price risks could disrupt supply chain activities, erode South Africa competitiveness, and jeopardise deployment ambitions.” (Participant 16)

“Installations should be preceded by a thorough review of locations to ensure that replacement parts can be easily supplied, especially via road for inland areas. This will help minimise potential disruptions and reduce negative impacts on the supply chain.” (Participant 26)

“Supply chain is dependent on reliability. The wind energy generated would need to be reliable enough to support the supply chain network (located in a place that supports production, so supply is reliable etc.)”. (Participant 32)

“Difficulty accessing specialised equipment such as cranes. The industry uses specialised crane specific to the sector. Roads and bridges encountered to site of delivery which could be lower and not permit the loads to move, requiring modifications or alternative routes where feasible.” (Participant 33)

Some participants go on further to question collaboration as a lever to drive adoption of various technologies (in this instance renewable wind energy).

“If it was feasible to collaborate, projects would benefit from economies of scale due to the size of the orders and reduced logistics costs. Improved efficiency increases the chances of successful project delivery. There is a potential for expanding market demand due to proven feasibility of projects thus attracting more players.” (Participant 33)

4.2.2. Cost Drivers

This theme is concerned with key factors that influence the overall cost efficiency and economic rationale for collaboration. These costs are linked to the associated costs of doing business or establishing such energy projects. The following sub-themes were identified:

4.2.2.1 Shared Infrastructure Costs

A few participants highlighted that supply chain collaboration could result in the reduction of operational and transportation costs through shared logistics and infrastructure. Organisations can share the utilisation of transportation networks (e.g., shared fleets, optimised routes), and delight in reduced delivery costs through collective delivery systems that run from ports to the inland regions. Some participants expressed how shared facilities (warehouses) can eliminate the need for individual investments and running costs. However, on the topic of land, ownership and associated licensing costs remain vague and there is still uncertainty on acquisition of such land. Tribal challenges (communication, ownership, and costs) might increase the cost of having such risks mitigated. Participant responses highlighted concerns over maintenance and operational costs.

“Imposing high import duties/tax on RE equipment when the local manufacturing is not properly geared up to meet the industry requirements and the cost is not competitive to the international markets.” (Participant 16)

“If these enterprises are not close to suppliers, it is costly to access parts or repairs when experiencing breakdowns.” (Participant 18)

“Difficulty in sourcing for key resources and increased costs due to logistics.” (Participant 22)

"1. A shortage of materials required for manufacturing or installing wind energy equipment, can result in delays or failure to achieve the desired outcome. Government support for alternative energy sources can create price pressures on the wind energy sector, potentially leading to compromises in the quality of individual components, which may cause conflicts among stakeholders." (Participant 26)

“If it was feasible to collaborate, projects would benefit from economies of scale due to the size of the orders and reduced logistics costs.” “…Difficulty accessing specialised equipment such as cranes. The industry uses specialised crane specific to the sector. Roads and bridges encountered to site of delivery which could be lower and not permit the loads to move, requiring modifications or alternative routes where feasible.” (Participant 33)

4.2.2.2 Bulk Purchasing and Economies of Scale

Some participants also expressed how the lack of transparency and trust between stakeholders could lead to a missed opportunity in sharing related costs and leveraging off economies of scale. This speaks to the cost of procuring raw materials, leveraging on discount power for high volume purchasing (bulk purchases). Some participants highlighted the missed opportunity that comes with negotiating reduced rates for the levelised cost of renewable energy, which organisations may face.

“They can take advantage of economies of scale by clustering together, enabling larger volumes and ultimately giving enough volumes for manufacturers to consider localising. This will decrease cost of equipment and levelised cost of electricity.” (Participant 9)

"Quality, the supplier not understanding the requirements. The supplier not understanding the requirements at tender, therefore under quoting. The supplier not engaging with logistics support at tender stage, to ensure right first time." (Participant 28)

“Optimising costs through economies of scale, policy incentives that reward collaboration and mitigation of non-delivery risk”. (Participant 33)
“Moreover, the improved efficiency will enable the team to understand the cost of the project and because the cluster works as a team, this reduces the lengthy process to procure hence the possibilities of cost reduction.” (Participant 42)

4.2.2.3 Technology and Innovation (R&D) Costs

Some participants expressed that supply chain collaboration could enable industrial clusters to minimise capital expenditures by co-investing in common facilities and technology. A fair group of participants suggested that collaborative efforts may reduce duplication of efforts and costs. Shared investment in pilot projects and testing facilities for new technologies may be beneficial to the cluster as it will ensure that adequate risk mitigation strategies are in place.

"Lack of transparency in related costs, misaligned objectives across supply chain partners, inadequate policy/regulatory support". (Participant 32)

4.2.2.4 Labour and Skills Development Costs

Another aspect highlighted by participants was the link between enabled resource pooling and cost reduction. Participants listed the value add of how shared resourced can facilitate cost reductions, particularly in ensuring increased market participation by local suppliers and fast track developing the required skills that organisations will need in order to sustain such developments. Other participants argued how such efforts can have the opposite effect, because South Africa might struggle with retaining a competitive edge if levelled against global suppliers who offer competitive pricing for components and labour.

"Low labour costs from overseas competitors may threaten local supplier competitiveness, especially for labour-intensive operations such as blade manufacturing…" (Participant 16)

"Collaboration among industrial cluster partners is vital as it enables resource pooling to reduce costs and accelerate innovation, shares risks to lessen challenges for individual firms, and collectively influences policy for a supportive regulatory environment. This synergy enhances competitiveness and adaptability to market and regulatory changes across the industry." (Participant 21)

"A new supplier/ company trying to enter or participate in the market could benefit from a partnership with a knowledgeable and experienced partner with good reputation. Sharing of resources instead of duplicating the same resources and gain sharing for sharing of information will result to costs effectiveness." (Participant 22)

4.2.2.5 Sustainability Initiatives

Further to unpacking the cost drivers that influence supply chain collaboration is joint investments in sustainable practices. Participants expressed that in an industrial cluster reduced penalties or fines by collectively adhering to environmental regulations can support the accelerated adoption of renewable energy and fast track the just transition mandate through various programs.

"Access to resources: Transition to renewable energy sources, will require access to funding for Just Energy Transition Programs." (Participant 29)

"Sustainability goals often conflict with cost reduction efforts which in my experience is the number one priority for South African organisations. If sustainability can somehow be partnered with cost reduction through regulatory support, organisations would be more driven to prioritise development of renewable energy such as wind." (Participant 32)

4.2.2.6 Risk Pooling and Insurance Costs

Some participants shared that collective risk-sharing reduces the cost of supply chain disruptions (e.g., natural disasters, market fluctuations) that may lead to non-delivery, and organisations can benefit from lower premiums for group insurance policies covering inventory, equipment, or transport.

"Optimising costs through economies of scale, policy incentives that reward collaboration and mitigation of non-delivery risk." (Participant 33)

4.2.3. Talent and Skills Development

Talent and skills development is a critical aspect of collaborative supply chains within industrial clusters. The findings in some of the participant responses illustrated some of the below sub-themes:

4.2.3.1. Workforce Upskilling

Participants highlighted that collaboration could facilitate joint training programs and workshops tailored to industry needs. Organisations can strive to leverage on sharing resources to drive skills development within the industrial clusters, such as introducing new training centres and e-learning platforms that support the required skills.

"This (collaboration) will assist in the just transition imperatives for the inland region where some of the areas are coal regions with the inevitable de-commissioning of the coal-fleet power plants in the region. This will mitigate the potential loss of jobs. The current skills can be re-purposed to new skills that can be utilised in the RE space...". (Participant 16)

"…Expected new workforce demand to serve the industry is likely in the hundreds of thousands. Additional education and training programmes are expected to be necessary. (Participant 16)

4.2.3.2. Knowledge Sharing and Mentorship

A participant highlighted that organisations within the cluster could share best practices and expertise. This form of capability building could see experienced professionals mentoring new talent, enhancing skill transfer across the cluster.

" The expansion of the market together with more professional skills in the field could increase the potential of inland projects succeeding." (Participant 39)

4.2.3.3. Innovation through Diverse Perspectives

Most participants that justified this approach indicated that collaboration amongst firms could introduce diverse skill sets, fostering creativity and innovation. Multidisciplinary teams working on cluster-wide projects might create new opportunities for talent growth, therefore increasing the opportunity for enhanced innovation.

“Transfer of skills and development of new skills (new and old companies). Stimulate participation of more suppliers in the market and create competitive pricing. New and innovative ideas of doing things, development of new processes and management tools.” (Participant 22)

“…Expected new workforce demand to serve the industry is likely in the hundreds of thousands. Additional education and training programmes are expected to be necessary.” (Participant 16)

4.2.3.4. Alignment with Future Trends

Other participants expressed a view that collective focus on upskilling for emerging technologies, such as Artificial Intelligence (AI), Robotic Process Automation (RPA), Big Data, and renewable energy was a need, in order to retain a competitive edge amongst other global players.

“With the advent of new technologies, it requires new skills to be developed as long as it is included as part of the strategy for transfer of skills to ensure sustainability; moving away from fossil-based energy will require innovative advancement to take place…” (Participant 15)

4.2.3.5. Shared Responsibility for Talent Development

This sub-theme suggests that organisations can collaborate on apprenticeship and internship programs, and drive cost-sharing for skill development initiatives in order to reduce incurring these costs in silos. Participants expressed that talent and skills development is both a driver and an outcome of collaborative supply chains, reinforcing the cluster’s ability to innovate, adapt, and remain competitive. Such compelling growth strategies will attract investment where there is a need for funding.

” … Investors with a sustainability drive might be interested and it would be a new sector growth which could support the development of new skills and talent.” (Participant 32)

” The expansion of the market together with more professional skills in the field could increase the potential of inland projects succeeding.” (Participant 39)

4.2.4 Conclusion on Objective 1

It is evident in the narrations that most participants understood the rationale that justifies the need for a collaborative supply chain within an industrial cluster. The responses also address the challenge on the development of wind energy projects within inland regions. The data highlighted the efficiency challenges that the location of such initiatives can introduce, and the impact this can have on driving economic activity at regional level. The data also confirmed that most participants perceived that South African organisations are not deliberate enough with their collaboration efforts, as a lot of gaps were highlighted relating to the resource inefficiencies, no active strategies to address cost reduction (and funding models) and the lack of collective plans on talent and skills development programs to build the required capabilities. Most participants expressed that collaboration efforts of an industrial cluster should prioritise these three (3) elements as a starting point for a supply chain framework. These elements reflect the strategic and operational benefits that determine the need for a collaborative supply chain efforts within industrial clusters located inland.

4.3 Results pertaining to Objective 2

Objective 2: Identify the challenges associated with establishing a collaborative supply chain within an industrial cluster.

The objective was to explore and highlight challenges that can be viewed as barriers to establishing a collaborative supply chain framework to advance the adoption of renewable (wind) energy within industrial clusters that are located inland. Participants were asked to review themes that are presenting as obstacles to building collaborative supply chains in industrial clusters. While selecting potential barriers, the participants were asked to elaborate and justify their answers, to capture a detailed understanding of these challenges. In this section, the top three (3) received aligned responses from 57% of the participants, therefore as majority, only these themes will be unpacked.

H2 Ananlysis at parent level	303
H2: Barriers to building collaborative supply chains in industrial clusters > Communication and Coordination Issues	48
H2: Barriers to building collaborative supply chains in industrial clusters > Resource limitations	36
H2: Barriers to building collaborative supply chains in industrial clusters > Regulatory & Legal constraints	34
H2: Barriers to building collaborative supply chains in industrial clusters > Benefits unclear	34
H2: Barriers to building collaborative supply chains in industrial clusters > Technology gaps	34
H2: Barriers to building collaborative supply chains in industrial clusters > Competitive edge	31
H2: Barriers to building collaborative supply chains in industrial clusters > Funding	27
H2: Barriers to building collaborative supply chains in industrial clusters > Trust and relationship challenges	20
H2: Barriers to building collaborative supply chains in industrial clusters > Cultural & organisational differences	19
H2: Barriers to building collaborative supply chains in industrial clusters > Market volatility & uncertainty	15
H2: Barriers to building collaborative supply chains in industrial clusters > Uneven commitment and engagement	2
H2: Barriers to building collaborative supply chains in industrial clusters > Logistical complexities	2
H2: Barriers to building collaborative supply chains in industrial clusters > Power imbalances	1

Figure 6: Summary table of the themes and their ranking as per responses for Objective 2. *(Source: Maxqda project as created by Author)*

This analysis has provided a comprehensive understanding of the challenges and barriers that organisations are currently facing in relation to supply chain collaboration to advance renewable (wind) energy development. From the findings depicted in figure 6, it was established that *Communication and coordination issues* were most prevalent. *Resources limitations* were found to also be a barrier. The third (3rd) barrier identified by participants resulted in a tie between three (3) sub-themes: regulatory and legal constraints, unclear benefits, and technological gaps. These sub-themes are discussed in detail below:

4.3.1 Communication and Coordination Issues

Participants expressed observations on the lack of coordination on some key aspects and decision points. Out of the 32 participants who selected this factor as a challenge, 4 of them expressed various obstacles that lead to coordination issues amongst stakeholders, which is encapsulated by poor communication channels that result in misaligned goals. Participants highlighted that such barriers could limit cluster partnerships from succeeding.

"These obstacles can lead organisations to view collaboration with scepticism, perceiving it as risky or ineffective. They may prioritise individual goals over collective efforts, leading to missed opportunities for innovation and growth. Overcoming these barriers requires fostering trust, aligning interests, and demonstrating the tangible benefits of collaboration in addressing shared challenges.' (Participant 21)

“Obstacles like regulation and policy barriers, incompatible processes, unavailable skills, and competition concerns make organisations hesitant to collaborate. They see collaboration as risky, inefficient, and resource-intensive, fearing delays, additional costs, and competitive disadvantages. These challenges discourage cooperation, limiting broader partnerships in the wind energy supply chain.” (Participant 30)

4.3.2 Resource Limitations

On this theme, participants highlighted different resources that faced limitations. Participants outlined the need for compatible execution models across various organisations to streamline objectives. Another participant highlighted how certain supply chain activities could impede on competition, which plays on the element of trust and communication amongst, not only organisations, but key stakeholders as well. It was highlighted that other barriers can have a direct impact on coordination and communication challenges as well.

“The supply of energy is not allowed to be directly supplied to the industrial clusters - industrial spaces are not exempted from loadshedding or load reduction and the regulation barriers contribute to poor coordination and the benefits do not directly reach those that invested.” (Participant 15)

“Organisation's execution models are not compatible, leading to different objectives at different phases of collaboration.” (Participant 20)

“The roles of the various Market participants and allocation of licensing will reduce ambiguity and increase trust among the role players since their competitive elements will be clear, thus allowing collaboration in areas where they do not feel compromised, e.g. supply chain activities " (Participant 29)

“Obstacles like regulation and policy barriers, incompatible processes, unavailable skills, and competition concerns make organisations hesitant to collaborate. They see collaboration as risky, inefficient, and resource-intensive, fearing delays, additional costs, and competitive disadvantages. These challenges discourage cooperation, limiting broader partnerships in the wind energy supply chain.” (Participant 30)

"As an industry association, our primary concern is the development of the wind sector holistically. In order for us to continue to advocate for the sector, an investment in skills development as well as alignment amongst all stakeholders can contribute positively towards growing the sector more and getting more wind on the grid." (Participant 31)

4.3.3 Regulatory and Legal Constraints

On this theme, participants highlighted challenges pertaining to slow clarification and adoption of policy and regulation can hinder progress for the establishment of collaborative supply chains. Participants highlighted how bureaucracy issues can delay adoption of policy in certain instances, particularly in the early stages of formation where land acquisition and licensing needs require urgent and proactive action. Furthermore, participants expressed the lack of supportive policies or incentives for supply chain collaboration, on the topic of renewable (wind) energy. Participants failed to outline the difficulties that industrial clusters may face when navigating overlapping local, regional, and national regulations.

