DIGGING DEEPER THAN PLATINUM: SOUTH AFRICA’S PARTICIPATION IN AN EMERGENT FUEL CELL INDUSTRY

by

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Abstract

South’s Africa’s position as global platinum supplier provides a unique opportunity for an emergent fuel cell industry. The innovative technology’s reliance on platinum has sparked interest in the mining sector, promoting the clean energy-producing devices in their own operations. This research focuses upon contemporary structures of racial oppression within the industry, to analyse how these dynamics influence the development and implementation of innovative technology. It also challenges the sustainability discourse associated with fuel cell technology in South Africa.

The study follows a qualitative research approach, incorporating a political ecology focus to highlight the politicized nature of these interactions. The methodology incorporates a literature review, key informant interviews, fieldwork observations and document analysis. Findings indicate that the implementation of fuel cell technology in South Africa’s platinum mines will disproportionately burden historically disadvantaged South Africans, with the lack in technical knowledge-base considered a major challenge. Additionally, it was found that sustainability claims surrounding fuel cell technology are largely based on environmental characteristics. This has resulted in an oversimplification and a depoliticised account of the impacts of the technology.

This study looked critically at the convergence of history and innovation, placing emphasis on context, power relations and knowledge to provide a more holistic account of the research problem. Opportunities exist for making a meaningful and viable contribution towards development and sustainability by means of investing in a South African fuel cell industry. The challenge will be in deliberately seeking pathways which address the more complex components of sustainability, benefitting all stakeholders and paying particular attention to the historical, political and social contexts from which the technology emerges. It is this particular context which allows for a questioning and perhaps even a re-evaluation of the sustainability narratives broadly applied to fuel cell technology.
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# Table of Contents

Abstract ......................................................................................................................................................... ii
Acknowledgements ........................................................................................................................................ iii
List of Figures .................................................................................................................................................. vii
List of Tables ................................................................................................................................................ viii
List of Abbreviations ...................................................................................................................................... ix
Chapter 1 ....................................................................................................................................................... 1
Introduction ................................................................................................................................................... 1
  1.1 Introduction .......................................................................................................................................... 1
  1.2 Background .......................................................................................................................................... 2
  1.2.1 The Emergence of South Africa’s Mining Industry ................................................................. 2
  1.2.2 Policy Reforms & Struggles in the Newly Democratic South Africa ........................................ 6
  1.2.3 Emergence of the Platinum Sector .............................................................................................. 8
  1.2.4 South Africa’s Position as ‘Leader’ of the Continent; Development, Climate Change &
      Technological Fixes .............................................................................................................................. 10
  1.3 Conclusion .......................................................................................................................................... 12
Chapter 2 ..................................................................................................................................................... 13
Methodology & Study Design ...................................................................................................................... 13
  2.1 Introduction .......................................................................................................................................... 13
  2.1.1 Research Problem, Question & Objectives ............................................................................... 13
  2.1.2 Data Collection & Analysis ........................................................................................................ 15
  2.1.2.1 Literature Review .................................................................................................................. 16
  2.1.2.2 Key Informant Interviews ..................................................................................................... 17
  2.1.2.3 Fieldwork Observations ....................................................................................................... 22
  2.1.2.4 Document Analysis .............................................................................................................. 26
  2.2 Significance .......................................................................................................................................... 27
  2.3 Theoretical Framework ...................................................................................................................... 27
  2.4 Sustainability Assessment ................................................................................................................... 29
  2.5 Positionality ...................................................................................................................................... 32
  2.6 Conclusion ...................................................................................................................................... 33
Chapter 3 Exploring South Africa’s Platinum Deposits & Fuel Cell Technology ........................................... 35
  3.1 Introduction ...................................................................................................................................... 35
  3.2 Geographical and Geological Significance of the Bushveld Igneous Complex .......................... 36
3.3 Formation and Significance of the BIC ................................................................. 40
  3.3.1 Viability of Platinum Resources ................................................................. 40
3.4 Demand, Supply and Price .............................................................................. 43
  3.4.1 The Emerging Fuel Cell Industry ............................................................... 45
3.5 Platinum’s Physical and Chemical Properties .................................................. 46
3.6 Fuel Cells ......................................................................................................... 47
  3.6.1 Fuel Cell Components and Functionality ............................................... 48
  3.6.2 South Africa’s Emergence as Leader in Fuel Cell Development ............... 51
3.7 Contribution to South Africa’s Economy ......................................................... 51
3.8 Conclusion ....................................................................................................... 53

Chapter 4 Implementation of Fuel Cell Technology in South Africa’s Platinum Mines ........... 54
  4.1 Introduction ..................................................................................................... 54
  4.2 Aboveground Applications .......................................................................... 54
    4.2.1 Energy Security ...................................................................................... 55
    4.2.2 Challenges Associated with Aboveground Fuel Cell Applications .......... 56
  4.3 Underground Applications ............................................................................ 57
    4.3.1 Motivations for Underground Fuel Cell Implementation ...................... 58
    4.3.2 Challenges Associated with Underground Fuel Cell Applications .......... 60
  4.4 Shift to a High-Tech Mining Industry: Modernisation and Mechanisation .......... 61
    4.4.1 Motivations for Shifting to a High-Tech Mining Industry ...................... 64
  4.5 Conclusion ..................................................................................................... 65

Chapter 5 Impacts of Fuel Cell Implementation in South Africa’s Platinum Mines & Potentials for an Emergent Industry ......................................................................................... 67
  5.1 Introduction ..................................................................................................... 67
  5.2 South African Context .................................................................................... 67
    5.2.1 Employment ............................................................................................ 68
    5.2.2 Growth & Development ......................................................................... 70
    5.2.3 Procurement ............................................................................................ 72
  5.3 Emphasis on the Knowledge-Based Economy ................................................ 74
    5.3.1 Skills Training & Education .................................................................... 75
    5.3.2 Stakeholder Collaboration ....................................................................... 77
  5.4 Re-evaluating Sustainability Narratives .......................................................... 79
    5.4.1 Environment (Q3) .................................................................................. 79
    5.4.2 Economy (Q4) ....................................................................................... 82
List of Figures

Figure 1-1: Lonmin’s Marikana Platinum Mine, at Nkaneng near Rustenburg................................................. 9
Figure 2-1: Marikana Memorial Event .............................................................................................................. 22
Figure 2-2: Attendees of the Annual Marikana Memorial Event ........................................................................ 23
Figure 2-3: Police Vehicles Surround the Marikana Memorial Event ............................................................... 23
Figure 2-4: Underground Site Visit at Shaft #14 .......................................................................................... 24
Figure 2-5: The Platinum Reef ....................................................................................................................... 25
Figure 2-6: Underground Health & Safety Room ........................................................................................... 25
Figure 2-7: Seven Questions to Sustainability Framework ............................................................................. 32
Figure 3-1: Geographical Location of South Africa’s BIC .............................................................................. 36
Figure 3-2: Map of SA’s Bushveld Igneous Complex, Ore Bodies & Ownership ............................................. 38
Figure 3-3: Fuel Cell Components & Chemical Reaction .............................................................................. 49
Figure 4-1: SA’s First Baseload Stationary Fuel Cell, Powering the Chamber of Mines ............................... 55
Figure 4-2: Diesel-Powered LHDs at Implats’ Shaft #14 .............................................................................. 59
Figure 4-3: Underground Transport System ................................................................................................ 63
Figure 4-4: Underground Primary Ore Crushing at Shaft #14 ..................................................................... 63
Figure 5-1: Opportunities and Challenges of an Emergent South African Fuel Cell Industry using the 7Q Framework ................................................................................................................ 85
List of Tables

Table 2-1: Thesis Content Analysis Outline ................................................................................................................. 16
Table 2-2: Key Informants, Interview Type, Discussion Topics & Link to Research Objectives...................... 20
Table 3-1: Fuel Cell Types, Associated Specificities & Applications ................................................................. 48
Table 5-1: Importance of the Knowledge-Based Economy as it Relates to all other Identified Research Themes ........................................................................................................................................... 75
## List of Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
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<tr>
<td>7Q</td>
<td>Seven Questions</td>
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<tr>
<td>ANC</td>
<td>African National Congress</td>
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<td>AMD</td>
<td>Acid mine drainage</td>
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<td>BEE</td>
<td>Black Economic Empowerment</td>
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<td>BIC</td>
<td>Bushveld Igneous Complex</td>
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<tr>
<td>CoM</td>
<td>Chamber of Mines</td>
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<tr>
<td>CIMERA</td>
<td>Centre of Excellence for Integrated Mineral and Energy Resource Analysis</td>
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<tr>
<td>CMMS</td>
<td>Centre for Mechanised Mining</td>
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<tr>
<td>COMRO</td>
<td>Chamber of Mines Research Organization</td>
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<tr>
<td>CSIR</td>
<td>Council for Scientific and Industrial Research</td>
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<td>DMR</td>
<td>Department of Mineral Resources</td>
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<td>DoE</td>
<td>Department of Energy</td>
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<td>DEA</td>
<td>Department of Environmental Affairs</td>
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<td>DST</td>
<td>Department of Science and Technology</td>
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<td>DTI</td>
<td>Department of Trade and Industry</td>
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<td>EGRI</td>
<td>Economic Geology Research Institute</td>
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<td>FC</td>
<td>Fuel cell</td>
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<td>GDP</td>
<td>Gross Domestic Product</td>
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<td>GHG</td>
<td>Greenhouse gas</td>
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<tr>
<td>GRI</td>
<td>Global Reporting Initiative</td>
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<tr>
<td>HDSA</td>
<td>Historically Disadvantaged South African</td>
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<td>HySA</td>
<td>Hydrogen South Africa</td>
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<td>IPA</td>
<td>International Platinum Group Metals Association</td>
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<td>LCA</td>
<td>Life Cycle Assessment</td>
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<tr>
<td>LHD</td>
<td>Load haul dumper</td>
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<tr>
<td>MMSD</td>
<td>Mining, Minerals and Sustainable Development</td>
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<td>MPRDA</td>
<td>Mineral and Petroleum Resources Development Act</td>
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<tr>
<td>NASA</td>
<td>National Aeronautics and Space Administration</td>
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<tr>
<td>NDP</td>
<td>National Development Plan</td>
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<td>NUM</td>
<td>National Union of Mineworkers</td>
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<td>R&amp;D</td>
<td>Research and Development</td>
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RDO: Rock drill operator
RSA: Republic of South Africa
SA: South Africa
SAMCODE: South African Mineral Codes
SEZ: Special economic zone
STEM: Science, Technology, Engineering and Math
PGE: Platinum group elements
PGM: Platinum group metals
UG2: Upper group 2
VA: Value-added
VOC: Dutch East India Company
Chapter 1

Introduction

1.1 Introduction

South Africa (SA) is host to the world’s largest known platinum group metal (PGM) reserves, a grouping of six noble and precious metals\(^1\) with similar properties, which are used in a wide variety of applications. The country is well-known for one PGM in particular, platinum, a metal of increasing interest in the energy sector. Already, the automotive industry depends on platinum catalytic converters to reduce harmful greenhouse gas (GHG) emissions. The rise in global environmental challenges has prompted research and development (R&D) into other ‘purifying’ applications for platinum in sustainable technology\(^2\). Most notably, it is a key catalytic component in emergent fuel cell technology.

The push for sustainable technologies, particularly in the energy sector, is expected to translate into an increase in global platinum demand. This places South Africa in a unique position, presenting both opportunities and challenges to capitalize on the technological shift. In fact, the country is exploring the possibility of an emergent fuel cell industry in-country, to address its energy security issues while stimulating demand of its platinum deposits. However, South Africa has a long history of political and socio-economic inequalities, rooted in the mining industry and deeply embedded in governance structures. This has resulted in material, structural and discursive expressions of power (Scoones, Newell & Leach, 2015) with severe social and economic development impacts. This thesis aims to explore the possibility of

\(^{1}\) Ruthenium, rhodium, palladium, osmium, iridium, and platinum.
\(^{2}\) For the purpose of this research, sustainable technology as a concept, “cannot be reduced to a formula or a method, but requires ongoing reflection, learning and interaction with stakeholders” (Mulder, Ferrer & Van Lente, 2011, p.7). That being said, it is generally used when technology is in harmony with environmental articulations, such as reduced emissions, pollutants, or overall use and type of material. In general, “the concept refers to the big challenges that global developments pose … often located in the domains of social, economic and ecological concerns. … The term allows the alignment of different stakeholders with their own perspectives, so facilitating joint efforts” (Mulder, Ferrer & Van Lente, 2011, p.236).
a South African fuel cell industry, while acknowledging these historically-structured power dynamics, examining their influence and potential impacts on such an industry.

This chapter provides some background on the country’s socio-economic and political history, alongside the emergence of its extractive industries, associated power relations, and an overview of the physical, political, economic and social development impacts which ensued.

1.2 Background

South Africa’s political and economic spheres have historically been shaped by its abundant mineral deposits. The extensive history of racialized inequality and segregation were politically motivated by the country’s extractive industries, profoundly influencing its development pathway. While the mineral revolution succeeded in sparking industrialisation and development in South Africa, creating employment and wealth for many, it also simultaneously perpetuated and deepened racial divisions, resulting in extreme poverty and suffering for others (Wilson, 2001). The governance structures which emerged have left legacies that continue to perpetuate in the platinum sector today. This section seeks to situate the contemporary research topic of fuel cell technology in South Africa within the broader historical context of the country’s extractive industry and associated development pathway.

1.2.1 The Emergence of South Africa’s Mining Industry

Until the late 19th century, control over South Africa’s territory remained a complicated landscape of various pre-industrial and pre-capitalist polities, including chiefdoms, settlements and colonies, with native Africans largely maintaining their political autonomy (Worden, 2007). The purpose of the first European settlement was originally as a halfway port for the Dutch East India Company (translated from the Dutch: *Vereenigde Oost-Indische Compagnie*; VOC), a highly lucrative trading enterprise, on its journeys between Europe and Southeast Asia (Butler, 1998; Davenport, 2013; Worden, 2007). Historians now generally agree that the distinguishing factor which drove colonial forces to seek more direct, interventionist control of the
territory was the rumor of precious mineral deposits, spurring new found economic interest for the British Empire and profoundly influencing the landscape of modern day South Africa (Atmore & Marks, 1974; Butler, 1998; Davenport, 2013; Worden, 2007). Despite over 150 years of copper mining attempts (Davenport, 2013), it was the confirmed discovery of diamond and gold deposits in 1867 and 1886 respectively, that initiated the beginnings of the South African capitalist society and subsequently spurred unprecedented development of the land (Butler, 1998; Worden, 2007).

Due to the high economic potential for the white ruling minority, government policies were largely influenced by the extractive industry (Butler, 1998; Worden, 2007). Race was a defining factor influencing land and labour policies in the late 19th and early 20th centuries, providing a cheap and abundant source of labour to the mines. Land rights policies and legislation³ created physical racial division through the establishment of “Bantustans” or homelands: remote rural locations comprised of merely 7% (later expanded to 13%) of the total land area where native Africans were forced to live. These areas were overcrowded, reducing the amount of arable land for subsistence, and heavily taxed, resulting in dismal living conditions. This placed native South Africans in vulnerable positions of extreme poverty (Worden, 2007), strategically paving the way for an abundant source of cheap migrant labour which was needed within urban areas and especially, within the mining industry.

With expansion of the industry, demand for cheap labour intensified, resulting in an extended system of migrant workers not only from the reserves of South Africa (most notably from the Eastern Cape), but also from much of rural southern Africa; most labour came from Lesotho and Mozambique, but Botswana, Swaziland and Malawi labour was also prominent (Wilson, 2001)⁴. Racialized inequality was further

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³ The Glen Grey Act (1894), the 1913 Natives Land Act and the Natives (Urban Areas) Act of 1923 were all influential in this regard (see Worden, 2007).
⁴ During the 1970s, both the diamond and gold industries abolished the migrant labour system, with the percentage of South African mine labour increasing from 22% in 1971 to 46% in 1999, using increased wages to attract local employment (Wilson, 2001).
entrenched in the mining labour system; policies such as the Mine and Works Amendment Act (1926), also known as the ‘Colour Bar’ Act, solidified racial divisions and inequality, reserving higher-paid, skilled jobs in the mines for whites (Wilson, 2001; Worden, 2007). While whites received union recognition as early as 1913, black miners were denied trade-union representation until 1980 (Wilson, 2001).

Racial segregation became further legitimized and socially entrenched during the apartheid regime (1948-1994). The apartheid system further intensified inequality by enforcing an oppressive class system, disproportionately affecting blacks. As an extension of the colonial land policies, mineral rights in the Bantustans under the apartheid regime were governed by the State, allowing the major mining conglomerates to gain control over majority of the BIC’s resources (Capps, 2012). This translated into geopolitical control of global platinum deposits and profits for the white ruling minority. However, as Capps (2012) points out, the political transition in the early 1990s would coincide with the platinum ‘boom’, subsequently attracting the attention of mineral policy reforms from the new post-apartheid government, threatening to dismantle their attempts to maintain direct control over the deposits. The effectiveness of these has been however, remains criticised, further explored in the next section:

The structures of apartheid were shaped in no small measure by mining industries that remain a central factor in the nation’s economy. Until these industries are transformed in such a way as to deal with the more serious of their own legacies, the transition to democracy will remain incomplete. (Wilson, 2001, p.119)

Inevitably, the apartheid system of ‘separate development’ (Wilson, 2001) which emerged from the country’s mineral revolution has had long-lasting socio-economic consequences, most notably and

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5 Initially, mine laborers consisted of both white and black workers, however, treatment and conditions for the workers were racially divided; practices such as forced strip searches (to prevent diamond smuggling) and compound housing (to cut wage costs) were reserved solely for the black laborers (Wilson, 2001; Worden, 2007).

6 Whites however, were entitled to hold private mineral rights, allowing them access to significant resource wealth of the exploited property (Capps, 2012).
unsurprisingly, within the mining sector. Policy reflected the racial segregation stimulated and entrenched by the mining industry and played a definitive role in laying the foundation of contemporary SA. This established the historical precedence for cheap migrant workers within the mining industry, while setting the precedent for racialized inequality embedded in the political structures of power, which remains prominent in the democratic South Africa of today. According to Humby (2014), “the number of black mineworkers recruited by the Chamber of Mines between 1904 and 1994 ranged from 80,000 in 1904 to about 550,000 in 1992. The majority of these workers were “foreign” (including workers from the former homelands)” (p.657). The migrant labour system predicated on recruited cheap wage-labour housed in a single-sex compound system, resulting in increased vulnerability for mineworkers to HIV transmission due to both behavioural and situational conditions (Cronje, Reyneke & van Wyk, 2013). According to the most recent South African Community Survey (CS, 2016), there is still a lot of in-migration, with Zimbabwe, Mozambique and Lesotho are the top sending countries (40%, 20% and 11% respectively). The migrant labour system has left legacies of xenophobia in South Africa, creating tensions in areas with higher levels of migrants (Cronje, Reyneke & van Wyk, 2013).

