A Systems Thinking Approach to a Transition Towards Renewable Energy in South Africa

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Declaration

This Dissertation is the result of my work and includes nothing which is the outcome of work done in collaboration except where specifically indicated in the text.

This dissertation does not exceed the word limit of 15,000 words.

If you would like to know any further detail, please contact me on lodusem@gmail.com.

Lonwabo Mgoduso

In loving memory of

Mam'Dolly Doreen Mokgatle

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Along with the knowledge gained from this course, this research will inform my future approaches to dealing with complexity and addressing sustainable development challenges that exist in South Africa and across the world. May this research be a call to action in for a dedicated movement to drive South Africa towards a sustainable future, which benefits and improves the lives of her people.

Abstract

South Africa continues to rely on a coal-intensive energy system to drive employment and growth of the economy. In light of the global climate crisis, this is no longer sustainable due to coal's substantial carbon emissions. The rising concerns around energy security, coupled with the urgency for climate change mitigation, pose significant challenges to the country's electricity sector. This research focuses on South Africa's current electricity generation system. It investigates the opportunities, implications and barriers for renewable energy (RE) in response to climate change. Through a systems thinking (ST) approach, this dissertation develops critical intervention strategies to facilitate a just and fair transition away from coal. Finally, a high-level Theory of Change (ToC) framework consolidates research outcomes and maps out a transition pathway.

The review of literature focuses on the context of South Africa's electricity supply and its historical efforts to shift towards low-carbon technologies. It highlights that over the past decade, South Africa has continued to fall short of its mitigation commitments due to poor policy implementation as a result of political interference. Additionally, there have been rolling blackouts across the country due to financial and operational challenges experienced by the state-owned energy utility, Eskom. The literature highlights the existing drivers and barriers for RE and suggests cost-effective mitigation pathways. It presents the economic and political cases for RE in South Africa, rooted in a 'just transition' from coal.

A systems analysis based on semi-structured interviews with key stakeholders indicates the socio-economic complexities of a low-carbon transition, such as the resultant job losses, destruction of mining communities, and lack of consensus-building between stakeholders and government institutions. Visualising the system through a causal-loop diagram, leveraging points within the system are identified. Eleven intervention strategies are developed to drive the advancement of RE and a possible just transition. The critical actions proposed include (i) unbundling Eskom's monopoly into separate generation, transmission and distribution entities; (ii) establishing a free market with a diverse set of independent sellers to increase RE capacity and dynamism in the sector; (iii) developing a *Just Transition Plan* that addresses the human and environmental impacts. In summation, this dissertation identifies opportunities for future inter-sectoral coordination guided by the ST approach of this research, to inform a successful and just transition towards a new green economy in South Africa that benefits all.

Impact Statement

As part of South Africa's National Development Plan (NDP) 2030, produced in 2011, the government has aimed to reduce inequality and unemployment and the elimination of poverty (NPC, 2012). Delivering electricity is one of the critical elements in achieving a decent standard of living for all South Africans (DMRE, 2019). The NDP foresees that, by 2030, South Africa shall have an energy sector that delivers affordable, reliable and environmentally sustainable energy access across the country. With the signing and ratification of the Paris Agreement on Climate Change, the government has affirmed its commitments to reducing carbon emissions through the energy sector. Therefore, it is critical to ensure that the country transitions towards renewable energy in a manner that supports its energy-intensive economy, promotes socio-economic development and mitigates environmental impacts. In light of this, this research aims to address South Africa's developmental challenges in driving change towards a just energy transition to renewable energy. This research explores the following principles of sustainability: **dealing with complexity** through a systems approach, **dealing with uncertainty** in developing future pathways, **dealing with change** by challenging the existing coal-dependent paradox, **dealing with environmental limits** to promote repurposing of coal regions, and **dealing with people** by encouraging collaboration.

A systems approach presents an opportunity to understand the causal linkages between critical activities within the electricity sector that can advance renewable energy in South Africa. The causal loop diagram of the system illustrates how elements within the system interact across the sustainable development dimensions, namely, environmental, social, institutional, economic and technical. This research proposes interventions and a framework that should drive further stakeholder engagement amongst government, state institutions, the energy parastatal Eskom, the energy industry, academia, energy affiliated unions and other groups engaged in the sector.

This dissertation provides initiatory knowledge on the necessity to develop and implement a masterplan for a new green economy. It should be used in conjunction with engagements between relevant stakeholders to establish consensus on the way forward. The current South African education system may not be equipped to prepare its citizens for a high-skilled intensive green economy, which may lead to more significant socio-economic issues. Therefore, future studies should also consider the necessary education system reform that will support the transition of the electricity sector and the resultant overhaul of the economy.

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List of Acronyms and Abbreviations

ANC	African National Congress
B-BBEE	Broad-Based Black Economic Empowerment (formally known as Black Economic Empowerment BEE)
CLD	Causal Loop Diagram
COSATU	Congress of South African Trade Unions
DoE	Department of Energy (2009 – 2019)
DEA	Department of Environmental Affairs
DME	Department of Minerals and Energy (1997 – 2009, previously the Department of Minerals and Energy Affairs)
DMRE	Department of Mineral Resources and Energy (2019 on)
DPE	Department of Public Enterprise
Escom	Electricity Supply Commission
Eskom	post-1987 name for Escom (now known as Eskom Holdings Limited)
GDP	Gross Domestic Product
GHG	Greenhouse Gases
ILO	International Labour Organisation
IPCC	Intergovernmental Panel on Climate Change
IPP	Independent Power Producer
ISMO	Independent System and Market Operator
IRP	Integrated Resource Plan
JET	Just Energy Transition
MEC	Minerals-energy complex
NCCRWP	National Climate Change Response White Paper
NDP	National Development Plan
NDC	Nationally determined contributions
NERSA	National Electricity Regulator of South Africa
NPC	National Planning Commission
NUM	National Union of Mineworkers
PPA	Power Purchase Agreement

PPD	Peak, Plateau and Decline
RE	Renewable Energy
REDZ	Renewable Energy Development Zones
REFIT	Renewable Energy Feed-in Tariff
REIPPP	Renewable Energy Independent Power Producer Procurement
ST	Systems thinking
ToC	Theory of Change

Units

GW	Gigawatt
GWh	Gigawatt hour
$MtC0_2$	Metric tons of carbon dioxide equivalents
MW	Megawatt
ZAR	South African Rand

1 Introduction

1.1 Background

Energy is a crucial driver of economic development throughout the world. However, its sourcing, production and use have resulted in significant drawbacks. These include the poor governance and regulation of the energy system and the severe environmental and social issues associated with the system on both a local and global level (Davidson *et al.*, 2006). Although efficiency has improved through development, increased demand has only elevated pressures on the environment through greenhouse gas (GHG) emissions. Coal power remains the backbone of South Africa's economy and energy system and is significantly supported by the state through subsidies and public finance directed to new power plants and mining activities (Burton, Marquard and McCall, 2019). In 2017, South Africa had the 14^{th} highest carbon dioxide emissions in the world, as it has maintained a heavy dependence on fossil fuels (IEA, 2020). The energy sector is the main contributor to the country's emissions (80%), of which, 40% of results from electricity generation and liquid fuel production alone (DMRE, 2019).

The over-dependence on coal creates greater urgency for low-carbon transition within the electricity subsector. In 2011, the South African government developed the Integrated Resource Plan (IRP) for electricity as an electricity infrastructure development plan to ensure a least-cost electricity supply and demand balance that would be continually revised (DMRE, 2019). It has facilitated the introduction of RE generation capacity into the electricity mix, procured from technologies such as wind, solar PV and small amounts from hydro, landfill gas and biomass energy (Eberhard, Kolker and Leigland, 2014).

1.2 Problem Statement

The rising demand for energy coupled with climate change mitigation poses significant challenges for the coal energy-intensive South Africa (Winkler and Marquard, 2009). Electricity security and reliability has been a constant concern over the past decade, as Eskom, South Africa's primary electricity utility, has experienced ongoing financial and operational crises. Eskom's insecure power supply system has resulted in long periods of rolling blackouts (commonly known as load-shedding) across the country since 2007 (Maune, 2019). Eskom's failure to successfully construct new generation capacity since the 1980s, the rising cost of coal and the country's climate change mitigation requirements have exacerbated electricity security challenges (Baker, 2016).

Under the Paris Agreement, South Africa's current climate change policy projections remain "highly insufficient", making it ever more pressing that there is a push to decarbonise the electricity sector (Mccall *et al.*, 2019; Climate Action Tracker, 2020). The recently approved IRP (IRP2019) includes a detailed plan to phase out coal-fired power plants and increase the adoption of renewables and gas (DMRE, 2019). However, it still indicates a continued reliance on coal capacity beyond 2050. South Africa would need to adopt more ambitious targets of entirely phasing out coal-fired power generation by 2040 with the inclusion of additional RE capacity (Climate Action Tracker, 2020).

Corrective strategies will need to be developed to address the socio-economic impacts that the energy transition will have on fossil-fuel regional communities and workers. The overall goal of a "just energy transition" (JET) is to enable an energy shift that is both for the betterment of the environment and is fair and just for societies that would be endangered by the change. A JET is critical in ensuring the success of not only the economy and of mitigation policy, but also in contributing to the broader development agenda of South Africa (Burton, Marquard and McCall, 2019).

1.3 Aims and Objectives

A transition to renewable sources of power in South Africa remains a complex and contentious issue given its historical context of a coal-dependent energy system and economy. This research uses a systems thinking (ST) approach to address this complexity by exploring opportunities and barriers for RE in response to climate change and the mechanisms to facilitate a just and fair transition. A vital outcome of the research is a Theory of Change (ToC) framework which aims to articulate and communicate a potential pathway that will inform the success of a shift towards RE in the South African context. Identifying the various system inputs and stakeholders are necessary to understand the possible pathways that would facilitate the country's just transition towards renewable energy. The research questions are presented in and linked to the research activities used to explore them:

1. What are the key development challenges facing South Africa in the energy transition?

- Literature Review (section 2)
- Semi-structured interviews with stakeholders (section 3.2)
- Identifying system variables (section 4.1)

2. What are the existing drivers, barriers and implications for a successful transition to RE sources for electricity in South Africa to meet targets?

- Creating and analysing a causal loop diagram (CLD) of the system (section 4.2)
- Identifying system leveraging points (section 4.3)

3. What are the possible intervention strategies and mitigation pathways, and who are the main actors that should drive a JET?

- Interviews with stakeholders to discuss interventions (section 4.4)
- ToC framework to guide a pathway forward for stakeholders (section 5.1)

Figure 1: Linking the research questions to research activities

1.4 Scope

The research is limited to the transition away from coal, focusing on the production, transmission and distribution of electricity. It does not focus on the energy sector in its entirety and demand-side elements. It shall discuss the production's links to coal mining but will not extend further to other uses of coal, such as coal-to-liquid processes. This research considers the social, environmental, economic, political, and technical implications of a transition towards renewable energy for electricity generation, with particular focus on the existing electricity mix of South Africa and in alignment to the intended aims provided in existing government policy and the Integrated Resource Plan (IRP).

Chapter 2 presents the literature review, which details the developmental challenges associated with the energy transition from a historical context and suggests considerations for and JET in South Africa. Chapter 3 articulates the ST methodology along with the Theory of Change (ToC) Framework that is developed from the systems analysis findings. Results are presented and discussed in Chapter 4 and 5. Finally, conclusions and recommendations are drawn for future studies in Chapter 6.

2 Literature Review

This Chapter provides an overview of the electricity sector in South Africa, summarising the historical context of coal-power generation and the climate change policy response in the country. It explores the introduction of RE in the country and investigates existing barriers to renewable technology advancement. The Chapter ends with a brief overview of proposed mitigation pathways and an exploration into a just transition away from coal to RE in South Africa.

2.1 The investigative approach used for the literature review

The investigative approach used was adapted from the Seven-Step Model for a comprehensive review of the literature (Onwuegbuzie and Frels, 2016). It is summarised in Figure 2 below:

Figure 2: Six-step flow of investigative approach undertaken - adapted from (Onwuegbuzie and Frels, 2016)

Literature ranged from peer-reviewed articles and books on the historical context of the electricity system and climate change efforts in South Africa, to grey literature that included government energy and climate policy along with NGO and academic reports that cover the concept of a just transition. Over 40 articles and papers were reviewed. Literature was deselected if it fell outside the of the scope of this research. Step 3 was an integral part of the investigation as information gathered during Steps 2, 4 and 5 was stored and organised, and Step 4 and 5 create a feedback loop to expand and refine the information that has been gathered before further analysis and synthesis can occur at Step 6.

2.2 Legacy of South Africa's reliance on coal

Coal has played an integral part in both South Africa's energy system and economy over the past few decades but has become increasingly uncompetitive with the decreasing prices of other alternatives, most notably renewable solutions (Burton, Marquard and McCall, 2019). Over the past century, the rising coal exports and use of coal for electricity and liquid fuels resulted in increased dependency of coal through state-owned entities and economic development policy (Marquard, 2006; Burton, Marquard and McCall, 2019). With its continued growth over many decades of coal has been the primary fuel for energy in the country, making up 61% of the primary energy supply (as of 2017) and is used to produce 92% of its electricity (DoE, 2017; Burton, Marquard and McCall, 2019).

Built on "the country's social, political and economic legacy of apartheid", the minerals-energy complex (MEC) is central to the historical reliance on the cheap labour of coal for electricity, which in turn fuels the interests of the export-orientated sector (Baker, 2016). The development of the South African energy system has been characterised by its persistent dependence of coal to fuel its energy-intensive mining and industrial activities, extreme energy poverty for in rural areas, and the significantly high consumption of electricity as a percentage of final energy demand (Marquard, 2006). Coal mining accounted for 2.3% of the country's GDP in 2012 and has been a critical input across the industrial sector, namely in the production of various metals. Coal has also accounted for 12% of merchandise exports from SA between 1993 to 2015 (Burton, Marquard and McCall, 2019).

Up until the 1980s, the South African electricity system was based primarily on low-grade coal-powered generation model, as it was the cheapest and most reliable source of energy and played an essential role in the country's economy. In the 1970s and 1980s, there were massive investments into infrastructure for coal mining and coal power plants garnered by rising support by the state. Overestimations of demand caused additional investment into other electricity sources in the 1980s to increase diversity in the energy mix but lead to a long period of oversupply of electricity. By 2000, 92% of the country's electricity generation was from coal, approximately 6% from nuclear power and the reminder from hydroelectricity, solar thermal power and other sources (DME, 1998; Marquard, 2006). In 2007, the existing generation capacity was fully utilised, and there was a significant increase in demand for electricity (DME, 1998). More poor planning by Eskom forced substantial state investment into mega coal-fired plants to compensate for a rapid rise in demand in the late 2000s. These two large power plants, Medupi and Kusile, are critical to maintaining generation capacity as more plants reach their end of life but are still under construction (Burton *et al.*, 2018).

South Africa is the 7th largest coal-producing country in the world (IEA, 2019). However, over the past 15 years, domestic prices of coal have significantly increased (Burton *et al.*, 2018). Coal mining operating costs have increased, and access to mining sites has become more challenging, which has profoundly impacted the price of coal purchased for power generation by Eskom. The South African coal exports are highly dependent on India, along with other middle eastern and Asian countries. However, global coal plant closures and cancellation of new-build coal plants will see the potential decline in demand (Burton *et al.*, 2018; Burton, Marquard and McCall, 2019). This trend is likely to continue due to changes in response to energy transition taking place in these regions.

Powerful economic and political actors have resisted renewable alternatives. Actors include Eskom, the state-owned national utility that is still committed and heavily invested in coal, and coal sector firms that anticipate significant job loss. As global markets continue to shift, there will be higher financial risks when investing in new high-carbon emitters not only in electricity but also in related sectors such as liquid fuels, international railway for exports and other mineral mining firms (Burton *et al.*, 2018). A well-managed coal phase-out is critical as mismanagement can lead to economic and sectoral risks.

In 1994, the election of the African National Congress (ANC) marked the ending of the racially oppressive apartheid regime. As a means to redress the imbalances of the past administration and alleviate poverty and inequality, the ANC government implemented the policy of Black economic empowerment (BEE) in 1994 (Makhunga, 2008). Later amended in the Broad-Based Black Economic Empowerment (B-BBEE) Act of 2003, B-BBEE is a strategy that aims "to advance economic transformation and enhance the economic participation of Black people in the South African economy", who include "woman, workers, youth, people with disabilities and people living in rural areas" (Makhunga, 2008; Business in South Africa, 2020). In this context, "Black" refers to African, Coloured (mixed-race) and Indian people of South Africa as these groups were previously systemically excluded from any significant participation in the country's economy by the apartheid government (The Presidency: Republic of South Africa, 2004). The energy and mining sectors have been an important entry for Black people and woman into the formal economy in the country post-apartheid. In alignment with the B-BBEE framework, these sectors have enabled Black and women industrialists to establish employment, appointment at management and leadership level, and ownership for over the past two decades (Makhunga, 2008; Eberhard *et al.*, 2016; Nkoana, 2018; Burton, Marquard and McCall, 2019). However, Black people are now heavily invested in a declining sector, which has reinforced political resistance to a transition away from coal (Atteridge, 2020).

The coal-producing province, Mpumalanga, is under significant threat as coal mining and coal power are an essential part of their economy and account for approximately 7% of employment. Mpumalanga is starved of employment opportunities and relies heavily on mining communities and coal miners salaries that typically support three dependents (Burton *et al.*, 2018). As coal mines and power plants reach the ends of their lives, the resulting job losses for coal workers will be devastating for the livelihoods across the region. Therefore, transition support for these workers and communities is critical.

2.3 The development of the electricity system and the role of Eskom

South Africa's Electricity is characterised by its vertically-integrated monopoly parastatal Eskom that is responsible for the generation (>90%), transmission (95%), and distribution (>50%) of electricity across the country (Baker, 2016; Eskom Holdings, 2019; Bowman, 2020; Ting and Byrne, 2020). The system consists of 51.7 GW of total installed generation capacity with a diverse energy mix, as displayed in Figure 3**Error! Reference source not found.**. The primary consumers of electricity in South Africa are separated into several distinct groups, namely 1) energy-intensive industries (such as mining and smelting), 2) the railways, 3) regional authorises (local municipalities), 4) agricultural interests, and 5) residential and commercial users (Marquard, 2006).

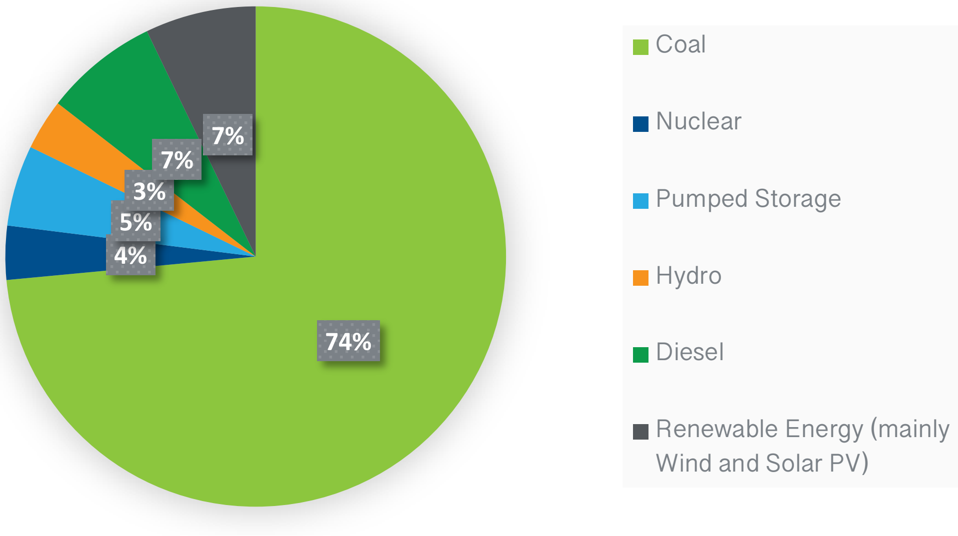

Figure 3: South African Electricity Mix - adapted from (DMRE, 2019)

The state utility, the Electricity Supply Commission (Escom, changed to Eskom in 1987), was legally established in the 1922 Electricity Act and started operating in 1923 (Marquard, 2006). Initially, Escom role was to supply cheap electricity, which would support industrial development, and promote electrification where it was required. The government was responsible for expansion planning and coordination of electricity production and supply until the 1960s when Escom took over these function. This reinforced their central responsibility "for technical operation and expansion, and the promotion of optimal solutions to electricity problems nationally" (Marquard, 2006).