"The supply of energy is not allowed to be directly supplied to the industrial clusters - industrial spaces are not exempted from loadshedding or load reduction and the regulation barriers contribute to poor coordination and the benefits do not directly reach those that invested." (Participant 15)

"The slow implementation of new policy and regulation hinders progress of programmes. The stakeholders required in the approval process of the execution of the programmes are lagging behind." (Participant 16)
"Purely transactional, organisations view collaboration as only a financial transaction or purely for compliance with the off taker/client's requirements. True benefits of collaboration are not realised." (Participant 22)

"The simplification and streamlining of the Regulatory environment need to be expedited." (Participant 29)

"Obstacles like regulation and policy barriers, incompatible processes, unavailable skills, and competition concerns make organisations hesitant to collaborate. They see collaboration as risky, inefficient, and resource-intensive, fearing delays, additional costs, and competitive disadvantages. These challenges discourage

cooperation, limiting broader partnerships in the wind energy supply chain." (Participant 30)

"From Eskom point of view. Policy and regulation are the biggest challenges." (Participant 40)

"They make it take too long to define partnership constructs because there is limited funding for projects, risks policy and regulatory risks are not always clear -can cause delays on the project, reducing the chances of gaining access to the power transmission grid, making the overall economic viability uncertain." (Participant 43)

4.3.4 Unclear Benefits

On this theme, participants expressed concerns over the benefits that supply chain collaboration would introduce and highlighted the uncertainty and clarity that is lacking from the attempts to collaborate on supply chain facets. Participant responses implied that there is doubt around the feasibility and efficiency of organisations collaborating on supply chain activities. Participant feedback also highlights a correlation between transparency and communication that can be leveraged to clarify the benefits for all stakeholders.

"Mostly it's a result of lack of alignment on local social issues and unclear sustainable benefits." (Participant 12)

"These obstacles can lead organisations to view collaboration with scepticism, perceiving it as risky or ineffective. They may prioritise individual goals over collective efforts, leading to missed opportunities for innovation and growth. Overcoming these barriers requires fostering trust, aligning interests, and demonstrating the tangible benefits of collaboration in addressing shared challenges." (Participant 21)

"Purely transactional, organisations view collaboration as only a financial transaction or purely for compliance with the off taker/client's requirements. True benefits of collaboration are not realised." (Participant 22)

"Collaboration may be hampered if benefits for each organisation are not defined clearly. Bigger organisation will maintain monopoly, giving them a competitive edge over smaller organisation. This could result in a lack of coordination between organisations." (Participant 24)

“Obstacles like regulation and policy barriers, incompatible processes, unavailable skills, and competition concerns make organisations hesitant to collaborate. They see collaboration as risky, inefficient, and resource-intensive, fearing delays, additional costs, and competitive disadvantages. These challenges discourage cooperation, limiting broader partnerships in the wind energy supply chain.” (Participant 30)

“Collaboration between organisations is challenging if there is not a clear benefit as the effort to align the organisations is typically high (if it is not a customer, service provider relationship).” (Participant 32)

“Companies could benefit from collaborating but competition and the uncertainty of how they could benefit from one another could hinder this.” (Participant 39)

4.3.5 Technological Gaps

Participants identified aspects that support technological gaps as a barrier, where the impact is depicted through incompatible execution models that contribute to organisations driving different objectives. Here, participants were required to highlight any operational technologies that could hinder seamless integration to facilitate the transfer of information within the cluster. Participants did not highlight any supporting opinions regarding data security when sharing information across multiple organisations that could be direct competitors within the region.

” An organisation’s execution models are not compatible, leading to different objectives at different phases of collaboration.” (Participant 20)
“Wind energy projects are best developed in areas that have high-capacity factors, which are generally far from existing industrial clusters traditionally based on fossil energy, therefore requiring significant upgrades to the energy transmission infrastructure.” (Participant 43)

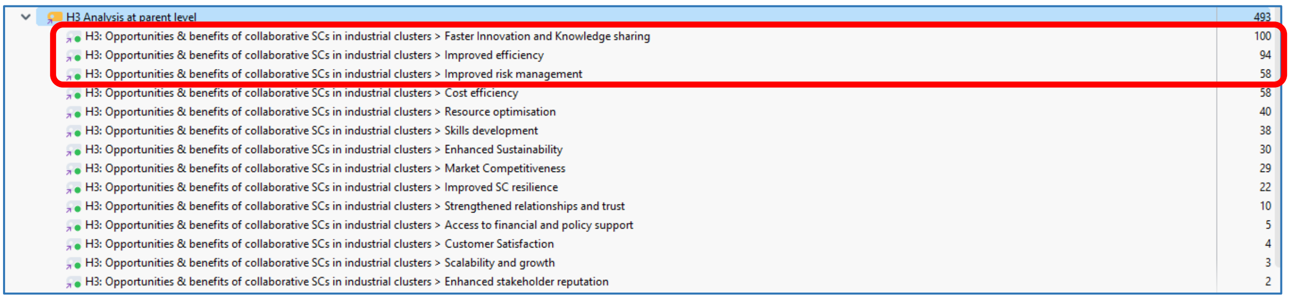
4.3.6 Conclusion for Objective 2

The responses received from participants on Objective 2 highlighted important challenges that imply that any effort to collaborate more compelling. The data confirmed that most participants understood these barriers to be deal breakers towards ambitions of witnessing industrial cluster partnerships come into effect. Some of these barriers include technology gaps to facilitate the transfer of data between the various cluster partners. Challenges surrounding unclear benefits, communication and coordination issues were attributed to poor communication channels that result in misaligned goals. Participants highlighted how bureaucracy issues can delay adoption of policy in certain instances, and the lack of supportive policies or incentives for supply chain collaboration, on the topic of renewable (wind) energy. Participants further outlines how the lack of various resources could limit the need for compatible execution models across various organisations to streamline objectives. These five (5) elements signal the barriers that can result in collaborative efforts amongst cluster partnerships failing.

4.4 Results pertaining to Objective 3

Objective 3: Identify anticipated benefits in establishing a collaborative supply chain.

The objective was to understand the positive outcomes and value creation associated with implementing a collaborative supply chain framework to advance the adoption of renewable (wind) energy within industrial clusters that are located inland. Participants were asked to review themes that are perceived as valuable and favourable to building collaborative supply chains in industrial clusters. While selecting the associated benefits, the participants were asked to expand on how the advantages of supply chain collaboration would benefit industrial cluster partnerships. In this section, we will unpack only the top three (3) themes, which received aligned responses from 77% of the participants, representing the majority.



H3 Analysis at parent level	493
H3: Opportunities & benefits of collaborative SCs in industrial clusters > Faster Innovation and Knowledge sharing	100
H3: Opportunities & benefits of collaborative SCs in industrial clusters > Improved efficiency	94
H3: Opportunities & benefits of collaborative SCs in industrial clusters > Improved risk management	58
H3: Opportunities & benefits of collaborative SCs in industrial clusters > Cost efficiency	58
H3: Opportunities & benefits of collaborative SCs in industrial clusters > Resource optimisation	40
H3: Opportunities & benefits of collaborative SCs in industrial clusters > Skills development	38
H3: Opportunities & benefits of collaborative SCs in industrial clusters > Enhanced Sustainability	30
H3: Opportunities & benefits of collaborative SCs in industrial clusters > Market Competitiveness	29
H3: Opportunities & benefits of collaborative SCs in industrial clusters > Improved SC resilience	22
H3: Opportunities & benefits of collaborative SCs in industrial clusters > Strengthened relationships and trust	10
H3: Opportunities & benefits of collaborative SCs in industrial clusters > Access to financial and policy support	5
H3: Opportunities & benefits of collaborative SCs in industrial clusters > Customer Satisfaction	4
H3: Opportunities & benefits of collaborative SCs in industrial clusters > Scalability and growth	3
H3: Opportunities & benefits of collaborative SCs in industrial clusters > Enhanced stakeholder reputation	2

Figure 7: Summary of the themes and their ranking as per responses for Objective 3. *(Source: Maxqda project as created by Author)*

4.4.1. Faster Innovation and Knowledge Sharing

The following sub-themes were identified:

4.4.1.1 Co-development of technologies

Participants highlighted opinions on how innovation and knowledge sharing could result from joint research and development efforts undertaken by organisations within the cluster, to collaborate on innovative wind energy products or processes that will benefit the industrial cluster. Participants further expressed how such benefits would extend towards improved product development cycles.

"…Enhanced innovation emerges from joint research efforts, pooling expertise to create advanced wind technologies" … "Also, pooling resources for research and development allows companies to innovate more efficiently, developing better turbines or solutions for low-wind areas, enhancing the overall supply chain success." (Participant 30)

"Pooling of resources can facilitate innovative advancements if managed in a positive manner; and be the foundation for sustainable and environmentally sound operations." (Participant 15)

4.4.1.2 Access to diverse expertise

In relation to this sub-theme, participants indicated that through collaboration, organisations could leverage off the knowledge and skills of other cluster members. Participants highlighted that this cross-industry collaboration would foster learning from other participants in the cluster to create unique solutions to cluster specific challenges.

"Leveraging of resources and synergising efforts contributes towards improved efficiency, cost savings, and advancement in innovation." (Participant 15)

"Sharing information, leads to widening the knowledge pool." (Participant 20)

4.4.1.3 Access to best practices

Participants on this sub-theme believed that knowledge sharing would give organisations access to learning effective processes and strategies from other cluster-participants.

"Access to information and data can enable the sector to learn from other industries or companies for the benefit of the sector, without compromising any commercial interests or concerns from members companies." (Participant 31)

"Sharing of learnings within enterprises and common best practices build trust and an understanding of challenges in the rest of the rest of the supply chain." (Participant 18)

"Adoption of best practices and technologies based on information from co-collaborators." (Participant 20)

4.4.1.4 Training and upskilling

There were 39 participants that responded to this question, and only 9 participants expressed how supply chain collaboration could enable joint programs to enhance workforce capabilities. The 9 participants explained that this form of collaboration could improve problem-solving efforts through facilitated brainstorming and decision-making as a group.

" …and innovation will be enhanced as different set of skills and resources are brought into the problem." (Participant 25)

"To enhance efficiency, the sharing of ideas and knowledge will be essential. This exchange fosters innovation, improves problem-solving, and enables more streamlined and effective processes across all stakeholders involved." (Participant 26)

4.4.1.5 Shared data analytics

Participants shared that the use of pooled information could result in better market insights and performance metrics that the cluster participants could use to make better informed decisions. Other participants expressed that this form of information sharing would also validate the trust amongst the cluster participants.

"Sharing of information. Organisations operating in the same market face similar risks and challenges, and sharing of information, lessons learned, and best practices can improve efficiency and risk management." (Participant 22)

"This creates a clear understanding what capabilities that what Suppliers Vs Customer can do, lastly give an opportunity to more understanding on how Entrepreneur can be innovated to tap into the market, with clear understanding." (Participant 12)

"Sharing of helpful information may improve transparency between organisations." (Participant 24)

"Collaboration across different clusters leads to cross pollination of information pools, leads to improvement is skills retention and engagement of resources." (Participant 20)

"During collaboration suppliers can share market intelligence and effective strategies of managing high risks and challenges in the market. Develop new and innovative ideas for managing specific processes in the supply chain management cycle." (Participant 22)

4.4.2 Improved Efficiency

The second theme under objective 3, relating to benefits of supply chain collaboration is "Improved Efficiency". Most participants linked this theme to the need for improved processes, streamlined logistics, reduced duplication of efforts and improved supply chain visibility and resilience, as subjects that can enable faster decision-making to respond efficiently to demand signals.

"You tap into each other's intelligence, resources…" (Participant 19)

"In an industrial cluster partnership, improved efficiency can be achieved through shared logistics and standardised processes." (Participant 30)

“Consolidation of resources such as shared warehouse hubs, aligned transport routes, high volume discounts when negotiating agreements such as sea shipments can all introduce efficiencies and cost savings.” (Participant 32)

“The Consolidation and collaboration will highlight the increase demand for various components which can eventually open opportunities for new industries in the country. This would reduce the need for reliance on imported components and thus positively impact on sustainability and environmental impacts.” (Participant 29)

“A cluster may provide opportunities for local manufacturing and supplier development which will in turn increase the local skills and capabilities in the country and the region…” “There is a possibility to do tower manufacturing of the wind turbines by suppliers outside of the Western Cape. In Gauteng there is a potential supplier who was identified with the potential capability to manufacture steel towers for instance. South Africa has capability to do transformers, however, the transformers are different. South Africa needs to gear up technically to these.” (Participant 16)

“Collaboration in inland wind energy can lead to joint infrastructure development, where organisations share costs for roads and grid connections, improving logistics. Also, pooling resources for research and development allows companies to innovate more efficiently, developing better turbines or solutions for low-wind areas, enhancing the overall supply chain success.” (Participant 30)

“Collaboration through industrial cluster partnerships in wind energy can drive innovation, reduce costs, and enhance competitiveness. It fosters stable supply chains, ensuring consistent delivery of components while creating jobs in local economies. Ultimately, this approach leads to a more resilient and sustainable wind energy sector, adapting effectively to market changes.” (Participant 21)

4.4.3 Improved Risk Management

This theme ranked 3rd in the data analysis for objective 3 and addresses the benefits that risk management can introduce in collaborative supply chains within industrial clusters. Participants expressed that industrial cluster partnerships could reduce individual exposure of organisations to supply chain disruptions. Organisations would be less vulnerable to disruptions and reduce the dependency on a single source through shared supplier networks. Some participants indicated that shared risks could also enhance the supply chain's resilience because of the collaborative planning effort that goes into risk mitigation strategies. Some comments from participants noted that joint risk management will drive improved compliance through active tracking of individual risks to ensure adherence to regulatory standards.

"The risk is better managed as a group of participants than individual players. Each member is also able to share their knowledge and expertise on the projects." (Participant 16)

"Risk Management: Better handle on risks since the industry will be collaborating and thus the risk is shared." (Participant 29)

"… Better risk management is realised by distributing project risks, ensuring that disruptions are shared and mitigated collectively within the cluster." "Innovation and Technology (Knowledge Sharing) for faster advancements, Risk Mitigation to distribute and manage uncertainties, and Skills Transfer and Talent Development to build a stronger, skilled workforce. These factors collectively improve operational efficiency, resilience, and expertise within the industrial cluster pursuing wind energy initiatives." (Participant 30)

"Risk can be shared, activities performed by players who are most suited, resulting in increased efficiency and decreased cost." (Participant 37)

4.4.4 Conclusion for Objective 3

The data analysis outlined three (3) top themes and several sub-themes on benefits related to supply chain collaboration. Participants indicated that through collaboration, organisations could leverage off the knowledge and skills of other cluster members. Participants highlighted that this cross-industry collaboration would foster learning from other participants in the cluster to create unique solutions to cluster specific challenges. Some participants explained how training and upskilling could improve problem-solving efforts through facilitated brainstorming and decision-making as a group. Some participants signalled that knowledge sharing would give organisations access to learning effective processes and strategies. Some comments from

Participants noted that joint risk management will drive improved compliance through active tracking of individual risks to ensure adherence to regulatory standards.

Lastly, some participants provided views on how supply chain collaboration emphasised the need for improved processes, streamlined logistics, reduced duplication of efforts and improved supply chain visibility and resilience, as subjects that can enable faster decision-making to respond efficiently to demand signals. The findings relating to Objective 3 affirm that participants perceived the identified themes as valuable and favourable to building collaborative supply chains in industrial clusters.

4.5 Results pertaining to Objective 4

Objective 4: Determine the key supply chain elements that will enable successful, sustainable, and accelerated adoption of renewable (wind) energy through industrial clusters.

Objective 4 was aimed at identifying the critical components and strategies required to drive the successful implementation and sustainable integration of renewable (wind) energy within industrial clusters. Participants were asked to assess themes that are could be perceived as contributing towards and driving the successful and sustainable integration of renewable energy, based on a conceited effort to pursue a collaborative supply chain.