Beyond migrant labour however, other factors including “poverty, unemployment, poor housing and infrastructure [and] prostitution,” (Cronje, Reyneke & van Wyk, 2013, p.3) have culminated into major social issues. Housing and living conditions remain challenging, as well as access to basic services within local communities. The North West province (where Rustenburg is located, comprising Implats’ platinum mines and a significant portion of the PGM deposits) has the highest percentage of informal dwelling (18.4%) of all the provinces, with 44% indicating a lack of safe and reliable water supply as the leading challenge in the province (CS, 2016). In addition, mining companies still employ a lot of contract labour, which often makes education investments “a waste of money,” (Cronje, Reyneke & van Wyk, 2013, p.10) as workers are not able to maintain long-term learning commitments. This prohibits their advancement to higher-paid positions requiring higher skill levels and education.
1.2.2 **Policy Reforms & Struggles in the Newly Democratic South Africa**

The contemporary mining sector is perhaps the clearest indication of the short-comings of post-apartheid democracy and the perpetuation of inequality. The mineral revolution⁷ and its associated governance structures have left legacies of racial oppression, disproportionately affecting the black majority, also known as the Historically Disadvantaged South Africans (HDSAs). One of the key strategies outlined by the newly elected governing party in 1994, the African National Congress (ANC), was to overhaul the existing mineral property system by nationalising South Africa’s mineral rights. Yet despite these reforms, improvements remain questionable. The Mineral and Petroleum Resources Development Act (Act No. 28 of 2002) (MPRDA) was enacted to regulate the industry, ‘to make provision for equitable access to and sustainable development of the nation’s mineral and petroleum resources’ (as paraphrased in Sorensen, 2011, p.627). The defining feature of the MPRDA was making the State custodian of the mineral rights of the country. It is thus the state’s responsibility to ensure that the economic benefits generated by its extractive industries are redistributed to the larger population, with particular attention to HDSA’s and those directly affected by the mining operations (Republic of South Africa [RSA], 2002). Furthermore, the Mineral and Petroleum Resources Royalty Act (Act No. 28 of 2008) (MPRRA) came into effect a few years after, “to impose a royalty on the transfer of mineral resources and to provide for matters connected therewith” (as paraphrased in Sorensen, 2011, p.628). While the State has been expected to gain greater returns with the policy reforms through taxes and royalties, many are skeptical of its ability to redistribute them: “It is debateable that this revenue will find its way back into the mining communities given the lack of ‘service delivery’ by the South African government” (Sorensen, 2011, p.642).

In addition, section 100 of the MPRDA called for the Broad-Based Socio-Economic Charter for the Mining Industry (Charter, 2002), in order to, “create a mining industry that will proudly reflect the promise of a

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⁷ Referring to the discovery of gold and diamonds, which spurred South Africa’s development and industrialization pathway (Republic of South Africa [RSA], n.d.).
non-racial South Africa” (as paraphrased in Sorensen, 2011, p.627). The Charter’s associated ‘scorecard’ was developed in order to ‘measure’ the redistribution of economic wealth generated by SA’s extractive industries to HDSA’s by means of transferring ownership through Black Economic Empowerment (BEE). The Charter states that companies transfer 26% of their equity to BEE owners within 10 years of its implementation. In this regard, following democratisation, the mining sector underwent a ‘globalised restructuring’ strategy, unbundling the mining conglomerates and disposing of the less profitable mining ventures (in guise of BEE), while keeping the most valuable ones under white control (Capps, 2012). BEE has also been heavily criticized for serving corporate elite interests; the government has been accused of creating and manipulating strategic partnerships for political interests rather than facilitating economic and social transformations (Freund, 2007).

The result has been the systematic enrichment of a select few members of a previously well-off black elite, while the vast majority is left behind (Sorensen, 2011), excluded from the anticipated benefits of the newly democratic society. For the most part, HDSA’s remain undereducated and unskilled, therefore under-represented at the operational level in the mining sector and prohibiting their participation in these processes (Sorensen, 2011). To address these concerns, the Broad-Based BEE was developed and incorporated into the legislation in 2005, using scorecards to expand BEE beyond solely black ownership. The scorecards include seven elements: Equity Ownership (20%); Management (10%); Employment Equity (15%); Skills Development (15%); Preferential Procurement (20%); Enterprise Development (15%); Socio Economic Development (5%) (DTI, 2007). However, correcting the BEE’s loopholes has been challenging and mistrust of the system remains strong (Freund, 2007). The new elite faces the challenge of true structural transformation, deferring to old, familiar ways of business which primarily depend on resource-based economies with limited evidence of improvement for the majority of the population (Freund, 2007).

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8 It is worth noting the 11% of this ownership could be offset by investing in mineral beneficiation. However, according to Sorensen (2011), “by 2008, there had been no successful application for offsets” (p.628).
1.2.3 **Emergence of the Platinum Sector**

The platinum mining industry really took off in the early 1990s, replacing gold as the country’s primary contributor to gross domestic product (GDP) and was stimulated, to a large extent, by the increase in global demand for catalytic converters in the automotive industry. Thus, as Capps (2012) points out, the platinum ‘boom’ coincided with SA’s democratic shift and associated mineral policy reform. Despite these simultaneous transitions, the platinum sector exemplifies the legacies of inequality embedded in the mining industry. Historical structures are manifested through longstanding labour struggles for black mineworkers, inadequate delivery or nonexistence of social services to mineworkers and the surrounding communities, and the outsourcing of production schemes. With little support from the mining companies, union leaders, or government, workers are left with limited options to meet their demands for equality and social justice.

The Marikana Massacre which occurred August 16, 2012 is a reflection of these persistent inequalities within the industry and the continuation of racialized governance structures which work against HDSAs. Suspecting corruption and ill-representation from the National Union of Mineworkers (NUM)\(^9\), thousands of mineworkers from the Lonmin platinum mine located in Marikana, began to strike on August 13, 2012 (Figure 1-1).

\(^9\) The NUM was the dominant mineworkers’ union after gaining representation in 1980, until the Marikana Massacre when the Association of Mineworkers and Construction (AMCU) replaced it.
Beyond wages, underlying socio-economic issues, the migrant labour system, failure of development to remote areas, political factors and the prevailing power dynamics all culminated into the protest (Ashman & Fine, 2013; Bond & Mottiar, 2013; Chinguno, 2013; Magaziner & Jacobs, 2013). Magaziner and Jacobs (2013) claim that the strike was about struggles for equality in post-apartheid, industrial South Africa, a “demand to short-circuit time, rather than negotiate for a marginally larger wage” (p.142). The response from NUM, Lonmin and police forces (upon orders from the ANC government) was abysmal, resulting in the killing of 34 mineworkers, the worst case of police violence on civilians since the end of the apartheid era. Yet, as Magaziner and Jacobs (2013) point out, in the ongoing struggle for true democracy, equality and development, “violence has been, and, apparently, remains, the quickest way to short-circuit time” (p.142). Unless drastic measures are taken to address the historical legacies outlined in this section, there is a danger that the introduction of fuel cell technologies could serve to further exacerbate these already precarious conditions, with risk of more Marikana-like events likely to occur.
1.2.4 South Africa’s Position as ‘Leader’ of the Continent; Development, Climate Change & Technological Fixes

Despite this historical trend of political and social struggles, South Africa is commonly referred to as a ‘leader’ when compared to other countries on the continent. This is due to its comparatively high GDP (second only to Nigeria) and classification as an upper-middle income country (World Bank, 2013). To a large extent, the country’s integration within the global economic system can be attributed to the exploitation of its mineral resources. The country prides itself on this claim of leadership and understandably, seeks to maintain this position by exploring innovative strategies to position not only itself, but also the African continent, well within the globalised capitalist system.

While South Africa’s development pathway has led to relative economic prosperity, it has also resulted in extreme environmental costs. South Africa’s gold mining industry specifically has left legacies of toxic acid-mine drainage (AMD) of the Witwatersrand and surrounding areas; AMD enters the surface and groundwater bodies, causing extensive pollution which continues to affect ecological systems and South Africans today (Durand, 2012). In addition, the country’s development and mineral activities have depended on abundant and accessible coal reserves (sixth largest global reserves) as its primary source of energy (Pegels, 2010), resulting in extensive air pollution concerns. In 2005, South Africa contributed 1.1% of global GHGs, yet despite these abundant coal deposits, the country has struggled with energy distribution issues (Pegels, 2010) which challenge further development. With growing climate change concerns (to which South Africa is particularly vulnerable and susceptible10), there is increasing global pressure to reduce greenhouse gas (GHG) emissions. Thus, in response to both climate change and energy security

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10 South Africa’s socio-economic and environmental contexts make it vulnerable to a changing climate (DEA, 2011). Already facing water scarcity, South Africa is expected to experience more extreme weather variability “with an increase of extreme events such as flooding and droughts” (DEA, 2011, p.17). This will further impact the agriculture and forestry industries, and by extension, the health of the population, disproportionately affecting the poor. It is also expected to affect urban, rural and coastal settlements to varying degrees, with biodiversity and ecosystem impacts anticipated (DEA, 2011).
issues, the government is exploring alternative, cleaner methods of energy production (Department of Energy [DOE], n.d.). Fuel cell technology has been presented as a possible solution, and attracted the attention of the platinum mining industry as well; the devices produce independent energy, seen as a direct contribution to a long-term solution for energy security, and by extension, development. Fuel cells also contribute to GHG reductions, and thus are considered a cleaner method of energy generation (Bauen, Hart & Chase, 2003).

These environmental benefits have resulted in the labelling of fuel cells as a ‘sustainable technology’ (Edwards, Kuznetsov, David & Brandon, 2008; Implats, 2016), a description used to promote the devices and to justify their implementation in the mines themselves. But as Mulder, Ferrer & Van Lente argue, classifying technologies as ‘sustainable’ must go beyond the technology itself to include characteristics such as:

- The way a technology is perceived and used in a social context;
- The way in which it affects or even transforms this context;
- The way it interacts with technological systems and its physical context;
- The time frame of analysis, [and];
- The quantity of use. (2011, p.2)

In other words, the term sustainability is not based on any singular characteristic, but must be expanded to include multiple characteristics that encompass not just environmental articulations, but a broad range of articulations. The way in which the concept of sustainability is currently being used in relation to fuel cells in South Africa fails to take account of context and the plurality of the term itself. This will be analysed using a sustainability assessment framework further outlined in section 2.4.

Because most fuel cells require a platinum catalyst (see Table 3-1), they have significant potential within the South African context, where the vast majority of global platinum deposits are located. However, the socio-political challenges presented here are significant and require particular attention when exploring the possibility of an emergent fuel cell industry in this context. The success or failure of such a transition lies
in the way in which policy and power interact, which in turn, will have varying outcomes on the country’s human-environment relations. These interactions will be explored in this thesis, specifically via the platinum mining sector.

1.3 Conclusion
This chapter has provided a brief overview of historical patterns of racial oppression and political structures which have shaped and continue to plague the South African mining industry. It has also summarized the environmental implications of the country’s development pathway, presenting fuel cell technology as an option worth exploring, not only for national purposes, but equally within the platinum mining sector itself. The next chapter will outline the research question and associated methodology of the thesis.
Chapter 2
Methodology & Study Design

2.1 Introduction
This chapter begins by outlining how the research project was conducted, including the research problem, question and associated objectives that guided the research, before providing a detailed description of the data collection and analysis methods. Finally, this chapter emphasizes the research significance, while highlighting the theoretical framework and sustainability lens used to guide the thesis, ending with my positionality as a researcher.

Based on Merriam (2009), the nature of this study follows a qualitative research approach, incorporating the four main characteristics of this type of research: generating understanding and meaning, using the researcher as the primary instrument of data collection and analysis, applying an inductive process to build concepts, hypothesis or theories, and incorporating rich description to convey the results (p.14-16). The philosophical perspective applied is one of critical research; beyond the understanding of phenomena and meaning for participants, “in critical inquiry the goal is to critique and challenge, to transform and empower” (Merriam, 2009, p.34). Critical research focuses less on the individuals of the study and places emphasis on the context and power relations, alongside issues of knowledge construction (Merriam, 2009).

2.1.1 Research Problem, Question & Objectives
South Africa’s rich mineral deposits, the history of exploitation and subsequent development, along with associated racial segregationist practices and policies have been extensively researched. More recently, following the country’s democratic transition in 1994 and the end of the apartheid era, scholarly attention has focused on the struggle to redress the resultant political and social structures of inequality. Contemporary changes in the political structure and associated legislation changes, while seemingly more equitable and inclusive, face many obstacles in their implementation, as well as challenges in remediating
past harms. Meanwhile, the extractive industry has also transformed, with gold and diamonds making way for the newly emergent platinum sector, taking over as the country’s largest mining industry. The sector continues to deal with historical structures of racialized oppression and inequality, subject of much scholarly and worldly attention thanks to social issues and subsequent economic implications on the industry. At the same time, there is a desire to move away from the historical labour-intensive methods towards a more high-tech industry in the platinum sector. Simultaneously, industry and government alike have expressed high levels of interest in an emergent fuel cell industry (DST, 2008; HySA, n.d.; Implats, 2016), endorsed in the particular context of platinum mining, as a sustainable solution to energy, mechanisation and platinum demand issues.

The platinum mining sector remains particularly under-researched in areas concerning this technological shift, particularly the associated fuel cell industry, which is gaining significant attraction. Despite these events occurring simultaneously and to a large extent, in conjunction with each other, there is very little discussion on how they interact, influence and impact the surrounding context (Mulder, Ferrer & Van Lente, 2011). While issues surrounding mechanisation of the industry are beginning to receive scholarly attention (Stewart, 2015; Valicek, Fourie, Krafft & Sevenoaks, 2012) and media discussion (Seccombe, 2014; Stoddard, 2014), focus is generally placed on the technical feasibility, or the potential labour impacts of this transition. Discussions have yet to embrace a more multidisciplinary, holistic discussion concerning the influences of knowledge, power and technology in these issues. Therefore, the purpose of this study is to examine the way in which a fuel cell industry is manifesting itself within the contemporary South African context, while drawing on a historical understanding of the structures of power in place. This will serve to analyse the holistic implications of this innovative technology in regards to its implementation within the mining sector itself. The following research question and associated objectives were used to guide this study;
Research Question:

*Given its strategic position as global platinum supplier, what are the opportunities and challenges for South Africa to participate in and benefit from the emerging sector of fuel cell technologies reliant on this precious metal?*

Objectives:

1) Identify the significance of the platinum deposits and linkage to the development of fuel cell technologies and their applications;

2) Examine the political and socio-economic history of the platinum mining industry in South Africa;

3) Explore the fuel cell technologies applications and potential in the platinum mining industry;

4) Analyse the sustainability impacts of fuel cells as they apply to the South African context.

2.1.2 Data Collection & Analysis

The methodology applied to the research objectives incorporated four methods of data collection, namely, a literature review, key informant interviews, fieldwork observations and document analysis. The method of analysis is outlined in each corresponding subsection. Overall, I used the triangulation method to maintain validity and reliability of the data collected. I applied Denzin’s (1978) method, incorporating multiple sources of data, as well as data from people with differing perspectives to add significance and credibility to the thesis (see subsections). It is important to note that the thesis structure is organized thematically, with each chapter covering a different aspect of the research problem and associated objectives. The methods used and triangulated analysis are therefore spread throughout the chapters (Table 2-1).
Table 2-1: Thesis Content Analysis Outline.

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Theme</th>
<th>Objective</th>
<th>Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>History of South African context &amp; mining</td>
<td>2</td>
<td>Literature</td>
</tr>
<tr>
<td></td>
<td>industry</td>
<td></td>
<td>Document analysis</td>
</tr>
<tr>
<td>2</td>
<td>Methodology</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>3</td>
<td>Platinum deposits &amp; fuel cell technicalities</td>
<td>1</td>
<td>Literature</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Document analysis</td>
</tr>
<tr>
<td>4</td>
<td>Application of fuel cells in South Africa’s</td>
<td>3</td>
<td>Literature</td>
</tr>
<tr>
<td></td>
<td>platinum mining</td>
<td></td>
<td>Interviews</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fieldwork observations</td>
</tr>
<tr>
<td>5</td>
<td>South African context &amp; sustainability</td>
<td>4</td>
<td>Literature</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Interviews</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Document analysis</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fieldwork observations</td>
</tr>
<tr>
<td>6</td>
<td>Conclusion</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

2.1.2.1 Literature Review

An extensive literature review was done throughout the research process (Merriam, 2009), reviewed and organized by thematic content. At first, a broad search yielded literature on the South African context and development history, with particular attention to the mining sector. The purpose was to gain an understanding of the country’s socio-economic and political context and how this was shaped by the mining industry. Through this literature, the theoretical framework was derived; given the complex structures of power influencing the country’s development pathway, a political ecology approach was found to be the most suitable for the research project (see section 2.3).

Technical literature was also consulted to justify the significance of the research topic (that of fuel cell technology and platinum deposits). It was found that the literature base remained particularly ‘silhoed' in nature, with very little overlap pertaining to the social, economic or political impacts of implementing the technologies into the South African context. The lack of socio-technical analyses in the literature provided justification for the current thesis, adding to these knowledge bases. In addition, given the recent emergence of fuel cell technology itself, it was found that there was a general lack of knowledge in regards to the
impacts of its implementation, and very little acknowledgment or understanding of the localised impacts a
global fuel cell industry might have on the very unique South African context.

I also consulted sustainability literature, particularly focusing on the contributions of innovative technology
to this knowledge base. There was again, an identified gap in knowledge, specifically pertaining to the role
of fuel cell technology. As such, this research also contributes to expanding on sustainability concepts and
its various articulations. It also calls for the addition of fuel cells to the sustainable technology debate,
expanding this knowledge base.

2.1.2.2 Key Informant Interviews

Eight key informant interviews were held in person over the course of the month of August, 2015 as part
of my fieldwork in South Africa. Most interviews took place in Johannesburg, where universities, the
Chamber of Mines (CoM) and mining companies’ head offices are conveniently located. In addition, two
informal interviews were conducted, both during a site visit to the Impala Platinum Mine Shaft #14 in
Rustenburg. All interviews were semi-structured in nature, ranging from 30 to 75 minutes in length
(interview discussion topics and sample questions can be found in Appendix C). With the exception of the
informal ones, interviews were audio-recorded for in-depth analysis and use of quotes where appropriate.