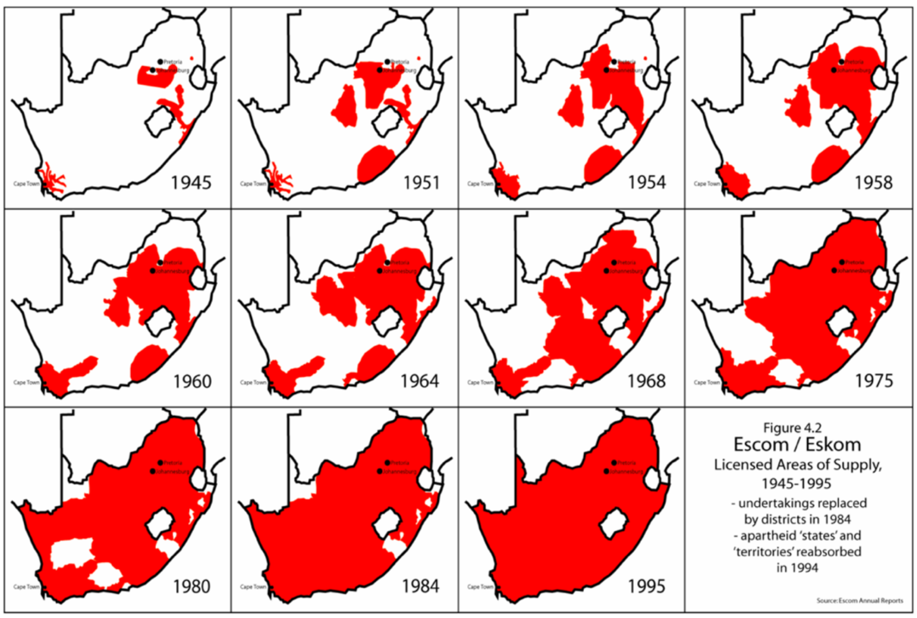

Figure 4: Licenced areas of supply in South Africa from 1945 to 1995 (Marquard, 2006)

Escom/Eskom had a great deal of autonomy in performing their roles up until 1985. This would change with the introduction of four new spheres of governance. The first saw the change when the governance structure shifted to a two-tier structure: a Management Board that dealt with daily operations of the utility and the introduction of an Electricity Council that included government officials and primary consumer representatives (Marquard, 2006). This was later replaced by an ordinary corporate governance structure in 2001 when Eskom was established as a fully public company held by the state as the sole shareholder (The Presidency: Republic of South Africa, 2001).

The second sphere involved the establishment of government oversight of Eskom functions. From 1994, Eskom was held accountable to the Department of Public Enterprise (DPE) as the primary shareholder and would report to the Department of Minerals and Energy Affairs (now the DMRE) for energy policy matters and electricity (Marquard, 2006). The third sphere saw the formation of the National Electricity Regulator (now known as NERSA) to regulate electricity pricing, implement energy policy and law and to license electricity generators (independent power producers (IPPs), transmitters, distributors and traders (Baker, 2016). The final sphere was the development of a long-term relationship between Eskom and the "industrial, political elite" (Marquard, 2006). Ties with these elites would instruct key policy developments in the across energy sector and government.

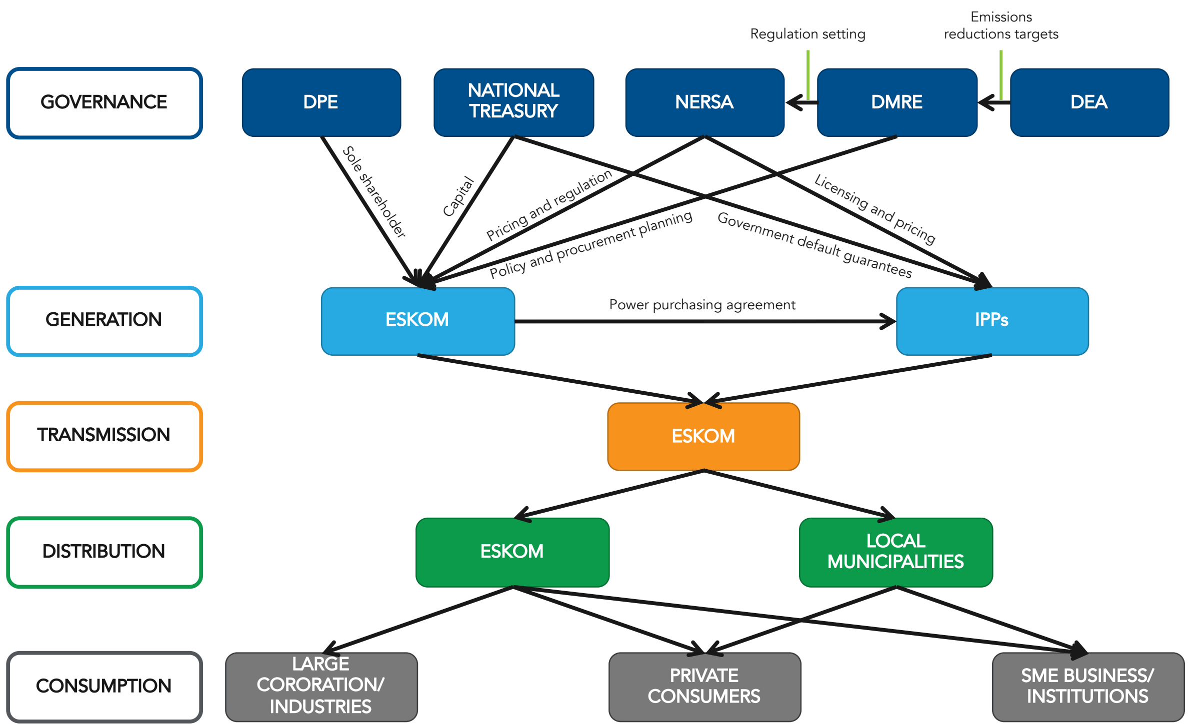

Figure 5: Structure of South Africa's electricity market adapted from (Morris and Martin, 2015)

The DPE has released the *Roadmap for Eskom in a Reformed Electricity Industry (2019),* which highlights intentions to unbundle Eskom, separating the utility into its generation, transmission and distribution functions while remaining under the overall Eskom Holdings umbrella. This change would have significant ramifications on the role of Eskom as the single-buyer of electricity and would serve to modernise the energy sector and open up the market to independent renewable power producers (DMRE, 2019; Oelofsen, 2020). This is not the first time the unbundling strategy was proposed, as the *White Paper on the Energy Policy* of 1998 had stated the government's objectives in restructuring Eskom into its separate entities to relieve financial strain and to improve its electrification efforts (DME, 1998). However, the recently appointed Eskom CEO, André De Ruyter, affirms that "if you look at trends in the energy and electricity industry, the days of the vertically integrated monolithic utility like Eskom are behind us" (Omarjee, 2020).

2.4 Eskom Crisis

Over the past 25 years, the electricity sector has moved from a state of "over-capacity and low-priced reliable supply to under-capacity and unreliable supply" (Trollip *et al.*, 2014). Having added 33910MW of new generation capacity in the period between 1970 and 1994 after significant shortages of supply, Eskom entered into "an era of cheap, abundant and unconstrained power" (Bischof-Niemz and Creamer, 2018), which coincided with the ending of apartheid. This prompted the government to actively seek more opportunities for energy-intensive investments, which included mining and smelting operations (Bischof-Niemz and Creamer, 2018).

Despite early warnings of the imminent shortage of electricity from 2007 from the Department of Energy's (DoE) 1998 White Paper, the government and Eskom was destined to repeat earlier planning mistakes. This paper necessitated strategies to ensure the construction of new generation capacity that accounts for expansion lead times (DME, 1998). Additionally, unbundling Eskom would enable competition to be introduced and new private investment for IPPs. Following the white paper, confusion arose as the Ministry of Energy and NERSA began to develop generation expansion plans excluding Eskom. In 2004, government plans were then abandoned, in fear of the looming power shortages, and Eskom assumed its traditional responsibilities of supply, power sector planning and new investment, with the Ministry of Energy deciding what plans would be adopted (Eberhard *et al.*, 2016). However, by that point, Eskom was behind on investment and commissioned the construction of two 4.8 GW coal-power plants, Medupi and Kusile, with their generating units coming online after 2014. This delay resulted in rolling blackouts, or "load-shedding" from 2007 (Eberhard *et al.*, 2011).

Over the past decade, Eskom has spiralled into operational, financial and political crises. Subsequent load shedding in 2008, 2014-2015 and 2018-2020 along with soaring electricity prices, have profoundly affected economic activity across all sectors. Eskom has acquired multiple state bailouts to prevent bankruptcy and has accumulated 440 billion South African Rand (ZAR) of debt (Bowman, 2020). During the tenure of former president Jacob Zuma, from 2009 to his resignation in 2018, Eskom became afflicted with political conflicts over procurement spending, control over their board and energy policy. These conflicts were linked to the "state capture" controversies associated with Jacob Zuma and his political allies. "State capture" refers to the systemic corruption and "capture" of government entities, such as Eskom, by "private interests seeking to utilise state powers and resources to their advantage (Bowman, 2020). Since 2007, there have been 12 chief executive changes at Eskom and radical board changes instituted by the DPE Ministry, which fundamentally destabilised its corporate governance. The hollowing out of the board and executive governance and granting these positions to "inept and corrupt individuals" (Eberhard and Godinho, 2017) led to the coordination of corruption and political influence, and irregular expenditure (DPE, 2017).

In Eberhard and Godinho's *Eskom's Inquiry Booklet* (2017), evidence suggests that corruption in Eskom's operating costs totals to ZAR140 billion per year over the Zuma's presidency. The source of which were over-priced coal contracts and coal mining acquisitions by Zuma's allies, the Gupta Family. Moreover, the cost to complete the construction of Medupi and Kusile has now doubled their original budgets, and commissioning of these power plants has been delayed due to corrupted procurement planning and implementation (DPE, 2017). In 2008, Eskom projected the completion of Medupi's generating units in 2014, and Kusile's in the following year (Bowman, 2020). To date, both power stations are incomplete.

The cost overruns at the new coal power plants, along with the increases in Eskom's primary energy costs have resulted in the rapidly rising electricity price, putting significant pressure on both the sustainability of Eskom and the country (Burton *et al.*, 2018). The rising cost of coal, coupled with poor coal procurement practices by Eskom, has further entrenched their financial challenges. These practices have led to the increased cost of coal from ZAR42,79/ton in 1999 to ZAR393/ton in 2017 (Burton *et al.*, 2018).

The instability in electricity supply has resulted in an increase of self-generated capacity at both domestic and industrial level. Many businesses and middle to upper-class households across the country have installed diesel generators and rooftop solar PVs to compensate for the periods of load-shedding (DMRE, 2019). There is approximately over 3500 MW of installed back-up generators, resulting in GHG emissions that are often in densely populated areas (Pretorius, Piketh and Burger, 2015). The movement to self-generation is likely to continue with extended periods of load-shedding and increasing electricity tariffs.

Restructuring Eskom into its three entities is essential in relieving the debt stronghold and will provide a more robust platform from which it can recover and will accelerate private investment into the sector and promote competition (Merten, 2020). Moreover, it will limit electricity price increases and stimulate financial viability and electricity security in the sector (Eberhard and Godinho, 2017).

2.5 SA's ambitious targets to decarbonise

The total GHG emissions in South Africa (excluding forestry and land use) were 544.3 $MTC0_2e$ in 2010, with their emissions per capita sitting at 10.3 $tC0_2$ per person, significantly higher than the global average (6.3 $tC0_2$ per person) (Altieri *et al.*, 2016). The countries emissions per capita are significantly higher than the United Kingdom's, while its GDP is less than a sixth as much (Baker, 2016). Energy emissions account for approximately 80% of these emissions, with coal-related combustion being most responsible (Burton, Marquard and McCall, 2019).

In 2009, South Africa pledged "to reduce GHG emissions below business-as-usual (BAU) levels by 34% by 2020 and 42% by 2025" (Altieri *et al.*, 2016). The *National Climate Change Response White Paper (NCCRWP,* 2011) published by the Department of Environmental Affairs (DEA) articulates South Africa's national climate change policy (DEA *et al.*, 2011). The white paper defines the country's GHG emissions goals as a "peak, plateau and decline" (PPD) trajectory range, which would see the peak in emissions in 2025 (between 398 and 614 $MtC0_2eq$), a decade-long plateau and a decline in emissions to between 212 and 428 $MtC0_2eq$ by 2050 (DEA, 2015). In 2015, these goals were ratified as part of South Africa nationally determined contributions (NDC) submitted in the Paris Agreement.

Achieving these emissions targets is a time-sensitive issue, from both a climate change mitigation and an economic perspective. South Africa increase its mitigation efforts and revise its future NDCs to meet the Paris temperature goal of well below 2 degrees and account for necessary additions underlined in the Intergovernmental Panel on Climate Change (IPCC) Special report on 1.5 degrees (IPCC, 2018). Low-carbon technology investment options have become cheaper in comparison to high-emitting options over the past decade (Mccall *et al.*, 2019). This has more significant implications on previously suggested intervention strategies which considered low-carbon technologies that were more expensive at the time.

The current mitigation commitments are "highly insufficient" when considering the current policy projections under the NDC, in terms Paris Agreement, according to the Climate Action Tracker[1] (2020) mitigation assessments (Climate Action Tracker, 2020). As seen in Figure 6, this rating is based on the upper range of the NDC from 2030. An analysis by McCall et al. (2019) suggests that to ensure compatibility with the Paris Agreement goals, South Africa would have to phase out coal in the electricity sector by 2040 for a cost-optimal pathway. It also suggests that both Medupi and Kusile power stations would have to be decommissioned before 2040. However, their operating life extends beyond 2050, meaning that they would become stranded assets that Eskom would be burdened by the resultant debt.

[1] Climate Action Tracker (climateactiontracker.org) is an independent source that assesses countries' NDCs in terms of the Paris temperature goals (Climate Action Tracker, 2020).

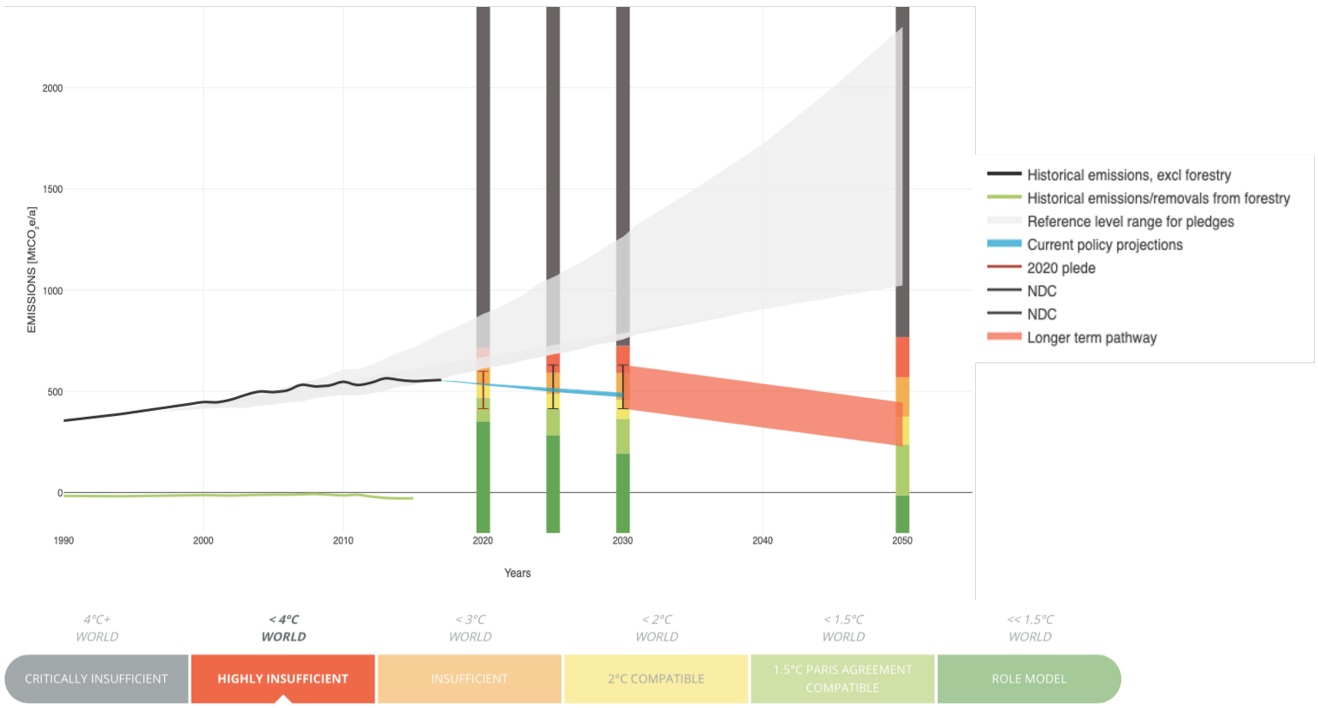

Figure 6: South Africa's emissions projections based on current policy (Climate Action Tracker, 2020)

2.6 The development of climate change policy around renewable energy in South Africa

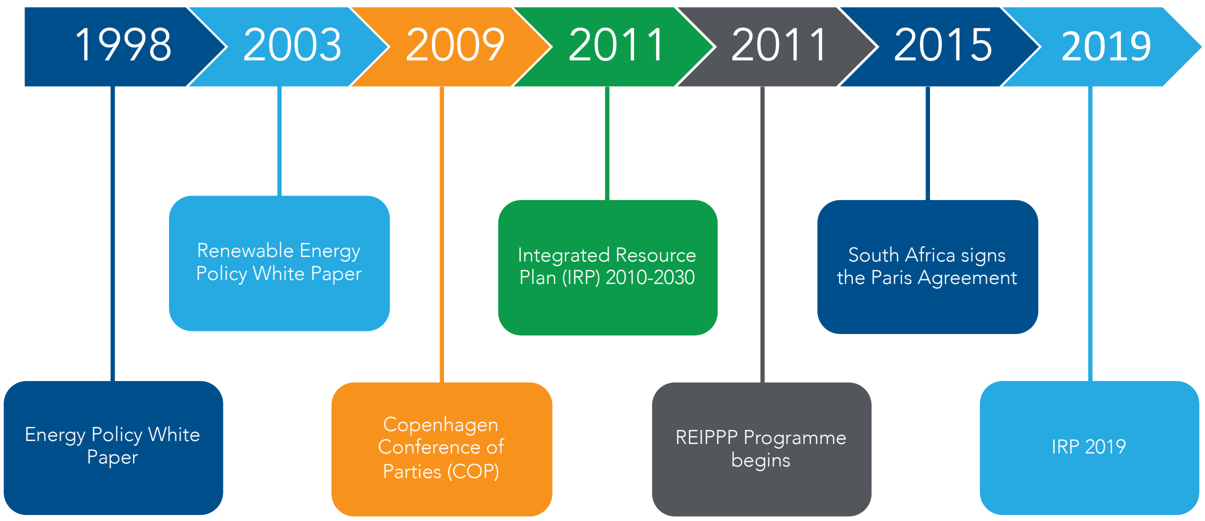

Figure 7: Timeline of South Africa's policy and planning to advance Renewable Energy

The White Paper Energy Policy of 1998 presented new energy objectives of introducing competition into the generation market and increasing diversification of the energy mix, with the government authorising a 30% generation increase from IPPs. The White Paper on Renewable Energy published in 2003 brought more clarity of the source of the new energy, as it envisaged reaching 10,000 GWh of new RE added to the generation mix (DME, 2003; Morris and Martin, 2015). Following the White Paper, the Electricity Regulation Act (2006) clarified NERSA's role as the regulator within the guidelines of the IRP, and Eskom as the sole purchaser of electricity from IPPs. This act also had significant implications on the subsequent development of the Renewable Energy Independent Power Producer Procurement (REIPPP) programme (Morris and Martin, 2015).

The IRP 2010-2030 was then published and approved in May 2011: a primary climate policy instrument establishing the energy mix for 20 years, which also formed the basis for the procurement of RE investment by the government (Morris and Martin, 2015; Burton, Marquard and McCall, 2019). The IRP was intended to be a "living document" thought should be revised and updated depending on changes to energy demand and supply in the country (Morris *et al.*, 2020). Other implementation instruments include the Carbon Tax, which is set at an ineffectively low level, and the carbon budget system which would place sectoral targets based on the PPD emissions range (Burton, Marquard and McCall, 2019).

The preparation by the government Copenhagen Conference of Parties (COP17) in 2011 was a seen as a catalyst in initiating procurement strategies for RE, that were in line with maintaining emissions caps detailed in the NCCRWP, and the IRP 2010-2030 published earlier that year (Eberhard, Kolker and Leigland, 2014). As a result, The DoE initiated the bidding process for the REIPPP Programme in 2011 to bring additional power into the electricity system through private sector investment in RE to diversify the current energy mix (Ratshomo and Nembahe, 2018). IPP Projects were selected based on a 70/30 split between price and economic development considerations, where project design had to meet specific environment, land, financial, technical and socio-economic requirements. Successful projects would enter into a power purchase agreement Eskom as the sole buyer (Eberhard, Kolker and Leigland, 2014).

The REIPPP programme has received large amounts of private investment from international project developers for and investors in both Solar PV and Wind, as well as smaller amounts from hydro, landfill gas and biomass energy (Eberhard, Kolker and Leigland, 2014). The programme has seen the completion of four bid rounds up until 2015, fostering competition with continuous price reductions as the technologies has decreased in price, as seen in Figure 8 (Eberhard, Kolker and Leigland, 2014; Burton, Marquard and McCall, 2019). Since its inception, the energy sector has procured 6 422 MW, with 3876 MW of RE made available to the national grid, which represents 18%

of 2030 national targets for renewable energy capacity according to the NDP (Ratshomo and Nembahe, 2018; DMRE, 2019).