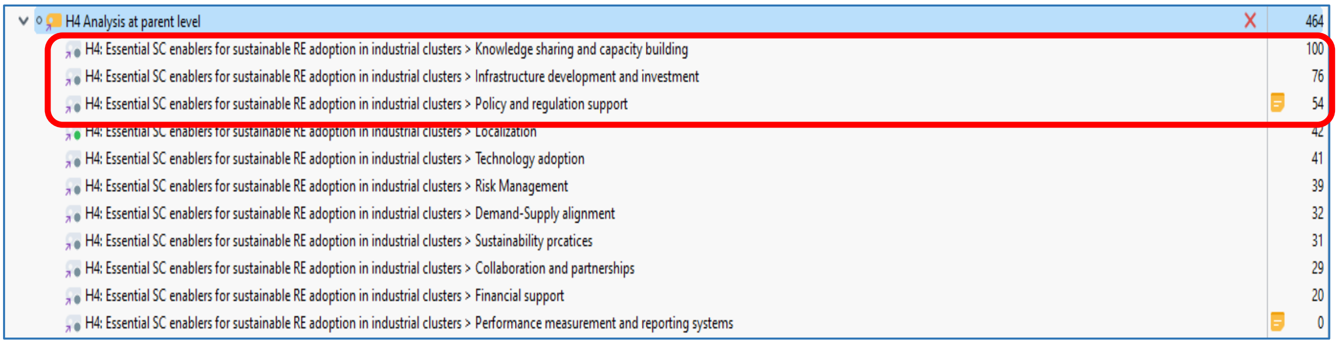


Figure 8: Summary of the themes and their ranking as per responses for Objective 4. *(Source: Maxqda project as created by Author)*

Participants were required to discuss which supply chain elements would aid in maintaining long-term success and sustainability of wind energy development across inland provinces. Furthermore, participants were required to determine advise on which supply chain practice might not succeed in this regard. Participants were also asked to advise whether a collaborative supply chain framework would enable industrial clusters to succeed in advancing the development of wind energy farms in inland provinces. On this section, 79% of the participants ranked the themes below as the top 3 themes, which will be unpacked in detail.

4.5.1 Knowledge Sharing and Capacity Building

On this theme, participants provided their experiential opinions on how knowledge sharing could make the supply chain more robust through implementing sustainable sourcing strategies (through localisation). This level of transparency will build trust amongst key stakeholders and fast track problem-solving interventions. Participants further highlighted how collaborative efforts might introduce challenges or red tape on Intellectual Property (IP) and conflict of interest issues amongst cluster partners. However, the sharing of knowledge and capacity within the cluster will act as an advantage to fast tracking the adoption of renewable (wind) energy.

"Shared resources will allow for shared risk and benefits - making supply chain more robust. Companies can also band together to implement practices of sustainable sourcing. Partnering amongst the various stakeholders can work to driving." (Participant 3)

"Involving local players and engaging key stakeholders within the community and purchasing from local sources, will contribute to the long-term success of the project." (Participant 26)

"The practices can maintain long-term success and sustainability by fostering technology integration and knowledge sharing, which drives innovation and operational efficiency" …" Transparency among key partners builds trust, leading to effective collaboration and faster problem-solving." (Participant 30)

“Shared resources and knowledge ensure continuous support from multiple parties to ensure the sustainability of the initiative and localisation also integrates it into the community (limiting the impact of external disruptions).” (Participant 32)

“The manufacturing of parts and components at the local scale to meet the technical specifications and willingness of MNCs to transfer the skills to local firms who can produce the volumes within the cost requirements/economically.” (Participant 15)

“…shared resources and investment may not succeed, as it may impeded competitiveness.” (Participant 18)

“Shared resources - it present IP and conflict of interest issues.” (Participant 31)

“It supports wind energy development by facilitating resource sharing, enhancing stakeholder coordination, and promoting localisation with local suppliers. This reduces costs, streamlines regulatory compliance, and strengthens project execution.” (Participant 21)

“Collaboration by its very nature presupposes that the industry players will be willing to share information and data openly. Therefore, the critical success factor becomes clarity in regulatory framework, clear market segmentation and allocation of licenses.” (Participant 29)

"A collaborative supply chain framework can help industrial clusters advance wind energy farms by fostering strong partnerships. It encourages resource sharing, promotes innovation. Also, collaboration enables joint problem-solving to navigate regulatory challenges and market uncertainties." (Participant 30)

“Share resources. Share knowledge as well as industrial access (industry partners). Make the benefit transparent to all. Make the costs transparent to all.” (Participant 32)

“Framework can provide indication of capabilities and capacities that can be leveraged for risk sharing, increased efficiency, decreased cost.” (Participant 37)

4.5.2 Infrastructure Development and investment

Participants highlighted some of the logistical challenges that limit infrastructure development and investment from enabling the adoption of renewable (wind) energy.

Concerns resonated more towards blade manufacturing and availability of larger equipment during the project phase. Participants also expressed concerns over grid capacity, after the construction projects conclude…what then? If the South African Transmission grid cannot meet the facilitation of electricity demand and supply forces in south Africa. Furthermore, participants highlighted how such infrastructure costs could influence the investment initiatives that organisations would like to embark on the more challenges experienced by project developers, the higher the project costs and this would mean additional investment. Currently it is difficult for projects to confirm their project costs, and those that have calculated long-term investment costs, have been uncertain about the availability of government bonds; tax incentives; or any other form of funding that could assist. Participants further stressed how supply chain collaboration could distribute financial and operational risks to ensure the load is shared based on each organisation's strengths. Overall, participants indicated their understanding of collaboration amongst cluster members to reduce the individual financial burdens.

"Expanding technology research, development, and demonstration through the public and private sectors to enhance the wind supply chain competitiveness and reduce logistical requirements, such as blade manufacturing automation, additive manufacturing of large castings and forgings, and modularisation and onsite manufacturing of large components such as blades and towers"…"Introduction of unrealistic localisation and local content targets which may push the price of development high. Not introducing tax incentives and incentivising the industry to grow the sector. Not providing financial support in the form of loans and grants for development expenditure." (Participant 16)

"…shared resources and investment may not succeed, as it may impeded competitiveness." (Participant 18)

"Supply chain practice which might not succeed in acceleration include highway underpass heights limiting the size of wind towers, availability of cranes able to lift and install nacelles, and the trucking fleet's difficulty in transporting longer wind blades." (Participant 25)

"Cost reduction practices would hinder the adoption of wind energy development…" (Participant 32)

"Collaboration and implications for competitiveness amongst players, limited demand for projects and infrastructure limitations." (Participant 33)

"Local turbine suppliers may not succeed if the costs cannot compare with cheaper turbines that can be imported from Chinese suppliers." (Participant 36)

"There should be incentives for such clustering as it may crowd in investment by enterprises." (Participant 18)

"The framework should prioritise the establishment of a sustainable energy supply to reduce energy costs. All strategies, and initiatives must support these two key objectives. By focusing on sustainable practices, the framework can create a more resilient energy system." (Participant 26)

4.5.3 Policy and Regulatory Support

"Policy and Regulatory Support" ranked in as a 3rd theme on Objective 4. Responses from participants highlighted the pivotal steer that policy and regulation play in the energy sector, particularly with establishing green supply chains. Participants further expressed the difficulties experienced when trying to acquire licenses for various project activities, this complexity and rigidness can cause unwarranted delays. Some participants have narrated how cluster partners can collectively lobby for specific regulations that will remove bottlenecks in the process of developing renewable (wind) energy projects inland.

"Enabling regulatory environment facilitates collaborative partnership which is based on synergising of efforts and leveraging resources." (Participant 15)

"By integrating these supply chain practices wind energy developments can create resilient, adaptive, and sustainable operations across inland provinces. This strategic alignment ensures long-term success by enhancing stakeholder relationships, ensuring regulatory adherence, and fostering economic benefits within local communities." (Participant 21)

"… adherence to regulatory compliance will also ensure that the suppliers that the company choose to work with are operating within the bounds of the law and sourcing their products ethically." (Participant 25)

“Acquiring licences (water use, transportation of equipment) before project execution. “(Participant 27)

“… Advocating regulatory compliance ensures adherence to standards, reducing delays and enhancing credibility.” (Participant 30)

“Regulatory compliance will go a long way, particularly in ensuring the removal or reduction of red tape in the interest of project development.” (Participant 31)

“Frequent engagements between cluster should take place to improve the policies and advise about mitigating various risks encountered. Purchasing green shall be a norm and be advocated by all clusters.” (Participant 42)

“Advocating for regulatory compliance may be perceived negatively if the core issues of achieving a sustainable energy supply and reducing costs are not addressed effectively.” (Participant 26)

“Advocating regulatory compliance may not succeed in accelerating wind energy adoption. While necessary for project approval, complex and varying regulations can create bottlenecks, leading to delays. This focus might hinder rapid development and discourage stakeholders from pursuing wind energy initiatives, especially if regulations are viewed as complicated or restrictive.” (Participant 30)

“The cluster is also better placed to lobby for enabling policies to accelerate the net-zero industrial cluster ambitions. Additionally, it makes it easier for securing finance.” (Participant 16)

“It supports wind energy development by facilitating resource sharing, enhancing stakeholder coordination, and promoting localisation with local suppliers. This reduces costs, streamlines regulatory compliance, and strengthens project execution.” (Participant 21)

“Therefore, the critical success factor becomes clarity in regulatory framework, clear market segmentation and allocation of licenses.” (Participant 29)

4.5.3 Conclusion for Objective 4

Objective 4 highlighted themes that participants perceived as contributors towards driving the successful and sustainable integration of renewable energy, based on a conceited effort to pursue a collaborative supply chain. Responses from participants highlighted the pivotal steer that policy and regulation play in the energy sector, particularly with establishing green supply chains. This was further supported by a view that cluster participants can collectively lobby for specific regulations that will remove bottlenecks in the process of developing renewable (wind) energy projects inland. Participants highlighted some of the logistical challenges that have had an impact on the progressing infrastructure development on these types of projects and need for combined financial models that can facilitate funding and cost reductions. Lastly, participants provided their observed opinions on how knowledge sharing could make the supply chain more robust through implementing sustainable sourcing strategies (through localisation). Participants expressed that this level of transparency will build not just capacity, but also trust amongst key stakeholders, whilst fast tracking problem-solving interventions.

4.6 Summary of the results/findings

In Chapter 4, a report on the expert opinions of participants with knowledge and experience on the renewable energy and supply chain topic, was provided. These findings were answered in respect of the research questions that were asked, with the intention of achieving the research objectives. Chapter 5 will focus on discussing the results of the study based on the literature review of the study.

4.7 Comparison of literature review and own findings

Table 9: Consistency table summarising the research questions, data collection details and data analysis methods.

RQ #	Objective	Prop #	Findings from literature review	Findings from own study
1	**Outline the rationale that justifies the need for a collaborative supply chain within an industrial cluster.**	**1**	• Limited availability of infrastructure to enable RE development at high rate. • Minimise the risk of supply chain disruptions. • Foster a learning culture within an ecosystem. • Cost reduction. • Influence Policy and regulation support to drive sustainability goals. • Talent and skills development / retention with a regional focus. • Market access.	• It is perceived that South African organisations are not deliberate enough with their collaboration efforts, as many gaps were highlighted relating to the resource inefficiencies, no active strategies to address cost reduction (and funding models) and the lack of collective plans on talent and skills development programs to build the required capabilities. *Key enablers: Improved resource efficiencies; cost drivers and talents and skills development*
2	**Identify the challenges associated with establishing a collaborative supply chain within an industrial cluster.**	**2**	• Challenges of collaborative supply chains in industrial clusters include competition and cooperation balance, resource sharing, supply chain integration, regulatory compliance, risk management, availability of skills, market volatility, and an innovative ecosystem.	• Technology gaps are failing to facilitate the transfer of data between the various cluster partners. • Challenges surrounding unclear benefits, communication and coordination issues were attributed to poor communication channels that result in misaligned goals. • Bureaucracy issues can delay adoption of policy in certain instances, and the lack of supportive policies or incentives for supply chain collaboration, on the topic of renewable (wind) energy. • There is a lack of various resources that could limit the need for compatible execution models across various organisations to streamline objectives.
3	**Identify anticipated benefits in establishing a collaborative supply chain.**	**3**	• Identified benefits include competitiveness through shared strategic and operational capabilities, mutual planning and problem-solving efforts, knowledge sharing, reduced costs through economies of scale, improved market access, greater resilience to disruptions through risk sharing and diversification of suppliers.	• Through collaboration, organisations can leverage off the knowledge and skills of other cluster members to create unique solutions to cluster specific challenges. Training and upskilling can improve problem-solving efforts through facilitated brainstorming and decision-making as a group. • Knowledge sharing will give organisations access to learning effective processes and strategies. • Joint risk management will drive improved compliance through active tracking of individual risks to ensure adherence to regulatory standards. • There is a need for improved processes, streamlined logistics, reduced duplication of efforts and improved supply chain visibility and resilience, to enable faster decision-making to respond efficiently to demand signals.

RQ #	Objective	Prop #	Findings from literature review	Findings from own study
4	**What are the key supply chain elements that will enable successful, sustainable, and accelerated adoption of RE through industrial clusters.**	**4**	• Identified elements include robust infrastructure for renewable energy production and distribution, material, and distribution assessments to enable sourcing plans and minimise supply chain disruptions, enhance skills and knowledge sharing between cluster partners, understanding of operation and maintenance requirements. • Technological innovation to improve the efficiency and reliability of renewable energy systems. • Recycling and Disposal of RE components to ensure the environmental impact is kept to a minimum.	• Policy and regulation can provide steer in the energy sector with regards to establishing green supply chains. • Industrial cluster partners can collectively lobby for specific regulations that will remove bottlenecks in the process of developing renewable (wind) energy projects inland. • Logistical challenges have an impact on progressing infrastructure development, with a need for combined financial models that can facilitate funding and cost reductions. • Knowledge sharing can make the supply chain more robust through implementing sustainable sourcing strategies (through localization). This level of transparency can build not just capacity, but also trust amongst key stakeholders, whilst fast tracking problem-solving interventions.

CHAPTER 5: DISCUSSION OF THE FINDINGS

5.1 Introduction

This study was aimed at establishing a framework that guides and encourages collaborative supply chain networks within industrial clusters with key partners that have been looking to support renewable energy development initiatives across South Africa. The study set out to assess the various elements of the supply chain network design and identify common aspects that organisations in an industrial region may collaborate on, to help fast-track the decarbonisation of that region through renewable energy solutions. In Chapter 5 the results of the study were presented based on the responses received from the participants in relation to the four (4) research objectives identified in Chapter 1. This Chapter focused on presenting the discussion of the documented findings and interpretation of the significance of the results in relation to relevant literature regarding the topic.

5.2 Demographic profile of respondents

The qualitative study was shared with over 75 energy professionals who have different skills and expertise linked to renewable energy. Only 45 responses were received. Following an extensive review and profiling participants, the responses received were enough to formulate an answer to the research question. The years of experience indicated the 0-5 years to make up 11% of the participants. Only 1 participant recorded over 36 years of experience (2.3%) and 8 participants with 21 -35 years of experience, made up 20.5 % of experience. It is also to be noted that the participants with 11-15 years and 16 – 20 years of experience, tied at the top of the groups at 29.45% each.

These participants are mainly concentrated in the energy sector, but some operate directly within other sectors while engrossed in energy matters as a result of the close relation and reliance on energy and the transition journey. The professional roles of the participants in industry were also a focus, as this gives an indication of the influence and attention that the topic is getting from a strategic perspective.

Participation from Supply chain professionals was 17.78%, Engineering / Technical professionals was the highest at 28.89%, Senior Management / Executives was 24.44%, while grouped support functions (e.g. business and market development, quality, finance) recorded 13.33%. Participants in project management and contract management were on 11.11% and lastly the advisory, stakeholder management, and policy and regulation participants were on 4.44%.

The participants were asked if they had direct experience or knowledge on supply chain and renewable energy. Seventy-one percent (71%) responded “yes” to Supply Chain experience or knowledge, while 78% responded “yes” to renewable energy experience or knowledge. The “no” responses amounted to 28.89% because 13 participants responded “no” to having supply chain experience or knowledge, whilst 10 participants responded “no” to having renewable energy experience or knowledge. As a follow up to this, it was important to understand the renewable technology that the participants had experience and knowledge in, because of the different supply chains designs that may be assumed. The research study was deliberate in focusing on wind energy, but due to some similarities and partnered projects within the renewables energy sector, wind technology was compared to solar technology. Participants were limited to these 2 choices, including an option for both technologies. Wind technology as a stand-alone, recorded 6 responses, solar technology recorded 15 responses, and participants with knowledge and experience for both technologies were recorded 24 responses.