It should be noted that consent from all interviewees, with the exception of one, was granted to have their
names and position used in the thesis project (Appendix A). Once the interviews were conducted, they were
transcribed manually, categorized and coded. This was largely based on Merriam (2009) coding methods,
moving from descriptive open coding of individual interviews to more analytical coding, finding meaning
in, between and across interview codes and creating emergent themes. I proceeded to sort the interview data
into these themes, identifying similarities, gaps and linkages to help guide further document analysis.
2.1.2.2.1 Sample Selection for Key Informants

Key informants were chosen by means of purposeful sampling (Patton, 2002), whereby specific interviewees were selected based on the following criteria (in order of importance): organization type, specialty or expertise, and position or level (when possible). I applied maximum variation sampling, seeking a well-rounded sample of organization types in order to offer a holistic perspective on the topics of discussion. The purpose of this type of sampling is to identify, “any common patterns that emerge from great variation … capturing the core experiences and central, shared experiences of a setting or phenomenon” (Patton, 2002, p.234, as cited in Merriam, 2009, p.79). Beyond pre-departure networking with professors from the University of Witwatersrand in order to initiate and facilitate connections, interviews were arranged through preliminary background research and sending email requests (see Appendix B for a sample email interview request). I also incorporated the snowball sampling technique, asking informants for other key contacts post-interview, which proved particularly useful within the mining sector. Interviewees ranged from academia, to private consulting, to multinational mining corporations, to industry. After this, I sought to interview people with specific expertise in areas such as: mining processes, fuel cell technology, mechanisation, sustainability, and training and education. When possible, I attempted to interview people in positions of authority (such as management or executives) with influence in decision-making or policy-making to understand the thought processes and considerations taken into account in these organization types.

Unfortunately, due to the limited time available for the fieldwork, the lack of contacts prior to arrival and the political-temporal contingency\(^\text{11}\) of the research topic (during a period of instability or uncertainty within the mining industry due to low platinum demand, ongoing strikes and negative press), it was not

\(^{11}\text{Whereby timing of the research interferes with local political events and processes (Ward & Jones, 1999). Beyond positionality and power dynamics, political-temporal contingency further complicates access to information by making it more difficult to secure interviews with key informants, particularly when the nature of the research is sensitive to such events, as was the case here with the sensitivity surrounding the issues of platinum mining.}
possible to get interviews with mining companies other than Impala Platinum (Implats). Implats is the second largest platinum producer, after Anglo American Platinum (Amplats). Furthermore, I was unable to solidify any key informants in government and therefore, information pertaining to that stakeholder was obtained through document analysis. Despite these limitations, the key informants range in organizational background and expertise, providing a well-rounded array of information and adding credibility to this research. Descriptions of the interviewees and the respective topics covered, as they relate to the research objectives, are summarized in Table 2-2.

It is important to acknowledge that the populations directly affected by the mining industry were not directly consulted in the research process due to time restraints, along with the main technological focus of the research. Analysis regarding their wellbeing and possible hardships associated with the implementation of fuel cell technologies in the platinum mines was thus restricted to historical trends, literature review and perceptions of other informants who were interviewed. Without hearing from those most vulnerable to, and directly affected by, this technology, perceptions and conclusions regarding their wellbeing remain preliminary. Further research involving these key stakeholders would add further depth and understanding to the research.
Table 0-2: Key Informants, Interview Type, Discussion Topics & Link to Research Objectives.

<table>
<thead>
<tr>
<th>Interviewee</th>
<th>Organization</th>
<th>Position</th>
<th>Type of Interview</th>
<th>Audio-Recorded</th>
<th>Interview Topics (Associated Objective #)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cindy Mogotsi</td>
<td>Impala Platinum Limited</td>
<td>Group Executive; Sustainable Development</td>
<td>Formal; Semi-Structured</td>
<td>Yes</td>
<td>• Social impacts of mining on surrounding communities; housing, service provision and employment (3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Economic issues; Diversification of economies for nearby communities (4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Socio-economic issues; mechanisation of the industry (3)</td>
</tr>
<tr>
<td>Martyn Fox</td>
<td>Impala Platinum Limited</td>
<td>Group Executive; Technical Services</td>
<td>Formal; Semi-Structured</td>
<td>Yes</td>
<td>• Fuel cell implementation at Impala's Springs Refinery (1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Economic impacts of fuel cell implementation (3)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Implementation of fuel cells underground (3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Partnerships for fuel cell development &amp; procurement (3)</td>
</tr>
<tr>
<td>Paul Jourdan</td>
<td>Independent Consultant</td>
<td>Resource-Based Development Consultant</td>
<td>Formal; Semi-Structured</td>
<td>Yes</td>
<td>• Mechanisation of the mining industry; historical and global perspectives/examples (2, 3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• South African context, development &amp; production (national vs outsourcing) (4)</td>
</tr>
<tr>
<td>Declan Vogt</td>
<td>The Center for Mechanised Mining Systems (CMMS)</td>
<td>Director</td>
<td>Formal; Semi-Structured</td>
<td>Yes</td>
<td>• Mechanisation of the mining industry; feasibility, timeframe, major constraints/barriers (1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Development &amp; production (national vs outsourcing), lessons from other sectors (4)</td>
</tr>
<tr>
<td>Jeanette Hofsajer-Van Wyk</td>
<td>Chamber of Mines of South Africa</td>
<td>Manager; Head of Information Services</td>
<td>Formal; Semi-Structured</td>
<td>Yes</td>
<td>• Fuel cell technology implementation; motivations, benefits, drawbacks, challenges (1, 3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Social impacts of mechanisation; consequences and responsibilities, diversification potential (3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Development &amp; production (national vs outsourcing) (4)</td>
</tr>
<tr>
<td>Name</td>
<td>Organisation</td>
<td>Position</td>
<td>Style; Conversational</td>
<td>Structured</td>
<td>Yes/No</td>
</tr>
<tr>
<td>-----------------</td>
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</tbody>
</table>
| Judith Kinnaird | University of Witwatersrand       | Director; (EGRI\(^{12}\)) & Co-Director; (CIMERA\(^{13}\)) | Formal; Semi-Structured |            | Yes    | • Environmental impacts of platinum mining; tailings, remediation possibilities (3)  
|                 |                                    |                                         |                       |            |        | • Informal mining; potential, challenges, scale (3)                    |
| Fahmida Smith   | Impala Platinum Limited           | Fuel Cell Co-ordinator                  | Informal; Conversational |            | No     | • Fuel cell implementation; possibilities underground, challenges, benefits (3)  
|                 |                                    |                                         |                       |            |        | • Economics; present and long term plans, development and production (3)  
|                 |                                    |                                         |                       |            |        | • Training and education; fuel cell development, production and use (4)    |
| Anonymous       | Impala Platinum Limited           | Lead Engineer                           | Informal; Underground Site Visit/Tour |            | No     | • Process of platinum mining extraction; steps, equipment, underground channels (1)  
|                 |                                    |                                         |                       |            |        | • Worker conditions; health and safety, daily shifts, positions & roles (3)  
|                 |                                    |                                         |                       |            |        | • Equipment and function; machinery, transport, mechanisation (3)         |

\(^{12}\) Economic Geology Research Institute.  
\(^{13}\) Centre of Excellence for Integrated Mineral and Energy Resource Analysis.
2.1.2.3 Fieldwork Observations

Evidence from two fieldwork observations was included in the analysis. The first observation I attended was the third annual Marikana Memorial Event (Figures 2-1, 2-2 & 2-3). This took place at Lonmin’s Marikana mine at Nkaneng, near Rustenburg, in commemoration of the massacre which took place there August 16, 2012. Observations regarding housing and living conditions of the informal settlement beside the mine were made. In addition, I had the opportunity to be guided along the path of the shootings, where a scholar explained in detail the events of the Marikana Massacre, location of shootings and ongoing investigations. This observation provided data in relation to objective #2.

Figure 0-1: Marikana Memorial Event. Mineworkers, family members and community members gather at the massacre site in commemoration of the 34 mineworkers killed. Source: Author photo.
Figure 0-2: Attendees of the Annual Marikana Memorial Event. People show their support for the Association of Mineworkers and Construction Union (AMCU), now the majority union for Lonmin, Anglo American Platinum and Impala Platinum. Source: Author photo.

Figure 0-3: Police Vehicles Surround the Marikana Memorial Event. The same vehicles were present during the massacre. Source: Author photo.
The second excursion involved a visit to Shaft #14 at Implats Mine in Rustenburg, where I had the opportunity to go underground. One of the lead engineers provided a four-hour guided tour of the mine. The mine’s production scheme was clearly outlined (Figure 2-4), providing insight into a modernised platinum operation. Working conditions were also observed, including the narrow tunnels to extract the platinum reef (Figure 2-5) and the health and safety of the underground environment (Figure 2-6). This observation provided data in relation to objective #3.

**Figure 0-4: Underground Site Visit at Shaft #14.** Explosives are lined up for the next blasting cycle. Source: Author photo.
Figure 0-5: The Platinum Reef. Platinum-containing reefs are clearly visible as a dark line running through the ore body. Source: Author photo.

Figure 0-6: Underground Health & Safety Room. Where some underground health and safety training takes place. It is also the room where workers are taken in the event of an accident. Source: Author photo.
These fieldwork observations allowed me to deepen my knowledge and understanding of the processes involved in platinum mining in the South African context. I was able to observe some of the key issues within the platinum mining sector, as identified in the literature, particularly related to modernisation and mechanisation, health and safety, housing and social service challenges and socio-economic inequalities. The data collected were triangulated with interview and document data to validate the findings. Not only did these visits reinforce the significance of this research project, but having occurred at different times throughout the fieldwork, they were also able to contribute to the framing of some of the interview questions that took place afterwards.

2.1.2.4 Document Analysis

The fourth method applied to this research project was document analysis. Public documents from both government and industry were used to identify key trends and initiatives within the mining sector, political influences, social, environmental and economic impacts from the industry, alongside fuel cell technology potential and implications. This was in response to objectives 1 and 3. Government documents pertaining to policies and initiatives for both the extractive industry (such as the MPRDA, the Charter) and the energy sector (Hydrogen South Africa (HySA) for example) were examined. In addition, government departments such as the Department of Energy (DoE), the Department of Minerals and Resources (DMR) and the Department of Environmental Affairs (DEA) were other sources of official documents. For industry, sustainable development reports, factsheets and integrated annual reports were examined for content pertaining to sustainability, mechanisation and fuel cell feasibility and implementation. These documents guided much of the interview discussions and questions with industry. In addition, public documents such as media and newspaper sources were consulted to gain an understanding of intentions and potential impacts of government initiatives still in the development phases.

At first, documents were analysed for key concepts, initiatives and concerns surrounding the research topic. These initial searches helped identify knowledge gaps, and guided the research and interview questions.
Post-interviews, and having done some data analysis in constructing themes, more documents were examined (and others re-visited) to address any gaps and gain further data.

2.2 Significance

The potential impacts of an emergent fuel cell industry in South Africa, and within its platinum mines specifically, cannot be understood outside of discussions involving power and politics of the context. Providing a holistic account will add to discussions on historical trends of power relations and social justice issues within this sector. I hope to expand upon commentary on contemporary structures of racial oppression within the industry and how these dynamics come into play when discussing, developing and implementing innovative technology within the mining industry. In addition, I hope to challenge the sustainability discourse associated with technological development, advancement and implementation, in order to acknowledge the historical structures that shape and are affected by these transitions.

This research aims to combine both hard and soft politics (Scoones, Newell & Leach, 2015), moving beyond the technical, material aspects of fuel cells within the South African context, to include discussions on knowledge and power which are intricately intertwined, making explicit their influence on broader social justice issues. This is where I hope to make my contribution and shed some light on problematic areas which must be brought to the negotiating table when discussing a South African fuel cell industry, particularly their integration within the platinum mining sector.

2.3 Theoretical Framework

The problem and purpose of this research project are situated in the theoretical framework of political ecology. This framework guides both the choice of methods, and the analysis of the data collected in the study, presented here in terms of, “the relationships between economics, politics, and nature,” with the unifying goal of “politicizing” issues surrounding human-environment interactions (Robbins, 2004, p.5). According to Bryant & Bailey, there are three underlying assumptions amongst political ecologists: “the
idea that costs and benefits associated with environmental change are for the most part distributed among actors unequally … [which inevitably] reinforces or reduces existing social and economic inequalities … [which holds] political implications in terms of the altered power of actors in relation to other actors” (as cited in Robbins, 2004, p.11). South Africa’s Bushveld Igneous Complex (BIC) is no exception, where the vast majority of global platinum deposits are located. The geography and geology of the country’s mineral deposits profoundly influenced issues of power dynamics, social justice and human-environment relations in this region. Understanding these dynamics as they play out in the contemporary South African context will be essential to analysing the effects of new technologies within this longstanding system of environmental and human exploitation.

Robbins (2004) identifies four keys narratives of research, which he classifies as the theses of political ecology. Each thesis or narrative seeks to answer different questions, therefore finding relevance in different types of research. The theses include: degradation and marginalization; environmental conflict; conservation and control; and environmental identity and social movement (Robbins, 2004, p. 14). In-depth explanations of what each is used to explain are provided via separate chapters within his book. I use the ‘environmental conflict thesis’ which aims to explain ‘why’ and ‘who’ is granted access to environmental resources. This narrative is useful in highlighting the power relations that influence this access (based on gender, race and class) and subsequent conflicts which arise as a result (Robbins, 2004). Rights, access, and responsibilities of the various groups involved are central to the environmental conflict thesis.

I use this theoretical approach as critique in order to expose the deeply politicized nature of the social and environmental issues facing South Africa’s platinum mining industry, “demonstrate[ing] the undesirable impacts of policies and market conditions, especially from the point of view of local people, marginal groups, and vulnerable populations” (Robbins, 2004, p.12). It is also used to expose the potential benefits and challenges associated with the implementation of fuel cell technologies within this deeply politicised
industry and context, including how fuel cell technologies might contribute towards a shift to clean energy generation. As Newell (2015) notes, “since energy use, in particular, is closely correlated with growth, there is tremendous political sensitivity around proposals to transform its provision and distribution” (p.71). Findings from this research can therefore be used to expand the range of political ecology approaches when looking at extractive industries, bringing forth different perspectives in how we think about the role of the environment and natural resources in the social and political issues that surface from their exploitation.

2.4 Sustainability Assessment

Complementary to the theoretical framework, my research also incorporates a sustainability lens. With increasing global concerns surrounding climate change issues, specifically within the energy sector, sustainability has emerged as both a key concept and evaluation tool. As Mulder, Ferrer and Van Lente (2011) point out, the evaluation itself is not new; we are always looking to improve our societies. Rather, it is the scale and interconnectedness of global issues we are facing that is unique to the sustainability narrative. As a response, innovative technologies, which are used to improve our societies, are increasingly evaluated using this sustainability concept. Fuel cell technologies are no exception, heavily promoted by industry\(^\text{14}\) using a sustainability narrative. The ambiguity lies in the criteria used to define this narrative. As mentioned previously, there is no definitive construct of criteria for sustainable technology; rather, it is a fluid concept particular to the context and articulations of the technology. Unfortunately, this fluidity can lead to the misuse or misapplication of the term: “calling a technology ‘sustainable’ can often be a way of derailing any criticism of it” (Mulder, Ferrer & Van Lente, 2011, p.237). Thus, one of the objectives (#4) of this research is to unpack industry’s meaning of sustainability as it is applied to fuel cell technology in the South African context, exposing the characteristics used, and those overlooked, in promoting the devices as ‘sustainable technologies’. A sustainability assessment will be used as a guiding framework to evaluate

\(^{14}\) Including platinum mining companies, the Chamber of Mines South Africa and fuel cell companies alike.
and critique this narrative in order to explore the potential impacts of the devices within the South African context (chapter 5).

Sustainability assessments aim to provide a deeper understanding and analysis, using an integrative framework and avoiding the traditional ‘siloed’ approach to sustainability (typically economic, environmental and social pillars, but may include others such as cultural, political, etc.). They are, “committed to positive overall contributions through identifying best options (rather than just acceptable undertakings) and designed to achieve multiple reinforcing gains (rather than mere avoidance of problems and mitigation of adverse effects)” (Gibson, 2006, p.178). Many comprehensive frameworks in the literature remain conceptual and theoretical in their approach and thus, largely unapplied. Within the mining industry today, the global reporting initiative (GRI) is the most widely used framework for sustainability assessments, including South Africa’s platinum mining sector. The latter is considered a leader in sustainability reporting and transparency (Mudd, 2012). However, like many other frameworks, the GRI has been critiqued for having a ‘siloed’ approach, leaving issues such as governance, trade-offs and synergies largely excluded from indicators, alongside a lack of geographical or spatial focus (Fonseca, McAllister & Fitzpatrick, 2013).

To avoid these limitations, I chose the Seven Questions to Sustainability (7Q) framework, resulting from the Mining, Minerals and Sustainable Development (MMSD) North America project. The 7Q framework defines sustainability as, “much more than environmental protection in another guise. It is a positive concept that has as much to do with achieving well-being for people and ecosystems as it has to do with reducing stress or impacts” (MMSD, 2002, p.7). The objectives are as follows:
- **Objective 2A**: to develop a set of *practical* principles, criteria and/or indicators that could be used to guide or test the exploration for, design, operation and performance monitoring of individual operations, existing or proposed, in terms of their compatibility with concepts of sustainability.

- **Objective 2B**: to suggest approaches or strategies for effectively implementing such a test/guideline (MMSD, 2002, p.vii).

The objectives of this framework proved the most suitable for this research project in terms of the practicality of applying the framework, its long-term focus (using a life-cycle approach), its use of scale in terms of mining projects or operations, and its integrative approach (guiding decision-makers towards value-laden trade-off and synergy considerations). While the framework was originally designed to guide the sustainability assessment of mining projects or operations, I have adapted it for the current research project by considering fuel cell technology implementation as a specific project currently being pursued within the industry, contributing to its operations.

The seven components of the framework are outlined in Figure 2-7. Each component poses a question and provides an ‘ideal’ answer, while listing hierarchal objectives in order to assess whether the mining project or operation will contribute to sustainability in a positive or negative way over the long term. For the purpose of this thesis, specific indicators and metrics for each question have not been formulated; rather, the project’s impact has been assessed using the data collected and comparing this to the corresponding question and ideal answer provided in the framework.
By promoting fuel cells in their own operations, platinum mining companies are stimulating growth of their industries, while simultaneously supporting and contributing to the development of these technologies. Analysing the sustainability of this strategy by using the 7Q framework will shed light on the broader, integrated impacts such an approach may have, while challenging the sustainability narratives used in the promotion of the technologies in this context (see chapter 5).

2.5 Positionality

Positionality, “refers to the stance or positioning of the researcher in relation to the social and political context of the study – the community, the organization or the participant group” (Rowe, 2014, para. 1). This influences many aspects of the research, and ultimately, the knowledge which is produced as a result. Decisions ranging from what is to be studied, how the study is designed and conducted, to the way in which informants are solicited, to how the information is analysed, disseminated, and acted upon, (Rowe, 2014,
para. 1) are all influenced by my personal positionality as a researcher. No doubt, my education and lived experiences have shaped my research interests, along with this project. As such, I acknowledge that the outcomes of this research project and the specific framing of the knowledge produced, is a reflection in some ways of my positionality, whether intentional or not. These dynamics are particularly interesting for research within the South African context. Given historical contexts of colonization and apartheid, performing research as a white, foreign female, with Dutch heritage (clearly identifiable from my name and familiar in South Africa), could have affected the experiences and research outcomes during fieldwork.