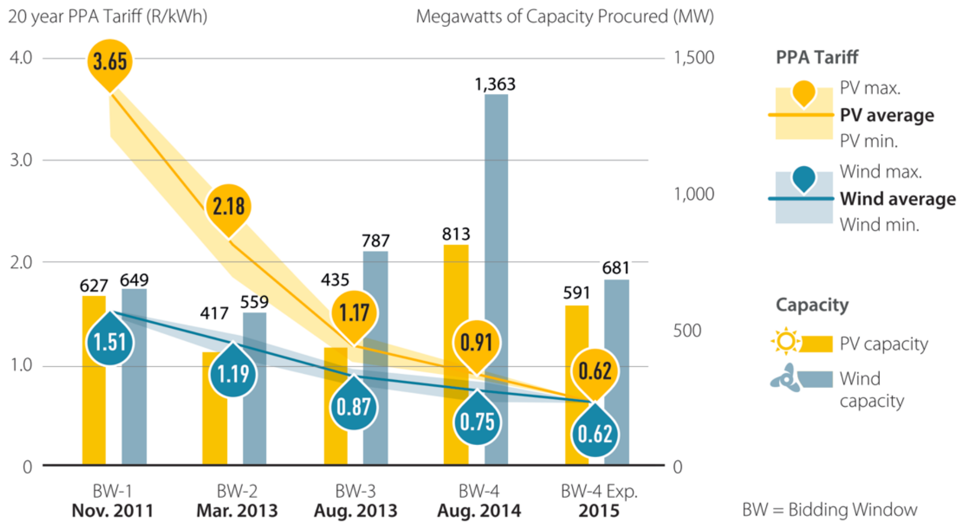

Figure 8: Historical Solar PV and wind REIPPP prices and procured capacity for each round (Burton, Marquard and McCall, 2019)

Coal has become uncompetitive for electricity production in South Africa (Burton, Marquard and McCall, 2019). The construction of new renewable plants to power South Africa has become considerably more favourable than a coal alternative as renewable energy. When comparing tariff prices on power purchase agreement (PPA) contracts, bids for new renewable projects are approximately 40% lower than that of new independent coal power plants and one-third less of the costs of new Eskom coal plants (Steyn, Burton and Steenkamp, 2017).

2.7 Structural barriers to the inclusion and expansion of renewables into the system

Climate change policy has been beset with implementation challenges. There has been significant push back on these instruments from special interest groups, business and organised labour. The politicisation of electricity in South Africa had led to substantial delays in updating the IRP over the past decade (Bischof-Niemz and Creamer, 2018). During the Zuma presidency and state capture controversies, the ensuing divisions within and between Eskom, the ruling party (ANC) and other government agencies resulted in paralysis of electricity procurement. This division was reflected in delays in REIPPP and delays in the IRP policy revisions, caused by disputes over the roles of coal, RE and highly contested nuclear, which was endorsed by Zuma's allies (Bowman, 2020). As a result, there has been no new procurement of RE by Eskom since 2015.

These policies also do not address coal extraction and the resulting coal reduction directly. Current climate policy does not take into account the socio-economic impacts and risks or the potential benefits (reduced air and water pollution, reduced price of electricity) (Burton, Marquard and McCall, 2019).

There are tensions between the mining and energy policy on the one end and climate change policy on the other, as the former has promoted the continued extraction of coal while the latter suggests a reduction in use in the medium to long-term. Currently, there are several government policy contradictions (Burton, Marquard and McCall, 2019):

- The continuous subsidisation of coal to support coal-fired electricity and the development of coal mining in new areas
- State-owned finance institutions still plan to invest in new coal mines
- The long-term coal contracts that exist between Eskom and coal mining corporations
- The inclusion of new coal-fired power plants and suggestions of nuclear in the IRP, which require subsidies from the state
- Lack of enforcement of environmental compliance in mining regulations for protected areas

The IRP is a critical instrument that will drive the decline of coal in electricity production. It is predicted that the upper and mid-PPD targets are most likely to be met without significant policy integration and probably driven by the low-carbon technology cost reductions. However, the country is not expected to achieve the most ambitious target "without high political, economic and social risk" (Burton, Marquard and McCall, 2019). Although RE makes up approximately 10% of the South African electricity mix remains significantly lower than the global power generation mix, which is almost 26% (Enerdata, 2016).

Effective implementation of policy in South Africa is usually determined by the "dynamic interactions and negotiations amongst key stakeholder, each with their agendas, levels of governance and power and susceptibility to adverse outcomes" (Morris and Martin, 2015). The DME and NERSA have come under increased scrutiny regarding their slow bureaucratic processes and decisions with regards to the procurement of electricity generation capacity over the past decade. One such criticism is that any electricity procured from IPPs by the DME may only be sold to Eskom as the designated buyer of electricity, under PPAs (Yelland, 2020b). Therefore, control of the electricity mix remains with Eskom and their capacity to buy electricity from these IPPs. This control inhibits any opportunities for power from RE to be fed directly back into localised regions.

There is substantial regulatory red-tape and complex licensing processes that have continued to stifle embedded generation for domestic (limited to <100 kW), commercial (limited to <1 MW), and industrial installations (limited to <10 MW) (Yelland, 2020a). With the lack of electricity security, many consumers have sought to invest in their generation. However, the centralised generation capacity procurement process that goes through NERSA inhibits consumers from doing so.

Having not provided predictability and certainty around future procurement of RE, the government has missed an opportunity for driving green industrialisation. Failing to sustain the REIPPP bidding process and continued uncertainty around the IRP has dismantled budding localisation movements down the RE supply chain (Morris *et al.*, 2020). During the early rounds of the REIPPP Programme, local manufacturing capacity had increased for high-value components such as wind turbines and blades. However, due to the significant risk due to the delayed round 5 of REIPPP (Eberhard, Kolker and Leigland, 2014; Yelland, 2020a).

2.8 Mitigation pathways to reaching emissions targets

McCall et al. (2019) modelled two mitigation scenarios that would be compared and interrogated against existing IRP policy projections. The reference scenario considers the least-cost mitigation plan that includes realistic changes to the cost renewable energy and batteries along with feasible new plant availabilities and compliance of the existing fleet (Mccall *et al.*, 2019). When compared with the IRPs low-carbon scenario, it argues that current policy does not reflect the least-cost pathway and pricing of low-carbon technologies is outdated. The second scenario proposed was an ambitious least-cost mitigation scenario that would be compatible with achieving the Paris Agreement's temperature rise limit (Mccall *et al.*, 2019). This would see the future supply coming primarily from wind and solar PV, with no new coal or nuclear power plants constructed or developed and with pre-existing plants requiring subsidies from consumers (Mccall *et al.*, 2019).

With regards to the reference scenario, the electricity sub-sector would not fully decarbonise and will include large-scale retrofitting of 31 of Eskom's power stations to reduce emissions by 2025. This scenario would still result in lower emissions than the proposed emissions budget allocated to the electricity sector in the IRP 2019 (Mccall *et al.*, 2019).

The least-cost mitigation scenario incorporates emissions budgets. Compared with the reference scenario, the accelerated investment would see RE increase to 99% of the electricity mix by 2050. According to an analysis conducted by McCall et al. (2019), economic pressure is likely to cause significant reduction in coal production, resulting in a decrease on demand for coal-powered electricity generation (Burton, Marquard and McCall, 2019; Mccall *et al.*, 2019). As seen in Figure 9, the accelerated investment into RE will result in coal capacity coming offline by 2040. This study illustrates the importance of large-scale procurement programmes for battery technology to ensure that there is sufficient storage capacity for variable renewable energy. It also highlights that the current climate policy targets can be more aggressive, even in the reference case in comparison, achieves lower emissions than the IRP budget (Mccall *et al.*, 2019).

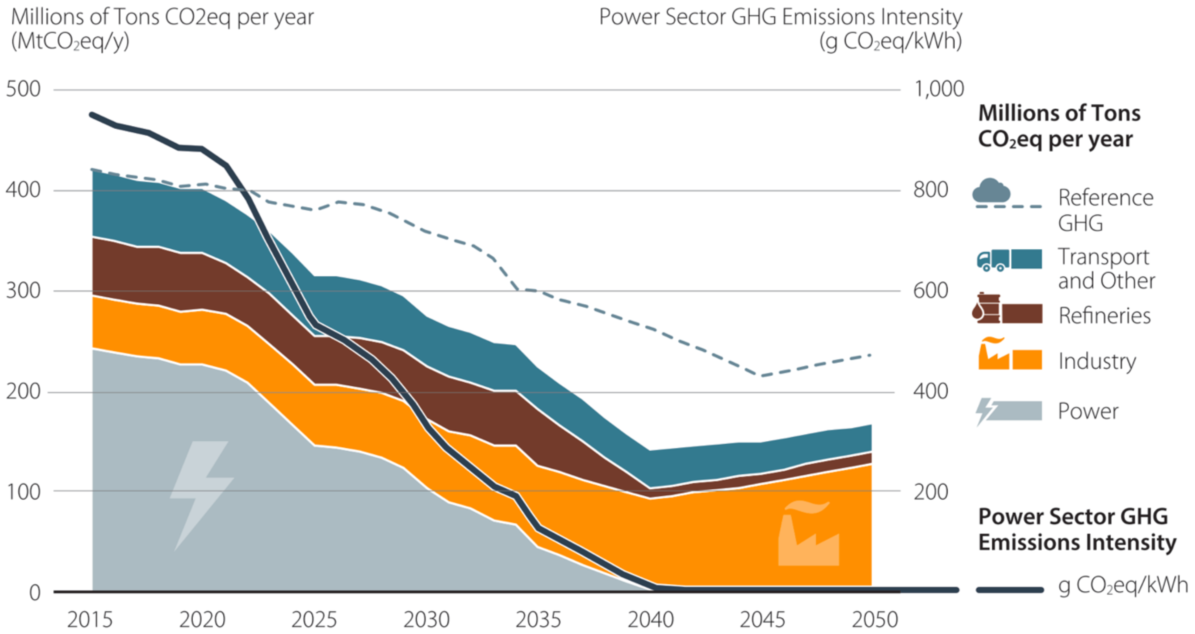

Figure 9: Sectoral Emissions in the least cost, Paris Agreement Compatible Pathway (Burton, Marquard and McCall, 2019)

Natural gas has been used as a transitional fuel globally as it produces less GHG emissions as fossil fuels such as oil and coal and has compensated for the stable and dispatchable electricity that those fuels provide (DMRE, 2019). The main challenges for South Africa in following previous transition model is establishing reliable sources and infrastructure for transitional fuels. The IRP includes an increase of power procurement from gas in the next 10 years to complement increased RE capacity. In the short-term, natural gas would need to be imported and piped gas systems would need to be developed from neighbouring countries or potential domestic regions (DMRE, 2019).

2.9 Achieving a "Just Energy Transition"

According to the ILO guidelines, a "just transition is one that considers the interrelated economic, social and environmental dimensions of sustainable development" (ILO, 2015; Burton, Marquard and McCall, 2019). ILO guidelines on what constitutes a just transition are "coherent policies across the economic, environmental, social, education/training and labour portfolios need to provide an enabling environment for enterprises, workers, investors and consumers to embrace and drive the transition towards environmentally sustainable and inclusive economies and societies" (ILO, 2015).

Over the past two years, the RE debate has shifted from the technical feasibility of the energy transition to the required policies to manage the transition. Transition policies for coal regions need to coincide with climate change mitigation policy. Any coal transition strategies must consider and promote socio-economic development more broadly due to the increased fragility of the country's economy (Burton, Marquard and McCall, 2019). The Congress of South African Trade Unions, along with its affiliated National Union of Mineworkers (NUM), have for long supported and advocated for a JET, but have called for a clear transition plan to be developed that ensures that coal miners are retrained and reabsorbed into the new green economy (COSATU, 2012; IndustriALL, 2018).

Strategies that ensure the coordination of stakeholders working on "coal closures, local economic development and national energy, education and development priorities" are also needed in this transition (Atteridge, 2020). In groundWorks report *"The Destruction of the Highveld"* (2017), the critical elements of a JET are (Hallowes and Munnik, 2017, p. 180):

- "a new energy system based on socially-owned renewables;
- new jobs in renewables;
- large scale restoration and detoxification of ecosystems injured by the fossil fuel economy on the Highveld;
- a new and healthier food economy;
- healthier and climate-wise housing;
- a new and healthier transport economy;
- a reorientation and expansion of municipal services;

- a basic income grant for all. "

There have been positive signs that have come from a government that seeks to ensure the development of coal communities as coal plants are decommissioned. The Minister of the DEA has moved ahead with plans to declare coal and gold towns as RE development zones (REDZ) across the country. These are seen as "priority areas for investment in the electricity grid" and will enable increased penetration of RE (Creamer, 2020b). This also aims to be a catalyst for the reestablishment of localisation of RE component manufacturing in South Africa.

The new roadmap for Eskom from the DPE (2019) indicates that the government and the parastatal aim to mobilise the resources needed for a JET, coordinating the relevant stakeholders to "ensure minimal impact on communities and workers" (DPE, 2019). Eskom has established its Just Energy Transition office and has begun to assess options for repurposing their decommissioned coal stations (Creamer, 2020c).

2.10 Context of this research within the current literature

In summation of the review of literature, the historical context of the electricity system and the introduction of RE over the past 25 years, illustrates "the complexity of involving both state-owned utilities and IPPs in hybrid power markets" (Eberhard *et al.*, 2011). The importance of establishing governance mechanisms for fair and transparent capacity expansion, precise allocation of planning and procurement functions, and maintaining flexible and up-to-date IRPs has been highlighted. Aligned to this, it re-emphasises the significance of moving away from a monopoly system controlled by the state and Eskom. It presents South Africa's intentions and movements towards RE along with proposed mitigation pathways. It concludes with drawing significance to strategies that establish a "just" transition away from coal.

Although the complexity and challenges for the JET are clear, there has been a limited effort in aligning holistic pathways and articulating the possibilities for collaboration of relevant stakeholders. In order to address this gap, analysis of the electricity diagram using systems thinking (ST) methodology, along with insights from relevant stakeholder perspectives, are then used to identify and coordinate intervention strategies that will facilitate a just and fair transition.

3 Methodology

This chapter presents the methodology that was followed to answer the research questions of this study. It discusses the systems-thinking (ST) approach that was used to explore the research along with the process used to develop a ToC framework.

Meadows (2009) describes a system as "an interconnected set of elements that is coherently organised in a way that achieves something" (Meadows, 2009). This qualitative system mapping exercise assumes that a successful energy transition within the electricity system is a result of the interplay between a range of factors and elements, for example, how "policy setting and implementation" by the government enables the "regulation of IPP procurement" in the electricity sector (presented in Chapter 4.2 below). Therefore, the electricity system was defined as the sum of all relevant factors and interdependencies that determine the conditions of a transition towards RE sources of generation in South Africa. The ability to see the electricity transition challenge at a systems-view level enables one to understand the interconnectedness of the critical elements and factors within the system and identify the leverage points to affect the desired long-term change (Sterman, 2002). This method draws from literature and interviews with key stakeholders to define system elements and identify the causal linkages between the elements in the system.

3.1 Literature Review

A key input to the ST approach is the literature review. The investigative approach used to conduct a review of the literature is presented in Chapter 2.1.

3.2 Semi-structured interviews

The semi-structured interviews would serve two purposes: to complement the review in establishing an in-depth and nuanced understanding of the research problem needed for the construction of the systems model; and determining the critical intervention strategies and actors that could drive a just transition. The interview included open-ended questions that covered the participants' experience, the drivers and barriers of the transition to RE from their organisation's perspective, critical considerations for a JET, current and potential intervention strategies to promote a JET and stakeholder coordination to that purpose. The themes and broader questions covered are summarised in Appendix A.

Interviews were conducted over one-hour long periods to enable sufficient depth in discussion that would encourage participants to speak freely and reduced constraint. Twenty participants were selected across the various electricity sector stakeholders and based on their experience and engagement with the transition towards renewable energy. Due to availability and time constraints, findings did not include contributions from municipalities and labour unions. These are important stakeholder groups that were referred to within the interviews; however, whose narrative was not sufficiently reflected on with the participants. As a result, trade union and municipality responses to the transition were explored through literature. As mentioned, the energy and mining sector is key to addressing gender inequality and promoting Black empowerment in South Africa (The Presidency: Republic of South Africa, 2004; NPC, 2012). Therefore, gender and race were considered in determining the diverse grouping of men and women that were interviewed. Aligned with the ethical consent provided, only some personal details were included in this dissertation, namely the type of stakeholder group they represent, type of organisation, role, and years of experience in the electricity sector will be revealed. Table 1 provides a list of the participants' details, with personal detail.

Table 1: Interview Participants' details

Participant No.	Role	Type of Organisation	Years of Experience
1	Founder and CEO	RE Independent Power Producer	10+
2	Former CEO/Founder	Public Electricity Utility/RE Independent Power Producer	30+
3	Former Senior Executive/Co-Founder	Public Electricity Utility/Power Sector Consultant	30+
4	Study and Design Engineer	RE Independent Power Producer	10+
5	Head of Origination and Investment	Battery Storage and RE Independent Power Producer company	10+
6	Vice President/Chairman	Business Association: Policy development for Private Business in the energy sector/State and Business Advisory	20+
7	Energy policy researcher focusing on the South African coal sector, electricity, and industrial policy.	Energy Research Group at a tertiary institution	10+
8	Energy Sector Analyst/Energy Advisor	Media Publishing in Energy and Technology/State Institution	40+
9	CEO	RE Independent Power Producer	10+
10	Emeritus Professor	Energy Research Group at a tertiary institution	35+
11	CEO	Battery Storage Company	30+
12	MD/Director	RE Private Investment Company/RE Independent Power Producer	30+
13	Junior Research Fellow	Energy Research Group at a tertiary institution	10+
14	CEO	Coal Mining	20+
15	Power and Renewables	RE Private Investment Company	10+
16	Energy & Environment Policy Manager	Business Association: Policy development for Private Business in the energy sector	10+
17	CEO/Former Board Member Responsible for Electricity	RE trading company/National Energy Regulator	30+
18	Director/Non-Executive Director/Board Member/Former Deputy-Director General	Energy Research Group at tertiary institution/Public Electricity Utility/Energy Regulator/DME	30+
19	MD/Former CEO/Former Deputy Director-General	Power Sector Consultant and RE Private Investment/Energy Regulator/DME	30+
20	Former Director-General	DEA	10+

Interviews took place over an online platform (i.e. Microsoft Teams and Skype). With prior ethical approval and participant consent, interviews were recorded and transcribed. Thematic coding was conducted to analyse the interviews, using Atlas.ti software. As codes emerged from both the literature review and interviews, an abductive coding approach for content analysis was used to group codes and identify parallel themes (Leech and Onwuegbuzie, 2007). Examples of coding and groupings are presented in Appendix B. To evaluate the credibility of the findings, a validity check was performed based on Harding's *Qualitative Data Analysis* (2019) and a method of Triangulation, discussed further below (Hastings, 2012; Harding, 2019). These methods included evaluating the consistency of data by reading through the transcripts more than once, reviewing notes taken during interviews with the participants, discussion of findings with other professionals and academics in the energy sector in the South African context, and comparisons with literature.

3.3 Systems-thinking approach

ST methodology helps to provide a holistic view of a complex system, by creating a broader perspective of a multifactorial problem that is useful to develop solutions (Tejeda and Ferreira, 2014). It has been applied in various studies within the context of renewable energy across the world (Sterman, 2002; Meadows, Randers and Meadows, 2004; Tejeda and Ferreira, 2014; González *et al.*, 2016; Lee *et al.*, 2017; Rebs, Brandenburg and Seuring, 2019; Tan and Yap, 2019; Sunitiyoso *et al.*, 2020). Therefore, a ST approach is useful in exploring a renewable energy transition that would promote just energy transition in South Africa. The method is explained in greater detail in the sub-sections that follow.

3.3.1 Defining the system elements

The system elements in this research, also referred to as "factors" or "variables", are the characteristics that can influence the transition towards renewable energy in the electricity system. The knowledge base of the system's variables consists of an extensive review of literature, contributions from the stakeholder interviews. When using this systems approach, the boundaries of the systems need to be clearly defined (Lee *et al.*, 2017). In this study, the boundaries are determined by the context of electricity supply in South Africa, the research questions and the scope, provided in Chapter 1.4. Having identified key themes in the literature review, open-ended questions were developed for the semi-structured interviews to identify nuanced elements and their interlinking relationships.