Lastly, the participants were required to display an understanding of industrial clusters and whether the organisations that they work for, form part of industrial clusters, in order to understand the scope of operational needs that the partnering organisations wish to realise. Participants that work for organisations that form part of industrial clusters and responded “yes” tallied to 26, with 15 participants responding “no”, and 4 participants expressing that they do not know this detail. The participants were asked to select the operational sites of their organisation, to obtain an understanding of the organisation’s inland presence, in relation to this study’s focus on industrial clusters that are located in land. Although participants were requested to select all locations that apply, this question was still able to encapsulate the inland presence as this might determine the understanding afforded to the role a location plays. For inland locations, the participant responses, indicated Gauteng and Mpumalanga, at first and second place respectively, to have the highest organisational footprint (ranking order summary provided in table 9) and may inform where potential industrial cluster partnerships can be shaped.

Table 10: Summary of the Demographics, Source: Author's own.

	Highest Qualifications	**# Participants**	**% Percentage**
Highest Qualifications	High School	0	0%
	Bachelor's degree	12	25%
	Postgraduate diploma / Hons degree	15	34.10%
	Master's degree	16	36.40%
	Doctorate degree	2	4.50%
		45	**100%**
		# Participants	**% Percentage**
Professional Roles	Supply Chain	8	17.78%
	Engineering / technical skills	13	28.89%
	Snr Management / Executives	11	24.44%
	Support functions (Finance, Business & Market Development, Quality)	6	13.33%
	Project Management / Contract Management	5	11.11%
	Advisory, Policy, Stakeholder relations	2	4.44%
		45	**100.00%**
		# Participants	**% Percentage**
Renewable Energy knowledge / experience	Wind & Solar	24	51.16%
	Wind only	6	13.95%
	Solar only	15	34.89%
		45	**100.00%**
		# Participants	**% Percentage**
Organisation's Location	GP	27	59.10%
	MP	18	40.90%
	KZN	9	20.50%
	NW	9	18.20%
	FS	16	34.10%
	LP	8	18.20%
	WC	16	34.10%
	EC	15	31.80%
	NC	16	34.10%
		# Participants	**% Percentage**
Organisation runs operations in an industrial location?	Yes	26	56.80%
	No	15	31.80%
	I don't know	4	11.40%
		45	**100.00%**
		# Participants	**% Percentage**
Years of experience	0-5	5	11.40%
	6 to 10 yrs	4	6.90%
	11 to 15 yrs	13	29.50%
	16 to 20 yrs	13	29.40%
	21 to 35 yrs	9	20.50%
	36 to 45 yrs	1	2.30%
		45	**100.00%**
		# Participants	**% Percentage**
Industrial Sector that particpant's work under?	Automobile	1	2.22%
	Chemicals	1	2.22%
	Energy	31	68.89%
	Finance	2	4.44%
	Government Institution	3	6.67%
	Manufacturing	1	2.22%
	Oil & Gas	3	6.67%
	Other	1	2.22%
	Petroleum	1	2.22%
	Construction	1	2.22%
		45	**100.00%**

5.3 Discussion pertaining to Objective 1

Objective 1: Outline the rationale that justifies the need for a collaborative supply chain within an industrial cluster.

The study was able to outline the rationale that justifies the need for a collaborative supply chain within an industrial cluster. Participants highlighted the challenges relating to the development of wind energy projects within inland regions. Most participants expressed that collaboration efforts of an industrial cluster should prioritise the three (3) themes that were ranked of highest priority, as a starting point for a supply chain framework. The themes were ranked as highest priority are: (i) Improved efficiency, (ii) Cost drivers, and (iii) Talent and skills development.

The study identified the top three (3) themes in Objective 1 as critical for strategic and operational benefits, justifying the need for collaborative supply chain efforts within inland industrial clusters. According to feedback from The Presidency's 2024 SONA address, renewable energy would lead to lower electricity costs for users, benefiting not only developers and partnering organisations of an industrial cluster, but ultimately the end users as well. Partnering organisations within the industrial cluster can also be considered as end users, therefore more of a return on investment benefit to them. Another highlighted benefit was providing dependable electricity to these users. Developing renewable wind energy inland would enhance efficiency and directly benefit end users. Despite concerns about wind profiles in inland regions, repurposing inland coal power stations can maintain reliable electricity availability through a transition between solar and wind energy.

Additionally, the South African government has acknowledged that job creation can be sustained if impacted regions prioritise talent and skills development (The Presidency – SONA, 2024). This approach will ensure that minimal jobs are lost when coal power stations are decommissioned, as the workforce could be retained through renewable energy-focused talent and skills development programs. Porter's (2020) literature emphasises that upgrading skills, access to finance, and infrastructure can advance the strategic objectives of organisations using industrial clusters to collaborate on such initiatives, which is aligned to the findings of this study. Consistent with the cost driver theme, the findings highlighted the critical elements that impact cost efficiency and the economic rationale for collaboration. These factors are related to the costs associated with conducting business or initiating energy projects.

The participants of this study expressed concerns over location being a challenge to progressing collaborative strategies in renewable wind energy development, there was also a positive sentiment from the participants, on the benefits that the location of the wind farms could unlock, with the right outlook on collaboration. However, Porter's research (Porter, 2020) outlines location placement should not be deemed a challenge but rather a motivation that industries with similar ambitions, could provide prospects to address opportunities and challenges more effectively through working together rather than individually (Porter, 2020). Newman's study also found that the location of clusters played a role in the success of similar initiatives based on how the cluster prioritises and advances the localised needs and development of a region (Newman, et al., 2016). Literature by Forrest (2024), highlighted that location is an important factor in the success of any supply chain, and in support of ECA's (2023) literature, it was deduced that industrial clusters might inform the viability of determining (i) how and where renewable energy raw materials would be stored, (ii) when and how the renewable energy materials would reach their final destination (i.e., the consumer) in a more coordinated and collaborative manner (ECA, 2023). Literature from ECA (2023) further confirms that a central focus that leveraged each partner's strength was key (ECA, 2023), which is in align with the findings of this study.

In Pfanelo's study (2017), one of the findings indicates that manufacturing organisations (including SMEs) in South Africa were more likely to perform when collaborating with other companies than when working in silo (Pfanelo, 2017). The finding is supported by this study, because participants highlighted that collaboration could drive the efficiency of renewable (wind) energy supply chain, if coordinated through an industrial cluster. Some participants went on further to question collaboration as a lever to drive adoption of various technologies (in this instance renewable wind energy). Findings from O'Rourke (2014), highlighted that the ambitions of collaboration driving efficient supply chains, would rely heavily on data sharing and integration, from global systems to local platforms to fast-track real-time decisions that are aligned to global trends (O'Rourke, 2014). This would enable integration of logistics networks, cost information and strategies, and facilitate talent and skills development through e-learning platforms and live simulation videos.

Participants of the study highlighted how collaborating on supply chain elements that focus on cost drivers, would lead to economies of scale. This study found that enabling larger volumes and ultimately giving enough volumes for manufacturers to consider localising. This will decrease cost of equipment and levelised cost of electricity. Spekman's findings support this finding by outlining that at the core of such partnerships was the movement of materials and equipment that would ensure that the partners leveraged economies of scale and prioritisation of resources (Spekman et al., 1998). Additionally, participants conveyed that in an industrial cluster, the collective adherence to environmental regulations, which leads to reduced penalties or fines, can facilitate the accelerated adoption of renewable energy and expedite the just transition mandate through various programs.

With regards to talent and skills development, Porter (2020) had similar findings to Eitan, et al. (2020) that industrial clusters provide opportunities for workforce development and knowledge exchange through training programs, skill-sharing initiatives, and collaboration on talent recruitment and retention strategies (Porter, 2020) (Eitan, et al., 2020). Participants of this study expressed that organisations should strive to leverage on sharing resources to drive skills development within the industrial clusters, such as introducing new training centres and e-learning platforms that support the required skills. Participants further argued that using industrial cluster partnerships and the drive to collaborate is an opportunity to build capabilities that can result in experienced professionals mentoring new talent and enhancing skills transfer across the cluster. This collaborative effort will drive the retention of critical skills as incumbents would be allowed the opportunity to work cross-functionally with other firms.

The data from this study confirmed that most participants perceived South African organisations as not being deliberate enough with their collaboration efforts, as a lot of gaps were highlighted relating to the resource inefficiencies, no active strategies to address cost reduction (and funding models) and the lack of collective plans on talent and skills development programs to build the required capabilities. The study conducted by Viviers et al. (2015) found that the concept of industrial clusters to be a deliberate economic strategy that would gain more attention in the latter part of the 20th century (Viviers et al., 2015). Therefore, this practice has been refined over the years, but as new technologies and economic challenges come to light, there is a need for organisations to exert more intentionality towards this strategic option.

In conclusion, this study revealed that there is a need for organisations to foster collaborative supply chains that can be coordinated by industrial clusters for the adoption of wind energy in inland regions.

The study therefore proposes:

Proposition 1: To advance the adoption of renewable wind energy, this study proposes that industrial partnerships should focus on the top three (3) highest-ranked themes. This targeted approach will help establish the basis and mandate of the industrial cluster, concentrating on the organisational stakeholders involved in the collaboration. Aligning stakeholder interests with these themes will provide a foundation for collaborative supply chain efforts, ensuring that each partner participates with intent and addresses key supply chain elements to resolve historic challenges more efficiently.

5.4 Discussion pertaining to Objective 2

Objective 2: Identify the challenges associated with establishing a collaborative supply chain within an industrial cluster.

The results of the study identified the barriers to establishing a collaborative supply chain framework to advance the adoption of renewable (wind) energy within industrial clusters that are located inland. As part of the findings, this study analysed only the top 3 challenges that presented as themes.

5.4.1 Communication and coordination

The findings by Anderson et al. (2022) indicate that communication opportunities significantly affect coordination among partners. Participants in this study expressed that aligned communication could lead to a more cooperative approach among partners by aligning decisions with expectations and reducing competition, ensuring that each cluster partner realises the agreed-upon benefits. Page (2015) highlighted that a lack of end-to-end visibility and fragmented information flow are major challenges for supply chain coordination. Such issues can lead to inefficiencies and misalignments among cluster partners, thus hindering effective collaboration. Pfanelo (2017) further outlines that partnerships, collaboration, and integration significantly influence supply chain performance. Consequently, challenges related to transparency and effective communication among partners can prevent the partnership from achieving the set benefits. O'Rourke (2014) also highlighted that limitations in sustainability measurement and weaknesses in systems to translate data into actionable information pose significant challenges to transparency and coordination in supply chains. These challenges hinder companies' ability to predict and prevent unsustainable practices. One participant of this study expressed that "these obstacles can lead organisations to view collaboration with scepticism, perceiving it as risky or ineffective. They may prioritise individual goals over collective efforts, leading to missed opportunities for innovation and growth. Overcoming these barriers requires fostering trust, aligning interests, and demonstrating the tangible benefits of collaboration in addressing shared challenges.

The study by Anderson et al. (2022) found that communication has a direct impact on coordination among cluster partners. It supports the findings of this study by echoing similar sentiments that communication among various cluster partners can lead to better alignment of goals, resource efficiency, and timely decision-making, ultimately progressing the development of wind energy projects. Page's (2015) study highlighted that the lack of end-to-end visibility and fragmented information flow are major challenges in supply chain coordination. Page (2015) further emphasised that ensuring end-to-end visibility in industrial cluster partnerships can help stakeholders track project progress, identify potential bottlenecks, and address issues promptly.

Participants in this study shared views that improved visibility and transparency could also foster trust among partners, as everyone would have access to the same information. This would reduce misunderstandings and conflicts in a timely manner.

5.4.2 Resources limitations

Findings by Brusset and Teller (2017) highlight that integration between various supply chain levels and increased flexibility are crucial for enhancing supply chain resilience (Brusset and Teller, 2017). However, achieving this level of integration and flexibility could impact resource efficiency, requiring significant investments in technology, training, and process improvements. Some participants of this study expressed that they view collaboration as risky, inefficient, and resource-intensive because cluster partners may fear delays, additional costs, and competitive disadvantages. According to some participant feedback, these challenges discourage cooperation, limiting broader partnerships in the wind energy supply chain.

Brusset and Teller (2017) further details that the perception of supplier risk could motivate partners to enhance integration capabilities, leading to higher resilience (Brusset and Teller, 2017). According to their findings, the perception of external risks may limit the effort to deploy external capabilities for achieving resilience, as resources might be scarce or allocated differently (Brusset and Teller, 2017). This emphasises the importance of resource sharing among partners to overcome such challenges and enhance resilience.

Participants of this study agreed with Brusset and Teller's (2017) findings and outlined that advocating for the energy sector would drive investment support for skills development and ensure alignment among all stakeholders. Furthermore, Brusset and Teller (2017) stress that effective resource allocation is essential for maintaining supply chain resilience (Brusset and Teller, 2017). Misallocation of resources can lead to vulnerabilities and inefficiencies, hindering the supply chain's ability to recover from disruptions (Brusset and Teller, 2017). Participants of this study expressed concerns that collaboration on resource limitations could be resource-intensive, requiring substantial investments in technology, training, and process improvements. It is stated that if these resources are not adequately allocated or managed, the lack of integration and flexibility could lead to inefficiencies and vulnerabilities, potentially causing the collapse of the cluster partnership. Participants further expressed that resources should be directed toward critical areas such as technology upgrades, infrastructure development, and skills training. Brusset and Teller's (2017) findings support this feedback by highlighting that misallocation of resources can lead to vulnerabilities and inefficiencies, hindering projects and potentially causing cluster partnerships to fail (Brusset and Teller, 2017).

5.4.3 Regulatory and legal constraints

In the literature, it was found that The World Economic Forum (WEF) (2023) report on transitioning industrial clusters emphasised four (4) strategic areas: Partnership, Policy, Financing, and Technology, aimed at fostering sustainability and economic growth at both global and local levels. This aligns positively with the findings of Stojčić et al. (2024), which highlight the importance of regulatory and legal frameworks in promoting innovation. Both sources underscore the need for supportive policies and collaboration to drive sustainable development and innovation (Stojčić et al., 2024). Participants of this study argued that the slow implementation of new policy and regulation hinders progress of programmes. Participants highlighted that the stakeholders required in progressing policy decisions and fast-tracking adoption and alignment, were lagging behind.

In the Anderson et al. (2022) study, the negative implications of this slow adoption are noted and linked to the cost implications barriers to entry that will result from overly restricted regulations (Anderson et al., 2022). While the WEF's strategic areas can provide a supportive framework for industrial clusters (WEF, 2023), the regulatory and legal constraints identified by Anderson et al. (2022) and the participants of this study, highlight potential challenges that need to be navigated carefully to ensure successful transitions, to ensure that industrial cluster partnerships are not set up for failure. Furthermore, participants of this study failed to outline the difficulties that industrial clusters may face when navigating overlapping local, regional, and national regulations. An aspect that the local organisations and government should be taking the lead on, based on the unique problems that South Africa faces.

5.4.4 Benefits unclear

In the Pfanelo's (2017) literature, it was found that several benefits can be considered to be unclear if no alignment amongst cluster partners exists on aspects such as supply chain performance, systems integration, innovation and learning. Amongst some of the findings, participants outlined that without alignment, there would be no sustainable benefits to be claimed. Participants further expressed that if the benefits of collaboration for each organisation are not clearly outlined, it can hinder effective cooperation. Larger organisations may dominate, gaining a competitive advantage over smaller ones. This imbalance could lead to a lack of coordination between the organisations involved. This study also found that participant feedback highlights a co-relation between transparency and communication can be leveraged to clarify the benefits for all stakeholders. The participants of this study stressed that to overcome these obstacles, it would be essential to build trust, align the interests of all parties, and clearly showcase the tangible advantages of collaboration in tackling common challenges. Both Pfanelo (2017) and the participants of this study reasoned that organisations frequently viewing collaboration as merely a financial transaction or a compliance requirement for off takers or clients miss out on the true advantages that collaboration can provide. Both literature and this study confirm that while clustering can provide benefits like access to markets and skilled labour, the exact benefits of active collaboration can sometimes be unclear. Therefore, the cluster partnerships need to be more intentional about with sharing information, building trust, and investing in a focused relationship with the goals in mind (as objectives that will be measured to determine the health of the relationship and a win-win approach).