Positionality also affects the type of information provided by interviewees, based on the subject and in accordance with the political-temporal contingency (Ward & Jones, 1999), making certain information more sensitive and therefore, more difficult to extract than other types of information. I acknowledge that this was most likely the case for my key informant interviews as well, particularly those within the platinum mining industry, some of whom explicitly stated their concerns about this research project portraying the industry in a negative way. For example, when framing questions around fuel cell technologies amidst discussion on mechanisation, information was quite difficult to obtain and was extremely vague in nature. However, when framing fuel cell technologies as a sustainable energy device, the discussion was much lighter, and information was readily provided concerning industry efforts towards implementing such projects.

2.6 Conclusion
This chapter has outlined the methodology of the thesis, explaining the research methods applied to gather data, as well as the frameworks used in the analysis. The research significance was highlighted, along with the researcher positionality, recognizing any potential influence this may have had on the design, data collection and analysis of the research. The next chapter will provide an in-depth analysis of South Africa’s platinum deposits, fuel cell technology, and the possibilities of their implementation within the mining sector specifically, serving to link the significance of South Africa in the fuel cell discussion. Following
this, chapter 4 will outline current plans for fuel cell implementation within the South African platinum mining industry. This includes both aboveground and underground applications, drawing on Implats’ projected developments in this regards. Finally, chapter 5 will explore the impacts of these implementations specific to the South African context, within the 7 Questions to Sustainability framework. Drawing on the historical context provided, topics such as policy, development, power, and knowledge production will be used to deepen the analysis on fuel cell technologies in South Africa.
Chapter 3
Exploring South Africa’s Platinum Deposits & Fuel Cell Technology

3.1 Introduction

The literature for this chapter provides geological insight into the unique nature of South Africa’s platinum deposits. This is used to emphasize the country’s geopolitical significance regarding fuel cell technology. The extraction of platinum has long historical roots, dating back to 700BC (Johnson Matthey, n.d.). While minor deposits can be found across the globe, the majority of extraction today is highly concentrated in South Africa’s Bushveld Igneous Complex (BIC), contributing 77% of global platinum production in 2010 (USGS, 2012). These deposits are by far the largest in the world, located in the northern provinces (Figure 3-1).

This chapter starts by highlighting the geographical and geological significance of South Africa’s platinum deposits and the long-term viability of these resources when considering a future fuel cell industry. Specificities of platinum and fuel cell technology are also outlined, while highlighting the linkages between the precious metal and this innovative technology. Finally, South Africa’s economic interest in developing such an industry is made explicit.
3.2 Geographical and Geological Significance of the Bushveld Igneous Complex

South Africa’s BIC encompasses Eastern, Western and Northern limbs, and is composed of three platinum group element (PGE)\(^{15}\) ore bodies, namely, the Merensky reef, the Upper Group 2 (UG2) reef and the Platreef (Figure 3-2). The ore bodies differ in their platinum concentrations, containing 55%, 46%, and 44% platinum respectively (Cawthorn, 1999). Geographically, the Eastern and Western portions are similar in geological composition, both containing the Merensky and UG2 reefs. These reefs are relatively thin (approximately 1m thick), with ore bodies spanning over 300km (Cawthorn, 1999) and extending to great depths, thus requiring narrow underground mining techniques (Mudd, 2012b). The Northern section is uniquely host to the Platreef and is differentiated both in terms of its physical size and resource deposits.

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\(^{15}\) As opposed to platinum group metals (PGMs), platinum group elements (PGE) is the terminology commonly used in geology, “as the elements generally occur in mineral, rather than metallic, form within an ore” (Cawthorn, 2010, p.214).
Its ore body expands merely 30km (Cawthorn, 1999), but is composed of much thicker reefs (anywhere from 4-200m) located near surface, therefore requiring open-mining techniques (Mudd, 2012b). It is the only body of the three which is 46% palladium-dominant (Cawthorn, 1999), making development in the Northern section historically less favorable for economic reasons.
Figure 3-2: Map of SA’s Bushveld Igneous Complex, Ore Bodies & Ownership. Source: SFA (Oxford) Ltd, 2015
The Merensky reef, named after its discoverer Dr. Hans Merensky, was discovered in 1924, initiating the platinum extractive industry in South Africa. It remained the country’s singular source of supply until the 1950s, at which point, technological improvements made the UG2 reef economically mineable\textsuperscript{16} (Cawthon, 1999; Mudd, 2012b). Today, the BIC is known to hold somewhere from 75-80\% of global platinum reserves; factors such as terminology, geographical boundaries (in the case of the Platreef\textsuperscript{17}) and industry regulations, make it difficult to determine exact platinum figures. The distinction in terminology here is important:

A \textit{proven} [emphasis added] reserve is defined as ore available for mining without further development; a \textit{probable} [emphasis added] reserve is ore available beyond existing development, but which has been fully evaluated by drilling. An \textit{inferred} [emphasis added] mineral resource is defined as one where there are reasonable and realistic prospects for eventual economic extraction, but where the database on quantity, grade and continuity have not been sufficiently rigorously evaluated to consider it a \textit{reserve} [emphasis added]. (Cawthorn, 1999, p.483)\textsuperscript{18}

In terms of industry regulations, today’s statutory codes restrict companies from disclosing deposits which, while geologically plausible, have not been explored extensively. Historical data published includes inferred ore which today would be considered outside of the scope companies disclose (Cawthorn, 2010). Additionally, due to the abundance of available minerals closer to surface, there is no immediate need to identify the deposits at greater depths with high accuracy, excluding long stretches of reef from reporting (Cawthorn, 1999). Despite this, upon comparing historical data with mining companies’ reports, Cawthorn

\begin{center}
\begin{footnotesize}
\textsuperscript{16}Although the UG2 reef was discovered first, in 1906, it was considered uneconomical to mine at the time due to technological challenges. Ironically, today it is considered the more valuable of the two (Vermaak, 1995, as cited in Cawthorn, 2010, p. 484).

\textsuperscript{17}It is much harder to estimate platinum resources in the Northern limb due to the less-definable boundaries in terms of PGM content and the irregularity of the lateral layers (Cawthorn, 2010).

\textsuperscript{18}More recent terminology used by the South African Mineral Codes (SAMCODEs) includes \textit{reserves} (encompassing both ‘proven’ and ‘probable’ reserves, with some added requirements such as environmental, social and legislative issues to be addressed), \textit{resources} (which include ‘inferred’ along with ‘measured’ and ‘indicated’ categories), and \textit{deposits} (accounting for the remaining ores which can be reasonably assumed through geological information, but for which no economically significant evaluations have been done) (Cawthorn, 2010). 
\end{footnotesize}
\end{center}
(1999) estimates some 800 million oz. of platinum for the 2km depth economically minable. This number can reasonably be expected to increase once mining to greater depths becomes possible within the platinum sector (which has been achieved in gold mining down to 4km in depth), inevitably increasing the figure of inferred resources available.

3.3 Formation and Significance of the BIC

South Africa’s BIC was formed by an extended period of magma layering, caused by repeated volcanic eruptions, occurring over a geologically short period of time. The slow-cooling of this magma, spanning 65,000km² and reaching 8km in depth according to Cawthorn (1999, 2010), caused a crystallization process, solidifying different minerals in parallel, horizontal layers (Cawthorn, 1999; Cawthorn, 2010). The BIC is the largest layered intrusion of its kind in the world.¹⁹

Not only is it the largest deposit of its kind, but it also contains the highest PGE ore-grade ratio, making it even more unique and especially economically valuable. The BIC is considered a PGE dominant ore, meaning it is primarily mined for its precious mineral content while producing other associated metals as by-products (such as copper (Cu), nickel (Ni) and cobalt (Co) for example). This is not the case for majority of other global PGE deposits; these can be made up of Ni-Cu dominant ores or miscellaneous ores, whereby economic viability of PGE extraction remains subject to the dominant ore minerals. This explains in part the reason they are less significant in the global economy and solidifies the BIC’s geopolitical significance, in both geographical and geological sense.

3.3.1 Viability of Platinum Resources

The longevity of platinum deposits is a controversial topic within the literature. Scholars defending the long-term prospects of platinum supply draw upon geological evidence to support their claims of viability

¹⁹ Other major deposits include (in order of PGE content): the Noril’sk-Talnakh (Russia), the Great Dyke (Zimbabwe), Skaergaard (Greenland) and Stillwater (USA). Countries with minor deposits include Canada, Australia, Finland, China, Brazil, Tanzania, Botswana and trace amounts in Argentina (Mudd, 2012b).
for at least another century (Cawthorn, 1999; Cawthorn, 2010; Mudd, 2012). Others remain unconvinc
d, using market conditions to highlight the unpredictability of global demand which can drain deposits much
quicker, particularly with the increasing dependence on technologies which rely on platinum as an essential
component (Gordon, Bertram & Graedel, 2006; Yang, 2009). While annual extraction rates have steadily
increased about 5% per year for the past few decades (Gordon et al., 2006), this has been intermingled with
periods of drastic upward shifts in demand. A prime example was the surge in demand between 1959 and
1979, when rates increased to 7.4% (Gordon et al., 2006), attributable to the integration of autocatalysts20
in automotive regulations in the USA and Japan. Another spike occurred in the 1990s, when the European
Union and various other countries followed suit, adopting similar ‘tailpipe’ regulations (Wilburn &
Bleiwas, 2004). 21 This is just one factor stimulating demand; platinum has an ever-increasing range of
applications (see next section), all influencing the long-term viability of deposits.

Relying on the physical availability of deposits, based on geological evidence and global demand alone, is
insufficient for this discussion; there are also important technical, political and social factors contributing
to the debate. Even with promising geological evidence, there are technological limitations to extraction of
the BIC’s resources. Research and development (R&D) into technology for mining at greater depths is
underway, a necessary element for maintaining or increasing production in the near future. However,
greater depths present health and safety concerns; already, expensive ventilation and cooling systems are
required underground to ensure adequate working conditions in the mines. Expanding operations means
major increases in these systems, which are very energy and cost intensive (Mudd, 2012b). Mechanisation
of the industry is being explored as a potential solution to both resource availability and health and safety
issues. This approach is inherently political in nature and will be further explored in the next two chapters.

20 Autocatalysts filter toxic exhaust emissions, converting them to less harmful ones, and were implemented as a
response to increasing air pollution concerns (British Geological Survey, 2009).
21 Other contributing factors increasing platinum demand include PGM jewellery as a status symbol in China and
technological advancements allowing for greater recovery at lower costs from both ores and by-products (Wilburn &
Bleiwas, 2004).
Finally, recycling is seen as another approach to this issue; given its finite nature, recovering and recycling of the precious metal is a logical approach to supplementing demand (Gordon et al., 2006). While platinum recycling is gaining traction, this type of supply remains relatively low; given the dip in pricing, platinum autocatalyst scrap hoarding has taken place, in anticipation of higher prices when it is expected that more scrap cars will enter the recycling scheme (Johnson Matthey Plc, 2015). The price of platinum fell by 2.3% from 2012 figures, averaging $1,487/oz in 2013 (CoM, 2014). Additionally, the ongoing strike and labour tensions affecting platinum supply have spurred discussions on the importance of recycling in response to the unreliability of South African supply (Chamber of Mines [CoM], 2014). The strikes of the platinum sector in 2012 caused an increase in recycling, from 63 tonnes that year to 64.6 tonnes in 2013 (CoM, 2014).

All in all, for now, emphasis remains focused on increasing primary extraction for the time being.

Clearly, platinum deposits are heavily influenced by environmental factors and technological developments over the long term. However, in the short term, the viability of South Africa’s platinum deposits themselves are not the primary concern, but rather, the social, economic and political aspects which will inherently combine to influence platinum’s future supply and production. As Cawthorn (2010) states, “Resolving social, political and environmental issues, together with ensuring water and electrical supply capacities, […] are the unknowns and unpredictables in the future of platinum mining in South Africa, not the availability of the ores” (p. 213). As Mudd suggests, “Overall, there is certainly room for optimism in the ability to increase PGE supply and resources in the medium term, mindful of [these] factors” (2012b, p.115).

All of the above must be considered when looking at platinum mining in South Africa, where a shift to fuel cell technology has the potential to exacerbate both physical resource limits and broader socio-economic, environmental and political issues. Understanding the historical supply and demand patterns will help provide some insight on future resource potentials.
3.4 Demand, Supply and Price

Understanding the global demand, supply, and pricing schemes of platinum is useful in establishing linkages between the precious metal and fuel cell technologies. South Africa’s prominent position in this regard heavily influences, and is influenced by, these dynamics. Global platinum demand has steadily increased for the past few decades, with annual consumption jumping from 0.3 million ounces in the 1950s to 5 million ounces by 1998, with South Africa contributing three quarters of market supply (Cawthorn, 1999). Geological estimates of the BIC suggest figures around 800 million oz of platinum for depths of just 2km (Cawthorn, 2010; Crowson, 2001 as cited in Cawthorn, 2010); however, much has already been mined in the layers close to surface, with about 550 million oz remaining for extraction for depths of 2km (Cawthorn, 2010). In contrast, annual production from the largest platinum producers\(^\text{22}\) is less than 5 million oz per year (Cawthorn, 2010). In 2013, South Africa contributed 71.8% of global primary platinum production (CoM, 2014). Despite these figures, demand can be extremely volatile, as was demonstrated by the effects of the global financial crisis; platinum demand dropped by 11.9% in 2009, largely attributable to the automotive sector taking a 39% drop (Johnson Matthey, 2010). Supply can also be volatile due to geopolitical factors. In 2001, worldwide supply and demand figures were 182.3Mg and 193.8Mg, respectively (Yang, 2009, p.1807). Yet quickly thereafter, the beginning of the 21\(^{st}\) century saw decreased supply from the 2 major global suppliers; Russia’s halt in export supplies (Christian, 2000; Yang, 2009), coupled with South Africa’s energy crisis in 2008 (which caused a 3% drop in global platinum supply), increased pricing volatility; platinum pricing jumped 40%, from $50 to $70/g (Yang, 2009). Soon thereafter, prices dropped significantly due to the global financial crisis and the subsequent decrease in automotive and jewelry demand. These incidents demonstrate clear linkages between geographical locations of resources and global economic impacts.

\(^{22}\) Anglo Platinum, Implats, Lonmin and Northam Platinum.
Platinum demand can be considered volatile due to the nature of its end-use, which spans over a vast range of applications. The precious metal is increasingly used as an investment in banks and other institutions (Christian, 2000; Owen, 1987), as well as communication networks, jewelry, glass-making, electronics, chemical and petroleum refining catalysts, dental alloys, medical applications and pharmaceutical industries (Christian, 2000). The majority (60%) of global platinum demand however, emerged more recently, from the automotive industry (Yang, 2009). As previously mentioned, automotive catalysts for emissions reduction are now a legislative requirement in many countries, using platinum, palladium and rhodium in the ratio of 67:26:7 respectively (Xiao & Laplante, 2004). Each vehicle requires approximately 1-5g of platinum (Yang, 2009) for the catalysts. After this sector, jewelry accounts for the second highest demand, mainly coming from Japan, where demand was 1.61M oz. in 1998 (Christian, 2000).

South Africa is by far the dominant force in the global platinum supply market, contributing 4.53million oz. in 2009, compared to supplies from Russia, North America, and Zimbabwe of 785,000 oz., 260,000 oz., and 230,000oz., respectively (Johnson Matthey, 2010). Industry must be wary of the risk of overproduction and supply, as this could lead to a drop in platinum pricing and thus, profits.23 Adjusting production to global demand is much easier in the BIC than elsewhere for two reasons: it holds majority of supplies and it produces platinum as a primary mineral as opposed to a by-product. Only two other regions also produce PGMs as a primary source, namely, the Stillwater Complex (USA) and the Great Dyke (Zimbabwe). Stillwater produces more palladium than platinum and is therefore, less flexible when it comes to fluctuations in global platinum demand. While the Great Dyke also produces platinum as its primary PGM, the ratio of platinum to palladium is 1.7, compared to the Merensky Reef where the ratio is greater than 2 (Cawthorn, 1999). For comparison, the UG2 and Platreef have ratios of 1.5 and 1.0, respectively (Cawthorn, 1999).

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23 While pricing plays a major role in production adjustments, infrastructure and geology are also factors to be considered in the short-term. For example, a lack of rail infrastructure, a local support industry and water, remain the greatest obstacles for development in the BIC’s Eastern region, which holds lower platinum ratios (Cawthorn, 1999).
1999). For these reasons, the BIC’s Merensky Reef is best able to adapt platinum supply to the shifting global demand.

3.4.1 The Emerging Fuel Cell Industry

Despite the volatility of platinum demand due to external factors, environmental concerns, particularly global GHG emissions from the global energy industry, can be expected to create a sustained interest in platinum. The emergence of a fuel cell industry is one such possibility, which could very well cause concern over the sustainability of the precious metal in meeting future demand. While this could be good for the platinum mining industry, the widespread implementation of fuel cell devices has the potential to further influence the volatility of platinum pricing. There are two major ways in which fuel cells could do this: vehicle applications and energy systems. While there is much talk and investment in the automotive industry, several scholars have iterated the impossibility of a large-scale conversion to fuel cell vehicles. For one, supply would be a major issue; given the high platinum demand, finite supply, and increasing number of vehicles on the road (which reached approximately 500 million in 2000), this industry could only be sustained for about 15 years (Gordon et al., 2006). While R&D has allowed for some reductions in platinum loading, further decreases are very difficult to achieve. Regardless, fuel cell vehicles would still require ten times more platinum than conventional gasoline-powered vehicles (Yang, 2009). Platinum supply is not the only barrier to fuel cell vehicles; such a transition would cause a major surge in demand, thereby stimulating increased pricing and making their widespread adoption impossible (Yang, 2009). Commercial distribution of fuel cells would clearly impact supply and demand. However, industry uses might be worth exploring, which has peaked interest in South Africa’s platinum mines, exploring both possibilities of fuel cell-powered vehicles underground, and energy-producing devices to run their operations. The feasibility, long-term plans and implications of this will be explored in the next chapter.
3.5 Platinum’s Physical and Chemical Properties

Platinum’s unique properties have resulted in an increased demand for the precious metal given its impressive range of applications. The precious metal’s vast array of uses is well established within the literature. The main physical and chemical properties making platinum such an attractive and useful metal over a diversified range of applications include its high melting point, excellent resistance to corrosion, and its exceptional catalytic activity (Owen, 1987; Xiao & Laplante, 2004). While platinum is a comparatively heavy metal, at the same time it is relatively soft and malleable (Soriano, 1998). Its excellent ability to absorb gases such as oxygen, hydrogen and carbon monoxide, is the basis for its use as catalyst in the chemical, petroleum refining, and automotive industries, while its corrosion-resistance property is useful in the chemical, electrical, glass, and dental-medical industries (Owen, 1987; Xiao & Laplante, 2004). These properties make platinum the metal of choice in a wide variety of applications, even more so than any other PGM, attributing to its high economic value. In combination with its scarcity, platinum is thus considered both a noble and a precious metal.