3.3.2 Mapping the electricity system

Having defined the system elements in the previous step, a qualitative CLD was created to illustrate the current layout and operation of the South African electricity system in alignment with a transition towards RE. This was created by identifying the various causal relationships between the system elements. A CLD serves as an aid to make sense of and communicate the systemic complexity of a problem as well as a means to identify opportunities to intervene (Vandenbroeck, Goossens and Clemens, 2007). An example of the Korean electricity system is presented in Figure 10:

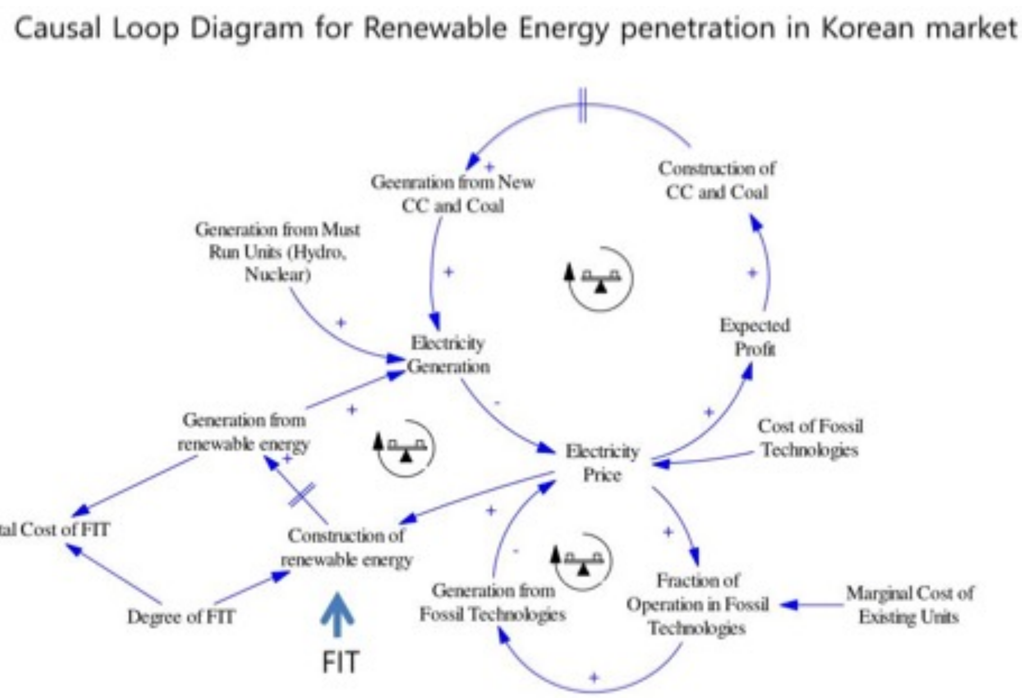

Figure 10 CLD of the Korean electricity system (Ahn, 2005)

The causal relationships between the system elements were based on findings from both the literature and interviews and logical reasoning. An iterative modelling approach was followed to update these relationships as more information was collated from the sources. The elements and the relationships between them are conceptually modelled and visually represented in a CLD. The CLD was developed to:

- Visualise, understand, and qualitatively analyse the complex systemic structure of the electricity sector in response to climate change
- Help identify and visualise gaps and leveraging points within the electricity system that will drive towards low-carbon technologies
- Develop intervention strategies necessary to drive towards a just energy transition

The system elements are categorised into their respective dimensions of sustainable development, namely, environmental, economic, social, institutional and technical (Mcneill, Verburg and Bursztyn, 2011). The causal relationships between the elements are represented by arrows that can either indicate a positive or negative causal effect, as seen in Figure 11. A positive (reinforcing) relationship suggests that the effect is positively related to the cause, which implies that a change in the "cause" will produce a change in the "effect" in the same direction. Conversely, a negative (balancing) relationship implies that a change in the "cause" will produce a change in the "effect" in the opposite direction (Fenner, 2019). The sign of the relationship (positive or negative) depends on the conceptual phrasing of the variable (element). Some causal relationships do not result in an immediate change in the affected variable as there may be a relative delay. If there is a time delay in the resultant change caused by an element, this is depicted with two lines that strike the arrow, as seen in Figure 11. For example, as depicted in Figure 10, there is a delay between "construction of RE" and the "generation of RE" because construction takes place over time. A variable can either be phrased negatively or positively, which would then have an impact on the sign of the causal relationship. Therefore, the modeller should take great consideration in ensuring that the variable is phrased intuitively and clearly (Vandenbroeck, Goossens and Clemens, 2007).

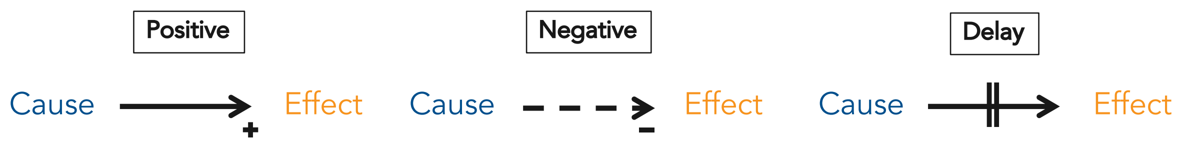

Figure 11: Representation of positive and negative causal relationships - adapted from (Fenner, 2019)

Feedback loops or circular causalities are significant features of a CLD that represent the dynamic behaviour that exists within a system (Vandenbroeck, Goossens and Clemens, 2007). A reinforcing (or positive) loop is self-enhancing sources of growth or decline. A balancing (or negative) loop is a source of stability in a system, as the chain of causalities drives the loop towards a state of equilibrium (Fenner, 2019). The R and B depicted in the systems maps (see Chapter 4.2) refer to a reinforcing loop and balancing loop, respectively.

3.3.3 Identifying leveraging points

To effect change within a system, leverage points are identified in the CLD of the electricity system. These leverage points refer to system elements that can affect systemic change, usually elements that are "hubs" for interconnections with other elements (Vandenbroeck, Goossens and Clemens, 2007). Meadows (1999) defines 12 places at which to intervene in a system (D. H. Meadows, 1999). These 12 leverage points range from "shallow points" that result in small changes to the system's behaviour, to "deeper points" that potentially yield significant "transformational change" (Abson *et al.*, 2017).

Having completed the CLD of the electricity system, the leveraging points are identified by calculating the number of outward causal relationships that each element has with other elements. The elements that cause change to multiple elements are isolated as they have a wider sphere of influence on the system. Meadows' model (1999) was then used to arrange these key variables in accordance with their level of effectiveness and feasibility. These 12 places to intervene are detailed in Figure 12 and are separated into four types of system characteristics:

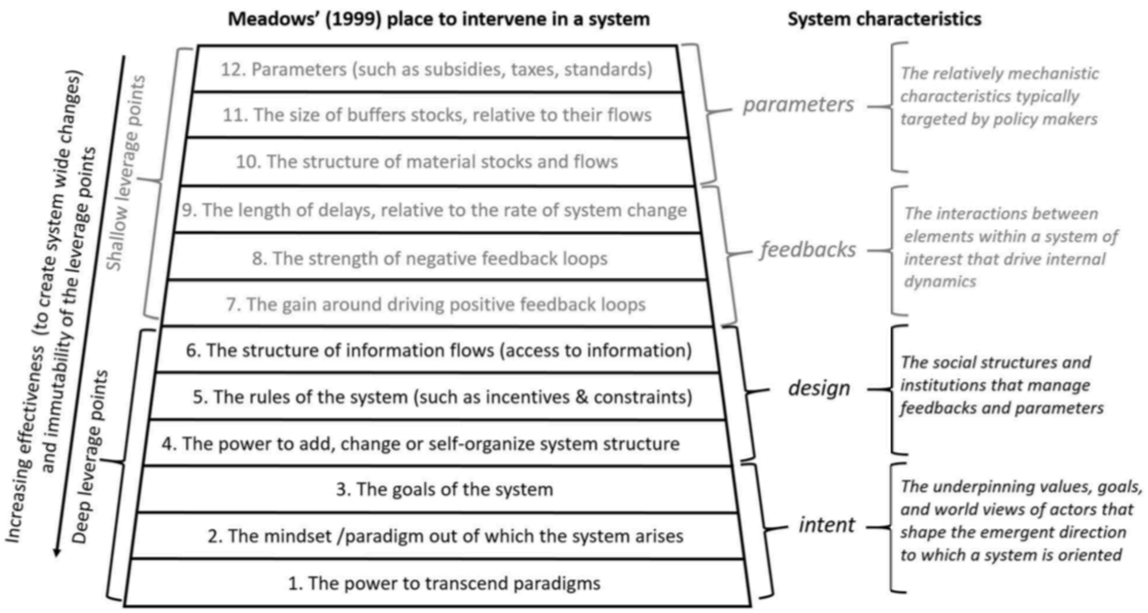

Figure 12: 12 Leverage points that are aggregated into four system characteristics (Abson et al., 2017)

3.3.4 Developing intervention strategies

The final step in the ST approach is developing intervention strategies that are aligned to the leverage points that have been identified. Through a process of data triangulation, interventions strategies were identified from the literature review and the thematic analysis of semi-structured interviews, as seen in Figure 13 below. Triangulation aims to align "multiple perspectives" gathered from different sources to "enhance the credibility of a research study", which usually include qualitative methods of research (Hastings, 2012). These intervention strategies were then organised into the broader dimensions of sustainable development mentioned above and aligned to the relevant stakeholders that would be responsible for implementation.

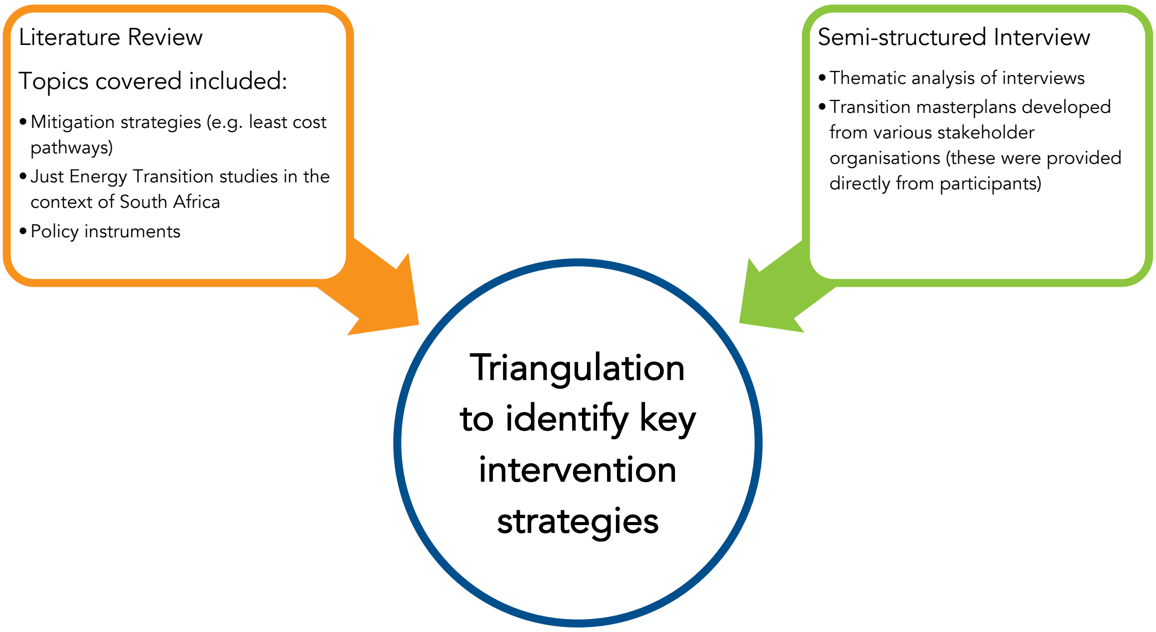

Figure 13: Triangulation process to develop key intervention strategies

Beyond what was presented in the literature review, more peer-reviewed and grey literature were explored to identify intervention strategies that would drive the success of a transition away from coal. These pieces of literature were recommended and provided by the interview participants. The broader topics they cover include:

- Mitigation strategies that focused on least-cost pathways to achieving South Africa's emissions reduction targets (Bischof-Niemz and Creamer, 2018; Lawrence, 2019; Mccall *et al.*, 2019; Roff *et al.*, 2020)
- Just energy transition planning (Halsey *et al.*, 2017, 2019; Hallowes and Munnik, 2019; Greencape, 2020; SAREC, 2020).
- COSATU's policy paper called *A just transition to a low-carbon and climate-resilient economy* (2012) was explored in detail as it that presents key initiatives that are focused on supporting coal regions in the transition (COSATU, 2012).
- Policy instruments used to drive change towards RE (Burton *et al.*, 2018; Yelland, 2020a)

As discussed previously in section 3.3.2, the complete CLD represents the electricity system in its current state based on findings. Having developed intervention strategies necessary for a transition, the complete electricity system CLD was modified to include the critical elements that would enable a successful transition towards RE. These critical elements are discussed in alignment with the identified intervention strategies

3.4 Theory of Change (ToC) Framework

In this research, the ToC framework was used to map out a pathway towards the desired and envisaged electricity system of the future. In this context, the desired future was informed by the national targets set out in the IRP (2019), the role of various stakeholders in the electricity sector in achieving goals set out in the NDP and commitments that are aligned to the NDC. This framework acts as a synthesis of findings and results developed in the ST approach.

ToC is a dynamic approach that defines how a series of interventions are expected "to lead to a specific development change, drawing on a causal analysis based on available evidence " (Norfund, 2019). This approach derives from program theory, where it was traditionally used in the context of improving evaluation theory and practice in the field of community initiatives in the 1990s (Stein and Valters, 2012). It has now evolved to be used widely in development and informed social programme practice and evaluation, from grass-roots initiatives in developing countries to large organisations (Stein and Valters, 2012; Vogel, 2012).

3.4.1 Core concepts of ToC

ToC refers to the development of a framework that articulates "the underlying logic, assumptions, influences, causal linkages and expected outcomes of a development program" (Jackson, 2013). ToC has a variety of purposes such as strategic planning, monitoring and evaluation, communicating a change process and a means to develop an organisational or programmatic theory (Stein and Valters, 2012). As Vogel suggests, ToC is a flexible approach that encompasses the following core concepts (Vogel, 2012):

- Social Science theory – a contextual understanding and situational analysis of social, political and environmental conditions and assessing opportunities and actors able to influence change
- Desired impact – statement of long-term change that results from a sequence of anticipated outcomes along an intended pathway
- Beneficiaries – understanding whom the interventions aim to impact and how
- Actors – the relevant stakeholders and supporting networks that influence change within the desired context. It is useful to use this framework to establish an accountability structure for the various interventions

- Assumptions – Assumptions are particularly important. These should be linked clearly to an aspect of the change process in providing the explicit interpretations of how change might occur in this context
- Sphere of Influence – Evaluating the ability of the interventions to effect the desired change in the sector
- Timeline – A projected timeframe or sequence of how the change will occur
- Indicators – metrics to investigate and track the impact

  Interventions – component of the project

Visual representations are used to communicate conceptual analysis of the framework that reveal the core concepts considered in the context it has been used and can articulate pathways for change (Vogel, 2012). It is useful to use a process-mapping approach to build out the change pathways (Vogel, 2012). Figure 3 is a diagram visualising the ToC roadmap, with details of each intermediary step:

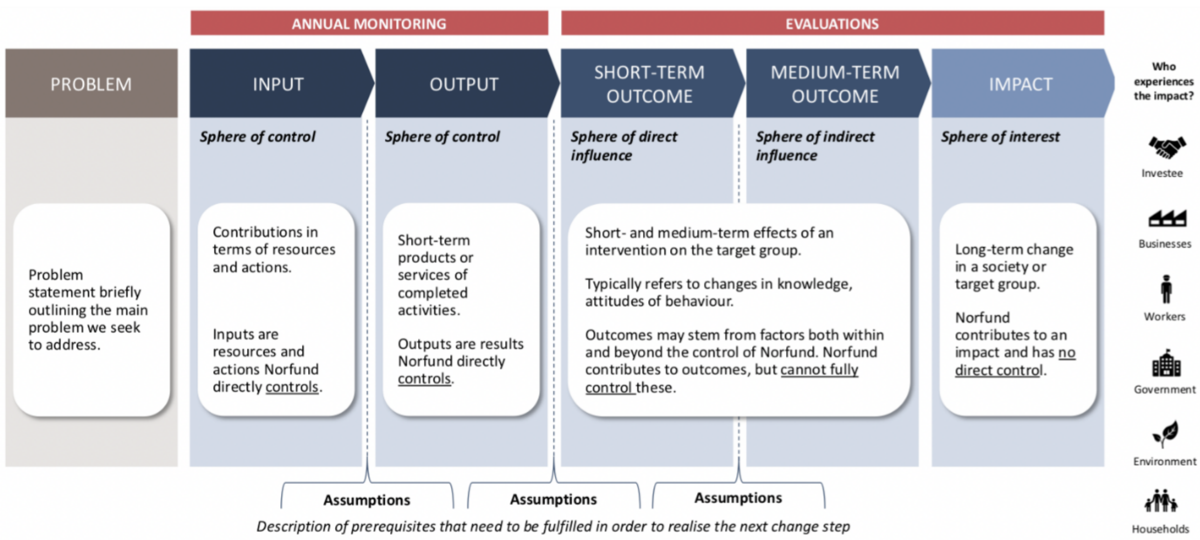

Figure 14: Theory of Change Framework (Norfund, 2019)

ToC is useful in aligning all relevant stakeholder needs and ensuring that there is an agreed understanding of the desired outcomes and impacts. Creating a clear ToC for interventions across the sector helps to create synergies and consensus amongst stakeholders and "provides an overarching theoretical framework which clearly identifies knowledge gaps" (De-Silva and Ryan, 2015).

As part of the discussion of results, the ToC aims to complement initial systems-thinking findings as a unifying framework for articulating and communicating potential strategic interventions and decision-making necessary to drive the electricity sector towards RE.

An in-depth understanding of the context and strategies to drive the energy transition are provided through the systems-thinking methodology. This was a useful starting point from which the ToC framework was developed as a blueprint to consolidate and sequentially link the proposed interventions leading to the desired long-term change.

An overview of the methodology that has been discussed in this chapter is presented below.

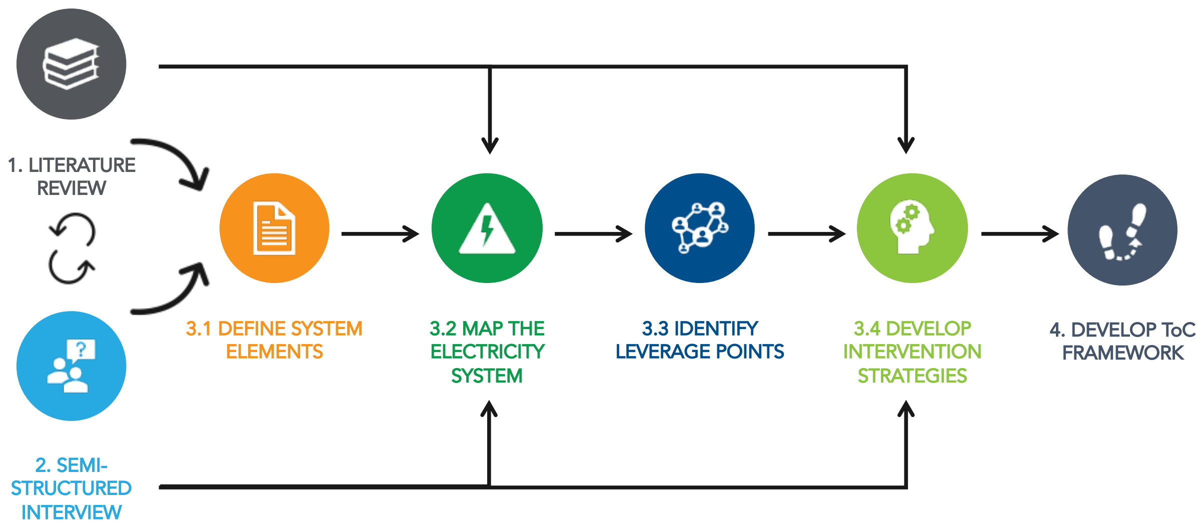

Figure 15: Overview of methodology

The ST approach and ToC Framework are developed and discussed in the Chapter that follows.

4 Results

This Chapter presents the findings from the methodology used in this study. It describes the results from the systems approach, detailing the system element interactions as per the CLDs that have been created, the leveraging points that were identified, and finally, the intervention strategies that were developed.

4.1 Systems elements

The various system elements were identified, having captured the current electricity sector structure, factors and causal outcomes, through a review of the literature and semi-structured interviews. In total, 67 elements were included in the systems map and categorised into their respective dimensions of sustainable development. The system boundaries are defined by the scope provided in the introduction.

4.2 Causal loop diagram of the South African Electricity System

In this section, CLDs of the South African electricity sector are presented under the sustainable development dimensions. The CLDs represent the current system at a high level with the key factors that were extracted and synthesised from literature and various stakeholders. In the following sub-sections, the system is analysed under the five main dimensions: institutional, economic, technical, social and environmental, respectively. Within these dimensions, key relationships, reinforcing loops (**R**), balancing loops (**B**) and interconnections between dimensions are discussed, drawing from themes explored in the interviews.

Figure 16 depicts the CLD of the complete electricity system in its current state, with each dimension being represented in a different colour. As can be seen, the significant number of causal relationships illustrates a high level of complexity and the many cross-dimensional interactions that take place in enabling the system to function. The arrows indicate the causal relationships; the solid arrows indicate that the effect is positively related to the cause and the dashed arrows indicate an inverse change to the effect. In the following sections, the system is analysed in the context of each dimension, where vital elements, causal relationships and feedback loops are discussed in detail.