5.4.5 Technological gaps

WEF's (2023) statement about fostering an innovation ecosystem within industrial clusters requires collaboration among industry, academia, communities and government stakeholders. This aligns with Brusset and Teller's (2017) finding that tighter integration between supply chain levels is crucial for enhancing supply chain resilience. Collaboration among these diverse stakeholders can lead to better integration, flexibility, and innovation, which are essential for a resilient and efficient supply chain.

The findings by Brusset and Teller (2017) regarding technology challenges in collaborative supply chains can significantly impact industrial cluster partnerships. When industrial cluster partners achieve tighter integration and enhanced flexibility, they can better manage disruptions and recover more effectively. This integration can lead to a more resilient supply chain, strengthening partnerships within the cluster. However, if partners fail to achieve this level of integration and flexibility, it could result in vulnerabilities and inefficiencies, potentially weakening the collaboration and leading to a collapse of the partnership.

Participants in this study confirm that a clear focus should be directed towards driving aligned technologies among the cluster partners. Participants highlighted challenges around grid infrastructure limitations within Eskom Transmission and the regional networks, which would need significant upgrades to allow for streamlined integration. Participants further expressed that cluster partners might observe a high level of supplier risk, leading them to invest more in integration capabilities, thereby increasing the resilience of the supply chain. This proactive approach can progress partnerships by ensuring that the entire cluster is better prepared to handle disruptions. However, Brusset and Teller (2017) argue that if the perception of external risks reduces the effort to deploy external capabilities for resilience, it may hinder the collaboration's effectiveness, causing the partnership to falter due to inadequate risk management (Brusset and Teller, 2017).

Unfortunately, participants of this study did not highlight any supporting opinions regarding risk management, as this would have sparked discussions about data security, which impacts how information will be shared across multiple organisations. It would also address system compatibility and determine how sharing information with direct competitors within the region would impact the success of the industrial cluster’s ambitions.

To conclude, the section has discussed in detail the challenges that negatively influence an industrial cluster’s ability to drive supply chain collaboration. The findings determined that by addressing the communication and coordination challenges, industrial cluster partnerships can progress more effectively, leading to successful wind energy development in South Africa's inland regions. Equally, if these challenges are not addressed, it could lead to delays, inefficiencies, and potential collapse of the partnerships. Failure to communicate and coordinate activities within the cluster partnership may discourage stakeholders from collaborating. Therefore, the findings of this study are aligned with literature that collaboration among various stakeholders, including energy developers, suppliers, and local communities can lead to effective integration and efficient resource allocation, which ultimately could reduce delays, and build a more resilient supply chain.

In summary, achieving tighter integration and addressing supplier risk perception effectively can progress industrial cluster partnerships by enhancing resilience and efficiency. However, failing to address these technology challenges could lead to vulnerabilities and potential collapse of the collaboration.

The study therefore proposes:

Proposition 2: Overcoming these challenges through strategic partnerships can progress industrial cluster collaborations and enhance supply chain resilience and efficiency. The challenge of aligning interests and priorities can be seen as a form of perceived risk. Therefore, this study proposes that communication and coordination be listed as a risk that is addressed at the initial phase of the partnership. Addressing this risk (challenge) through effective collaboration, can lead to stronger partnerships and a more resilient supply chain.

5.5 Discussion pertaining to Objective 3

Objective 3: Identify anticipated benefits in establishing a collaborative supply chain.

In this section, the study results highlight the benefits of establishing a collaborative supply chain framework to promote the adoption of renewable (wind) energy within inland industrial clusters. The findings specifically examined the top three (3) challenges that emerged as key themes. These themes are discussed in detail below.

5.5.1. Faster Innovation and Knowledge Sharing

Under this theme, participants shared views on how collaborative research and development efforts within the cluster could foster innovation and knowledge sharing. Participants expressed that joint initiatives on innovative wind energy products or processes would greatly benefit the industrial cluster. Joint research efforts lead to significant innovation by combining expertise to develop advanced wind technologies. Additionally, pooling resources for R&D enables companies to innovate more effectively, creating superior turbines or solutions for low-wind areas, thereby boosting overall supply chain success. When managed positively, this resource pooling can drive innovative advancements and lay the groundwork for sustainable and eco-friendly operations. However, findings by Eberhard et al, (2020) indicate that even with training interventions that facilitate knowledge sharing, failure to meet quality demands, along with factors like access to finance can result in failed efforts (Eberhard et al, 2020).

Furthermore, it was highlighted that these advantages would enhance product development cycles through joint research and development efforts within the cluster. By collaborating on innovative wind energy products or processes, organisations can benefit the entire industrial cluster. Additionally, participants expressed that such benefits would lead to improved product development cycles.

5.5.2. Improved Efficiency

On the basis of the empirical findings presented in chapter 4, participants highlight that through an industrial cluster partnership, improved efficiency can be achieved through shared logistics and standardised processes. The participants of this study outlined that consolidating resources, such as shared warehouse hubs and aligned transport routes, and leveraging high volume discounts for aspects like shipping agreements, significant efficiencies and cost savings can be realised. According to the participants, this collaboration not only highlights the increased demand for various components, opening opportunities for new industries within the country, but also reduces reliance on imported components, thereby positively impacting sustainability and environmental outcomes. This is a similar sentiment shared by the World Economic Forum (WEF, 2023)

Findings by Eberhard et al, (2020), highlight that there were benefits linked to foreign technology suppliers localising parts of their production activities or developers sourcing most of the Balance of Plant (BOP) components from local suppliers (Eberhard et al, 2020). However, the findings of this study express that there is still a need for collaboration which promises sustainable benefits for both international and local suppliers. Additionally, Eberhard et al, (2020) suggest that there may be a link between renewable energy deployment policies and industry localisation in developing countries, extending beyond just technology imports to include a local industry focusing on installation, operation and maintenance (Eberhard et al, 2020). These factors could lead to improved efficiencies in material availability within inland wind energy supply chains.

Through various literature, there is evidence that suggests that industrial cluster partnerships can significantly enhance efficiency by fostering local manufacturing and supplier development, thereby increasing local skills and capabilities. Participants of this study further stressed that collaboration on inland wind energy can lead to joint infrastructure development, where organisations share costs for roads and grid connections, thereby improving logistics. Participants of this study suggest that pooling resources for research and development can allow organisations to innovate more efficiently, and thus create better turbines or solutions for low-wind areas, which can - overtime, enhance the overall supply chain success.

Participants of this study further argued that cluster partnerships could drive innovation, reduce costs, and boost competitiveness, citing that in past attempts, collaboration was not at the core of such discussions, with little intervention and support from government as well. Participants agree with Eberhard et al, (2020) that a collaborative approach could foster steadily reliable supply chains, ensuring consistent delivery of components and creating jobs in local economies (Eberhard et al, 2020). Generally, there is consensus between tis study and that of (Eberhard et al, 2020), that a collaborative approach can lead to a more resilient and sustainable wind energy sector that can adapt effectively to market changes.

5.5.3 Improved Risk Management

In relation to this theme, participants of the study indicated that improved risk management within an industrial cluster can be achieved through collaborating and distributing project risks. This approach ensures that disruptions are shared and collectively mitigated, leading to a stronger and more resilient supply chain. This view is supported by Eberhard et al. (2020) who emphasise that improved risk management in the wind energy sector can be achieved through collaboration and shared responsibilities within industrial clusters. By distributing project risks and ensuring collective mitigation, disruptions can be managed more effectively (Eberhard et al, 2020). Participants also outlined that sharing risks and leveraging the strengths of each cluster partner can help manage uncertainties more effectively, enhancing operational efficiency and reducing costs. This view is echoed by Eberhard et al. (2020), suggesting that such a collaborative approach could enhance operational efficiency and foster innovation and skills development, leading to a more resilient and sustainable industry (Eberhard et al., 2020).

The study found that sharing innovation and technology knowledge, along with skills transfer and talent development, enhances workforce expertise and resilience in the wind energy sector. Supporting these findings, the World Economic Forum's 2023 Global Risks Report (WEF, 2023) emphasises that improved risk management in industrial clusters can be achieved through collaboration and shared responsibilities, which ensures effective mitigation of disruptions (WEF, 2023). This approach not only boosts operational efficiency but also promotes innovation and skills development, leading to a more resilient industry (WEF, 2023). Brusset and Teller (2017) further support these conclusions, stating that improved risk management requires strengthened integration and increased flexibility within supply chains (Brusset and Teller, 2017). They argue that closer collaboration and resource sharing enhance the ability to manage and mitigate risks, resulting in a more resilient and efficient operation (Brusset and Teller, 2017).

In conclusion, a collaborative supply chain within an industrial cluster partnership in the renewable wind energy sector offers substantial benefits. There is common understanding and views found between literature and the participants of this study regarding the benefits that a collaborative supply chain can be realised within an industrial cluster partnership.

The study therefore proposes:

Proposition 3: Collaborative supply chain practices in industrial cluster partnerships can enhance resilience by improving risk management, increasing operational efficiency through resource consolidation and shared logistics, and accelerating innovation and skill development, leading to a more competitive, sustainable, and adaptable industry.

5.6 Discussion pertaining to Objective 4

Objective 4: Determine the key supply chain elements that will enable successful, sustainable, and accelerated adoption of renewable (wind) energy through industrial clusters.

The results of the study identified the critical aspects required to drive the successful implementation and sustainable integration of renewable (wind) energy within industrial clusters. As part of the findings, this study analysed only the top 3 elements that the data analysis ranked as top themes. Findings are discussed as follows:

5.6.1 Knowledge Sharing and Capacity Building

Findings of this study are that enabling the successful, sustainable, and accelerated adoption of renewable wind energy through industrial clusters can be achieved by fostering knowledge sharing and capacity building. Participants outlined that shared resources and risks make the supply chain more robust, while organisations collaborating on sustainable sourcing practices drive overall efficiency. Participants expressed that involving local players and engaging key stakeholders within the community, alongside purchasing from local sources, can contribute to long-term project success. Findings by Larsen & Hansen (2020), similarly indicate that as part of capacity building, shared resources and investments improve stakeholder coordination and encourage local sourcing, which in turn lowers costs and simplifies regulatory compliance. These practices, which include technology integration and transparency among partners, build trust, foster innovation, and enhance operational efficiency. By ensuring continuous support and skill transfer, especially in local manufacturing, industrial clusters can limit external disruptions and bolster the industry's resilience and sustainability.

Furthermore, Larsen & Hansen’s (2020) research underscores the importance of effective collaboration and transparent governance in enabling successful knowledge sharing and capacity building, which ultimately drives innovation and enhances operational efficiency in the renewable energy sector. While the adoption of renewable wind energy through industrial clusters hinges on effective knowledge sharing and capacity building, participants elaborated that shared resources and investments might present competitiveness challenges and potential intellectual property (IP) conflicts, as these factors also foster resource sharing and stakeholder coordination, reducing costs and strengthening project execution. However, findings by Eberhard et al, (2020) argue that even with training interventions that facilitate knowledge sharing, failure to meet quality demands, along with factors like access to finance can result in failed efforts (Eberhard et al, 2020). Training local talent and sharing knowledge will not guarantee sustainable profits, especially with uncertainties on policy directives and investment security (Eberhard et al, 2020). Participant’s findings continue to stress that involving local suppliers promotes localisation and streamlines regulatory compliance, however effective collaboration requires transparency, clear regulatory frameworks, and open information sharing among industry players.

5.6.2 Infrastructure Development and investment

While infrastructure is a key enabler to a resilient and sustainable supply chain, investment, on the other hand, qualifies the infrastructure needed to efficiently run such a supply chain at global scale. Suharsono & Maulidia (2023) highlighted that careful project selection and demonstrating visible results are crucial for the success of JETP initiatives, in this case- wind energy development (Suharsono and Maulidia, 2023). Additionally, Suharsono & Maulidia’s (2023) research underscored the need for leveraging public funds to attract private investment and ensuring broad consensus across government bodies to mitigate risks and ensure fair allocation of funds and smooth project implementation (Suharsono and Maulidia, 2023). In this study, participants highlighted the importance of introducing realistic localisation and local content targets, as unrealistic goals could increase development costs. Shared resources and investments may face challenges in maintaining competitiveness, and collaboration among industry players needs to be carefully managed to avoid impeding competitiveness. Incentives for clustering could attract enterprise investments and prioritising sustainable energy supply will help reduce energy costs. All strategies and initiatives should support these objectives to create a more resilient and sustainable energy system.

Halsey, Overy, Schubert, Appies, McDaid, & Kruyshaar (2019) discuss the importance of infrastructure in the context of a just energy transition in South Africa. Their research underlines that transitioning from coal to renewable energy requires significant infrastructural changes, including the development of new energy systems and the upgrading of existing ones (Halsey et al, 2019). The authors further highlight that an integrated planning approach is crucial for addressing the challenges associated with this transition, ensuring that energy infrastructure can support the shift to renewable energy while minimising disruptions and maximising benefits for all stakeholders (Halsey et al, 2019). Expanding technology research, development, and demonstration through public and private sectors is essential for enhancing wind supply chain competitiveness and reducing logistical challenges. Participants expressed that blade manufacturing automation, additive manufacturing of large castings and forgings, and modularisation and onsite manufacturing of large components such as blades and towers should be advanced. However, other participants argued that supply chain practices may face hurdles, such as highway underpass heights limiting the size of wind towers, the availability of cranes for nacelle installation, and challenges with transporting longer wind blades. This group of participants highlight that addressing these infrastructural constraints is critical to support the acceleration of wind energy development and can enable cluster partners to maintain the competitiveness of local turbine suppliers against cheaper imports from Chinese manufacturers. These two factors (infrastructure and investment) are closely linked together and through this study, there is an understanding of how they qualify each other.

5.6.3 Policy and Regulatory Support

Acquiring necessary licenses such as water use; equipment; land and transportation prior to project execution is essential for regulatory compliance. This can reduce delays in project development and enhance the credibility of the projects. In this study, some participants cited that enabling a regulatory environment will foster collaborative partnerships by synergising efforts and leveraging resources. Participants of this study also expressed that integrating effective supply chain practices will ensure that wind energy developments can create resilient, adaptive, and sustainable operations across inland provinces. As a learning from South Africa's JETP, Suharsono and Maulidia (2023) emphasised the importance of a robust energy policy to unify energy sector and accommodate new targets set by JETP (Suharsono and Maulidia, 2023). Despite the uncertainty around policy, participants highlighted that this strategic alignment could enhance stakeholder relationships, ensure regulatory adherence, and generate economic benefits for local communities.

Suharsono and Maulidia (2023) went on to corroborate the importance of carefully selecting projects to be included in the JETP Investment Plan (IP), in order to allow for demonstration of tangible results (Suharsono and Maulidia, 2023). According to their findings, this will unify the power sector and align the coal phase-out plans as outlined in the JETP IP. Suharsono and Maulidia (2023) confirm that translating the commitment to JETP into legislation is crucial for achieving long-term sustainability and accountability.

Participants firmly believe that advocating for regulatory compliance ensures adherence to standards and the removal of red tape, can facilitate project development. However, if the core issues of achieving a sustainable energy supply and reducing costs are not addressed, regulatory compliance may be perceived negatively and could hinder the rapid adoption of wind energy. Moser and Lowes (2017) emphasise the crucial role of supportive policies in enabling private-private partnerships to drive social impact in developing nations (Moser and Lowes, 2017). Their literature highlights that clear regulatory frameworks and policies are vital to fostering private sector involvement in social impact endeavours (Moser and Lowes, 2017). By overcoming obstacles and capitalising on opportunities, cluster partnerships can significantly enhance social impact and enable sustainable supply chains, as long as the policy environment supports such collaborations (Moser and Lowes, 2017). Participants shared the same view, and further cited that promoting green purchasing should be a norm within all clusters in order to support localisation, reduce costs, streamline regulatory compliance, and strengthen project execution. Clear regulatory frameworks and market segmentation are critical success factors for advancing net-zero industrial cluster ambitions and securing necessary funding.

To conclude, the views of participants on policy and regulation support are aligned. While there is an appreciation for the robust discissions held by the country leadership, it is evident that a huge gap still exists between ambition and reality. For policy and regulation to gain full traction, clear and realistic frameworks need to be determined, to provide the much-needed guidance to investors on the future of renewable energy in South Africa.