While alternatives have been and continue to be tested, nothing comes close to achieving the same efficiency or desirability. Clearly, this is good news for South Africa and platinum mining companies when discussing the possibility of a fuel cell industry as, “the chances of finding an alternative are slim” (Radoslav Adzic, as quoted in Sealy, 2008, p.67). However, economic and geopolitical factors have prompted explorations into different options (Sealy, 2008). Current research interests include reducing the amount of platinum in technologies, replacing platinum altogether (either with other precious metals or with abundant, non-precious alternatives), and vamping up recycling initiatives (Sealy, 2008). While substitutes for platinum may exist, they come with significant trade-offs:
In most of its industrial applications, platinum is either irreplaceable or can only be substituted with significant compromises in performance. In most cases, the only feasible substitutes for platinum are other PGMs, including palladium, rhodium, ruthenium, iridium, or osmium, but these are no more abundant than platinum. (Yang, 2009, p.1805)

Thus, in most fuel cells, platinum is relatively irreplaceable for the time being, allowing the South African government and mining industry a chance to establish their presence within this emerging market. Now for a closer look at the technology itself.

3.6 Fuel Cells

The concept of the fuel cell was invented over 175 years ago by William Grove, a chemist, physicist and lawyer, after discovering it was possible to create electricity by the reverse electrolysis of water. Since then, governments, agencies and companies alike have heavily invested in developing and refining the technology, and for good reason; fuel cells have great potential to provide a highly efficient, clean and safe source of energy production. However, developments and implementation of fuel cells didn’t materialize to a significant extent until the mid-20th century, when they were used to power various space missions executed by the United State’s National Aeronautics and Space Administration (NASA) (Behling, 2013). Despite extensive financial investment and experimental developments, the electrochemical cell still lacks large-scale market penetration; reliability, durability and cost are identified as the major barriers (Behling, 2013). South Africa seeks to break down these barriers in hopes of becoming global leader of fuel cell technologies.

There are several types of fuel cells, each with different characteristics making it distinct from the other. Generally speaking, fuel cells are named after the type of electrolyte used (see section 3.6.1), which in turn is determined by the operating temperature of the fuel cell (Behling, 2013). The lower-temperature fuel cells have a slow chemical reaction and thus, require a platinum catalyst to propel this reaction. Table 3-1
illuminates the different types of fuel cells and the distinctions between them. For South Africa and the platinum mining sector specifically, the phosphoric acid fuel cell (PAFC) and the polymer electrolyte membrane (PEM) fuel cell are those being promoted, due to their use of a platinum catalyst and their applications in distributed generation and transportation, respectively (chapter 4).


<table>
<thead>
<tr>
<th>Type of Fuel Cell (FC)</th>
<th>Decade</th>
<th>Operating Temperature (°C)</th>
<th>Platinum Catalyst</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alkaline (AFC)</td>
<td>1950-60</td>
<td>90-100</td>
<td>Yes</td>
<td>• Military</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Space</td>
</tr>
<tr>
<td>Phosphoric Acid (PAFC)</td>
<td>1970</td>
<td>150-200</td>
<td>Yes</td>
<td>• Distributed generation</td>
</tr>
<tr>
<td>Molten Carbonate (MCFC)</td>
<td>1980</td>
<td>600-700</td>
<td>No</td>
<td>• Distributed generation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Electric utility</td>
</tr>
<tr>
<td>Solid Oxide (SOFC)</td>
<td>1990</td>
<td>700-1000</td>
<td>No</td>
<td>• Auxiliary power</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Electric utility</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Distributed generation</td>
</tr>
<tr>
<td>Polymer Electrolyte Membrane (PEM)</td>
<td>1990</td>
<td>50-100</td>
<td>Yes</td>
<td>• Backup and portable power</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Transportation</td>
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<td></td>
<td>• Distributed generation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Specialty vehicles</td>
</tr>
</tbody>
</table>

3.6.1 Fuel Cell Components and Functionality

A fuel cell functions via an electrochemical reaction, converting “chemical energy supplied through channels from the outside to the cell, into electricity” (Sorensen, 2012, p.95). Simplified, a fuel cell is a device which directly converts chemical energy into electrical energy to be used as a power source. Figure 3-3 provides a basic representation of the components and functionality of the device.
The chemical energy is retrieved from two reactants, namely, a fuel source and an oxidant. The ideal fuel source for these systems is pure hydrogen, however in its absence, other fuels may be used. The oxidant in the reaction is typically oxygen in the form of ambient air. A single fuel cell is composed of four basic elements, namely, two electrodes, an electrolyte and an external circuit board (Sorensen, 2012). The positively-charged electrode (cathode) is separated from the negatively-charged electrode (anode) via the electrolyte. Fuel is supplied to the anode, while the oxidant is supplied to cathode, initiating the electrochemical reaction; the anode produces electrons which flow to the cathode via the external circuit board where they are consumed, producing the electric current in the process. Some electrodes require catalysts, such as platinum, to propel the reaction at a more desirable rate. This is generally necessary for low temperature fuel cells (200°C and below). Meanwhile, ions (H+) flow freely between the electrodes within the electrolyte. Positively-charged ions combine with the electrons at the cathode, producing water.

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24 "Ions are individual atoms that have an uneven number of protons and electrons, and thus possess a net positive charge […] called cations […] or a negative charge […] called anions" (Behling, 2013, p.9).
and waste heat (depending on the fuel source, other by-products are possible). While each single fuel cell produces small amounts of electricity, they can be connected with others in 'stacks' in order to achieve the desired power output.\textsuperscript{25}

Fuel cells are intriguing energy systems, mainly due to their efficiency capabilities as they convert chemical energy directly to electric power in one single step. Conventional energy systems producing mechanical power require multiple steps and conversions, which result in energy losses through incomplete combustion and heat (Behling, 2013). The advantage of fuel cells over conventional energy generation is quite obvious, but even when compared to electric batteries, there are also clear advantages. These include, for example, convenience due to shorter recharge rates, increased safety, due to the separation of storage and power production functions, and greater efficiency, with no electrochemical losses from refuelling (Miller, 2010). Theoretically, fuel cells are able to continuously produce energy, provided the two reactants (fuel and air) are supplied.\textsuperscript{26} In reality however, fuel cells’ lifespan is limited by either malfunctioning of the system, or physical degradation (such as corrosion) of its components (Behling, 2013).

With an increase in energy-related GHG emissions and global climate change concerns, the fuel cell’s ability to eliminate harmful emissions into the surrounding environment is also particularly enticing; when pure hydrogen in used in the reaction, the only waste produced is in the form of water and heat. If alternative fuels are used (as is more common due to availability, infrastructure and cost), such as natural gas, gasoline, ethanol, or methanol for example, there will inevitably be some pollutants released as by-products. Even so, achieving greater efficiencies means comparatively less emissions than current systems. Overall, fuel

\textsuperscript{25} It should be kept in mind that fuel cell stacks do not operate on their own; they require an intricate array of supporting infrastructure which make up the fuel cell system as a whole. This system includes, “fuel processing or reforming, air supply, thermal management, water management (and) electric power conditioning” (Behling, 2013, p.12). The equipment is specific to the type of fuel cell and fuel type used.

\textsuperscript{26} This is in contrast to batteries for example, which degenerate over time, “when the chemical reactants stored within the battery are consumed or discharged” (Behling, 2013, p.8). The chemicals contained in the battery are ‘fixed’, having a physically-defined lifespan.
cells are largely considered safer, cleaner and more reliable sources of power. They demonstrate excellent potential, presenting an exciting alternative for future energy production schemes.

3.6.2 South Africa’s Emergence as Leader in Fuel Cell Development

With its competitive advantage of global platinum deposits, it is not surprising that South Africa hopes to capitalize on fuel cell technologies. However, South Africa is entering the fuel cell field rather late, with other countries having long pursued investments in research and development (R&D) for such technology. According to Behling (2013), there are three global leaders when it comes to fuel cell technologies, namely, Japan, the European Union and the United States. These actors stand out when it comes to R&D expenditure, government’s consistency in policy and programs, soundness of program evaluations, robustness of industry and the extent of patenting (Behling, 2013).

Motivated by their lack in natural resources, a dependency on foreign oil and a need for new industry spurring economic growth, Japan easily exceeds in all categories, making it the global leader in fuel cell technologies. With South Africa aiming to position itself among these ranks, it will need to improve on all these areas. While the government has demonstrated commitment to this by means of a transition from a resource-based to a knowledge-based economy, the platinum mining industry remains focused primarily on Japanese imports for implementation within production schemes. With these divergent pathways being pursued, sound and consistent policies must be implemented with government-industry collaborations if South Africa is to become global fuel cell leader, let alone, be competitive within the established market.

3.7 Contribution to South Africa’s Economy

By this point, it has been well established that South Africa has a clear competitive advantage when it comes to PGMs, specifically, the most valuable of these precious metals, platinum. PGMs are the country’s second-largest export revenue generator (after gold), with platinum specifically contributing R45 billion (16.14%) of total mineral exports in 2012 (Department of Mineral Resources [DMR], 2014b). However,
the overall contribution this sector makes to South Africa’s GDP is relatively low; for that same year (2012), PGMs contributed just 2.2% (DMR, 2014b). All economic activities are categorized within three basic sectors: primary (raw material which is either used as final demand, or inputted into the secondary industry); secondary (where value-added products are either used as final or intermediate demand); and tertiary (which exists to consume or manage the products of the latter two sectors) (Stillwell, 2004). Historically, GDP was influenced largely by growth in the primary sectors. However, recent trends demonstrate a growing importance in tertiary sectors of economic growth, “now South Africa is moving towards becoming a knowledge-based economy, with a greater focus on technology, e-commerce and financial and other services” (“South Africa’s economy: key sectors”, n.d.). Given that the vast majority of platinum resources are exported in raw form, there is no value-adding process and therefore, comparatively minor contribution to GDP which, “is neither cash flow nor a profit, but an indicator of the value added during the production process” (Stillwell, 2004, p.2). Not only does this mean the country is essentially losing out on missed economic opportunities, but it also means that the value of the sector is determined by volatile demand, foreign exchange markets, and global economic conditions (Stillwell, 2004).

In order to take full advantage of the platinum deposits, capitalizing on opportunities which use the resources in secondary sectors, such as in the development of fuel cell technologies, would have greater impacts on GDP, while stimulating tertiary sectors of the economy. While the push towards sustainable technologies on a global level is advantageous for South Africa due to its platinum deposits, the government recognizes the increasing significance of developing a globally-competitive, value-added industry, making better economic use of these reserves. The Department of Science and Technology (DST) is investing in a fuel cell industry to accomplish this, by means of the National Hydrogen and Fuel Cell Technologies Research, Development and Innovation strategy, otherwise known as Hydrogen South Africa (HySA). Launched in 2008, the 15-year program aims to, “develop local, cost-competitive hydrogen generation, catalysis, and manufacturing systems based on existing and developing technologies, to supply 25% of
global catalyst demand by 2020” (Malik, 2013, p.364). The specific projects targeted by HySA include portable back-up power systems, decentralized power and heat sources using combined heat and power (CHP) systems, and fuel cell-powered vehicles (Hydrogen South Africa [HySA], n.d.). This initiative will be explored further in chapter 5.

3.8 Conclusion

This chapter has linked South Africa’s platinum mining sector to fuel cell technologies. By identifying the significance of the geographical and geological formations of the Bushveld Igneous Complex (BIC), South Africa’s position as global platinum supplier is clearly evident. This position will no doubt serve in the country’s favor when it comes to the emergence of fuel cell technologies, as the platinum mining companies are best able to adapt to the ever-changing global market conditions. That being said, industry and government will need to work together to ensure the long-term viability of these deposits, given the expected increase in demand for the precious and noble metal. Adapting effectively to supply and demand, while investing in a national fuel cell industry, will serve to increase wealth generation from these platinum deposits, contributing to both secondary and tertiary sectors of the economy. This would in turn increase platinum’s contribution to South Africa’s GDP, providing more opportunities for broader socio-economic development.

In addition, this chapter served to elucidate platinum’s unique chemical and physical properties, making it the ideal metal of choice in fuel cell technologies. Understanding the components and functionality of these systems is essential to understanding the country’s interest in investing in such an industry. The technicalities and uses of fuel cell devices were made apparent, opening up discussions on how the platinum mining industry plans on implementing these systems within their very own operations. This shall be examined in the following chapter.
Chapter 4

Implementation of Fuel Cell Technology in South Africa’s Platinum Mines

4.1 Introduction

An implicit motivation in the industry’s push for fuel cell technologies is the use of platinum as the main catalytic component. The platinum industry’s struggles with low commodity prices, demand recovery, and stable production have had severe financial impacts. Fuel cell technology is seen as a way to stimulate both platinum demand and pricing. Not only is there keen interest in participating in an emergent fuel cell industry, industry is also seeking to benefit from the technology itself. There are two ways in which this is being explored in the platinum mines, namely, in aboveground and underground applications. This chapter explores both the motivations and challenges of fuel cell implementation within South Africa’s platinum mining industry, while unpacking discussions surrounding mechanisation and modernisation processes of this transition.

4.2 Aboveground Applications

Fuel cell devices are already used by several major industry actors as decentralized energy systems, including Apple, Google and Walmart to name a few (Bloom Energy, n.d.). They are also taking off in South Africa, where the Chamber of Mines (CoM) recently installed the country’s first baseload stationary fuel cell at its headquarters in Johannesburg (Figure 4-1). The device provides 100kW of energy to the building and is connected to the inter-city natural gas pipeline. Impala Platinum (Implats) is hoping to follow suit and plans to implement several of these systems to run their Springs refinery. While the fuel cell take-off in South Africa is still in its infancy, several factors are driving the push for these off-grid, power-producing devices.

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27 The use of the platinum catalyst is also one of the reasons the technology has been slow to take off; the expensive catalyst presents financial challenges for implementation (Sealy, 2008).
4.2.1 Energy Security

Energy security was found to be the main motivation for pursuing aboveground fuel cell applications. As Group Executive for Technical Support at Implats, Martyn Fox describes this as a risk mitigation strategy to become less dependent on the national grid (2015). Facing infrastructural challenges, Eskom, the country’s national energy provider, is unable to meet increasing energy demands. Their subsequent load-shedding program, whereby specific areas are disconnected for several hours at a time, is negatively affecting the national economy. Particularly, manual and unskilled industries such as mining are affected (Du Preez, 2015), due to the high energy usage in underground processes (Altman, Mather, Fleming & Harris, 2008). Additionally, because the national grid often runs close to capacity, unplanned outages are not uncommon and projected increases in energy demand are expected to further impact the industrial sector.
(Fox, 2015). For Implats specifically, current load-shedding is minimal, occurring about once per week at the stage 1 level\(^{28}\) and having little (if any) impact on business. However, any progression past stage 1 significantly affects the company’s operations, resulting in lost production and revenue (Fox, 2015). Thus, planning for decentralization from the increasingly unpredictable and unreliable national grid system to increase energy security has become a financially-appealing avenue worth exploring.

Energy cost is another factor influencing the implementation of large, decentralized fuel cell systems; the national grid’s supply-demand disparity has caused a significant rise in power costs. According to the CoM, “electricity costs have been the fastest growing component of the mining sector’s cost base and have increased by over 300% over the past seven years” (2016, p.6). For Implats specifically, “as a proportion of total cost, power has gone from 8% to 14 or 15%” (Fox, 2015). These price hikes are partially explained by the addition of more coal-fired power plants to keep up with the growing energy demand, the price of which is then fed back into the consumer’s power cost (Fox, 2015). Concerned with the significant escalation in energy costs, “eventually the intention is to take the entire refineries off the grid. Initially it will be more expensive, but depending on the fuel cell lifespan … [eventually] it would be cheaper” (Fox, 2015). According to Jeanette Hofsajer-Van Wyk, Head of Information Services at the Chamber of Mines, their unit is already saving them on power costs, merely one year after installation (2015).

4.2.2 Challenges Associated with Aboveground Fuel Cell Applications

Fuel cell technology faces several challenges in aboveground implementation. Primarily, fuel availability is a major concern for industry. While hydrogen is the ideal source of fuel from an environmental standpoint, it is difficult to come by in South Africa, and expensive. Implats’ Springs refinery is uniquely located beside a pre-existing hydrogen pipeline to which the company has a favorable contractual agreement with the supplier, Sasol. Currently, they only make use of half this source and plan to use the

\(^{28}\) Stage 1 refers to outage periods of approximately two hours in duration (Eskom, n.d.).
other half to power a 1.8MW hydrogen fuel cell (Fox, 2015). However, this is insufficient to decouple the operation from the national supplier; the additional 20MW required to achieve complete decentralization will run off natural gas, provided a source can be found at decent pricing (Fox, 2015).

The pricing of fuel cell devices themselves is another barrier for aboveground applications. Declan Vogt, Director at the Center for Mechanised Mining Systems (CMMS), explains that, like any new technology, significant investment and competition are needed to achieve technological breakthroughs and drive down capital costs (2015). The capital cost of the system determines the energy cost per kWh, and for the Springs refinery’s 1.8MW hydrogen fuel cell, it will be double the current energy costs (Fox, 2015). The CoM’s fuel cell illustrated similar financial characteristics: “What I can say is it’s very high ‘capics’ [capital cost], but low ‘opics’ [operating cost]. It is a different funding model” (Hofsajer-Van Wyk, 2015). However, industry predicts cost savings over the long term; given the unsustainable increase in Eskom’s energy pricing, Implats projects, “that this [current energy pricing] will flatten off, but still be well above the inflation rate because of all the old infrastructure which will require maintenance” (Fox, 2015). Applying a different funding model makes the technology more attractive; typically, financial reporting is done over a five-year period, which is unrealistic for these devices: “the fuel cell lasts over 20 years, so looking at it from a 10-year financial plan [as opposed to 5] is really not that way out” (Hofsajer-Van Wyk, 2015). Overall, while long-term cost savings are seen as a motivation for fuel cell implementation in aboveground applications, both fuel input and capital expenditure, present major constraints at the moment.