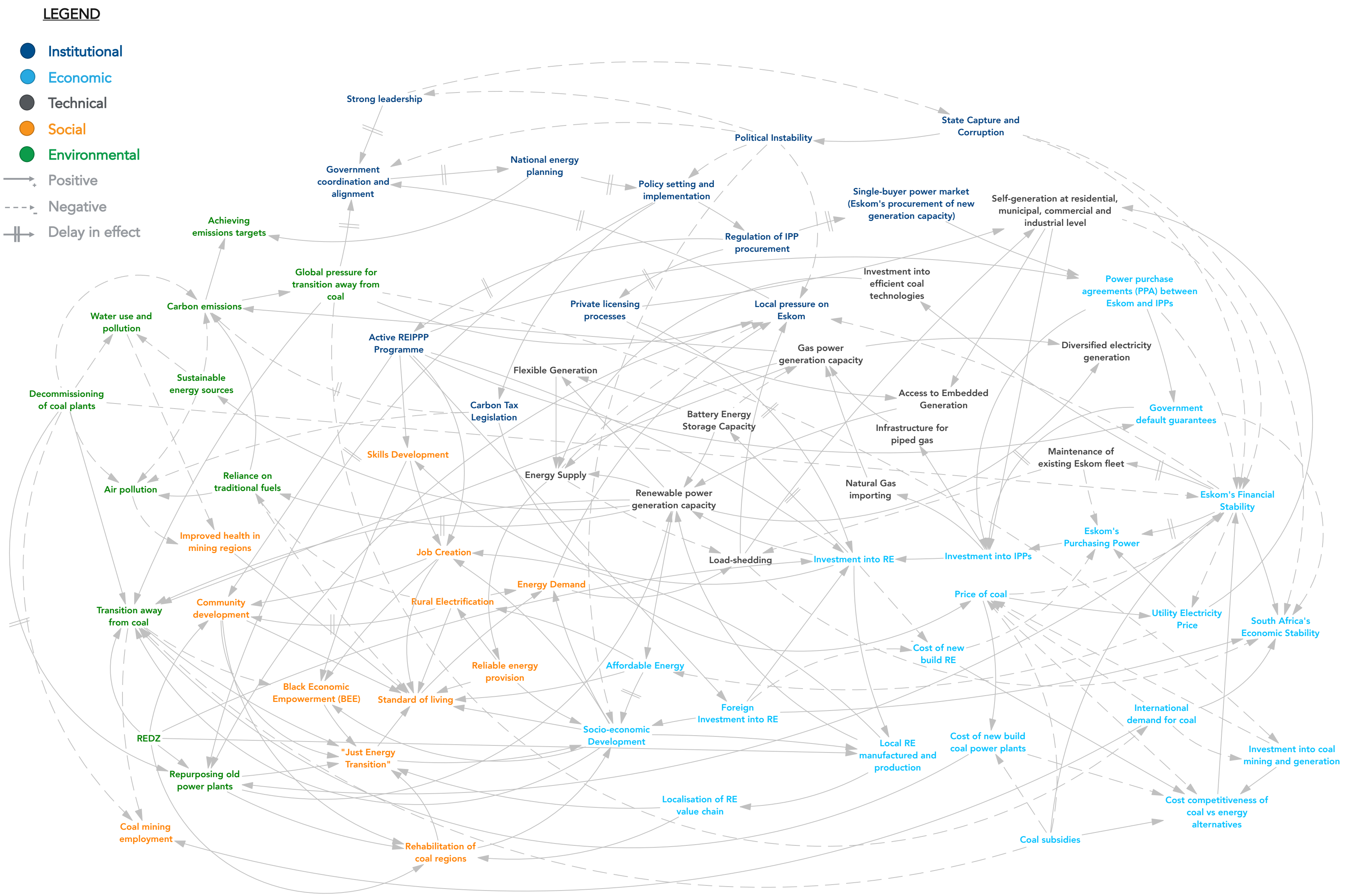

Figure 16: Full CLD of the South African Electricity System

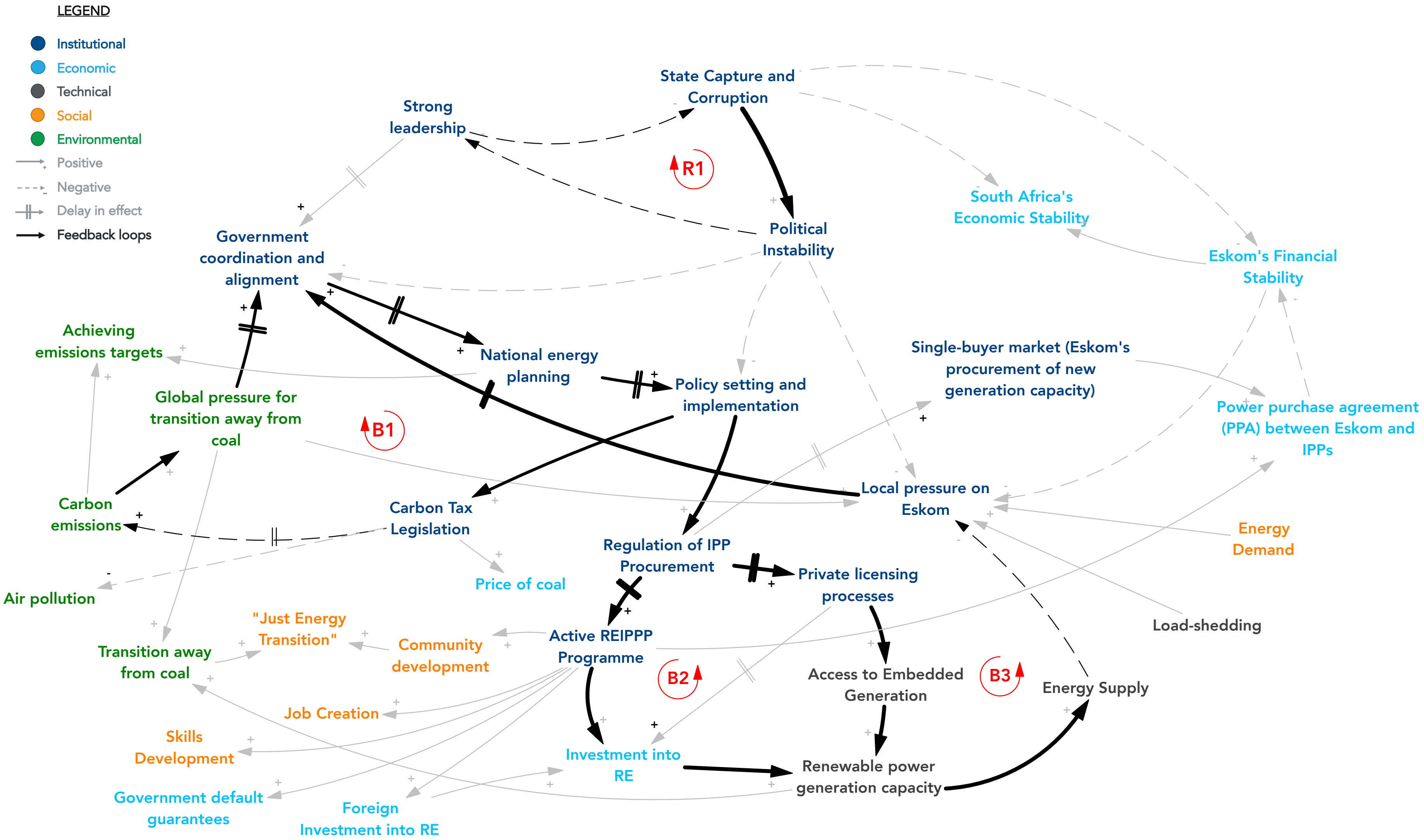

Figure 17: Institutional Dimension

4.2.1 Institutional Dimension

The institutional dimension (Figure 17) is at the core of the electricity system, as public entities are the driving force behind regulation, policy, planning, generation, transmission and distribution of the power supply. Unlike market-driven approaches to driving the system in the developed world, the state and its national utilities in most African countries are at the core as they control the planning and procurement function of electricity (Eberhard *et al.*, 2016). The institutional dimension comprises of 12 elements that interact with all of the other dimensions to produce three integral balancing loops and one reinforcing loop. It encompasses the influence of the governance structure of the sector, which includes the government departments, Eskom and other state institutions.

The electricity system has been heavily impacted by “state capture and corruption”, leaving the country in political turmoil. **R1** demonstrates how the continued “political stability” has significantly impacted the leadership within government, Eskom and other state institutions.

B1 represents the balancing loop indicates how a carbon tax could drive towards a carbon emissions reduction. “Global pressure to transition away from coal” has been a catalyst for response by the state to implement climate change mitigation efforts. Participant 20 has confirmed that the Carbon Tax Act of South Africa has now been put into law, that will require larger emitters to license their emissions activities and pay a yearly environmental levy.

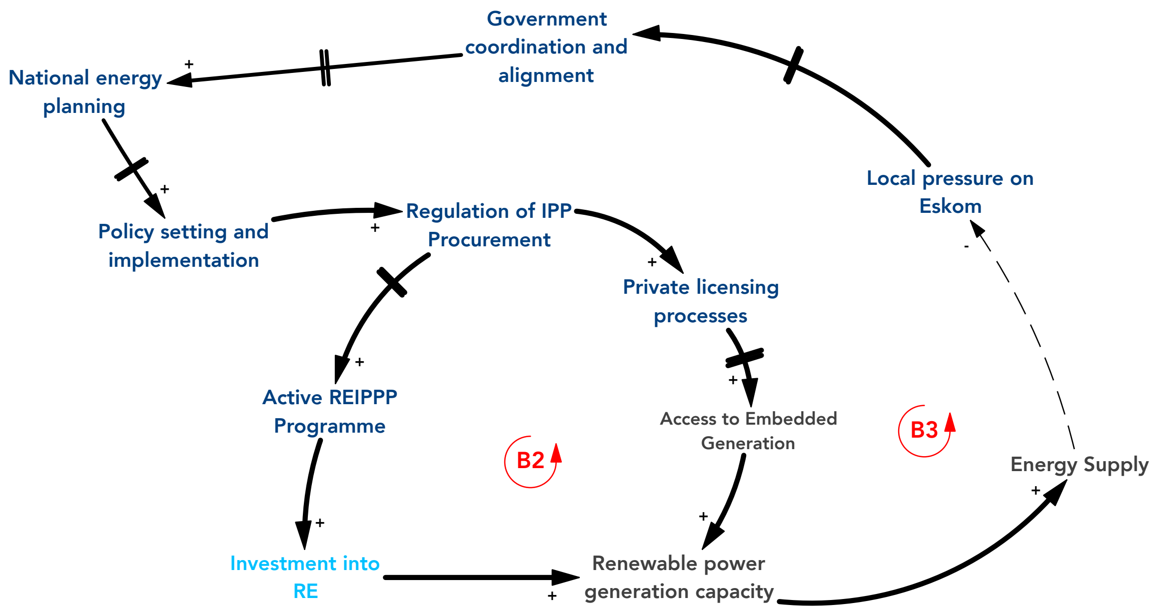

Figure 18: Loops B2 and B3

B2 (Figure 18) illustrates how an "active REIPPP programme" increases RE generation capacity, which in turn reduces pressure on Eskom. 16 participants have commended the globally recognised public bidding process because of the rigorous nature of the programme limited opportunities for corruption. Therefore, the REIPPP programme must remain independent of political interference once it is active.

11 participants have also argued that the system is plagued by bureaucratic regulation and procurement processes. This is evident in the delays in updating the IRP, which came nine years after the first IRP 2010-2030 policy report. Delays result in decision making that is outdated due to outdated assumptions for changes in technology and prices for RE. These participants have identified the need for planning that is more flexible and responsive.

In loop **B3** (Figure 18), the issuing of generating licenses for embedded generation reduces the strain on Eskom significantly. With the current unreliable electricity supply, many consumers have been driven to find alternative sources. However, 6 participants have affirmed that the current licencing regulation is slow and restrictive. The licensing process can take up to 2 years from the application, meaning that new capacity can only come online after 3 years. It is estimated that several mining groups are prepared to add 1500MW of Solar PV capacity in the near term, highlighting the need for energy regulation that is more supportive for private RE investments (Creamer, 2020a).

Participant 7 pointed out that, “government is not moving to renewable energy at the pace and scale that is required to address energy security constraints.” It must be noted; however, that the government is not a monolith as the various departments have different views on how the transition and the electricity sector reform should take place. As a collective, the “government’s role is to write the rules that would be needed to facilitate the engagement of the private sector” (Participant 7); however, this is not taking place. This is due to conflicting interests and a lack of alignment amongst government departments and other stakeholders. As mentioned in the literature, plans to unbundle the electricity sector date back to 1998. Participant 2 ascribes the failure to go forth with plans to unbundle to the failures in executing government policy. Delays in execution are indicated in the balancing loops above.

Associated with the “political leadership” element of the system, a bottleneck identified by 11 participants is the DMRE ministerial determination and approval required to move procurement and regulation plans forward. As explained by participant 2, it is a legislative requirement put in place to limit stranded assets (e.g. RE power plant), in the event when there is an investment into increasing generation capacity, but the power is not needed. This has halted the progress of the REIPPP programme since 2015 as leadership was influenced by political instability during Zuma’s presidency. Therefore, strong leadership is critical in advancing the RE industry. Alignment between all government departments is incredibly fundamental in driving the sector forward in any direction.

In July 2020, the minister of DMRE called for the formation of a Ministerial Renewable Energy Sector Engagement Forum for all stakeholders, that would aim to address bottlenecks that are currently “inhibiting the implementation of government policy and planning with regards to the delivery of RE in South Africa “(participant 8). Many of the participants interviewed attended the founding meeting and reflected on it being a positive step in the right direction towards providing a just transition.

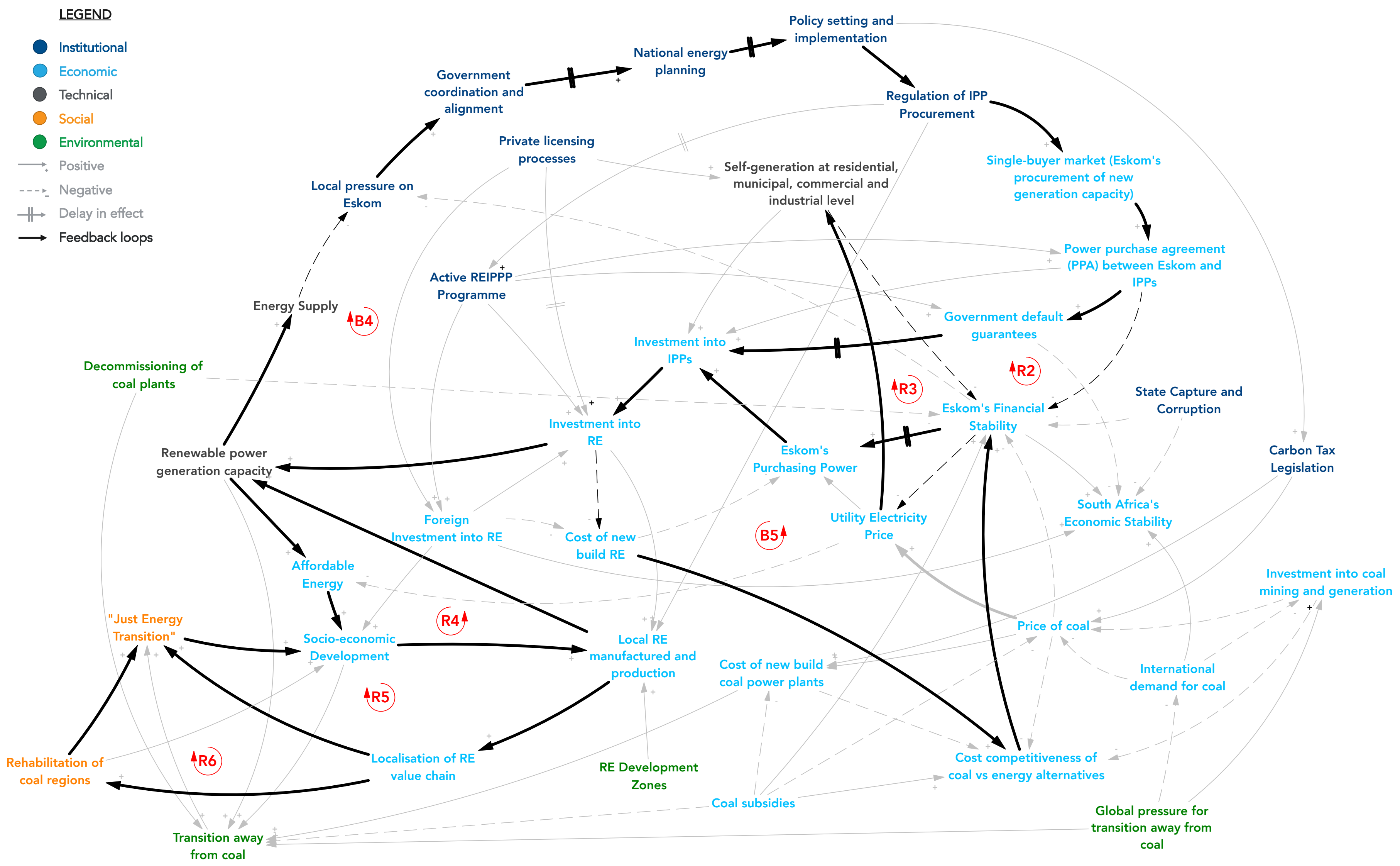

Figure 19: Economic dimension

4.2.2 Economic dimension

The economic dimension (Figure 19) illustrates the economic drivers of the system. It includes the RE development impacts as well as the economic impacts of the coal sector. The economic dimension comprises of 20 elements that interact to produce 2 balancing loops and 5 reinforcing loops.

The current system operates on a vertically integrated single-buyer model through Eskom, which is the significant barrier within the economic dimension. Participant 1 argues that "there's a lot of institutional resentment about renewables". This is in part due to Eskom's role in incurring the cost of transmission and distribution of the power generated from RE, and the government (the National Treasury) incurring the debt of PPA's through the government guarantee if the IPP defaults. Therefore, it is understandable that in Eskom's current governance, financial and operational situation, they would not be in favour of further investment into IPPs. Financial institutions are also risk-averse with regards to funding IPPs which necessitates the need for government guarantees. This is illustrated in the B4 and R4 feedback loops, seen in (Figure 20).

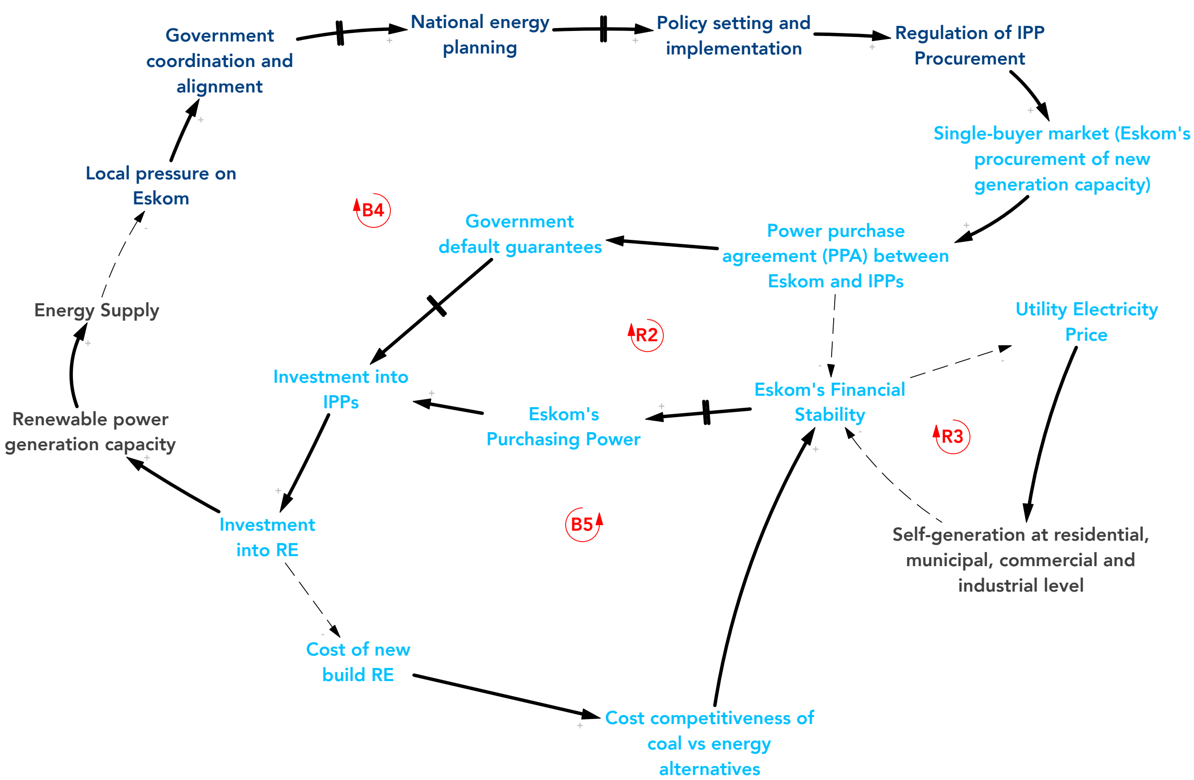

Figure 20: Loops B4 and R5, R2 and R3

B4 represents the current procurement process that is conducted through Eskom. When an IPP is selected, Eskom signs a PPA with the IPP, as security on the IPPs bank loan. This guarantees that Eskom will purchase the electricity from the IPP during the bank loan period. However, as Eskom is insolvent, a government guarantee is needed to ensure that the IPPs will be paid if Eskom defaults. The government is also financially strained and have limited the procurement of IPPs as a result. Participant 8 suggests that pre-existing contracts with regards to the RE developments in the early rounds of the REIPPP programme were also a significant barrier to a shift to renewables by the state and Eskom. During the bidding process and PPA contracting, the price of power is pre-determined, and Eskom is contractually obligated to pay them for electricity at that price for the life cycle of the RE development. When procurement started in the early 2010s, the cost of a new RE build was very high. Eskom is still subjected to paying off those developments. Even with the significant technological improvements and subsequent reduction of the price of RE new builds, there has been a reluctance to continue their investments since 2015.

On the other hand, there is a similar challenge with regards to pre-existing contracts with coal miners which are also a source of dispute with regards to the shift towards renewables. These two elements contribute to the high financial risk that is associated with the Eskom and their IPP investments. This points out the difficulty in finding consensus on the way forward and ensuring that all stakeholders will be satisfied with the way forward.