This study proposes:

Proposition 4: This collaborative supply chain framework can support and promote strong partnerships, innovation, and joint problem-solving to navigate regulatory challenges and market uncertainties. By making benefits and costs transparent to all, industrial clusters can leverage capabilities for risk sharing, increased efficiency to fast-track infrastructure development, and decrease costs significantly.

5.7 Conclusion

This chapter submitted discussions of the research findings. This was done by reviewing the findings of the study against the literature found on the topic. The general findings that were determined from the verbatim accounts of the research participants were aligned with the literature review.

CHAPTER 6. CONCLUSIONS & RECOMMENDATIONS

6.1 Introduction

Chapter 6 will discuss the study's conclusions, aligning them with the objectives and presenting a framework as set out. This section will also include recommendations for future research. The main objective of this study was to establish a framework for a collaborative supply chain network for renewable energy adoption through industrial clusters. Chapter 2 reviewed existing literature to set the foundation for the objectives. Chapter 3 outlined the qualitative research methodology. Chapter 4 presented the study's results, and Chapter 5 discussed these results in relation to the reviewed literature. The implications and recommendations derived from the findings will be covered in this chapter.

6.2 Conclusion of this study

This study revealed that there is a need for organisations to foster collaborative supply chains that can be coordinated by industrial clusters for the adoption of renewable (wind) energy in inland regions. The study further recognises that while some results are misaligned to existing literature, the majority of the findings presented in Chapter 5 are consistent with previous research on the subject.

Objective 1 highlighted *improved efficiency, cost drivers, and skills development and knowledge sharing* as key elements to driving collaboration of supply chains. As part of improving efficiency, renewable wind energy development relies on strategic location choices for industrial clusters. When establishing the industrial cluster, partnering organisations need to conduct critical location studies on the inland regions to determine the base of the need. Some inland regions may need a consistent supply of electricity but not in large volumes, so understanding the needs of the fence-line communities and organisations will ensure that there is alignment on location and the elements that the development needs to satisfy. Furthermore, the study found that data sharing and integration of global systems and local platforms can fast-track real-time decision-making that is aligned to global trends, in order to enable integration of logistics networks. In addition, the study confirms that to drive improved efficiency, the supply chain should be resilient and adaptable.

The study further highlighted the need for reducing costs through the identification of various cost drivers that can be leveraged. Sharing costs as part of joint development, accelerated innovation and sharing infrastructure and technology, were highlighted as key levers to unlocking cost savings. Furthermore, this study found that enabling larger volumes and ultimately giving enough volumes for manufacturers to consider localising. These economies of scale could lead to decrease cost of equipment and levelised cost of electricity. Additionally, the study did not dispute that shared costs could unlock a bargaining factor for cluster partnerships. The collective adherence to cost sharing could lead to reduced costs on transport, storage, land, licensing, skilled resources, penalties and fines, based on partnering organisations playing on their strong traits as an offering to aid the cluster. This approach to shared costs can accelerate the adoption of renewable energy and expedite the just transition mandate through various programs.

The study underscored the significance of talent and skills development within industrial clusters. Participants emphasised the need for training programs, skill-sharing initiatives, and collaboration on talent recruitment and retention strategies to ensure workforce development. Although supportive of collaborative efforts, the concerns raised around issues of limited resources were significant. This was a consistent theme throughout all objectives. The South African talent pool is stretched, with most specialised skilled force limited to specific regions that are more metropolitan. Upskilling the current labour force with renewable energy skills, in an aim to repurpose them from conventional energy skills, was a top concern in both the study and literature. For the adoption of renewable energy to scale up in line with the Jet Transition Plan Programme, the labour market requires a lot of intervention and funding to fast track the development and roll-out of various skills programmes. The development plan should also consider the future labour forces (labour force that is still in formal schooling, such as high school and further education institutions), on how to best prepare this population group for future work demands. Therefore, the intent for industrial clusters to collaborate on renewable(wind) energy supply chain needs, has to be founded on these 3 elements to rule out any ambiguity or misunderstandings of the need to partner. All partnering organisations should come with an intent to serve NOT observe.

<u>Objective 2</u> aimed to identify challenges associated with establishing collaborative supply chains within industrial clusters. The data highlighted the efficiency challenges that the location of such initiatives can introduce, and the impact this can have on driving economic activity at regional level. The study emphasised that collaboration among industry, academia, communities, and government stakeholders is vital for fostering an innovation ecosystem within industrial clusters. By working together, these diverse groups can enhance integration, flexibility, and innovation, leading to a more resilient and efficient supply chain. This form of collaboration is noted as an important agent for addressing technology and infrastructure challenges, which both influence the efficiency of the supply chain. If information cannot be exchanged quick enough and without quality challenges, this will create delays and disruption in the supply chain and limit the supply chain's response to disruptions. The same can be said for infrastructure. If the infrastructure is poor or faces other various limitations, this creates a break in the supply chain that leads to a slowed down response to disruptions, ultimately impacting performance, which often leads to incurring additional costs and compromised quality of products and services.

The study confirmed challenges around talent and skills development in the country. Significant investments in technology, training, and process improvements are essential to overcome resource limitations and manage disruptions. Advocating for skills development within the energy sector and aligning stakeholder interests can further enhance resilience and ensure successful collaboration. Effective resource allocation and stakeholder alignment are crucial for maintaining supply chain resilience and overcoming potential vulnerabilities.

The study confirms that addressing shared challenges through cooperation, allows industrial clusters to achieve strategic objectives more efficiently. Therefore, without a proactive approach to challenges, the industrial cluster's supply chain will lack resilience and will not adapt to the everchanging changing needs and risks that come with the energy transition. By focusing on improved efficiency, cost drivers, and talent and skills development, organisations can establish a solid foundation for collaborative efforts. This approach will help address shared challenges more effectively and promote sustainable development within the energy sector.

Objective 3 goes on to highlight the numerous benefits of establishing a collaborative supply chain framework within inland industrial clusters to promote the adoption of renewable wind energy. The study outlined innovation and knowledge sharing as a key benefit, where joint research and development efforts are noted as enablers to significant advancements in wind energy technologies. By pooling resources and combining expertise, organisations within the cluster can develop superior turbines and solutions for low-wind areas, ultimately boosting overall supply chain success. Improved efficiency was another major benefit identified in the study. The study further emphasises that industrial cluster partnerships can enhance efficiency through shared logistics, standardised processes, and consolidated resources, which have a direct co-relation to costs. This approach can lead to significant cost savings, reduced reliance on imported components, and steer positive sustainability and environmental outcomes. The study also found that fostering local manufacturing and supplier development through collaboration can increase local skills and capabilities, further enhancing supply chain efficiency.

This collaborative approach not only boosts operational efficiency but also promotes innovation and skills development, resulting in a more resilient and sustainable renewable (wind) energy sector. Overall, the study revealed that a collaborative supply chain within an industrial cluster partnership offers substantial benefits, and by focusing on these key areas, partnering organisations can create a more competitive, sustainable, and adaptable industry.

Objective 4 of the study set out to determine the key supply chain elements that will enable successful, sustainable, and accelerated adoption of renewable (wind) energy through industrial clusters. Knowledge sharing and capacity building emerged as critical factors. Shared resources and risks enhance the robustness of the supply chain. By engaging local players and key stakeholders within the community, organisations can drive sustainable sourcing practices and long-term project success. Effective collaboration and transparent governance remain crucial for building trust, fostering innovation, and enhancing operational efficiency. Careful project selection and demonstration of visible results to attract private investment and ensure broad consensus across government bodies remains a critical departure point for industrial clusters. While the JETIP advocates for localisation the aim to drive local content targets, along with incentives for clustering, can create a more resilient and sustainable energy system. However, this level of partnering requires collaboration between state entities, private corporations and fence-line communities, that is beyond just a localisation strategy partnership. Such a vision relies on the knowledge sharing traits and alignment on the technology to be adopted. By focusing on these key supply chain elements, organisations can enhance resilience, drive innovation, and promote sustainable development in the energy sector. Clear and realistic frameworks are needed to bridge the gap between ambition and reality, providing much-needed guidance to investors on the future of renewable energy in South Africa.

Overall, the study revealed gaps on collaborative supply chain efforts that influence and impact South African organisations that aim to partner in industrial clusters to advance the adoption of renewable (wind) energy. The study has highlighted the need for intentional strategies to address resource inefficiencies, cost reduction, and talent development for the energy sector.

6.3 Consistency table: research questions, conclusions and contribution to knowledge

Table 11: Consistency table summarising the research questions, data collection details and data analysis methods.

RQ #	Objective	State literature-based proposition or hypothesis	State conclusion or answer based on own research	Highlight key differences between your initial propositions / hypotheses and your findings – this is your contribution to knowledge
1	**Outline the rationale that justifies the need for a collaborative supply chain within an industrial cluster.**	• Limited availability of infrastructure to enable RE development at high rate. • Minimise the risk of supply chain disruptions. • Foster a learning culture within an ecosystem. • Cost reduction. • Influence Policy and regulation support to drive sustainability goals. • Talent and skills development / retention with a regional focus. • Market access.	• It is perceived that South African organisations are not deliberate enough with their collaboration efforts, as many gaps were highlighted relating to the resource inefficiencies, no active strategies to address cost reduction (and funding models) and the lack of collective plans on talent and skills development programs to build the required capabilities. • *Key enablers: Improved resource efficiencies; cost drivers and talents and skills development*	• There are no clear plans to address skills development and infrastructure development, prior to establishing renewable wind energy projects. • Government has placed a lot of reliance on international policy and regulations support needs; to drive investment but local organisations are more concerned about fit-purpose capabilities, to drive collaboration and adoption.
2	**Identify the challenges associated with establishing a collaborative supply chain within an industrial cluster.**	• Challenges of collaborative supply chains in industrial clusters include competition and cooperation balance, resource sharing, supply chain integration, regulatory compliance, risk management, availability of skills, market volatility, and an innovative ecosystem.	• Technology gaps are failing to facilitate the transfer of data between the various cluster partners. • Challenges surrounding unclear benefits, communication and coordination issues were attributed to poor communication channels that result in misaligned goals. • Bureaucracy issues can delay adoption of policy in certain instances, and the lack of supportive policies or incentives for supply chain collaboration, on the topic of renewable (wind) energy. • There is a lack of various resources that could limit the need for compatible execution models across various organisations to streamline objectives.	• International policy and regulation will not solve all of South Africa's challenges related to the adoption of a JET. South African organisations and institutions need to be more deliberate and intentional about addressing energy challenges. • Risk management, benefits realisation, and policy and regulation are sub-elements dependent on various theories that can be investigated in detail after the pre-feasibility of initiatives is proven. The success of these elements can leverage the strengths of individual organisations and does not rely solely on the partnership within the industrial cluster.

RQ #	Objective	Findings from literature review	Findings from own study	Highlight key differences between your initial propositions / hypotheses and your findings – this is your contribution to knowledge
3	**Identify anticipated benefits in establishing a collaborative supply chain.**	• Identified benefits include competitiveness through shared strategic and operational capabilities, mutual planning and problem-solving efforts, knowledge sharing, reduced costs through economies of scale, improved market access, greater resilience to disruptions through risk sharing and diversification of suppliers.	• Through collaboration, organisations can leverage off the knowledge and skills of other cluster members to create unique solutions to cluster specific challenges. Training and upskilling can improve problem-solving efforts through facilitated brainstorming and decision-making as a group. • Knowledge sharing will give organisations access to learning effective processes and strategies. • Joint risk management will drive improved compliance through active tracking of individual risks to ensure adherence to regulatory standards. • There is a need for improved processes, streamlined logistics, reduced duplication of efforts and improved supply chain visibility and resilience, to enable faster decision-making to respond efficiently to demand signals.	• Identified opportunities to collaborate on resource pooling and integrating systems for knowledge sharing. It was positioned that such efforts could fast track skills development. • The limited local production of key wind-turbine components presents an opportunity for industrial clusters to collaborate on building innovation hubs. These hubs can facilitate procurement partnerships with imported components, enabling localised production. Implementing supportive policies can expedite these efforts and promote localisation.
RQ #	**Objective**	**Findings from literature review**	**Findings from own study**	**Highlight key differences between your initial propositions / hypotheses and your findings – this is your contribution to knowledge**
4	**What are the key supply chain elements that will enable successful, sustainable, and accelerated adoption of RE**	• Identified elements include robust infrastructure for renewable energy production and distribution, material, and distribution assessments to enable sourcing plans and minimise supply chain disruptions, enhance skills and knowledge sharing between cluster partners, understanding of	• Policy and regulation can provide steer in the energy sector with regards to establishing green supply chains. • Industrial cluster partners can collectively lobby for specific regulations that will remove bottlenecks in the process of	• The industrial cluster should refrain from trying to resolve end-to-end supply chain needs but have a specific focus point to drive and realise results. This discretion will allow partnering organisations to retain their competitive edge.

	through industrial clusters.	operation and maintenance requirements. • Technological innovation to improve the efficiency and reliability of renewable energy systems. • Recycling and Disposal of RE components to ensure the environmental impact is kept to a minimum.	developing renewable (wind) energy projects inland. • Logistical challenges have an impact on progressing infrastructure development, with a need for combined financial models that can facilitate funding and cost reductions. • Knowledge sharing can make the supply chain more robust through implementing sustainable sourcing strategies (through localisation). This level of transparency can build not just capacity, but also trust amongst key stakeholders, whilst fast tracking problem-solving interventions.	• The cluster partners should streamline their supply chain objectives based on collectively improving efficiency, understanding cost drivers, and contributing to skills development and knowledge sharing for region specific initiatives.

6.4 Recommendations

The overall research study has identified ***improved efficiency, cost drivers, and skills development & knowledge sharing*** as the top three (3) elements of the supply chain framework, highlighting the need for collaborative efforts to address these elements strategically and operationally. Based on the insights from objectives 1-4, the recommended framework elements suggest a comprehensive approach that benefits developers and partnering organisations. It aims to provide a sustainable solution to electricity challenges that may also benefit end users and fence-line communities through job creation and talent and skills development programs.

As a 2nd level focus, benefit realisation, risk management, policy and regulatory support play a significant role in facilitating the adoption of renewable wind energy. These aspects are critical as an overarching tier that should be guarded and monitored, in line with the main 3 elements of the supply chain. Although as equally as important, they are driven by a bigger mandate and can be streamlined once the various problem statements of the supply chain are captioned.

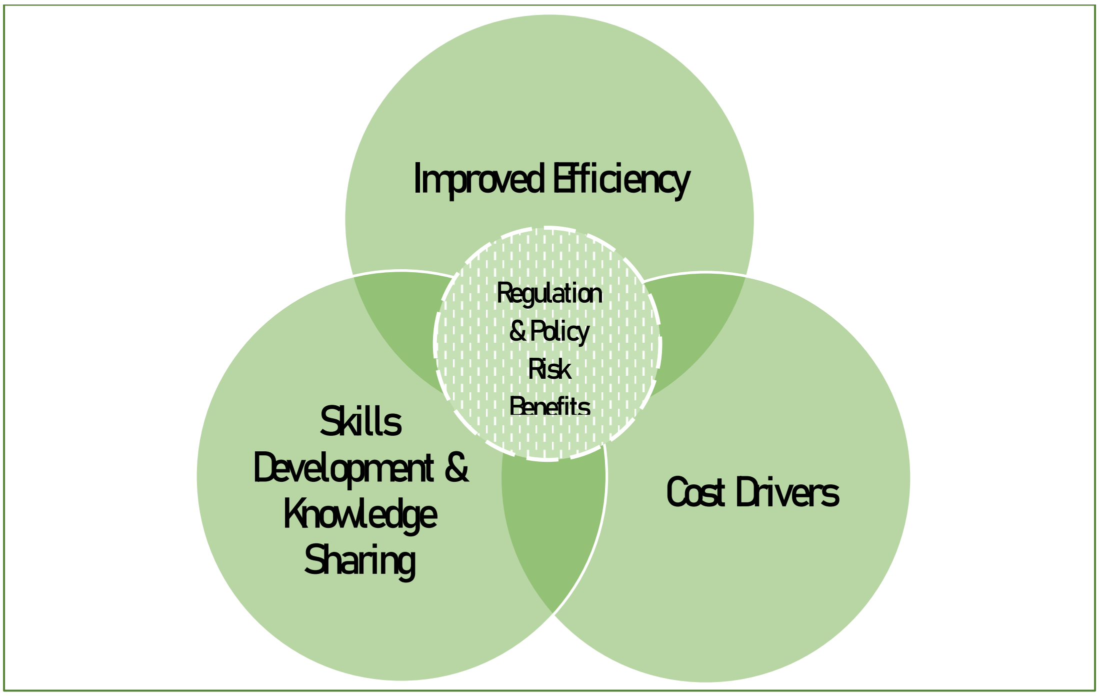


Figure 9: Proposed collaborative supply chain framework. *(Source: Author's own)*

In this section, the recommended framework will be unpacked in detail, with the 2nd level elements incorporated for clarity on ow to address this 2nd layer of collaboration.