### 4.3 Underground Applications

Industry is also exploring fuel cell implementation in the underground environment to power their trackless mining equipment. Both Implats and Amplats (Anglo American Platinum) are public about their plans to replace diesel engines with fuel cells on their mechanised fleets of equipment (Implats, 2015; Odendaal, 2012). However, underground applications have further reaching consequences due to the greater range of stakeholders implicated, which will be highlighted here.
4.3.1 **Motivations for Underground Fuel Cell Implementation**

Underground equipment is currently powered by diesel engines (Figure 4-2), which are heavily polluting due to carbon monoxide (CO), hydrocarbon (HC), nitrogen-oxide (NO\textsubscript{x}) and particulate matter (PM) emissions (Reşitoğlu, Altinişik & Keskin, 2015), or batteries, which are themselves new to this environment. Replacing these with fuel cells provides several technical and suitability advantages. First, the devices combine the best features of diesel and battery powered options, while avoiding their fallbacks: “A fuel cell powered vehicle has the mobility, power, and safety of a diesel unit, combined with the environmental cleanliness of a battery powered vehicle underground,” (Valicek & Fourie, 2014, p.325) without the drawbacks of trailing cable hazards and electrical-related risks, high life cycle costs, recycling issues and long recharging periods (Valicek & Fourie, 2014). They are also inherently well-suited to the types of equipment already used underground, particularly the load haul dumpers (LHDs). Paul Jourdan, Independent Mineral Policy Analyst with years of expertise in the field, emphasized the suitability of fuel cells underground, especially for vehicles use. While the significant weight of both the fuel cell and the accompanying hydrogen storage tanks is a disadvantage aboveground, reducing efficiencies, in the underground environment, “you *want* the weight. In fact, you [normally have to] put on weight on a front-end loader,” (Jourdan, 2015) to prevent it from tipping over when hauling ore. Betournay, Bonnell, Edwardson & Lidkea (2005) and Betournay, Laflamme, Miller & Barnes (2003) further emphasize the fuel cell’s ability to withstand the harsh underground environment, displaying no adverse impacts related to shock, dust or vibration exposure. These features make fuel cells very suitable to the underground mining environment.
According to industry, the main motivation for powering trackless mining equipment with fuel cell technologies is to increase health and safety underground while boosting productivity (Mogotsi, 2015); in addition to technical advantages, fuel cells also bring significant health benefits by improving underground air quality. NO₃ emissions released from diesel-powered engines are considered toxic, and, “are a direct concern of human lung disease” (Reşitoğlu, Altinişik & Keskin, 2015, p.19). Roughly 67% of diesel exhaust is composed of NOₓ (Reşitoğlu, Altinişik & Keskin, 2015), heavily compounding underground air quality and causing major health concerns. Diesel engines are also loud and inefficient, losing a lot of energy as heat. Confined in small tunnels underground, these factors combine to create a very poor and unsafe work environment. For example, avoidable accidents between workers and machinery, in part resulting from noise-induced hearing loss, have occurred, not to mention decreases in workers’ health from exposure to harmful emissions which affects productivity (Anonymous, 2015). Meanwhile, fuel cells produce little to no emissions, boast high efficiencies with comparatively little heat loss, and are very quiet machines (Betournay et al., 2003; Betournay et al., 2005). These properties are evident by the operational fuel cell at

Figure 4-2: Diesel-Powered LHDs at Implats’ Shaft #14. Source: Author photo.
the CoM, barely audible to passersby, let alone building occupants (Hofsajer-Van Wyk, 2015) and fit well with the industry’s emphasis on health and safety.

Despite these advantages, research findings suggest that the main motivation for switching to fuel cell-powered machinery underground is for cost savings; the unsafe conditions to which the workforce is exposed has extensive indirect costs. Companies spend significant financial resources on intricate cooling and ventilation systems, not only to dilute pollutants and heat emitted from the machinery’s diesel engines and dust from the underground environment, but also to combat the geothermal gradient (the natural heat emanating from the rock underground) (Karsten & Mackay, 2012). The latter is particularly important in the BIC, which encounters a relatively high geothermal gradient at shallow depths; this point is reached around 800m for South Africa’s platinum mines, compared to about 1400m in its gold mines (Karsten & Mackay, 2012). This presents cooling and ventilation efficiency challenges, further compounded by energy costs and carbon footprint concerns (Karsten & Mackay, 2012). With plans to continue underground expansions, switching to fuel cell technologies for mining equipment would therefore allow improved environmental conditions in the form of air quality, coupled with significant cost savings in air flow and cooling requirements. These advantageous features are not only desirable for platinum mining, but also transferable to other mining sectors. If successful, this could significantly expand the demand for underground applications of fuel cell technologies.

4.3.2 Challenges Associated with Underground Fuel Cell Applications

In terms of major challenges for fuel cell implementation, once again, fuel storage is an important consideration. Technical and safety issues associated with fuel input become particularly important, and sometimes limiting factors, underground, especially when using hydrogen. On the technical side, pressurized tanks are particularly concerning underground, creating safety risks: “Another project was to just replace the diesel locomotive with natural gas and that got stopped because of the dangers associated with natural gas that would be in pressurized tanks [which] are a safety issue underground” (Vogt, 2015).
Hydrogen however, would be stored in metal hydrides, which are not under pressure and therefore, present less of a safety hazard: “metal hydrides are of low flammability. This is because hydrogen is trapped in the metal matrix or lattice, and the rate at which hydrogen atoms can file through the channels and be released is limited by the rate of heat transfer into the crystal” (Miller et al., 2012, p.539). Metal hydride storage systems are also very heavy (Miller et al., 2012), but since weight is not a barrier in underground machinery, this method of storage is promising as it provides more volume than traditional systems (Crabtree, Dresselhaus & Buchanan, 2004). Regardless however, hydrogen fuel storage underground makes people uneasy, “because if something happens, you know, it’s a confined environment and it can get very ugly, very quickly” (Vogt, 2015).

In addition to storage, refueling presents another challenge for underground applications. There are two options being explored in this regards, namely, above or underground refueling. Amplats is exploring underground refueling stations (Miller et al., 2012), maximizing on the fuel cell’s ability to quickly refuel and allowing for increased productivity, especially when compared to battery recharging alternatives. According to Fahmida Smith, Implats’ Fuel Cell Coordinator, they are looking at aboveground refueling. One of the reasons for this decision came from the workers, who have expressed reluctance about underground hydrogen refueling stations. Already, workers are exposed to multiple risks and hazards on a daily basis; adding hydrogen to an underground environment is perceived as just another, unnecessary, exposure for many of them (Smith, 2015). Overall, both refueling and fuel storage (with a particular concern regarding hydrogen) present major concerns for the implementation of fuel cell devices to power underground mining equipment.

### 4.4 Shift to a High-Tech Mining Industry: Modernisation and Mechanisation

The use of fuel cells is part of a larger plan to shift towards a more high-tech, service-oriented industry, involving mechanisation and modernisation processes. These are two ongoing trends in the mining sector and particularly sensitive topics in South Africa due to their labour implications. Mechanisation implies
replacing most of the manual labour underground with machines in order to reduce costs and increase productivity. It is primarily reserved for new mines, incorporated into the design during the development phase (Vogt, 2015). According to Jourdan, this is of particular interest for the platinum mining sector because the reef dips are very gentle (about 10-15 degrees) making them among the easiest to mechanise.\textsuperscript{29} Already, about 30\% of platinum comes from mechanised operations (Vogt, 2015).

Alternatively, modernisation mechanisms are reserved for older mines, incorporating both man and machine in combination. In the broader sense, modernisation means, “improved RT [real time] systems, improved tools, generally improved mining, but fundamentally the same mining methods. [So] using manual labor, but with some kind of assistance” (Vogt, 2015). As an expert on mechanised mining systems, Declan Vogt explains that layout incompatibilities of the older mines make it difficult, if not impossible, to fully mechanize these shafts. While mechanisation is a well-established concept, used throughout the global mining industry, modernisation is a relatively new concept, introduced by industry in 2014 (Vogt, 2015). Labour tensions were particularly high in that year with a new wave of labour strikes hitting the platinum mining sector hard, which could explain the emergence of this gentler term. Additionally, there may be mechanised sections of these older mines, thus, modernisation is meant to include both concepts: “Some parts will mechanise and some will modernise in a particular mine,” in which case, “mechanisation is just one component of modernisation” (Vogt, 2015). This was observed during the site visit to Impala Platinum’s shaft #14, where modernised aspects included underground transport systems (Figure 4-3) and underground primary crushing of ore (Figure 4-4).

\textsuperscript{29} Stewart (2015) on the other hand, finds that geological discontinuities and the need for narrow mining techniques to minimize “dilution of the head grade – in situ grams per ton,” (p.637) make it difficult and sometimes unfavorable to mechanise.
Figure 4-3: Underground Transport System. Mechanised transport allows employees to get to and from their work area quicker, increasing productivity. Source: Author photo.

Figure 4-4: Underground Primary Ore Crushing at Shaft #14. Source: Author photo.
4.4.1 Motivations for Shifting to a High-Tech Mining Industry

Serious considerations are being given to fuel cells at the forefront of the high-tech agenda; the devices present a unique opportunity for the platinum mines to push both modernisation and mechanisation processes forward, increasing productivity, while stimulating platinum demand simultaneously. Aside from the obvious economic benefits, industry must also prepare for potential regulatory changes; unlike those enforced in developed countries such as Canada, the United States and Australia, the South African mining industry is not yet subject to underground air quality regulations: “our current emission levels are much higher than those legislated levels (underground) … What will we do if we have to control our emissions?” (Vogt, 2015). With diesel particulate matter having been labeled as a carcinogen and a long history of silicosis among mineworkers (Vogt, 2015), it’s only a matter of time before new regulations force the industry to adopt cleaner practices. One way to ensure cleaner air flow is simply to pump more air underground; “if there’s more air then there’s less pollutant” (Vogt, 2015). However, there are physical limitations to this: “the mine [was] designed with a certain ventilation system and you can’t just put on more power. The air’s got to travel through the tunnels. The tunnels are the size they are. So people are looking at this and seeing a problem” (Vogt, 2015). As previously mentioned, this type of solution would also be extremely costly, even more so as operations extend deeper underground. Hence, replacing diesel engines with fuel cells in mechanised fleets presents a much more effective solution, seen as both a market solution strategy, and a proactive approach to anticipatory emissions regulations.

In relation to this, the health and safety of the workforce is the main motivation for mechanisation or modernisation of the mining industry. Paul Jourdan provided invaluable insight into the mechanisation issue in the South African context. As an Independent Mineral Policy Analyst and former President and CEO of Mintek, a South African R&D organisation specialising in mineral extraction, processing, beneficiation and associated technology, he has years of expertise in the field, providing a well-informed account of the challenges of mechanisation. In hindsight, he explains that health and safety presents a valid motivation:
“You actually want to mine remotely because that’s a terrible job. It’s extremely horrible. It’s dangerous; you’ve got a 50% chance of silicosis which is the same as being a chain-smoker. Ultimately, if we stand back, we don’t want people down mines. It’s not civilised work” (Jourdan, 2015). At the same time, this leads back to concerns surrounding job losses in the industry; despite the industry’s hopes of diverting attention away from the sensitive labour issue, there is a general agreement that modernisation of the platinum mining industry will inevitably affect the platinum mining workforce. This topic will be further explored in chapter 5. According to Jourdan however, the real motivation behind this all comes back to costs: “we have to mechanise because of costs, and we will mechanise because of the wage demands” (2015). Overall, the modernisation and mechanisation issue presents two possible outcomes, which heavily depend on the path chosen moving forward: “this could be wonderful, or it could be terrible. If it goes the wrong way, which it’s going, there’s going to be a lot of civil strife” (Jourdan, 2015).

4.5 Conclusion

Fuel cell technologies are slowly making their way into the South African economy, with the platinum mining industry actively supporting this emergence in their own operations. This chapter outlined the main motivations for pursuing the implementation of these devices in both aboveground and underground applications. Fuel cell technologies present multiple benefits which fit well within the needs and applications of the mining sector, such as opportunities to lower emissions, improve health and safety, and cut costs over the long-term. Despite these advantages, it must be stressed that, “quite frankly, the driving force for the fuel cells is not an environmental driving force. It is an eventual cost benefit and market driver for platinum” (Fox, 2015). The stimulation of platinum demand remains a motivating factor for industry’s shift to fuel cell technology applications. Being able to demonstrate their suitability and unique advantages in the harsh underground environment is a priority for the platinum mining industry. This is seen as a marketing strategy to stimulate further interest in the innovative technology, and by extension, platinum demand.
Fuel cell implementation in the platinum mining sector is also intricately linked to modernisation and mechanisation processes in the industry's transition to a high-tech, more service-heavy environment. While there are clear advantages to this transition, incorporating fuel cells, the way in which this is achieved must be carefully considered; beyond technical challenges, the device’s role in shifting to a more high-tech environment comes with challenges of its own. Understanding the localised impacts of this transition, beyond the potential economic benefits, is important in determining the overall implications of fuel cells in this context. These issues are explored further in the next chapter.
Chapter 5

Impacts of Fuel Cell Implementation in South Africa’s Platinum Mines & Potentials for an Emergent Industry

5.1 Introduction

The contemporary context of the platinum mining industry in South Africa remains challenging; despite attempts to reform the industry post-apartheid, in social justice and environmental terms, improvements remain questionable. Given the geopolitical and economic significance of the country’s platinum deposits, the multi-faceted impacts of fuel cell technologies must be carefully considered. This chapter attempts to provide this perspective in presenting the three main findings of my research: first, that the overall impacts of fuel cell technologies in South Africa cannot be understood without considerations of the historical, political and social contexts from which they emerge; second, that transitioning from a resource-based to a knowledge-based economy will largely determine these impacts; and third, that narratives of sustainability related to fuel cell technologies and an emergent industry must be re-evaluated given the previous two findings.

5.2 South African Context

Even with the best of intentions, implementing new technologies can be destructive if the context from which they emerge is not given careful consideration. Fuel cells are a prime example, where the South African context is both a point of emergence and of implementation for the technologies. At this point, the platinum mining industry continues to face historically-structured challenges which are problematic for an emerging fuel cell industry. Post-apartheid policy reforms of the sector have proven ineffective in redressing race and class inequalities and improving socio-economic conditions for the most marginalized. Attesting to this, a recent study commissioned by the Department of Mineral Resources (DMR) found that a decade after the Mining Charter’s implementation, aiming at redressing racial inequality within the sector,
economic empowerment for historically disadvantaged South Africans (HDSA’s), housing and living conditions, employment equity, skills development, mining community development and sustainable development all remain significant challenges (2015).

A lot of this has to do with the failure of policy to translate into effective action on the ground. Policy reforms have remained highly politicized (Capps, 2012), perpetuating both material and structural forms of power when it comes to issues of access and justice surrounding the extractive industries. Introducing innovative technologies such as fuel cells in this context presents several opportunities, but it also raises many concerns. Three context-specific themes emerged as the most challenging and pressing issues to overcome in order for this transition to not only be successful, but also equitable for all stakeholders: these are employment, growth and development, and procurement.

5.2.1 Employment

Arguably the most pressing issue related to the transition to a more high-tech and service-heavy mining environment is the labour implications, which threaten to adversely affect a significant portion of the workforce. This is particularly concerning in the platinum sector as it employs the majority of the country’s mining workforce with 37.5%, or 191,000 of the total number of mining employees in 2013 (Chamber of Mines [CoM], 2014). At Implats specifically, out of 26,000 employees at the Rustenburg operations, 77% of employees originate from South Africa, compared to 23% migrant workers originating from neighboring countries (Implats, 2005). As mentioned, labour issues in this sector remain particularly tense, marked by ongoing strikes and unrest, fuelled by the desire to challenge the historical structures which continue to disempower and impoverish HDSAs. Many of these events have been met with violence, most notably the 2012 Marikana Massacre, discussed in the introduction. Some sources claim that these labour manifestations are actually counter-effective, further driving industry towards mechanisation (Stoddard, 2014). If not done carefully, mechanisation could lead to vast unemployment and to intensification of already precarious conditions, further harming employee-industry relations.
According to Cindy Mogotsi, Group Executive for Sustainable Development at Implats, with modernisation a large portion of the workforce can be maintained with adequate re-training efforts. But as Paul Jourdan and Declan Vogt explain from a more technical point of view, the nature of mechanisation inevitably leads to job losses. With these processes projected to occur over the next 10-20 years (Hofsajer-Van Wyk, 2015; Mogotsi, 2015), industry expects no significant adverse impact on employment, claiming the high-tech transformation will coincide with the natural shrinkage\(^\text{30}\) of the workforce (Hofsajer-Van Wyk, 2015; Mogotsi, 2015; Vogt, 2015). However, this idealized linear progression laid out by industry contradicts the very nature of the current workforce: “Often, existing miners are illiterate and it’s very difficult to train the existing miners to move into mechanisation. So really, you need new people, and that involves some job losses” (Vogt, 2015). In terms of actual figures, according to Jourdan, there are going to be three groups: aging miners (about a third who are due for retirement in the next 10 years); the second group, maybe 20%, will be those who will be re-trainable; [and] the other half left, what do you do with that? They will be laid off. These are the skilled rock drillers. (2015)

The rock drill operators (RDOs) are comprised mostly of HDSA’s who have been heavily involved in the recent strikes and unrest. This critical mass of workers falls under neither the re-trainable, nor the natural shrinkage categories laid out by industry and will likely be severely impacted by this transition; often, mining is the only source of livelihood for this group of workers.

With each individual employed in the platinum sector supporting anywhere from 4 to 10 dependants (DMR, 2014b), projected layoffs would have severe social consequences. Jourdan refers to this as the ‘labour quandary’ of this technological transition in the mining sector. Measures must be taken in order to ensure

\(^{30}\) Natural shrinkage is a term used to define the process of the older, unskilled workforce naturally retiring and being gradually replaced by a smaller, younger and more skilled workforce.
opportunities for this population: “You need a very strong intervention around rural development to create livelihoods,” without which, racialized inequality of the sector will only strengthen, and presumably, “you’re going to have social disruption” (Jourdan, 2015). Vogt, from the Centre for Mechanised Mining Systems (CMMS) is in the midst of conducting a study on these potential impacts: “Everybody’s aware that it’s a potentially dangerous territory … There’s such a big gap between the mining companies and the communities that mechanisation [becomes] just part of a bigger problem” (2015). Quite obviously, the way in which the process is done will determine the extent of impact it has:

Mechanisation isn’t a decision; it will happen either way. It’ll either happen badly, or it’ll happen well. At the moment, it’s going to happen very badly. It’s going to create jobs in the old plundering countries (Europe and the off-shoots), and it’s going to lay-off jobs here. That’s mainly because the mining companies are transnationals, and transnationals don’t give a damn. (Jourdan, 2015)

5.2.2 Growth & Development

Growth and development was identified as another key theme of the research findings. To maintain job neutrality, this transition will have to be done in conjunction with growth and development strategies that benefit all stakeholders; specifically, there must be investments in other sectors of the economy which can accommodate laid-off mineworkers. This means capitalizing on in-country opportunities such as beneficiation31 and diversification industries. Platinum presents many opportunities in this regards: “The national competency in platinum beneficiation, for instance, spans technology, equipment, services and the development of human skills” (Sorensen, 2011, p.645). In this sense, although fuel cell technologies are part of the high-tech transition of the mining industry (and by extension the employment challenge), they can also be part of the solution. They present an opportunity to support employment by either manufacturing

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31 Beneficiation refers to, “the transformation of a primary material (produced by mining and extraction processes) to a more finished product, which has a higher export sales value” (DMR, 2011). There are a range of beneficiation processes which add more value with each successive level of processing; from large-scale activities such as smelting, to refining, to labour-intensive processes (DMR, 2011). Here, beneficiation refers to the manufacturing of platinum catalysts, which would fall under a higher-level of processes.
the fuel cells themselves (Hofsajer-Van Wyk, 2015; Mogotsi, 2015), or manufacturing of the surrounding machinery (Jourdan, 2015; Vogt, 2015). This was identified as a possible strategy to alleviating some of the forthcoming labour issues.