B5 indicates how coal has become less cost-competitive in relation to RE. It is anticipated that the cost of new-build RE will continue to decrease as "investment into RE" continues (Roff *et al.*, 2020).

R2 represents the current debt spiral of Eskom. Eskom is technically insolvent and relies on government funding to keep operating. It is, therefore, not in the best interest of the sustainability of Eskom to procure a new power as they would incur more debt and operational costs for transmission and distribution. As summarised by participant 8, "The legal framework in place prevents transactions between buyers and sellers and puts a middleman in place that is a monopoly, exclusive, single-buyer, and an insolvent company."

Continuous blackouts and rising electricity prices have driven municipalities, businesses and households to seek other generation alternatives. As seen in **R3** (Figure 20), as the "utility electricity price" increases, they lose significant portions of their consumers to self-generation alternatives. Eskom also sells its electricity to municipalities. As one participant pointed out, municipalities add their price margin on the power distributed to consumers, which adds another dynamic to the utility price of electricity. As consumers are shifting to rooftop Solar PV or other self-generation technologies to reduce their electricity costs, the revenue of Eskom and municipal distributors decrease. This has resulted in a decrease in revenue for Eskom, which further entrenches the parastatal in a debt spiral.

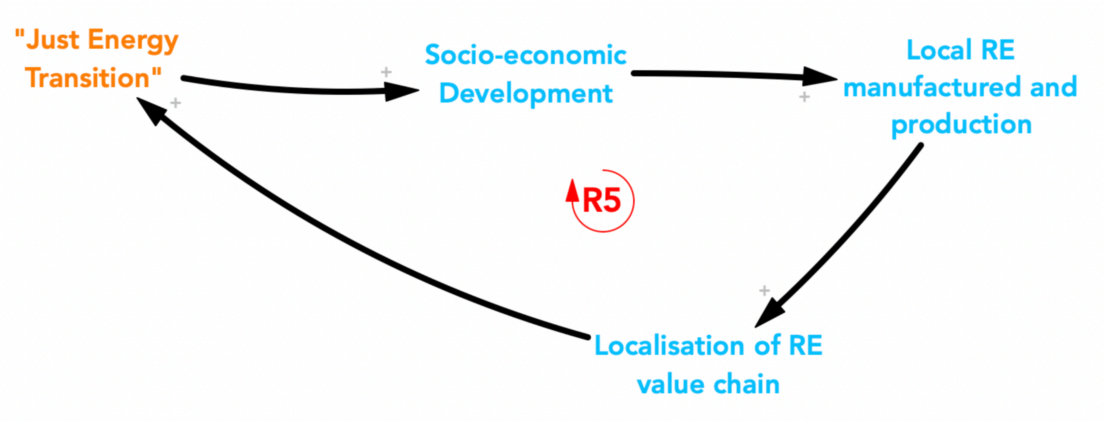

Figure 21: Loops R5

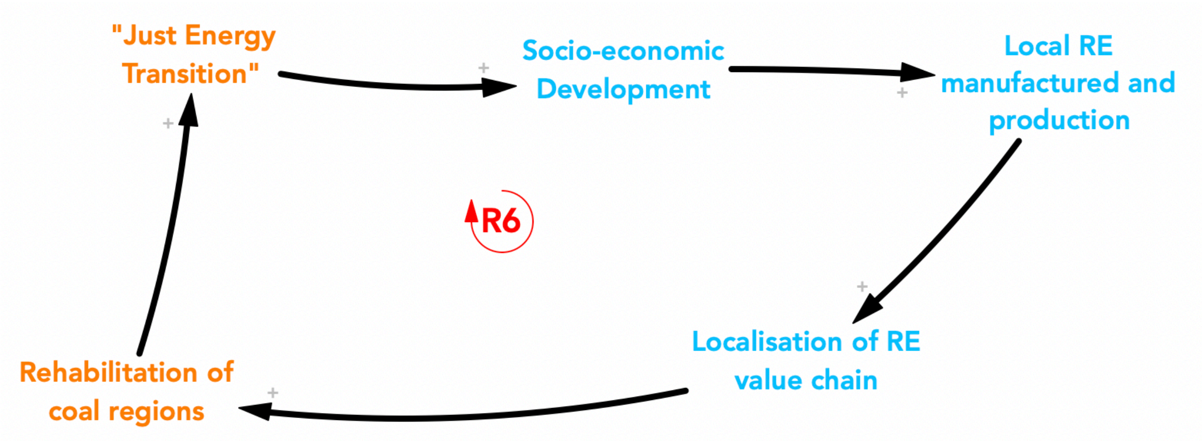

Figure 22: Loops R6

R5 and **R6** feedback loops, seen in Figure 21 and Figure 22 respectively, highlight the exponential growth opportunity in the RE industry that would drive a JET and sustained "sustained economic development. As discussed in Chapter 2.7, "Local RE manufacturing and production" was established successfully during the REIPPP programme with increased potential to grow as "investment into RE" continued. However, the inactive REIPPP programme forced manufacturing and production to close down. 14 Participants have stressed the need for policy certainty on the procurement of RE over the next few years to reinvigorate localisation of the RE value chain. **R6** also highlights that the new designated RE development zones in coal mining regions will help to rehabilitate these areas as RE manufacturing production is established.

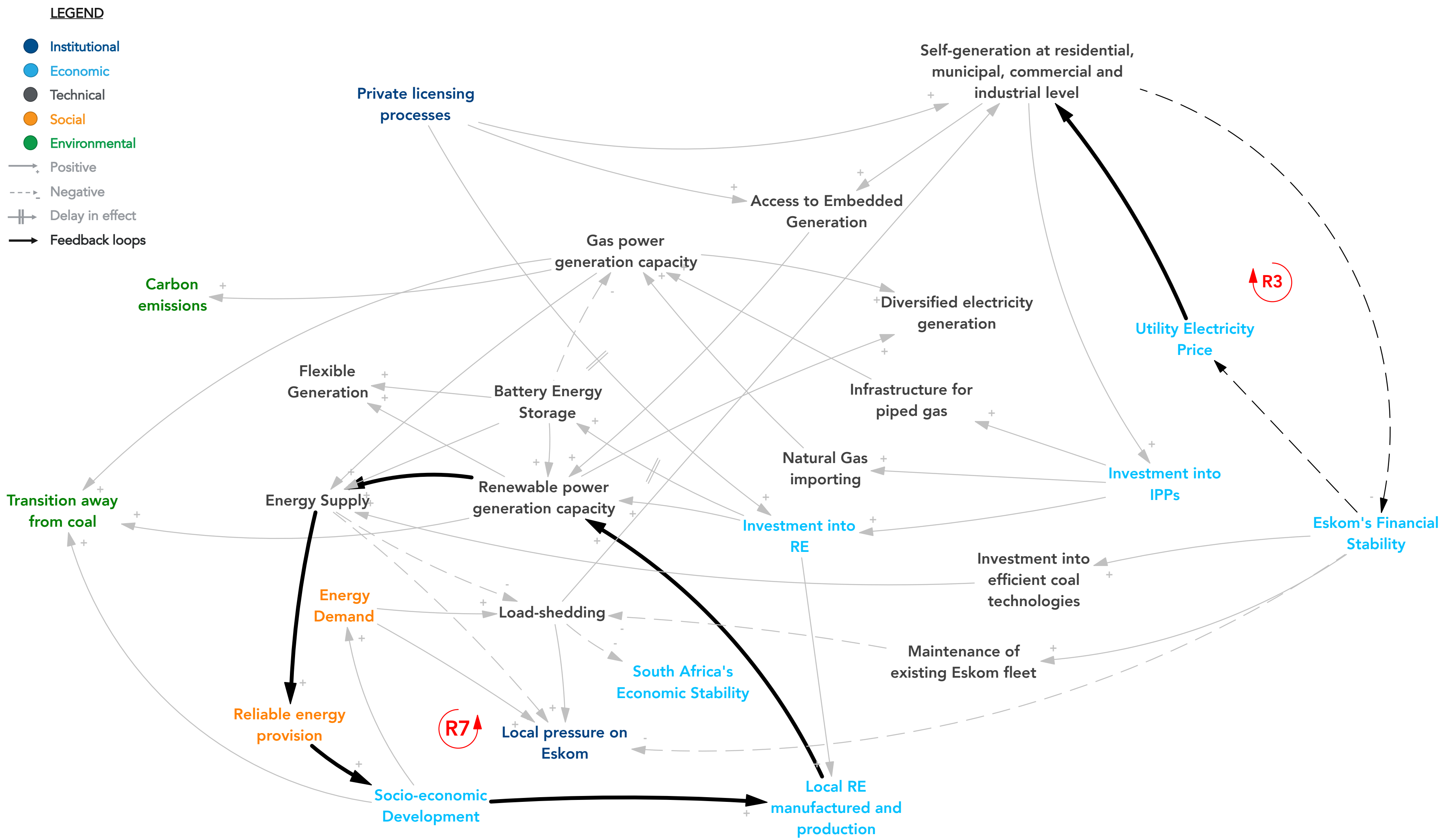

Figure 23: Technical Dimension

4.2.3 Technical dimension

The technical dimension (Figure 23) explores the technical elements that exist within the electricity system.

In Figure 23, **R7** illustrates the interaction between increasing RE generation capacity and the sustained "social-economic development" through "RE manufacturing and production". As discussed in Chapter 2, failures in completing the Medupi and Kusile power plants have set back the electricity sector significantly. The resulting load-shedding further entrenches the decline of the economy as mines, factories and other commercial businesses are impacted. Having a stable baseload is necessary to minimise load-shedding. As the country continues to experience energy supply challenges through coal generation, RE that is supported by gas and battery storage is increasingly pivotal to providing reliable energy to support its development in South Africa.

A bottleneck identified by Participants 8 and 18 is the lack of consensus in understanding how the electricity is used and how it needs to be aligned with the capacity building mechanisms across government departments. This has impacted the decision making around the implementation of the IRP over the past 5 years. The current system is characterised by dispatchable coal-fired generation. Participants have stated that the intermittency of RE, mainly wind and solar PV, has been a significant concern in providing sufficient base electricity load for the country throughout the day. With demand peaks occurring at times in the day when RE is not able to supply the required capacity, the DMRE believes that coal and nuclear will have a significant role for decades to come. However, the literature and findings from 5 participants suggest that reliable power supply is now best provided from a flexible generation model that comprises of RE, battery storage and gas, which is more economically competitive than coal and nuclear in South Africa.

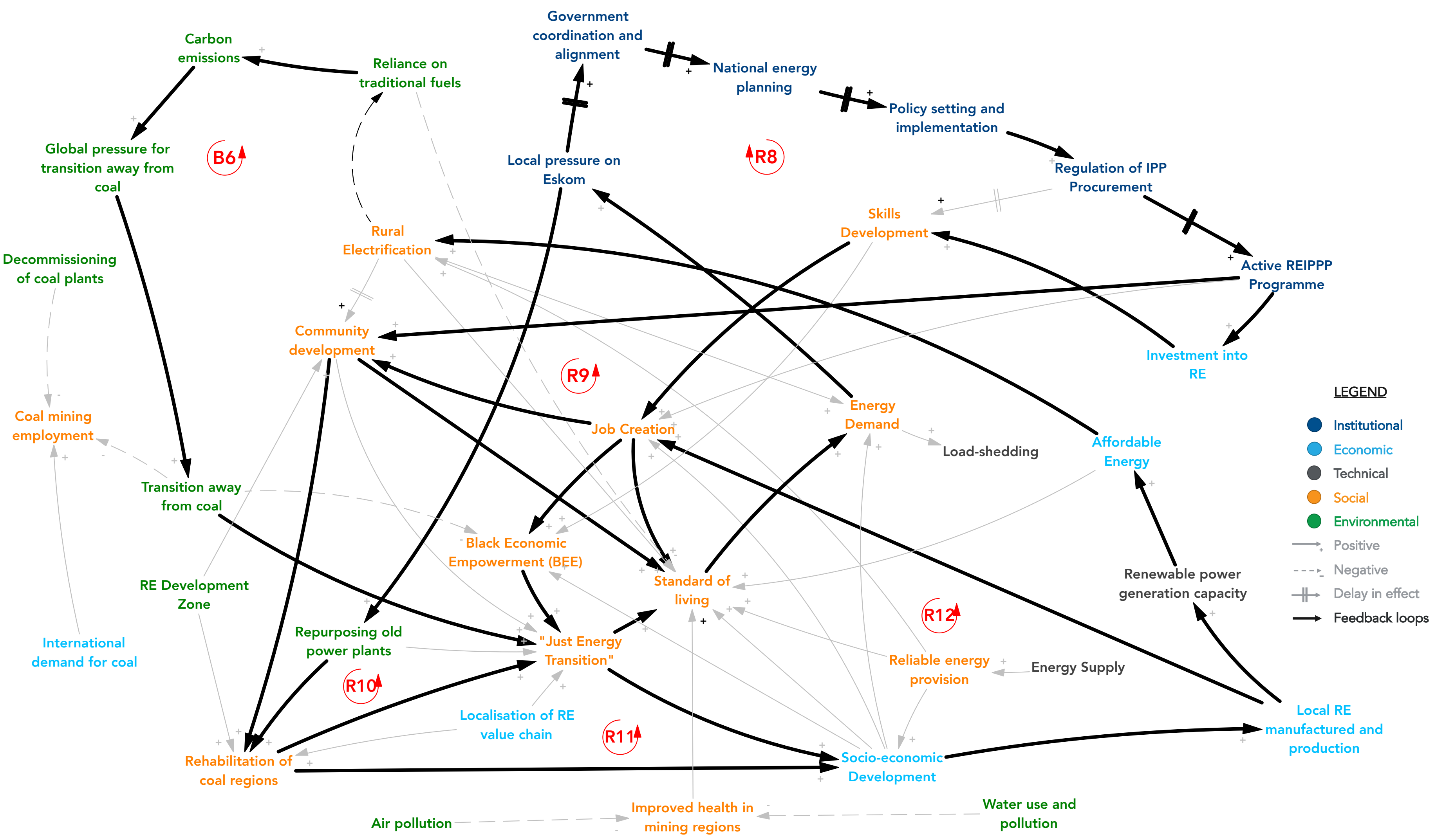

Figure 24: Social Dimension

4.2.4 Social Dimension

The social dimension (Figure 24) explores the social considerations that need to be taken into account with regards to JET. The energy sector is still considered an important role player in driving socio-economic development in South Africa.

The coal sector is a success story for the government regarding BEE. It has provided extensive development opportunities for the poverty-stricken Mpumalanga province. A concern presented by 3 participants is how foreign players that invest in RE in South Africa do not have the same social impact agenda and intentions that are associated with coal. Therefore, a big fear would be that international firms and capital that are not necessarily invested in the development of South Africa would take over the power sector. Participants had also noted that The DMRE minister has deep roots in the coal industry as he was involved in coal mining and their labour unions for many years before he joined the department. Therefore, there may be vested interests in delaying the transition away from coal.

Participant 6 and 7 indicated that job losses were exacerbated by corruption by the Gupta family, as they acquired many coal mines that have now been left stranded, along with thousands of workers. Therefore, a reabsorption mechanism for coal employees is critical.

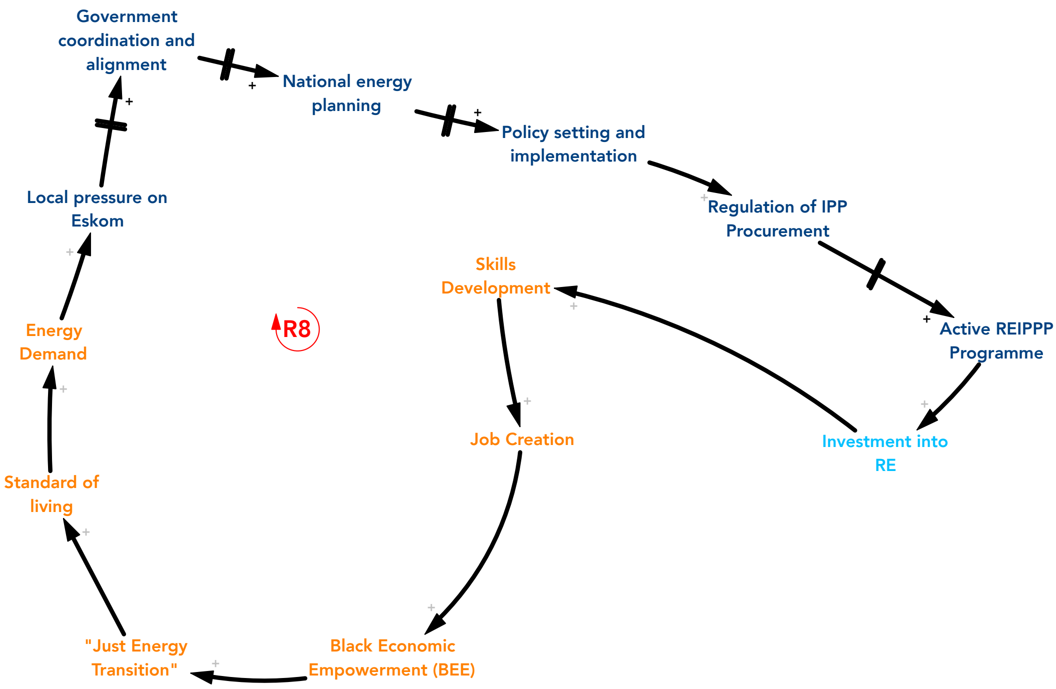

Figure 25: Loops R8

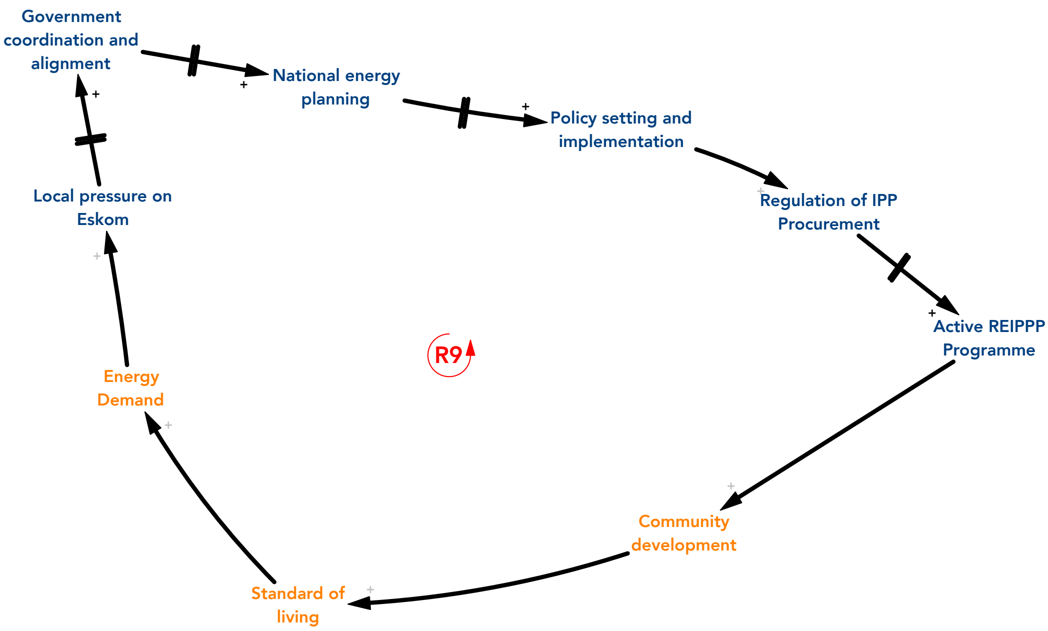

Figure 26: Loops R9

R8 (Figure 25) depicts the impact of an active REIPPP programme in promoting skills development, job creation, and BEE across the country. **R9** (Figure 26) illustrates how the programme has improved "community development" and their standards of living. As a result, there is increased demand for electricity across the country. 13 Participants had highlighted that the REIPPP program was very helpful in driving job creation in remote areas in the country where there are abundant sources of solar energy.

Participants also consider the education system to be a significant barrier in the transition as the skill set in South Africa would not support the high-skilled labour industry. As more renewable energy is introduced, localisation of the renewable energy value chain will need to be backed by high skilled education and training opportunities for South Africans. Building an education mechanism that is aligned with a green energy economy is therefore necessary.