6.4.1 Improved Efficiency

- Leverage collaborative efforts within industrial clusters to tackle location-specific challenges effectively. This approach allows partnering organisations to align desired benefits with the unique challenges and solutions of each region. By doing so, organisations can promptly address questions about the energy problems the cluster aims to solve and focus on achieving the desired outcomes. This strategy ensures that no organisation is excluded based on the realisation of benefits. Instead, cluster partners will concentrate on the potential achievements and address any limitations from the very beginning.
- Once a list of locations is finalised, large organisations, especially those with an international footprint, can develop a joint infrastructure plan for projects within the industrial cluster to share costs and resources. It's crucial to involve communities and government in prioritising development projects. By including communities in discussions and providing a clear roadmap of project timelines and solutions, engagements can effectively address pertinent issues. Organisations with an established footprint in inland regions can set up shared warehouse hubs, transport routes, and grid connections, as well as facilities requiring regular maintenance and repairs. Each partner should leverage their strengths and ensure community leaders are held accountable. This approach to infrastructure development planning will promote long-term scalability and support future growth.
- Create a detailed logistics network tailored to the location prospects. This can be enhanced by setting up smaller facilities in those regions, utilising innovation hubs to house multiple businesses that need to be in close proximity to reduce transportation costs. Additionally, utilising energy-efficient transportation methods, minimising waste, and optimising resource usage can be an added advantage as part of the clusters value proposition. Industrial clusters can leverage on digital solutions that use smart logistics and predictive maintenance tools to enhance operational productivity and performance.
- The development of hybrid power stations by repurposing sections of existing power plants rather than fully decommissioning them, these facilities can act as

supplementary support systems to meet electricity demand, particularly when wind conditions are favourable. This approach makes optimal use of land in remote areas where power stations are located. Additionally, the existing grid can integrate wind energy without requiring significant investment in new grid connectivity infrastructure.

- To promote local manufacturing and reduce dependence on imported components, it is recommended to introduce tailored policies that mandate partnerships between smaller SMMEs and large corporations for upcoming materials and services' needs. These partnerships should be established through long-term agreements that are based on negotiated targets that are realistic do not generalise. A fit-for purpose design. Over this period, the partnership can gradually scale down, allowing larger organisations to move on to different projects while the SMMEs prepare to take on full operations independently and sign new agreements as the main contract holders. This approach will not only foster skills development and knowledge sharing but also enhance the quality and sustainability of supply for local businesses. Clear deliverables should be set out, to ensure the right support is received from the cluster partners.

6.4.2 Cost drivers

- Joint effort in investing in advanced tools such as Artificial Intelligence (AI), Internet of Things (IoT), or automation technologies to fast track the onboarding process for all partnering organisations.

- The industrial cluster should focus on attracting diverse funding sources. Identifying opportunities from green bonds, venture capital, and public-private partnerships that are region specific, can unlock shared risks and savings.
- Clear return on investment (ROI): Currently the levelised cost of renewable energy (LCORE) is unclear. Through cluster partnering it is recommended that organisations account for the partnership costs as part of their OPEX budgets, and capped at a specific rand value, based on their specific service / product offering.
- Industrial clusters should advocate for incentives from government and local authorities. Government-backed funding such as grants and subsidies to support high initial capital requirements should be a priority. This united drive can secure

tax breaks, subsidies or reduced import duties as a benefit to cluster partnerships to advance renewable energy initiatives. This financial relief can unlock savings that can be redirected to other project needs, to accelerate project execution for such initiatives.

- To unlock benefits related to economies of scale, this study recommends the development of cost sharing models to promote cooperative procurement, this means cluster partners can collectively negotiate better prices for materials and services (related or unrelated). This can also be extended to transportation and labour costs.
- As a second layer to the feasibility of industrial cluster initiatives, long-term investment planning can entail establishing frameworks for sustainable funding and operational support. If the initial investment in pre-feasibility studies is self-funded, it will give investors' confidence that the initiatives will succeed.

6.4.3 Skills development and Knowledge sharing

- This study recommends that industrial cluster should focus on promoting data sharing and integration amongst cluster partners, to facilitate real-time decision-making aligned with global trends. This can include integrating logistics networks, cost information, and strategies to enhance efficiency. Data privacy policies can be placed on record between the cluster partners to ensure alignment, transparency and limited control to preserve competitive advantage of the partnering organisations.
- Current power station resources can be reskilled through development programs that ensure minimal job losses when coal power stations are decommissioned in future. A clear skills development plan should be positioned, with industrial cluster partners outlining which skills they can offer to the affected resource pool. The development programmes should be formalised into qualified accolades that employees can use to gain further opportunities in other clusters.
- Invest in technology and training, to allow for the flow of training material efficiently. Access control and adequate cyber security can be deployed to organisations that have partnered together to drive the adoption of industrial cluster. Strict access control measures should be put in place to ensure no IP will be misused. Partnering organisations should agree from the onset, what technology systems will be used

to store and transmit this training information or any other cluster related information. Organisations will also have to align and agree on technology upgrades, training programs, and process improvements.

- It is further recommended that the partnering organisations work hard to streamline and improve communication channels, to ensure end-to-end visibility among cluster partners. This will foster trust, reduce competition, and align decisions with expectations, leading to a more cooperative approach and efficient coordination.

As a first step, the industrial cluster project charter should prioritise three (3) main elements of the supply chain framework to ensure strong commitment from partners. Central to these three (3) elements, as recommended by this study, are three (3) sub-elements that form the foundation of successful partnerships, namely: *risk management, benefits realisation, and policy and regulation support.* It is crucial to discuss these sub-elements and confirm alignment on their impact on the supply chain framework, as they may present various supply chain challenges that could jeopardise the success of the cluster partnership. Catering and enabling discussions on these sub-elements, will further ensure that expectations from the various stakeholders are managed and well understood, to eliminate unwarranted assumptions. These sub-elements also require constant review mechanisms to keep the discussions relevant and adaptable to changing needs. Additionally, the study underscored the importance of improved risk management in affirming that through collaboration and evenly distributed project risks, organisations can collectively mitigate disruptions, leading to a stronger and more resilient supply chain. The study results highlighted that sharing risks and leveraging the strengths of each partner can help manage uncertainties more effectively, enhancing operational efficiency and reducing costs. As overarching sub-elements, the benefit realisation will enable stakeholders to align on benefits. Once the interests of all stakeholders within the industrial cluster are aligned, they will be able to provide a foundation for collaborative supply chain efforts and ensure that each partner participates with intent to address key supply chain elements effectively.

The study therefore supports the advanced adoption of renewable wind energy through industrial cluster partnerships that focus on the top three (3) highest-ranked elements: *improved efficiency, cost drivers, and talent and skills development.* This targeted approach will help establish the basis and mandate of the industrial cluster, ensuring effective collaboration and addressing key supply chain elements to resolve historic challenges more efficiently. By aligning stakeholder interests with these themes, collaborative supply chain efforts can be optimised to achieve strategic and operational benefits. Implementing these recommendations can help advance the adoption of renewable wind energy and enhance the overall efficiency and effectiveness of collaborative supply chain networks within industrial clusters.

6.5 Suggestions for further research

The study focused on establishing a collaborative supply chain framework for renewable wind energy development in inland regions. The objective was to have a framework that would provide a tool for stakeholders to optimise efficiency, reduce costs, enhance flexibility, and improve overall performance across the renewable energy supply chain in an industrial cluster. The industrial cluster's collaborative supply chain involved key players like manufacturers, suppliers, distributors, and retailers, all working hand in hand to achieve shared goals. While the cluster also included stakeholders such as non-profit organisations, residents, and government offices, this study focused solely on responses from individuals working directly within the supply chain network of renewable energy initiatives. A suggestion for further research is to explore qualitative research through one-on-one interviews with energy specific industrial clusters of definite regions. The one-on-one interviews might enable direct engagement with key stakeholders, which may help to build and strengthen trust, encourage open feedback, and uncover practical challenges and opportunities which the research methods in this study might have overlooked. Within this construct, the interviews can be limited to only the partnering organisations and their stakeholders. This future study can separately expand on the three (3) elements identified by this study, to unlock specific value for renewable (wind) energy initiatives:

i) Investigate and secure green finance and innovative financial models between partnering organisations to reduce capital costs and support economic feasibility.

ii) Research the development of a region-specific training program to enhance skills, knowledge sharing, and collaboration by addressing educational, cultural, and organisational barriers.
iii) Investigate strategies, tools, and technologies to improve resource efficiency within a specific region's industrial cluster organisations to improve and streamline monitoring and optimisation of renewable energy initiatives.

Furthermore, each renewable energy technology has unique supply chain requirements and challenges that must be understood to optimise efficiency, reduce costs, and enhance flexibility. It would, therefore, be valuable to investigate whether the dynamics are consistent for other renewable energy technologies that have not yet experienced significant growth and adoption in inland regions, such as biomass energy. By tailoring collaborative frameworks to regional needs, industrial clusters can effectively overcome specific obstacles. Expanding the focus to include various renewable energy technologies will foster collaboration among different clusters, promoting the broader adoption of renewable energy solutions and supporting a sustainable future.

It was interesting to note that some energy experts that were interviewed were not aware of the current inland wind energy project and prospects for future renewable energy initiatives for inland regions. It is therefore recommended that a thorough study on how inland regions can intensify the adoption of various renewable energy initiatives, that support and align to their immediate needs be carried out.

It is also recommended to investigate the challenges hindering the cross-skilling of energy and supply chain experts into various renewable energy technologies, with a focus on different regions within South Africa. Such a study would be valuable in developing a robust supply chain structure that facilitates collaboration irrespective of the end product. By aligning with the Just Energy Investment Plan opportunities, industrial clusters across various regions can leverage each other's strengths and design future-fit frameworks for cross-regional collaboration. This approach can leverage on building case studies of successful collaborations within industrial clusters to identify best practices and lessons learned. The insights gained will serve as a valuable resource for future research on the benefits and challenges faced by industrial clusters in the energy sector, ultimately enabling quick decision-making and encouraging the faster adoption of beneficial low-carbon energy solutions.

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APPENDICES

APPENDIX A: Research Instrument (includes participant agreement and questionnaire)

Participant Consent Form

Establishing a collaborative supply chain framework for advancing renewable energy development through industrial clusters

Name of researcher: Selogadi Mosehle

Dear Participant,

I am a Masters in Energy Leadership student at the Wits Business School and would like to invite you to participate in my research study titled: Establishing a collaborative supply chain framework for advancing renewable energy development through industrial clusters. The study sets out to assess the various elements of the supply chain network design and identify common aspects that organisations in an industrial region may collaborate on, to help fast track the decarbonization of that region through renewable energy solutions. Please use the link below to participate in the survey. Your task is to read the questions carefully and to answer the questions to the best of your knowledge. There are no right or wrong answers.

Before you proceed, please take note of the following:

1)	Answers to the research questionnaire will e submitted and stored through a digital platform and all answers will be stored on a cloud platform. Once downloaeded, the datasets will be kept anonymous and stored indefinitely on a password-protected computer.
2)	Only the researcher and related academic support who are involved in the research will have access to the raw data.
3)	**Voluntary participation and confidentiality:** Participation in this survey is entirely voluntary, and you can withdraw at any given moment without further consequences. All answers will be made anonymously. No identifying information (such as participant's name, employee number or contact number) will be requested or retained by Wits Business school.
4)	There are no risks involved in participating in this research study and all Ethical requirements have been satisfied. This study has received permission and ethical approval from the University of Witswatersrand Ethics Committee.
5)	The dataset might be utilised in future research, where the same confidentiality will be applied.
6)	**Consent:** Please confirm that you have read all the above information and indicate whether you consent to participate in the study. Please remember that participation is voluntary.

By accessing the link, you give confirm that you have read the above information and consent to participate in the study.

To proceed with the questionnaire please follow the link below:

https://.....**link will be updated once the data collection process begins**

APPENDIX B: Demographics Summary Table (Spreadsheet attached)

	Highest Qualifications	# Participants	% Percentage
Highest Qualifications	High School	0	0%
	Bachelor's degree	12	25%
	Postgraduate diploma / Hons degree	15	34.10%
	Master's degree	16	36.40%
	Doctorate degree	2	4.50%
		45	**100%**
		# Participants	**% Percentage**
Professional Roles	Supply Chain	8	17.78%
	Engineering / technical skills	13	28.89%
	Snr Management / Executives	11	24.44%
	Support functions (Finance, Business & Market Development, Quality)	6	13.33%
	Project Management / Contract Management	5	11.11%
	Advisory, Policy, Stakeholder relations	2	4.44%
		45	**100.00%**
		# Participants	**% Percentage**
Renewable Energy knowledge / experience	Wind & Solar	24	51.16%
	Wind only	6	13.95%
	Solar only	15	34.89%
		45	**100.00%**
		# Participants	**% Percentage**
Organisation's Location	GP	27	59.10%
	MP	18	40.90%
	KZN	9	20.50%
	NW	9	18.20%
	FS	16	34.10%
	LP	8	18.20%
	WC	16	34.10%
	EC	15	31.80%
	NC	16	34.10%
		# Participants	**% Percentage**
Organisation runs operations in an industrial location?	Yes	26	56.80%
	No	15	31.80%
	I don't know	4	11.40%
		45	**100.00%**
		# Participants	**% Percentage**
Years of experience	0-5	5	11.40%
	6 to 10 yrs	4	6.90%
	11 to 15 yrs	13	29.50%
	16 to 20 yrs	13	29.40%
	21 to 35 yrs	9	20.50%
	36 to 45 yrs	1	2.30%
		45	**100.00%**
		# Participants	**% Percentage**
Industrial Sector that particpant's work under?	Automobile	1	2.22%
	Chemicals	1	2.22%
	Energy	31	68.89%
	Finance	2	4.44%
	Government Institution	3	6.67%
	Manufacturing	1	2.22%
	Oil & Gas	3	6.67%
	Other	1	2.22%
	Petroleum	1	2.22%
	Construction	1	2.22%
		45	**100.00%**

APPENDIX C: Transcripts attached separately in a zipped file (due to size)

Only 1 of 45 transcripts enclosed on this report copy (randomly selected)

Responses from Participant 8:

1.1. Please indicate your highest level of qualification.
- Postgraduate diploma / Hons degree

1.2. Which industrial sector do you work in?
- Energy

1.3. What is your job title?
- Principal Specialist

1.4. How many years of work experience do you have?
- 11 - 15 years

1.5. Do you work / have you worked / have you been involved in Supply Chain activities?
- Yes

1.6. Do you work / have you worked / have you been involved in Renewable Energy activities?
- Yes

1.7. Which of the following renewable energy TECHNOLOGY do you have knowledge or experience in?
- Wind

1.8. Do you work for an organisation that runs operations in an industrial location?
- Yes

1.9. Where in South Africa is your organisation's operations located?
- Mpumalanga, Free State

Section 2

2.1 Are you aware of any inland wind energy projects in South Africa at the moment? If yes, list province.
P8: Yes, Mpumalanga

2.2. List 3 factors that you think could contribute to the failure of collaborating on a wind energy supply chain?
P8: Transport planning, availability of right trucks and demand.

2.3. In your opinion, what can drive collaboration between industrial cluster partners? Select 3 Options:
- Market Access
- Cost Reduction
- Policy & Regulation influence

2.4. Based on your selection in the previous question, briefly discuss why?
P8: The more certainty in policy, the more demand there'll be.