While policy reforms vaguely mention beneficiation, they lack clear targets that can be measured and evaluated. For example, section 26 of the MPRDA states that the Minister should promote beneficiation in-country, without further expanding on how this should be done (RSA, 2002). The section was later amended in 2008 to stipulate that companies must provide a certain percentage of their production of minerals for local beneficiation, without stating what percentage this might be (DMR, 2014a). Currently, there has been an overall lack of commitment to diversification strategies which has resulted in high mining dependency for mining communities, particularly in the Rustenburg area. According to Cindy Mogotsi, Group Executive for Sustainable Development at Implats, this became particularly evident after the five-month strike in 2014: “It was quite clear that a lot of businesses were impacted by that strike … the Rustenburg economy is still heavily dependent on mining. There is no diversification overall within that region” (2015).

Judith Kinnaird, Director at the Economic Geology Research Institute (EGRI) and Co-Director at the Centre of Excellence for Integrated Mineral and Energy Resource Analysis (CIMERA), also expressed concern for the lack of beneficiation strategies, resulting in lost economic opportunities: “We export virtually all the platinum; this country doesn’t do things with it. … We’re not producing fuel cells, we’re not producing catalytic converters, we’re not producing jewelry. And to me, this is a shame” (2015).

Thus, company’s value-added (VA) investments are primarily spent overseas, representing lost economic opportunities for South Africa’s VA ventures (Jourdan, 2015). Investing in secondary industries to decrease mining dependency of the surrounding communities would challenge this dependency and empower the local communities. The emerging Platinum Valley Special Economic Zone (SEZ) hopes to address these manufacturing and beneficiation gaps, “aimed at attracting investments that seek to add value to South
Africa’s platinum-group metals,” (T. Creamer, 2013). Another way to guarantee these investments is through the mining license where the country has levers; by stipulating that 3% of VA be spent on research and development (R&D) in-country, overseas expenditures wouldn’t count towards VA targets (Jourdan, 2015). Unlocking these economic opportunities however, inherently requires collaboration from both industry and local government (Mogotsi, 2015), something which is also lacking in the South African context.

5.2.3 Procurement

Both of the previous themes are linked to procurement; if local supply chains are in place, facilitated by investments in growth and development strategies, local employment is supported and more broad-ranging and inclusive benefits can occur. The platinum mining industry is currently outsourcing fuel cell technologies. Various partnerships and contractual agreements with suppliers have already formed, notably, between Implats and Mitochondria (South African based, but with international partners; products are not locally-produced), Amplats and Ballard (Canada), and the CoM and Fuji (Japan). This demonstrates the lack of commitment to localized development of the countries in which these multinational mining companies operate. According to Fox, this is a risk-mitigation strategy for companies; more bluntly, “they [multinational mining companies] don’t want to have too many assets in one place, so they prefer to develop outside. You don’t put all your eggs in the South African basket” (Jourdan, 2015). This results in lost economic opportunities for South Africans, positioning them as merely a storehouse of resources with little to no value-added investments and reinforcing the country’s historical role as resource provider for Western economies.

According to Vogt from the CMMS, this practice of outsourcing the fuel cell technologies themselves shouldn’t be painted in such a negative light: “You should be developing industry based on some advantage. And honestly, having platinum in your country is not an advantage. It’s not like steel, which is heavy and big. The amount of platinum you need to run a fuel cell business can travel by air” (2015). From his point
of view, it’s the bigger system which should be built locally: “We’ve already got mining machinery companies in South Africa. Most of our advanced machinery for platinum mines is imported, but there’s no reason why it couldn’t be done here. And that, to me, makes a lot more sense” (Vogt, 2015). The CoM on the other hand, doesn’t seem bothered by where the fuel cells are developed, as long as platinum demand is stimulated and secured: “The Chamber of Mines is per definition more resource-based, because it’s mines, and what we are doing is trying to promote the platinum aspect of it” (Hofsajer-Van Wyk, 2015).

Many believe one of the biggest mistakes during the democratisation process was in letting the mining companies leave; doing mechanisation in-country becomes much more difficult when you’re dealing with multinationals, whose only responsibility is to make money for their shareholders. “Our mining companies have become a 5th column. They’re now precocious and they do all their development there [out of country] that they would have done here before … But if you’re a national company, that’s your world. The root of this problem is the internationalization of companies … The Europeans see us as their supplier” (Jourdan, 2015).

With the shift to a more high-tech mining environment, particular measures must be taken to ensure that, as much as possible, the economic benefits of the platinum mines remain in-country; otherwise, current development issues and racialized material and structural power dynamics will not only persist, but risk being exacerbated. The challenge will be for the government to better regulate and enforce local procurement processes from the multinationals. With a more favorable regulatory environment, government could ensure that a greater portion of industry revenue be channeled into local initiatives, presenting an opportunity to achieve more broad-ranging socio-economic benefits from the precious metal. Meanwhile, the Charter lays out clear targets for industry in procuring capital goods, services and consumer goods from Black Economic Empowerment (BEE) companies at 40%, 70% and 50% respectively by 2014 (Charter, 2002). The DMR’s recent report (2015) indicated that most of the large companies were meeting these targets. The report, however, does not offer distinctions as to the PGM sector specifically.
One of industry’s main arguments used to justify outsourcing is that South Africa lacks the necessary research and skills base, and that it would take too long to ‘catch-up’ for any investments to make financial sense: “It’s obvious, when you’re a business, you’re there to make money. Return to shareholders is the only single mandate these companies have” (Jourdan, 2015). Thus, the plan is to continue importing and eventually, have technological and skills transfer from the external experts to the local populations: “Start with importing, and then training the people to operate and maintain it, and to make parts for it and then actually making it. This would be within that 10-year window” (Hofsajer-Van Wyk, 2015). The last step however seems highly unrealistic unless investments and steps are taken to set up facilities and programs now. The South African knowledge gap is a crucial factor to determining the country’s level of participation in an emergent fuel cell industry, explored further in the next section.

5.3 Emphasis on the Knowledge-Based Economy

The lack of a solid knowledge foundation in-country is a key factor in determining the impact of the mining sector’s transition to a high-tech environment using fuel cell technologies. Without a solid knowledge-base, there are very few opportunities for the socio-economic benefits of these devices to remain in-country. Skills training and education, along with stakeholder collaboration were identified as the two major challenges underpinning this finding. If this high-tech transition is to be done in-country, there must be the knowledge base and skills in place to allow adaptation for this; otherwise, it will happen externally, with severe consequences at the national and local levels. While all interviewees stressed the need for skills training of the workforce, discrepancies arose as to whose responsibility it was to address this issue, highlighting the need for more stakeholder collaboration. Table 5-1 emphasises the role of the knowledge-based economy and associated subthemes as they relate to all other previously explored themes of the current research project.
Table 5-1: Importance of the Knowledge-Based Economy as it Relates to all other Identified Research Themes.

<table>
<thead>
<tr>
<th>Theme</th>
<th>Relation to Knowledge-Based Economy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanisation</td>
<td>High-tech and therefore service-heavy environment requires an upskilled workforce for operations and maintenance of the machinery</td>
</tr>
<tr>
<td>Modernisation</td>
<td>Current labour must be re-trained to use new equipment and adapt to the new environment</td>
</tr>
<tr>
<td>Growth &amp; Development</td>
<td>Need for strong government role and industry partnerships to develop appropriate secondary economies to accompany the mining transition and accommodate laid-off mineworkers</td>
</tr>
<tr>
<td>Employment</td>
<td>Phased-approach to upskilling the workforce; re-training needed to adapt to the new environment of both primary and secondary economies</td>
</tr>
<tr>
<td>Procurement</td>
<td>Importance of government regulations and emphasis on local supply chains depend on having the appropriate skills and knowledge-base in place</td>
</tr>
</tbody>
</table>

5.3.1 **Skills Training & Education**

The need for skills training and education is particularly evident in the mining industry’s workforce which is mostly uneducated and largely considered unskilled labour. In terms of fuel cell technology specifically, there is a gap in knowledge pertaining to operations and maintenance; people lack the education and training to be able to build, run, maintain, and fix the systems (Mogotsi, 2015). This knowledge-base is essential for adapting in the transition to a new high-tech environment projected over the next decade or two, and equally essential for supplying labour to diversified economies such as fuel cell manufacturing. While industry has acknowledged the need for skills development and training efforts, little has been done to address these; their short-term solution has been outsourcing both the systems and the labour force needed
to install and service the devices. Both the CoM and Implats claim to have agreements with external companies for eventual skills transfer programs: “We got ours [fuel cell] from Fuji in Japan. They came to install it. Part of us getting it is that they are prepared to teach and educate South African people in how to maintain, look after, and install them” (Hofsajer-Van Wyk, 2015). At the same time, they are openly adverting any responsibility in this regards, leaving it up to the Department of Trade and Industry (DTI) to deal with these partnerships: “We need to focus on mining. On our staff and personnel and the communities around, but not necessarily on all sorts of other diversified stuff. That should be done at government level” (Hofsajer-Van Wyk, 2015). On their part, government has acknowledged skills training and education as priorities in the National Development Plan (NDP), emphasising its goal of transitioning from a resource-based to a knowledge-based economy (National Planning Commission, 2012).

In support of this shift, the DST’s innovative Hydrogen South Africa (HySA) programme is investing in building the country’s intellectual capacity by means of an emergent hydrogen economy and fuel cell industry. The 15-year programme is, “aimed at the parallel development of knowledge and technology across all areas of the Hydrogen and Fuel Cell value chain, allowing for the establishment of a strong R&D […] exporting added value PGM materials, components and products” (HySA, n.d.). While the initiative has made significant progress in a relatively short amount of time, it lacks large-scale investment from mining companies. This is explored further in the next section.

One of the reasons for this lack in capacity or knowledge base, as explained by Jourdan, was the breakdown of the Chamber of Mines’ Research Organization (COMRO)32 pre-democratisation to protect the white elite interests of the country. These interests seem to be stubbornly perpetuating in the mining industry, which refuses to invest in such capacity development in-country. While there are current targets in terms of

32 COMRO was once an internationally-recognised R&D hub for the mining sector. Following Mining Phakisa talks, it has very recently been reinstated, under the Council for Scientific and Industrial Research (CSIR) (M. Creamer, 2016).
training investment, Jourdan argues that these are misplaced: “There already is a 6% training target of payroll that needs to be adjusted to be STEM\textsuperscript{33}-skilled, so it’s not training in business science and rubbish marketing … What we really need is engineers and artisans” (Jourdan, 2015). So while investments are already underway for modernisation of the mining sector, investments in re-training programs are significantly lacking. Industry is simply shifting blame to government: “Our government can be very slow and cumbersome, so it is still in the process. There’s agreement from all parties that this should and will happen, it just hasn’t happened yet” (Hofsajer-Van Wyk, 2015). While providing little to no support, it is difficult to anticipate how this knowledge base will be developed. This leads to the second major challenge: stakeholder collaboration (or lack thereof).

5.3.2 Stakeholder Collaboration

Despite industry’s acknowledgement of skills training and education as a necessary element in the shift to a high-tech mining environment, there is a clear lack in collaboration when it comes to investing in and supporting knowledge-based programs. While national knowledge-based programs and initiatives do exist, they are simply not receiving enough support. Hydrogen South Africa (HySA) presents a good example, primarily funded by government, with minimal industry support: “they’ve [multinationals] spent much more on fuel cell research outside of South Africa than inside … HySA is [receiving] $30 million over 4 years … It’s 90% government and 10% companies, over even less” (Jourdan, 2015). In its first five years, HySA has worked on establishing competency in hydrogen and fuel cell technologies, collaborating with international experts to enhance technical knowledge and collaboration between academia and industry (Malik, 2013). The second phase now involves working on technology development and integration, with strong emphasis on South Africa based manufacturing (Malik, 2013). While HySA has made significant leaps in fuel cell development thus far, their goal of becoming an internationally competitive industry for

\begin{footnotesize}
\footnotetext[33]{Science, Technology, Engineering and Math (STEM).}
\end{footnotesize}
South Africa will be hard to achieve as companies continue to invest in overseas research and development, rather than in-country initiatives.

Another government-led initiative is Operation Phakisa, “designed to fast track the implementation of solutions on critical development issues,” (“Mining Operation Phakisa gets going,” 2015) as highlighted in the National Development Plan (NDP) 2030. The mining portion of the initiative is meant to, “identify key constraints to investment in and growth of the industry as well as develop a shared vision and growth strategy for the long-term development and transformation of the sector” (“Mining Operation,” 2015). Unfortunately, Phakisa is still in the development phase, with no indication as to when it will come into effect, what industry’s role is, or the impact the initiative might have.

There is a strong need for stakeholder collaboration in order to shift from a resource to a knowledge-based economy. South Africa faces many challenges in participating in a localized, emergent fuel cell industry, particularly surrounding access to, and the creation of, knowledge. While industry clearly wants to benefit from the technology by implementing fuel cells in their operations and reaping the economic benefits of an emergent industry, they are reluctant to invest resources into such knowledge bases in-country. Without support from this major stakeholder, South Africa, and HDSA’s specifically, risk being excluded from the potential benefits of this industry. Ultimately, the responsibility falls on both the mining companies and the government. The State has a responsibility to invest in skills development and education programs for its population, while industry must also be held accountable, by redressing historical structures of inequality which perpetuate and shape the industry today. The Mining Charter, and more informally, companies’ ‘social license to operate’ have been instated for this purpose, encouraging industry investment in local development. The uncertainty in government’s ability to transition from a resource-based to a knowledge-based economy, or lack of results thus far, has clear implications when it comes to moving forward with a
fuel cell industry and associated high-tech mining environment. Such implications affect the overall sustainability impact of the technology from a multi-faceted, holistic perspective, examined next.

5.4 Re-evaluating Sustainability Narratives

Fuel cell technologies are often promoted using a sustainability narrative, where the devices’ ability to contribute positively to environmental factors is heavily emphasized. This simplified use of the term ‘sustainable’ in relation to fuel cells in the South African context is critiqued here. In this final section, the research findings are analysed using the 7 Questions to Sustainability (7Q) framework (MMSD, 2002) in order to better understand the more holistic implications of the devices. As mentioned in the methods section, this framework was originally developed with the intention of assessing the global mining industry’s transition to sustainable development. It has been applied using fuel cell technology as the ‘project’ in the mining industry’s operations in order to explore the plurality of sustainability articulations affected by their implementation. For the purpose of this thesis, two of the seven categories of questions were left out of the analysis\textsuperscript{34}, due to both time and scope constraints. Analysis using the remaining five categories and associated questions are outlined in the subsections to follow. They are presented in descending order from opportunities to the main challenges.

5.4.1 Environment (Q3)

*Is the integrity of the environment assured over the long term?*

There are some clear benefits to implementing fuel cell technologies in South Africa’s platinum mines which present opportunities for both industry and government alike. Industry and government stakeholders alike focus primarily on the devices’ ability to contribute positively to environmental articulations; fuel

\textsuperscript{34} Q5) traditional and non-market activities; and Q7) overall integrated assessment and continuous learning. Q5 is simply beyond the scope of this research project, where I focus primarily on the contemporary labour and employment issues that the platinum mines bring to the surrounding communities. Given the implementation of these technologies is in the very early stages (through pilot projects), it was not temporally feasible to obtain enough information to be able to evaluate Q7 at this time.
cells present an opportunity for industry to reduce harmful GHG emissions, provide cleaner sources of energy, reduce both waste amount and toxicity, and diminish noise levels.

In a recent life cycle assessment (LCA) conducted by the International Platinum Group Metals Association (IPA), it was found that the mining process and subsequent ore beneficiation processes together make up 72% of the PGMs environmental impact\(^{35}\) due to the high energy intensity required for these steps (International Platinum Group Metals Association [IPA], n.d.b). This has a huge environmental impact in South Africa, given the country’s heavy reliance on coal as their primary source of energy. Fuel cells would allow for an offset of these environmental impacts, due to higher efficiencies and type of fuel source\(^{36}\) (with hydrogen being the ‘cleanest’ fuel option).

The MPRDA places particular importance on environmental articulations (RSA, 2002) as an attempt to redress past harms of the industry such as acid mine drainage and associated health-related illnesses of the gold sector. The smelting and refining processes of the platinum sector are less harmful, but not environmentally benign; massive amounts of tailings are being dumped by platinum mines. According to Kinnaird, Director at the Economic Geology Research Institute (EGRI), the low price of platinum (under $1000/oz at the time of the interview) is actually environmentally beneficial; it causes companies to, “be as lean and mean as possible,” (2015) being careful not to mine more ore than necessary. Regardless, there are still significant amounts of tailings produced, but since they are not toxic\(^{37}\), they can be vegetated, making them visibly appealing (Kinnaird, 2015), but also allowing opportunities for secondary industries in the agriculture or forestry sector (Mogotsi, 2015).

\(^{35}\) Smelting and refining to get the actual platinum make up an additional 27%, with recycling taking up the remaining 1% of PGM impact on the environment (IPA, n.d.a).

\(^{36}\) An LCA should also be done to look at the environmental impact of the device’s fuel source, as this plays a major factor in determining the environmental impact of these devices. This however, is beyond the scope of the current research project.

\(^{37}\) According to Kinnaird and Mogotsi (2015), South Africa’s platinum tailings are not subject to acid mine drainage (ADM), as are the country’s gold mines, which has created signification environmental impacts in the Witwatersrand basin.
In one sense, mechanisation processes can also help with tailings, not only reducing the amount of ore mined, and therefore producing less waste, but also in allowing more processes to occur underground, bringing less waste to surface. This was observed during my site visit to Implats’ shaft #14 where some of the ore crushing was done underground, to reduce the amount of ore hauled to the surface for processing (chapter 4). Fuel cells are advantageous for these types of machinery underground because they are known to produce less noise than their diesel-powered counterparts, a critical factor in the underground environment, where noise-induced hearing loss has been known to contribute to workplace accidents (Anonymous, 2015). However, it must be acknowledged that a fuel cell take-off (as is desired by industry and government alike) would lead to significant increases in platinum demand, thereby increasing production. Since tailings are related to the rate of production, there is a risk of exacerbating these tailings. Despite mechanisation advantages, more research must be done in order to determine the environmental impacts of such an increase in platinum demand.