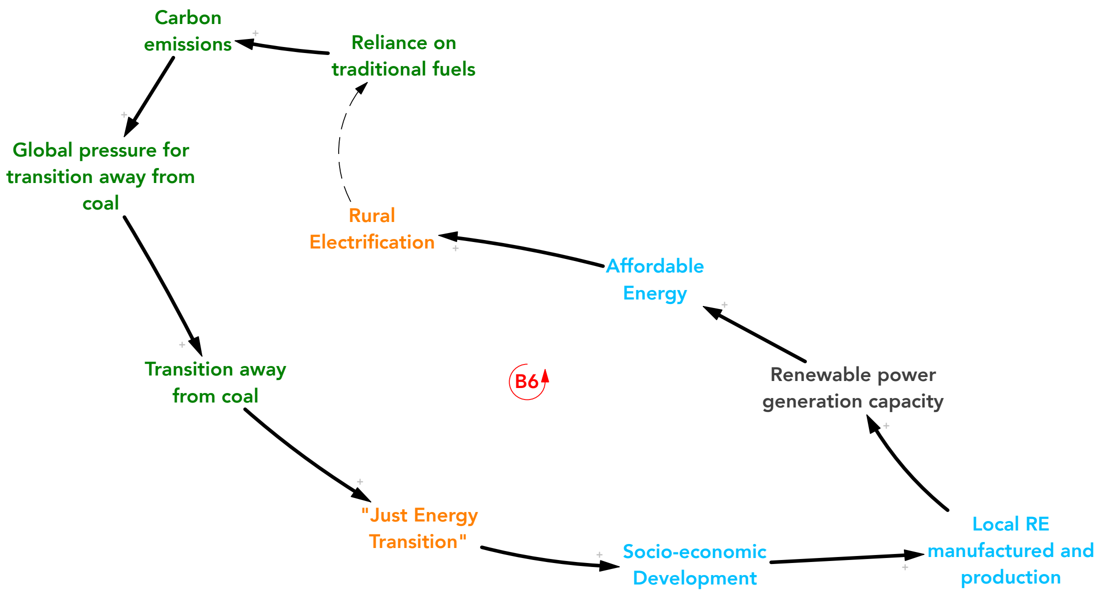

Figure 27: Loops B6

As 10 participants suggested, **B6** (Figure 27) indicates that renewable energy is also an excellent opportunity to provide more affordable energy that can be delivered to rural areas across the country. The resultant effect of "rural electrification" is that it reduces the reliance on traditional fuels (namely, coal and wood) to sustain livelihoods in those areas. This, in turn, reduces the emissions resulting from fuels that are used in rural households.

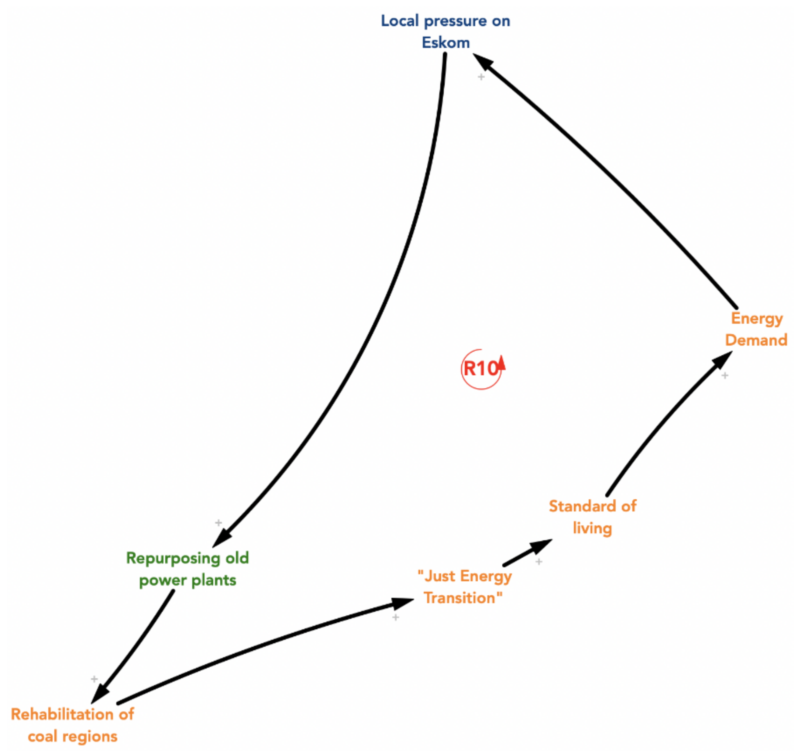

Figure 28: Loops R10

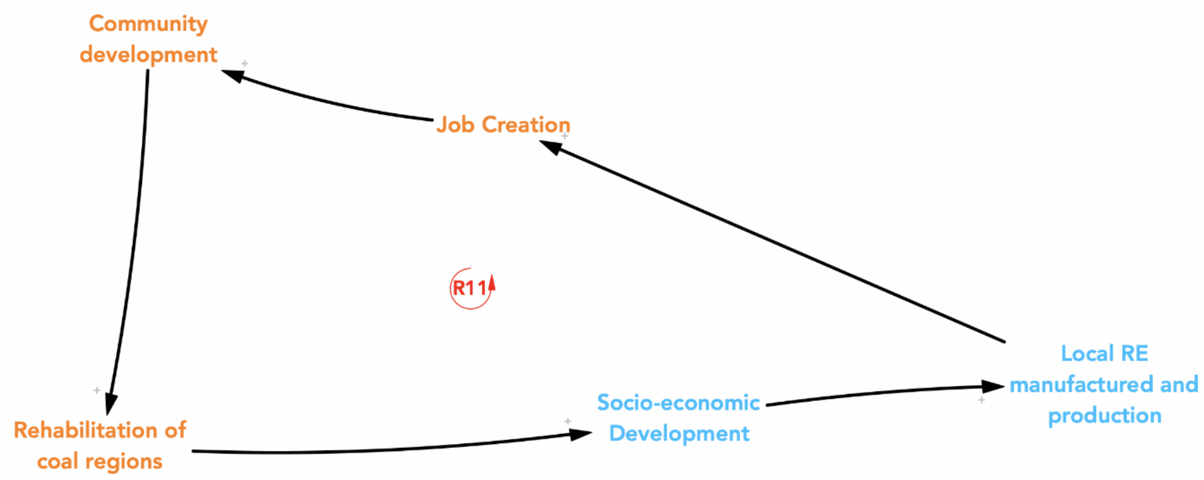

Figure 29: Loops R11

R10 (Figure 28) signifies the role of rehabilitation of coal regions in ensuring a JET. Participant 7 further stressed the fear shared by coal labour unions on the lack of clarity on a just transition plan. Although there are job opportunities in RE, it is not clear how and whether these jobs will be available for coal miners. Therefore, it is critical that through "repurposing old power plants" and localisation of the RE industry in REDZ, coal communities are reabsorbed into the green energy sector. This is further illustrated in **R11**(Figure 29) as continued local manufacturing and production can drive the rehabilitation of coal regions. Community development is also essential as the communities around the plants are integral to the sustainability of the business.

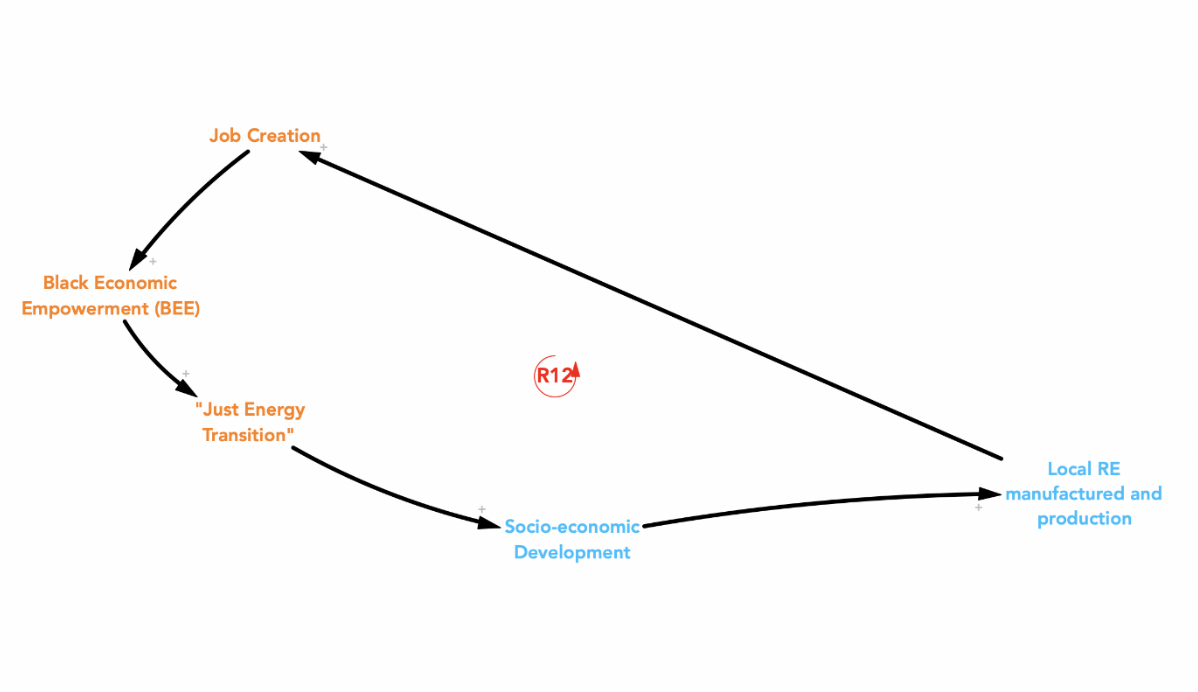

Figure 30: Loops R12

R12 (Figure 30) also indicates how increased job creation in remote areas as well as in coal mining regions supports BEE that is still critical to addressing equality in South Africa.

There will be a significant impact on coal regions and the workforce. Establishing a framework for a just energy transition is key to ensuring that these communities are not heavily impacted and that citizens are reabsorbed into the labour force required for renewable energy.

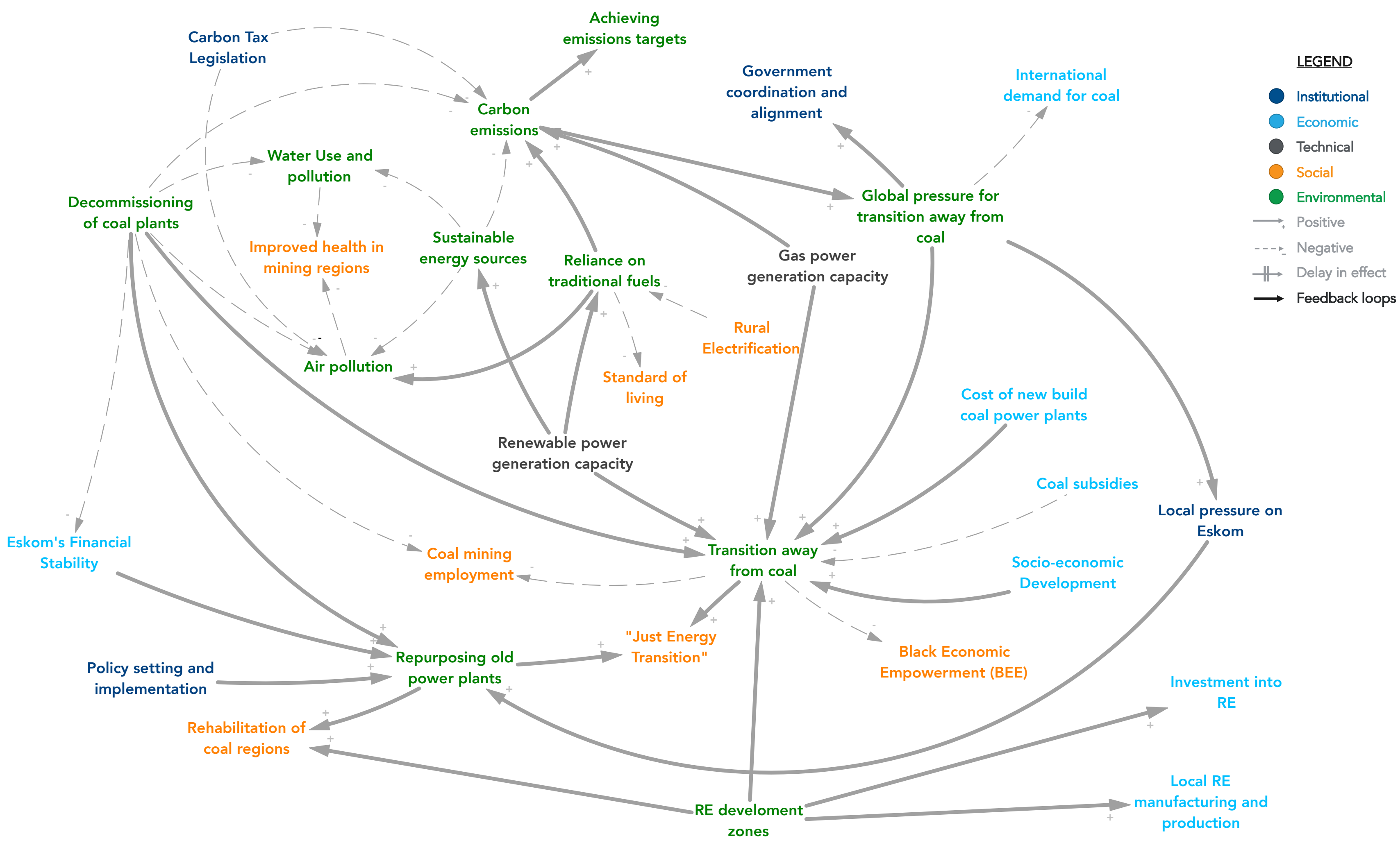

Figure 31: Environmental Dimension

4.2.5 Environmental Dimension

The environmental dimension (Figure 31) illustrates the environmental impacts of the electricity system. Coal mining regions have suffered from excessive air and water pollution resulting from mining operations and power generation. The older the plants get, the more air pollution they cause, along with an increased chance of plant breakdown, which creates greater electricity insecurity. This dimension explores how repurposing of old plants for renewable energy capacity generation can ensure that these impacts are reduced.

The coal sector is diminishing as global resistance impacts investment into new coal and mining. Participant 6 states that "financial institutions, domestically and globally, that will no longer invest in coal projects and won't invest in companies that operate in the coal sector, such as Anglo American (multinational mining company)". This points to the inevitability of a global transition away from coal.

7 Participants have also expressed that generating RE capacity in coal regions is also incredibly favourable as there is pre-existing transmission grid infrastructure needed to supply the country. Although other remote areas with greater sun exposure and wind intensities in the country yield greater generation capacity, the RE development zones situated near these regions are recognised as areas that can produce the required RE capacity and offer opportunities for rehabilitation and inclusion of coal mining communities. The implementation of government policy will need to be more effective in order to achieve carbon emission targets.

Participants 2, 17 and 20 also presented the argument that achieving more aggressive decarbonisation targets must also be considered against the fact that South Africa is still a developing country. These participants argued that their needs to be a balance between developed countries that have generated substantial GHG emissions in their development and the transition in the developing world. Another factor to consider is that many developing countries, like South Africa, do not have the financial capacities to implement these mitigation efforts due to a struggling economy. Therefore, it would be difficult for South Africa to implement aggressive mitigation strategies whilst still aiming to improve its economy. Participant 2 argues that "there should be a proportionate contribution (from countries) that is commensurate with the emissions that have been produced". This point is stressed by other participants as the transition should occur in favour of development in the South African context.

4.3 Leveraging Points

Having developed the system's CLD, the leveraging points within the system were identified. These leveraging points signify the key elements that have multiple outward causal relationships with other elements within the system and drive change towards the desired outcome. 41 key elements were identified as potential points at which interventions could take place. Table 2 lists these critical elements in descending order of outward causal connection:

Table 2: Leveraging points of the system

Leveraging points (key elements)		Dimension	Number of outward connections
1	**Eskom's financial stability**	Economic	7
2	**Decommissioning of coal plants**	Environmental	7
3	**RE Development zones**	Environmental	7
4	**Active REIPPP Programme**	Institutional	7
5	**Renewable power generation capacity**	Technical	7
6	**Socio-economic development**	Economic	6
7	**Investment into RE**	Economic	5
8	**Global pressure for transition away from coal**	Environmental	5
9	**Coal Subsidies**	Economic	4
10	**Foreign Investment**	Economic	4
11	**Price of coal**	Economic	4
12	**International demand for coal**	Economic	4
13	**Political Instability**	Institutional	4
14	**Rural Electrification**	Social	4
15	**Gas power generation capacity**	Technical	4
16	**Investment into IPPs**	Economic	3
17	**Power purchase agreements (PPA) between Eskom and IPPs**	Economic	3
18	**Utility Electricity Price**	Economic	3
19	**Sustainable energy sources**	Environmental	3
20	**Repurposing old power plants**	Environmental	3
21	**Policy setting and implementation**	Institutional	3
22	**Regulation of IPP procurement**	Institutional	3
23	**Carbon Tax legislation**	Institutional	3
24	**Private licensing processes**	Institutional	3
25	**State Capture and Corruption**	Institutional	3
26	**Community Development**	Social	3
27	**Job Creation**	Social	3
28	**Load-shedding**	Technical	3
29	**Energy Supply**	Technical	3

30	**Self-generation at residential, municipal, commercial and industrial level**	Technical	3
31	**Battery Energy Storage Capacity**	Technical	3
32	**Cost of new build RE**	Economic	2
33	**Government Guarantees**	Economic	2
34	**Carbon emissions**	Environmental	2
35	**Strong Leadership**	Institutional	2
36	**National Energy Planning**	Institutional	2
37	**Local pressure on Eskom**	Institutional	2
38	**Skills development**	Social	2
39	**Energy Demand**	Social	2
40	**Just Energy Transition**	Social	2
41	**Rehabilitation of coal regions**	Social	2

These key elements are prioritised, according to Meadows' (1999) 12 places to intervene. This assists in determining the level of effectiveness and feasibility in affecting change at that element within the electricity system. A summary of the key elements in descending order of effectiveness are presented in Table 3:

Table 3: Leveraging points arranged according to Meadows' model (D. Meadows, 1999)

Place of Intervention		Associated leveraging point	Rationale
1	**The power to transcend paradigms**	Strong Leadership	A shift in governance and leadership that will unanimously support and drive a JET to RE
2	**The mindset or paradigm out of which the system arises**	Global pressure for a transition away from coal; JET	The international urgency has manifested a global shift in perspective; all stakeholders should support the JET narrative
3	**The goals of the system**	Socio-economic development; Rural electrification; Job Creation; Sustainable energy sources; Rehabilitation of coal regions	In a developing country, these goals are any transformational change; this system aims to drive a green economy that ensures the absorption of mining regions
4	**The power to add, change, evolve, or self-organise system structure**	National Energy Planning; REDZ; Repurposing old power plants; Regulation of IPP procurement	National planning should support the restructuring of the energy sector; Having REDZ in coal regions will support the repurposing of old plants;

			regulation reform that will limit restrictions on RE
5	**The rules of the system**	Active REIPPP Programme; Power purchase agreements (PPA); Government Guarantees; Private licensing processes	Besides the REIPPP programme, the current legislation and IPP procurement process are filled with regulatory red tape; which is a significant barrier for RE
6	**The structure of information flows (access to information)**	Global pressure for a transition away from coal	A significant source of influence and knowledge regarding green technologies flows from the progress that has been made in the developed world.
7	**The gain around driving positive feedback loops**	Renewable power generation capacity; Skills development; Self-generation; Job Creation; Community Development	Reinforcing mechanisms that support the growth of these elements enable the exponential growth of the RE industry
8	**The strength of negative feedback loops, relative to the impacts they are trying to correct against**	Local pressure on Eskom; Cost of new build RE; Load-shedding; International demand for coal	The continued decline of the coal industry and cost of RE along load-shedding will drive a shift away from a coal-dependent economy
9	**The lengths of delays, relative to the rate of system change**	Investment into RE; Foreign Investment; Investment into IPPs; Eskom's financial stability; Policy setting and implementation; State Capture and Corruption; Political instability	The rate at which investment into RE, improvements to Eskom's financial status, policy implementation and addressing corruption can potentially delay the transition
10	**The structure of material stocks and flows**	Decommissioning of coal plants; Energy Demand; Energy Supply	The decommissioning of coal plants reduces the supply of energy and necessitates the need for IPP procurement to meet demands
11	**The sizes of buffers and other stabilising stocks, relative to their flows.**	Gas power generation capacity; Battery Energy Storage Capacity	Gas power and battery storage should act as a buffer to support the intermittency of RE
12	**Constants, parameters, numbers (such as subsidies, taxes, standards)**	Coal subsidies; Carbon Tax Legislation; Carbon emissions; Utility Electricity Price; Price of coal	Although these parameters are the most intuitive, these often do not bring about meaningful behavioural change and have a minimal long-term effect

4.4 Intervention Strategies

Intervention strategies were identified through a triangulation of information from the literature review and interviews. Each intervention is described and attributed to the leverage points identified and the respective level of effectiveness, along with the relevant stakeholders that it involves. These interventions are listed in Table 4 below:

Table 4: Intervention strategies aligned to system leveraging points

	Intervention	Relevant Stakeholders	Aim and Rationale	Actions	Leverage Points	Place to intervene	Sources of Information
1	**Formalising the Ministerial RE Sector Engagement Forum**	Associated government departments; labour unions; Minerals and energy associations; Business Associations; RE Associations; Academia and researchers; municipalities; Eskom; banks; NGOs	To address bottlenecks that are inhibiting policy and planning implementation regarding RE. To build trust and establish consensus and coordination on the way forward for the RE sector	• Establish a forum structure • Develop JET plan • Establishing RE financing structures • Develop Renewable Energy Masterplan • Actions must be aligned to the existing Presidential Coordinating Committee for Climate Change	35, 36, 13	1, 4, 9	Interviewees: 6, 8, 10, 12,14, 16 19, 20 References: (DMRE, 2020)
2	**Establishing an Independent System and Market Operator (ISMO)**	DMRE, NERSA	The government needs to reform the restrictive governance structure to enable a multi-lateral power procurement model, introducing competition and a mechanism for wheeling electricity from a generator to a willing buyer through the national grid. This will also eliminate the need for government guarantees and PPAs as finances would be managed through private investment	• The government must institute an ISMO that is independent of Eskom that can facilitate the transaction of electricity as described • Unbundle Eskom to open up the national transmission grid • IPPs that are wheeling electricity through the grid should provide transmission and distribution power support	22, 29, 5, 33, 17, 18, 16, 30, 7	4, 10, 7, 5, 12,	Interviewees: 1, 2, 3, 8 References: (Yelland, 2020a)