2.5. From the list below, select 3 potential economic benefits that supply chain collaboration can achieve for inland industrial clusters that are located in inland provinces, when developing wind energy.
- Market expansion
- Cost reduction
- Access to funding

2.6. What are the reasons for your choice in Question 2.5?
P8: Invalid

2.7. Explain how the location of wind energy establishments can negatively impact its supply chain?
P8: access to project sites may be challenging.

Section 3

3.1. What are the 3 main obstacles your organization faces when attempting to collaborate with other companies in the energy sector?

- The benefits of collaboration are unclear
- There is not enough funding
- Processes and systems across organisations are incompatible

3.2. Which constraints may limit industrial cluster's ability to engage in collaborative supply chain activities for wind energy development? Select only 3:

- Limited skills pool and resources
- Different organisational cultures
- Lack of coordination between organisations

3.3. Based on your selection in 3.1 and 3.2, how do these obstacles and constraints impact the way in which organisations view collaboration?

P8: Invalid

Section 4

4.1. Which 3 advantages can be anticipated when collaborating with other organizations on supply chain? Select only 3:

- Cost savings
- Better risk management
- More transparency

4.2. Elaborate on how the advantages you selected in 4.1, can be implemented by the industrial cluster partnership?

P8: Invalid

4.3. In your opinion, how can supply chain collaboration improve the efficiency of an industrial cluster looking to pursue wind energy initiatives? Select 3 options:

- Resource optimization
- Risk management
- Process optimization

4.4. What are the reasons for your choice in Question 4.3?

P8: Invalid

4.5. Provide 2 examples of how collaboration can contribute to a successful supply chain, particularly for inland wind energy development?

P8: Faster project timelines.

4.6. What long-term benefits do you foresee in wind energy developments if supply chain collaboration is established through industrial cluster partnerships?

P8: Lower project costs.

Section 5

5.1. In your experience, which supply chain elements would you deem critical for the successful adoption of wind energy in an industrial cluster located inland? Select only 3:

- Efficient logistics and transportation network
- Technology integration and knowledge sharing
- Shared resources and joint resource investment

5.2. From the list below, which supply chain practices can accelerate the adoption of wind energy by industrial clusters located inland?

- Technology integration and knowledge sharing
- Efficient logistics and transportation network
- Localization

5.3. Based on your choice in 5.2, how can the supply chain practices you selected, aid in maintaining long-term success and sustainability of wind energy development across inland provinces?

P8: Localisation driving participation.

5.4. With reference to 5.2, discuss which supply chain practice might not succeed in accelerating the adoption of wind energy by industrial clusters (particularly around inland provinces)?

P8: Transparency.

5.5. In your opinion, how can a collaborative supply chain framework enable industrial clusters to succeed in advancing the development of wind energy farms in inland provinces?

P8: Invalid

APPENDIX D: Consolidated code comparison sheet (attached as spreadsheet)

	H4: Essential SC enablers for sustainable RE adoption in industrial clusters	H4: Essential SC enablers for sustainable RE adoption in industrial clusters > Financial	H4: Essential SC enablers for sustainable RE adoption in industrial clusters > Localization	H4: Essential SC enablers for sustainable RE adoption in industrial clusters > Performance measurement	H4: Essential SC enablers for sustainable RE adoption in industrial clusters > Risk	H4: Essential SC enablers for sustainable RE adoption in industrial clusters > Demand-	H4: Essential SC enablers for sustainable RE adoption in industrial clusters > Knowledge sharing and	H4: Essential SC enablers for sust industrial clusters > Sustainability
Participant 14 response 04112024		joint investment Participant 14 response 04112024: 74 - 74 (0)					knowledge sharing Participant 14 response 04112024: 70 - 70 (0) Shared resources Participant 14 response 04112024: 74 - 74 (0)	
Participant 15 response 04112024			The manufacturing of parts and components at the local scale to meet the technical specifications and willingness of MNCs to transfer the skills to local firms who can produce the volumes within the cost requirements/economically. Participant 15 response 04112024: 79 - 79 (0)				knowledge sharing Participant 15 response 04112024: 70 - 70 (0) Shared resources Participant 15 response 04112024: 71 - 71 (0) Shared resources Participant 15 response 04112024: 73 - 73 (0)	Wind energy farms established inte necessary exemptions from Eskom bring innovative/niche offerings in th economy a competitive edge. Participant 15 response 04112024: Memo 6 Memo 7 Memo 8
Participant 16 response 04112024		Not introducing tax incentives and incentivizing the industry to grow the sector. Participant 16 response 04112024: 79 - 79 (0) Memo 12 Not providing financial support in the form of loans and grants for development expenditure. Participant 16 response 04112024: 79 - 79 (0)	Localization Participant 16 response 04112024: 75 - 75 (0) Introduction of unrealistic localization and local content targets which may push the price of development high. Participant 16 response 04112024: 79 - 79 (0) Memo 12			Expanding technology research, development, and demonstration through the public and private sectors to enhance the wind supply chain competitiveness and reduce logistical requirements, such as blade manufacturing automation, additive manufacturing of large castings and forgings, and modularization and onsite manufacturing of large components such as blades and towers. Participant 16 response 04112024: 77 - 77 (0)	knowledge sharing Participant 16 response 04112024: 73 - 73 (0)	Efficient logistics and transportation Sustainable sourcing Participant 16 response 04112024: Expanding technology research, de demonstration through the public a enhance the wind supply chain com Participant 16 response 04112024: Not introducing tax incentives and i to grow the sector. Participant 16 response 04112024:

APPENDIX E: Word clouds of codes per objective

Objective 1: Outline the rationale that justifies the need for a collaborative supply chain within an industrial cluster.

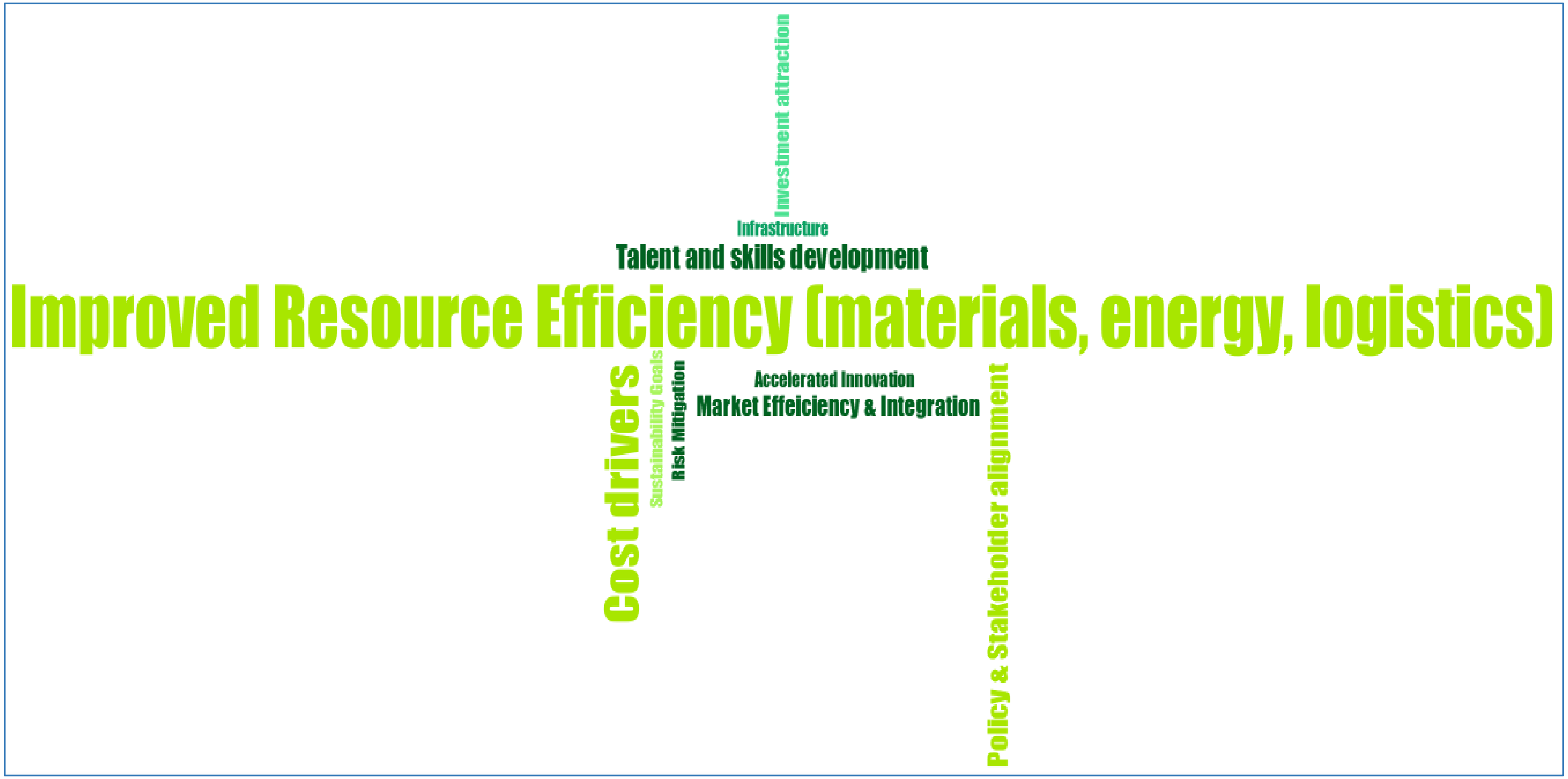

Figure 1: A depiction of all the themes from Objective 1. *(Source: Maxqda project as created by Author)*

Objective 2: Identify the challenges associated with establishing a collaborative supply chain within an industrial cluster.

Figure 2: A depiction of all the themes from Objective 2. *(Source: Maxqda project as created by Author)*

Objective 3: Identify anticipated benefits in establishing a collaborative supply chain.

Figure 3: A depiction of all the themes from objective 3. *(Source: Maxqda project as created by Author)*

Objective 4: Determine the key supply chain elements that will enable successful, sustainable, and accelerated adoption of renewable (wind) energy through industrial clusters.

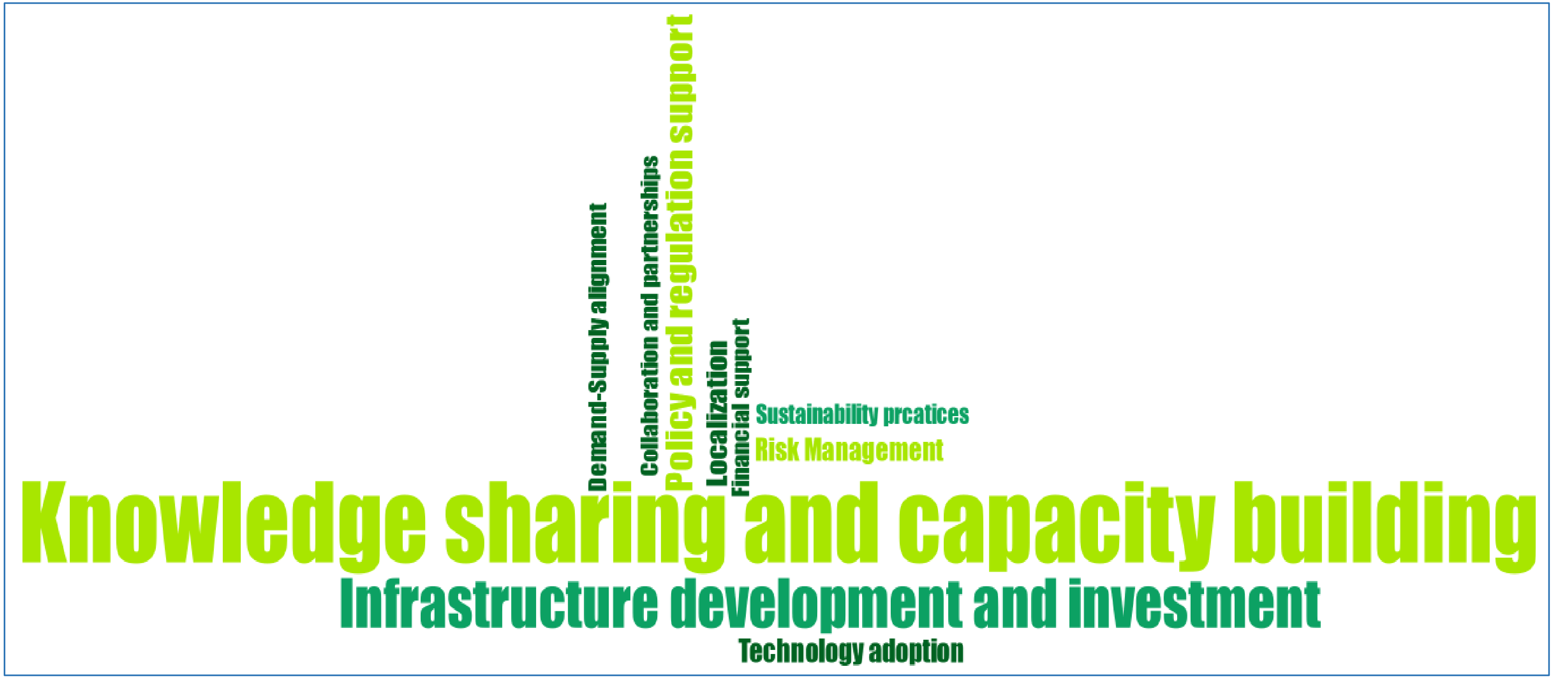

Figure 4: A depiction of all the themes from Objective 4. *(Source: Maxqda project as created by Author)*

APPENDIX F: Ethics clearance certificates

CERTIFICATE OF COMPETENCE IN RESEARCH ETHICS

Name: **Selogadi Mosehle**

Student No: **2513908**

Date of Certification: 14 August 2024- 13 August 2027 (This certificate is valid for a period of three years)

TRAINED BY:

PROF. JASPER KNIGHT

(RESEARCH ETHICS)

SIGNATURE:

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

This certificate is confirmation of successful completion of a training course in Research Ethics for Non-Medical human research, based upon achieving a minimum level of competence in different assessment tasks.

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/EL2513908/822

This certificate is only valid with a legitimate ethics protocol number and signed by the Researcher (below).

Project title	Establishing a collaborative supply chain framework for advancing renewable energy development through industrial clusters in South Africa.
Investigator / Researcher	Ms Selogadi Mosehle
Nature of Project	MM (Energy Leadership)
Decision of the Committee	Approved, provided stakeholders and participants are guaranteed confidentialty.
Issue Date of Certificate	26/08/2024
Expiry date	Date of submission of the project / research report
Chairperson	Dr Ayanda Magida ☎ +27 11 717 3953 ayanda.magida@wits.ac.za

Declaration by Researcher

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

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

Signed by:Selogadi Mosehle
Signed at:2024-10-19 14:17:26 +02:00
Reason:I approve

Signature	Date: 19/10/24

APPENDIX G: Acceptance of research paper to AABD Conference

Your Submission to AABD Conference

20 - 24 May 2025

2025 Academy of African Business and Development Annual Conference

https://aabdc2025.exordo.com

Dear Ayanda,

Thank you for your submission to aabdc2025.

Following review by the Programme Committee, I am pleased to inform you that your submission entitled '**COLLABORATIVE SUPPLY CHAIN NETWORKS ESSENTIAL FOR DEVELOPING SUSTAINABLE INDUSTRIAL CLUSTERS**' has been accepted for **Oral presentation** at the conference - congratulations.

You will find comments from the reviewers by logging in to your aabdc2025 Dashboard and clicking on the 'View All Decisions' prompt from your card. Please take these comments into account when preparing the final camera-ready version of your paper. Full details about how to submit your final paper and how to register for the conference will be circulated in a separate e-mail.

We hope that you can also take the time at this point to confirm the RSVP for your submission. This RSVP confirms the presence only of your submission at the conference, not of your own personal attendance. You can respond to the RSVP by clicking the 'Submit my RSVP' prompt from your card or using this link: RSVP your Submission. You (or your co-authors) can confirm or decline the attendance of your submission at any point until **Monday, 31st March 2025 @ 23:59 Africa/Johannesburg**.

Again, congratulations on your acceptance. We look forward to meeting you at aabdc2025!

Yours Sincerely,

Richard Hayes and Stella Zulu,

aabdc2025

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