4	**ESKOM unbundling and revival**	DPE, DMRE, National Treasury and Eskom	Encourages the use of diverse sources of energy' through introducing competition between Eskom's generation units and new IPPs. Provide an opportunity for financial recovery for Eskom	• Unbundling Eskom into 3 separate entities • Sell stranded assets (coal-power plants) • Restructure and finance Eskom's debt through private investment • Increase RE financing options • Reduce staff and coal costs	1, 37	9, 8,	Interviewees: 8, 18, References: (Bowman, 2020)
5	**Establishing Policy certainty for the continued procurement of RE**	DMRE	Planning needs to be more flexible and responsive to the ever-changing nature of technology. This will give investors confidence in the sustained demand for RE. This confidence will also help to ensure that local manufacturing and production is re-established	• The IRP needs to be consistent and regularly updated with a focus on least-cost generation options to meet demand	7, 36, 19, 10	9, 4, 3	Interviewees: 8, 10 References: (Yelland, 2020a)
6	**Reactivate REIPPP programme**	IPP Office, DMRE	The REIPPP programme has been inactive since 2015. The country is in desperate need to provide reliable and affordable energy to meet its demand.	• New IPPs must provide transmission and distribution power support to reduce the financial strain on Eskom and municipalities • Large utility projects should be split up to affect a wider set of communities, rather than having concentrated generation • Redeployment should occur in new REDZ that promote a social-economic footprint in associated communities • Improve monitoring and evaluation of the impact	4, 7	5, 9	Interviewees: 10, 18,16, 13,17

7	**Regulatory Reform**	**DMRE; NERSA**	**Remove regulatory red tape to promote self-generation. Create access to embedded generation to increase electricity capacity**	• **Enable** the **development of RE by minimising private** registration and **licensing processes for IPPs and private consumers** • **Do away with the ministerial determination to allow willing RE investors to invest**	**22, 30**	**4, 7**	**Interviewees:** **5, 8, 10** **References:** **(Yelland, 2020a)**
8	**Creating a "JET" plan supported by all stakeholders**	Government; Eskom; unions; RE associations; mining companies; communities; Department of Higher Education and Training; NGOs	Currently, there is no distinction between climate change and a just transition in policy or planning. Therefore, it is essential to develop a clear plan of development that is human-centric and promotes the improvement of mining communities. The project should aim to address the broader transformation of societies and protect the people who are negatively impacted by the transition.	• Identify a variety of work and job losses that you will need to substitute and replace. • Investigate existing skillset and profiles of workers within communities and how exactly a JET can benefit them • Develop a community representative programme to coordinate and manage pilot projects in alignment with the plan's activities • Set up task teams within communities to manage and lead interventions - establishing community ownership • Set up JET funding system from REIPPP tariffs	35, 36, 38, 40, 41	1, 4, 7, 2, 3	Interviewees: 10 References: (COSATU, 2012; Halsey *et al.*, 2017; Burton, Marquard and McCall, 2019; Hallowes and Munnik, 2019)
9	**Coal region rehabilitation and redevelopment**	DMRE; DEA; mining companies; unions; RE groups; banks; National treasury; IPP Office	Coal regions are very suitable for RE development as they have an existing industrial workforce, are very close to transport infrastructure, access to the transmission grid, close to areas of high energy demand	• Re-start procurement of utility-scale RE within REDZ • Introducing institutional rules in REIPPP programme to support the increased generation of these regions	40, 41	2, 3	Interviewees: 7,8 References: (Yelland, 2020a)

10	**Develop an ambitious SA Renewable Energy Masterplan**	Government; NGOs; Industry associations; unions; Academic institutions; Financial Institutions	Enabling a just transition by reindustrialising coal regions to fuel a new green economy. Developing a clear plan and policy for RE value chain localisation.	• Explore opportunities for repurposing the coal fleet for green hydrogen • Develop a focused strategy to support the development of green mining sector, electric cars and industrial electrification in South Africa • Develop and coordinate cross-sectoral plans o Agriculture o Education o Financial investment • Develop a strategic industrial policy for a new green economy which will include production and export of the following fuels: o Hydrogen o Green ammonia o biomass	35, 36, 13, 27	1, 4, 9, 7	Interviewees: 5, 12, 14, 18, 20 References: (Greencape, 2020; Roff *et al.*, 2020; SAREC, 2020)
11	**Residential micro and mini-grid ownership systems**	Municipalities; DMRE; NERSA; RE companies	Creating income-generating opportunities for low-income homes to sell electricity back into the grid, through rooftop solar PV. 3-million households still have no access to grid-based electricity across the country (DMRE, 2019).	• Conducting technical feasibility studies and assessing cost-benefit and risk • Explore small-scale battery storage in households.	29, 27, 14	7, 10, 3	Interviewees: 11 References: (Burton, Marquard and McCall, 2019)

4.5 The modified CLD of the electricity system

Having conducted a systems approach in analysing the current state of the electricity system and identifying key intervention strategies, the CLD of the complete system was modified to include seven critical elements that would unlock the shift towards RE. This systems map incorporates elements that represent desirable outcomes of a future South African electricity sector. These elements include:

- Policy setting, restructuring and implementation
- Reformed regulation of IPP procurement
- Unbundling of the electricity sector (i.e. Eskom)
- Minimised private licensing processes
- Independent System and Market Operator
- Generation competition
- Retraining coal miners

The final modified electricity system is presented in Figure 32 below. The new elements are underlined with their respective causal relationships shown in bold arrows:

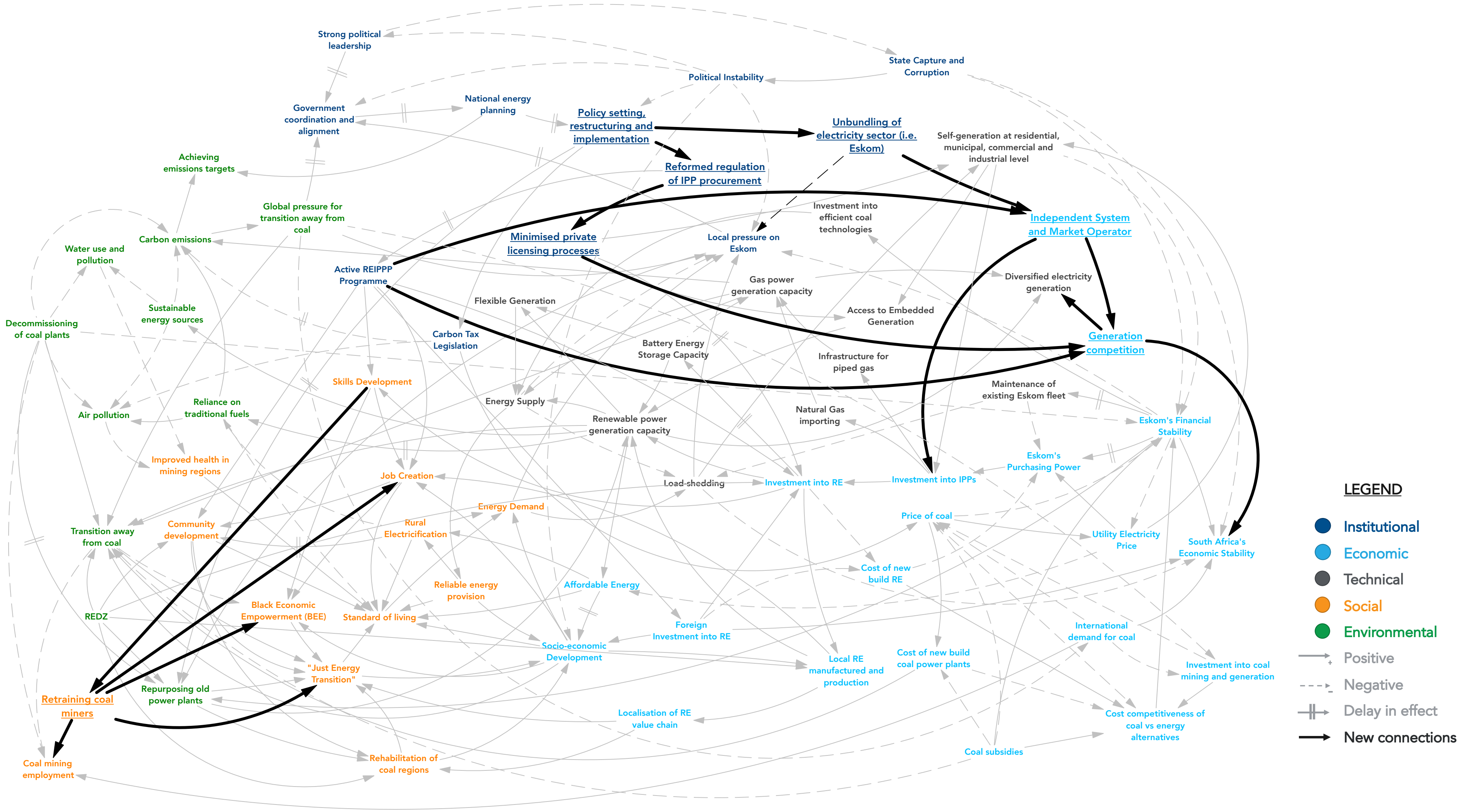

Figure 32: Modified final CLD of the electricity system

5 Discussion

This Chapter presents the ToC framework. It also discusses the contribution of the results and the limitations in the approach used in this study.

5.1 Theory of Change

Having used the ST approach to identify critical interventions to drive a shift towards RE, a ToC framework was developed as a roadmap towards the desired system change. In this context, the framework is used to organise the system elements and identified interventions into a visual causal pathway for a JET. The desired transition and associated system elements align with the core concepts of the ToC in the following manner:

- Social Science theory – This is informed by the ST approach conducted to assess and identify opportunities to influence change in the system
- The desired impact – In this case, it is to ensure that there is a transition towards RE will enable reindustrialisation of coal regions to fuel a new green economy, will support socio-economic growth, reduce environmental impact and provide affordable and reliable energy
- Beneficiaries – South African citizens and electricity consumers; and more specifically, citizens in coal mining regions
- Actors – Associated government departments; labour unions; Minerals and energy associations; Business Associations; RE Associations; Academia and researchers; municipalities; Eskom; banks; NGOs
- Assumptions – These assumptions will act as a support for ensuring sustained success. In this context, it is assumed that political instability has less of an influence on a new multi-lateral power procurement market facilitated by an ISMO. It is also assumed that the cost of RE and battery storage will continue to decrease relative to coal
- Sphere of Influence – It is essential that within the framework, robust and regular mechanisms of monitoring and evaluation are established to see if the pathways to success are still relevant and if any other challenges have arisen over its lifecycle, such as improvements to technology, changes in RE market prices
- Timeline – The IRP designed by the DMRE would guide timelines

- Indicators – the number of jobs created, and coal miners absorbed, carbon emissions reduction, renewable energy generation capacity, the reliability of energy provided

In Figure 33, a high-level ToC framework for a transition towards RE was mapped out similarly to Figure 14. It is based on the core concepts stated, and the system elements, interactions and interventions identified through ST.

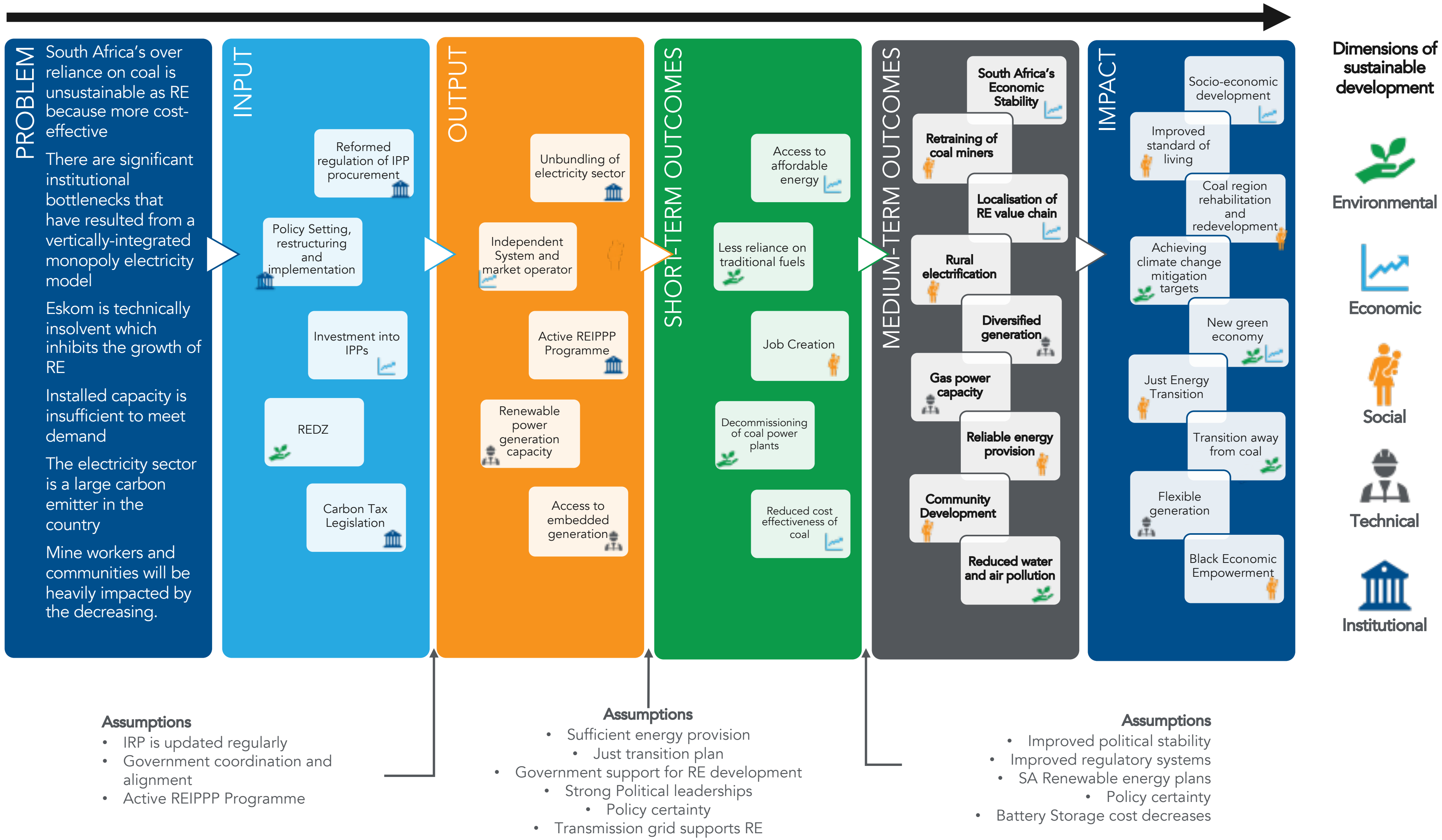

Figure 33: ToC Framework for a just transition towards RE

5.2 Contribution of results

The ST approach of evaluating the electricity sector creates a platform to understand how various elements and factors with a system connect and communicate with one another. As the system incorporates an extensive set of elements, CLDs create an opportunity to understand a complex system from a high-level. The systems map can be seen as a means to identify critical interactions and feedback loops amongst stakeholders and points at which desired change can be affected. In this context, the results indicate that there are many places to intervene; however, there are differing levels of effectiveness. Figure 32 shows how the intervention strategies developed can feedback into the system to promote the desired change.

The ToC framework provides a "broad conceptual framework for change" and can be used as a tool to identify opportunities for collaboration across the stakeholders in the electricity sector (Vogel, 2012). It also presents the pathway of change sequentially. As the government still maintains its responsibility in developing and approving the path of the electricity sector, this ToC framework can be used for high-level monitoring and evaluation in the planning and implementation of activities during the transition. Through monitoring and evaluation methods of collecting and analysing both quantitative and qualitative performance data, a ToC model can be tested against the actual results attained as interventions are implemented (Jackson, 2013). In the continual assessment of intervention outcomes, the following ToC elements should be continuously interrogated (Jackson, 2013):

- whether the ToC is valid, appropriate, relevant and accurate
- whether the change has occurred in the pathways that were previously described in the framework,
- other potential dynamics or pathways that may not have been already considered,
- whether there have been other unforeseen factors that may promote or limit change.

5.3 Limitations

Although the causal relationships between elements were determined through collating findings from literature and the interviews, it must be noted that these were a logical interpretation of the findings. This is viewed as an epistemological approach to systems thinking as the system "is bounded and defined by the subjective interests and pre-analytic assumptions of the researcher" (Abson *et al.*, 2017). To address this subjectivity, Meadows' hierarchical approach to aligning leveraging points their characteristics and level of effectiveness, provides a more robust approach to identifying interventions that can drive meaningful change. There is still room to explore more robust methods of defining system elements and key leveraging points.

When considering the causal modelling of the system, the strength and length of delays of causal relationships were not incorporated into the systems mapping. Even though causal delays were indicated between elements, some relationships would propagate change at different rates and effectiveness relative to others. For example, a strong relationship would mean that even the smallest of change in the tail element would have an impact on the element being affected; however, with weak connections, a higher input for change would be required to produce a significant effect. Taking this into account will also assist in identifying the most effective leveraging points and intervention strategies. Therefore, there is great value in considering these influences in future.

6 Conclusion

This research has explored the complex nature of the South Africa electricity system as it migrates away from an over-dependence on coal. It has explored an alternative way of addressing the country's energy challenges and proposes opportunities for maximum impact. The key findings and recommendations are presented in conjunction with the research questions:

1. Key development challenges – The ST methodology facilitates an in-depth understanding of the current electricity. complcKnowledge is gleaned from literature and interviews with key stakeholders to define system elements and identify the causal linkages between the elements in the system. The systems analysis presents development challenges in the context of the institutional, economic, technical, social and environmental dimensions of sustainable development.
2. Existing drivers, barriers and implications for a RE transition – Aside from the significant environmental benefits, RE is more cost-effective than new builds of coal and other alternatives. The introduction of RE in South Africa has brought job creation and the potential for new localisation opportunities. RE barriers are rooted in the institutional core of the system, which is politically and financially unstable. The governance and regulation structures are complex, which results in slow execution of policy and procurement of generation capacity and limits opportunities for self-generation at the consumer level. The advancement of RE would have significant implications on the coal sector, which has been an important entry for Black people into the formal economy.
3. Intervention strategies for stakeholders and mitigation pathways – From the CLD of the electricity system, key places to intervene were identified along with eleven critical intervention strategies that were developed with key stakeholders. These interventions highlight the need for the restructuring of the electricity system, regulatory reform, a clear JET plan and presents opportunities for stakeholder collaboration. Findings were then collated to develop a Theory of Change (ToC) framework to inform the success of a low-carbon transition in South Africa, one that provides opportunities for growth and employment in a new green economy.

6.1 Considerations for future studies

A study is needed to determine how to match the economy with the desired electricity system. With the current MEC that fuels the economy, there will be a need for dispatchable capacity that supplements the decrease in coal power. As RE remains inflexible without sufficient energy storage capacity, the energy system will struggle to supply the required loads for smelters and other mineral production. This is linked to the education system as it will be critical in aiming to shift the economy to one that has lower energy demands. A further investigation on how demand-side management can support a just energy transition is also recommended.

This research has identified the need for upskilling and retraining the current labour-force at a high-level. However, future studies would need to address how skills development and other interventions will take place in coal communities in order to address their unique set of needs, values and challenges (Hirmer and Cruickshank, 2014).

Transition pathways in other countries were explored; however, thorough comparisons were not made. It would be helpful to examine the efficacy of how RE has been developed in other countries in order to identify opportunities and potential challenges that may arise during the transition.

While more research is necessary, coordinated action is needed too. Due to the urgency of creating sustainable and reliable access to RE, the time to act is now.

7 Coronavirus Statement

Initially, it was planned that interviews would be carried out face-to-face, as I had intended to return to South Africa. However, due to the coronavirus, interviews were conducted via online meeting platforms, which still allowed for in-depth discussion. However, I was not able to complete online interviews with key stakeholders, namely, municipalities and labour unions, which would have increased the robustness and validity of findings from their stakeholder perspective. Other than this, the coronavirus pandemic has had no significant impact on my research and methodology.

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Appendix A

This Appendix includes the broader themes and questions covered in the interviews. It also includes interview participant details,

- What are your general impressions of the transition to RE sources for power generation in SA?
- What are the barriers to the advancement of renewables for electricity generation in SA? From the following perspectives:
    - Techno-economic
    - Socio-economic
    - Policy – gaps and shortfalls
    - Energy regulatory processes
- What are the best strategies to coordinate the various government departments and stakeholders?
- How should regulatory and procurement processes this change to enable a transition?
- How can a just energy transition away from coal be established; what are key considerations?
- What are most important interventions that need to occur in the electricity system within the next decade to lead the country towards its climate change mitigation goals

Appendix B

Herewith is an example of a coding tree that was extracted from Atlas.ti. As in the main body of this dissertation, themes were organised into the broader dimensions of sustainable development. In this case, the coding tree represents them linkages and code associations between the concept of a just transition, and mechanisms to enable it. Coding trees such as this were used to analyse findings from the interviews and to understand the system linkages.