Fuel cell technology will directly contribute to improved air quality, energy security, and improving climate change issues by reducing or eliminating harmful atmospheric emissions and providing independent energy solutions. At a time of global concern regarding climate change, to which South Africa is particularly susceptible, and impacted by, fuel cells can contribute to a shift towards more environmentally-friendly energy generation. While there is yet to be a formal LCA study done in this regards, it is clear that fuel cells, to some extent at the very least, help offset the environmental damages of platinum mining when it comes to GHG emissions. However, a fuel cell take-off would spur further mining development, which could potentially offset these benefits by stimulating demand and increasing production rates, thereby exacerbating tailings and other environmental impacts. Further research expanding these system boundaries of analysis is needed in order to determine the broader environmental impact of a South African fuel cell industry and more broadly, a global fuel cell take-off.
5.4.2 Economy (Q4)

Is the economic viability of the project or operation assured, and will the economy of the community and beyond be better off as a result?

Certainly, the main incentive for pursuing this industry aligns with Q4: Economy. This has been outlined extensively in previous chapters; analysis at the macro-level indicates that a take-off in fuel cell technology would simultaneously serve to stimulate platinum demand and increase production rates, while allowing for more mineral wealth to be issued to government to be used for development purposes. However, Q4 also highlights the importance of the project’s contributions to local and regional economies, with particular emphasis on opportunities for the less advantaged. Given high corruption levels, there is mistrust that these economic benefits are being allocated equitably, particularly when it comes to HDSA’s and the surrounding mining communities (Sorensen, 2011). Historical structures of power are reinforced, whereby government is allocated the economic gains from the mining industry and is made responsible for their re-distribution rather than having the economic gain distributed directly to the affected communities. The DMR (2015) report has proven that, in fact, there is still a large gap in service provision, a decade after mining policy reforms. At the moment, the long term economic contributions of fuel cells in the mining sector remain unknown, heavily dependent on the shift to a knowledge-based economy. All this being said, if industry is successful in stimulating demand for a fuel cell industry take-off, as well as modernization using fuel cells in its underground operations, mining expansions can be expected. It can be speculated that more machinery would be required to keep up with increased platinum demand. Such micro-economic scales of analysis must also be taken into consideration, and is suggested for further research.

5.4.3 Engagement (Q1)

Are engagement processes in place and working effectively?

Significant challenges remain when it comes to an emergent fuel cell industry in the South African context, which currently outweigh the opportunities presented above. Notably, the lack of Engagement (Q1) and
collaboration causes tensions amongst stakeholders and weakens the opportunities for broad-ranging benefits. Unfortunately, both industry and government are falling short on their commitments to migrant workers and local communities, who have very little opportunity to participate in the discussions surrounding mechanization and fuel cells. Workers’ unions have demonstrated difficulty in representing the rights of the mineworkers in such a way that allows for equitable decision-making in the trade-offs between all parties.

Ultimately, the lack of engagement of all stakeholders is failing those most affected by these issues, notably the HDSA’s they are meant to be supporting. HDSA’s remain for the most part, excluded from participating in these political processes surrounding technology development which directly affect them and ultimately, suffer the most from the lack of stakeholder collaboration. In this way, material, structural and discursive forms of power remain unchallenged, with HDSAs excluded from any benefits post-apartheid legislative changes were designed to bring. The lack of effective engagement processes is most clear in the ongoing labour tensions and strikes led by mineworkers in the platinum sector. As this research has shown, fuel cells and mechanisation processes threaten to exacerbate these tensions if appropriate measures are not taken to redress historical structures of power.

5.4.4 People (Q2)

Will people’s well-being be maintained or improved?

There remains important challenges for People (Q2) in the platinum mining industry which undermines the ability to engage with this emergent fuel cell industry and to foster an inclusive, successful secondary sector to the platinum mines. Specifically, there is a severe gap in skills training and education for HDSA’s to participate in the mining industry’s high-tech transition. In addition, the knowledge-base is clearly one of the major aspects affecting power relations when looking at fuel cell technologies in the mining sector.
Workers’ health and safety have the potential to be improved by implementing fuel cells in the underground environment, thanks to air quality improvements. However, these benefits are compounded by the potential impact of extensive unemployment and associated issues of poverty and dependence. In addition, as mentioned in the DMR (2015) report, as well as fieldwork observations at the Marikana Memorial, there remains a lack in basic infrastructure to nearby communities, which affects health and safety in the mineworkers’ home environment. This includes water, sewage, health services and energy issues.

It should also be noted that cases of health risks due to occupational exposure to platinum have been reported, for example in platinum refineries and catalyst production industries (Merget & Rosner, 2001; Ravindra, Bencs & Grieken, 2004). Respiratory sensitization and allergic reactions have been reported. While non-occupational exposure (resulting from platinum catalyst residues found in roadside dust for example) did not cause any health concerns (Merget & Rosner, 2001), more research is needed to assess the health risks of bioaccumulation of platinum in the surrounding environment, for example soil, vegetation and water (Ravindra, Bencs & Grieken, 2004). Despite health advantages of implementing fuel cells in the underground environment, given the potential for increased platinum demand if fuel cells gain significant traction, there are health risks associated with exposure to platinum in the smelting and refining stations, thereby shifting these risks from extraction phase to processing of the ore. Further research expanding the scope beyond the extraction process is needed to encompass these impacts.

5.4.5 Institutional Arrangement & Governance (Q6)

Are rules, incentives, programs and capacities in place to address project or operational consequences?

There is an overall lack in governance and capacity to address the implications of fuel cell technology implementation in the platinum mines. The lack in government capacity to enforce policy reforms, thereby

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38 For the purpose of this thesis, Q6 has been analysed solely in terms of government capacity; broader institutional arrangements have been excluded from the analysis due to time and scope restraints. This broader analysis would be useful for future research.
restructuring historical inequalities within the sector, has resulted in a perpetuation of social issues which threaten to be exacerbated by the introduction of fuel cells in the mining industry’s transformation. Government capacity to transition to a knowledge-based economy and enforce policy reforms on industry remain questionable, requiring strong stakeholder collaboration which is currently lacking in the South African context. Furthermore, the lack in growth and development strategies, thereby limiting the amount of diversification projects in local mining communities, reinforces mining dependency, entrenching racial inequalities.

5.5 Conclusion

Using the 7Q framework, it was found that sustainability is not being upheld in the context of this research topic, as illustrated in figure 5-1.

Figure 5-1: Opportunities and Challenges of an Emergent South African Fuel Cell Industry using the 7Q Framework.

Sustainability claims surrounding fuel cell technology are largely based on environmental characteristics, specifically, the devices’ ability to produce energy with little to no carbon emissions. This has simplified the impacts of the technology, facilitating a positive response from key stakeholders including industry and government. This narrative aligns with the literature, whereby, “sustainable product claims are often based on a single feature of the product, disregarding other possible articulations” (Mulder, Ferrer & Van Lente, 2011, p.3). However, the impacts of the technology extend beyond this singular articulation to include context-specific characteristics, illustrating the complexity of outcomes and impacts of these devices. As this research has shown, concepts of knowledge, governance and power are all intrinsically linked to the fuel cell discussion and sustainability outcomes in this context. This supports the literature in claiming that, “technologies can only be judged as part of a social process rather than as simply products” (Mulder, Ferrer & Van Lente, 2011, p.242). By limiting the scope of analysis to environmental factors, industry is projecting a false narrative of sustainability in the promotion of this technology. Rather, sustainable technology, “cannot be reduced to a formula or a method, but requires ongoing reflection, learning and interaction with stakeholders,” (Mulder, Ferrer & Van Lente, 2011, p.7) something which has been identified as lacking in this context.

Overall, while fuel cell technologies present several opportunities for the platinum mining industry, South Africa faces a lot of challenges if it is to participate in, and benefit from, this industry in such a way that is localized and inclusive. These challenges could tarnish the ‘sustainable’ label used in justifying the technology. Benefits such as air quality improvements, lower costs, and increased health and safety are expected, yet the transition to a high-tech environment via fuel cell technologies, particularly underground mechanisation processes, raises many concerns for employment, with the legitimate risk of exacerbating an already precarious situation. In addition, knowledge continues to be reserved for Western economies, with major investments going into fuel cell R&D overseas and outsourcing of the technologies as opposed to investing in local intellectual capacity building. These exclusionary practices undermine the socio-
economic development of the country with South Africans, and HDSAs specifically, excluded from participating in this emergent industry. Challenging historical structures of inequality which continue to persist today in the mining sector, particularly by means of investments into a strong knowledge-base for HDSAs, is a critical factor in redressing these issues.

And yet, South Africa has a major opportunity to actively participate in this industry in a positive way that would bring multiple reinforcing benefits. It has the platinum resources, with an active and successful mining sector, and the government has been very vocal about the need for more beneficiation and diversification strategies. Fuel cell technology presents an opportunity to invest in secondary industries of the economy which support these goals. Through knowledge, these power dynamics may begin to be dismantled and restructured, allowing for more broad-ranging benefits. However, stakeholder collaboration is a major factor in this solution, with the multinational mining companies playing a large role in this transition. Without sound collaboration from all stakeholders and investments in local knowledge-based initiatives, the economic benefits of this technological transition risk escaping the country, further enriching Western economies while having severe implications for South Africans, and HDSAs in particular. These conclusions expose the material, structural and discursive forms of power which continue to govern the platinum extractive industry, and ultimately undermine the sustainability of a fuel cell industry within the current South African context. Ultimately, this calls for a re-evaluation of the sustainability narratives with which these technologies are being promoted by industry and government alike.
Chapter 6

Conclusion

South’s Africa’s position as global supplier of platinum provides a unique situation for an emergent fuel cell industry; the reliance on platinum for this innovative technology has sparked interest in the mining sector specifically, hoping to promote the devices in their operations and lead to a fuel cell take-off. This thesis adds to the literature pertaining to technology and development, expanding discussions surrounding technology’s role in development, as well as sustainability narratives surrounding innovative technology. It does this while incorporating a political ecology focus to highlight the politicized nature of these interactions; while technology and development can be mutually reinforcing, there must be the proper conditions in place to foster this linkage. This has been largely ignored in the recent fuel cell discussions in South Africa; as a relatively new technology (commercially speaking) with limited implementation, the social impacts in particular remain largely unexplored. This research moves beyond technical discussions of fuel cells to include critical issues of power and knowledge into the discussion, and the impact these dynamics have on development and social justice issues in the South African context.

6.1 Contributions to the Literature

Supporting Bryant and Bailey’s political ecology assumptions (as outlined in Robbins, 2004, p.11), this research demonstrated that the implementation of fuel cell technologies, as part of the mining sector’s transition to a high-tech environment, will disproportionately burden South Africa’s HDSA’s, with exclusive benefits projected for the mining industry. In doing so, it will serve to reinforce existing socio-economic inequalities for HDSA’s, perpetuating the racially-skewed power dynamics of the sector. In line with the environmental conflict thesis (Robbins, 2004), this research highlights how, despite BEE policy which has allowed some form of black entry into the industry, for the most part, race remains the determining factor when it comes to who has access to South Africa’s platinum mining industry and who benefits from it. In this way, policy reforms have ultimately failed to redress historically structured power
dynamics, as they continue to be a factor in the transition to a high-tech environment involving fuel cell technologies. This holds true, unless discursive expressions of power are successfully challenged, providing opportunities for a local, inclusive technical knowledge-base, with particular attention awarded to HDSA’s access and entry into such a knowledge system.

This thesis also adds to the sustainability literature base, particularly surrounding articulations of sustainability when it comes to innovative technology. It was found that sustainability claims surrounding fuel cell technology are largely based on environmental characteristics, specifically, the devices’ ability to produce energy with little to no carbon emissions. This has resulted in an oversimplification and a depoliticised account of the impacts of the technology, disregarding factors such as power, governance and knowledge in the evaluation. By limiting the scope of analysis to environmental factors, industry is projecting a false narrative of sustainability in the promotion of this technology. Thus, this research has expanded technical discussion of fuel cells to incorporate a multi-faceted, complex array of characteristics and articulations which influence their sustainability impact, with particular emphasis placed on the specificities of the South African context. It challenges the intrinsic labelling of technology as ‘sustainable’ when based solely on environmental factors, demanding a broadened reflection incorporating spatial, temporal and political elements into the assessment.

6.2 Conclusion
On paper, with its abundance of platinum deposits, successful mining industry, and explorations into value-added industries, fuel cell technology presents an opportunity for inclusive, broad-based socio-economic development in the South African mining sector. Simultaneously, the devices would stimulate platinum demand, increase productivity in the mines, while addressing the pressing issues of energy security and, to a broader extent, climate change. However, as this research has shown, there is a large gap in effective policy, technical knowledge base, and equitable and inclusive stakeholder relations. These gaps present a real risk that this technology could worsen economic, social and power inequalities within the sector, while
further entrenching South Africa’s role as resource provider. Investing in the transition towards a knowledge-based economy could serve to alleviate some of the social challenges this entails, by means of growth and development strategies supporting beneficiation and local procurement processes. This presents its own challenges and opportunities, to be analysed in future research.

This study has looked critically at the convergence of history and innovation, placing emphasis on context, power relations and knowledge in attempts to provide a more holistic account of the research problem. In doing so, it adds to discussions on South Africa’s historical trends of material, structural and discursive expressions of power, to analyse contemporary issues of the development and implementation of innovative technologies in the mining sector. Opportunities exist for making a meaningful and viable contribution towards development and sustainability by means of investing in a South African fuel cell industry. The challenge will be in deliberately seeking pathways which address the more complex components of sustainability, benefitting all stakeholders and paying particular attention to the historical, political and social contexts from which the technology emerges. It is this particular context which allows for a questioning and perhaps even a re-evaluation of the sustainability narratives broadly applied to fuel cell technology. The perpetuation of historically structured power dynamics demonstrate that the current context of the South African platinum mines is not one that is ready for, or conducive to, the implementation of fuel cell technology. Without the appropriate structures in place, their implementation could prove detrimental.
References

Key Informants


Smith, F. (2015, August 26). Informal interview. Impala Shaft #14, Rustenburg, South Africa.

Literature


95


Magaziner, D., & Jacobs, S. (2013). Notes from marikana, south africa: The platinum miners' strike, the massacre, and the struggle for equivalence. *International Labor and Working Class History, 83*, 137. doi:10.1017/S0147547913000112


MMSD North America (2002). Seven questions to sustainability: How to assess the contribution of mining and minerals activities. International Institute for Sustainable Development (IISD), Winnipeg, Manitoba.


Appendix A: Letter of Information & Interview Consent Form

Letter of Information/Consent — For Key Informant Interviews

1. This research is being conducted by Melanie Jansen under the supervision of Dr. Allison Goebel of Queen’s University, Canada. This study has been granted clearance according to the recommended principles of Canadian ethics guidelines, and Queen’s policies.

2. The topic that is being researched is titled “South Africa’s Participation in the Future of Sustainable Technologies – Moving Beyond its Platinum Reserves”. The main purpose of the study is related to the use of South Africa’s platinum resources in emerging sustainable technologies including topics related to the mining industry as a whole such as migrant workers, labor issues, Black Economic Empowerment and corporate social responsibility. Other topics related to the socio-economic and environmental impacts this may have on surrounding communities are also explored.

The study also explores benefits of transitioning towards a knowledge-based economy through the case study of Hydrogen South Africa (HySA) while exploring the limitations and challenges of the current government structure and policies post-apartheid and the role played by the platinum mining industry in such.

3. Interviews will be conducted with people who have special knowledge in relation to one or more of these issues, including academic scholars, members of community organizations, business leaders, etc. In these interviews, the participants (you), will be asked to state their opinion on questions related to the topic under study for which they have some form of expertise.

4. You will be interviewed once which is expected to last for one hour (approximately) at a location that is convenient for both interviewee and interviewer; Wits University or the company or organization’s office are probable if space is available. There may be follow-up interviews to clarify or expand on points.

5. There are no known physical, psychological, economic or social risks involved with the participation in this research.

6. Participation in the research project is completely voluntary and you are free to withdraw at any point during the research for any reason. This may be done before, during, or after interviews by informing the researcher verbally (in person or over the phone) or electronically (by email) at any point. Again, contact information will be provided to you. Should you choose to withdraw, any data collected will be destroyed (deleted from recording device if one was used, notes and forms shredded).
7. You do not have to answer any question/questions that you are not comfortable with. You may ask to have any of your information removed from the study. Again, this may be done before during or after interviews by informing the researcher verbally (in person or over the phone) or electronically (by email) at any point.

8. In order to retain as much detailed information as possible post-interview, a digital audio-tape recording of the interview is preferable. You will be asked if you consent to the use of the digital recording of the interview. If you do not wish to have the interview recorded, hand-written notes will be taken of the interview.

9. Given your level of expertise on the interview topics and your professional experience, it is preferable that your name be used in the research paper. However, you will be given the option to remain unidentified should you choose. You will be given the option of being identified by your name, your position/title/occupation or to remain unidentified whenever possible. Given the nature of your position/title/occupation, it may still be possible to identify you even without your name being disclosed.

10. The information in the form of physical notes shall be kept safe in a locked drawer, while any recordings and subsequent transcriptions shall be kept on a locked, password-protected computer under the care of Melanie Jansen of Queen’s University, Canada.

11. This research will contribute to academic publications, including a Master’s Research Paper, by the professor and student involved. The academic community and any other interested person will have access to these publications.

12. There is no remuneration provided for participating in this research.

13. Any queries regarding the nature or manner of research can be forwarded to the following persons/bodies:
**Inquiries Related to the Research Should be Directed to:**

**Canadian Contacts**
Melanie Jansen (lead researcher)
13mbj1@queensu.ca
School of Environmental Studies, Queen’s University, Kingston, Ontario, Canada K7L 3N6.
Tel. (01) (819) 962-0625

Dr. Allison Goebel goebela@queensu.ca
School of Environmental Studies, Queen’s University,
Kingston, Ontario, Canada K7L 3N6.
Tel. (01) (613) 533-6000 ext. 77660

**South African Contacts**
Prof. Trevor Hill Hillt@ukzn.ac.za
Deputy Head of School, Environmental Sciences
University of KwaZulu-Natal,
Pietermaritzburg
Private Bag X01, Scottsville, 3209, South Africa
Tel: (27) (0) 33 260 6156
Facsimile (27) (0) 33 260 6157

**Inquiries Regarding Ethics Should be Directed to:**
General Research Ethics Board (Queen’s Canada), Queen’s University, Kingston, Ontario, Canada K7L 3N6
Chair.GREB@queensu.ca
Tel. (01)613-533-6081.
CONSENT FORM

Name (please print clearly): ________________________________________

1. I have read the Letter of Information and have had any questions answered to my satisfaction.
   
a) I understand that I will be participating in the study called “South Africa’s Participation in the Future of Sustainable Technologies – Moving Beyond its Platinum Reserves”. I understand that this means that I will be asked to state my opinion on questions related to the topic under study. Should I be interested, I am entitled to a copy of the findings.

2. I understand that my participation in this study is voluntary and I may withdraw at any time either before, during or after the interview. I am aware of the methods in which I can withdraw and that any data collected from me will be disposed of in a proper manner.

3. I understand it is preferable for the interview to be recorded on a digital recording device.
   
   o I agree to the use of a recording device during the interview for the purpose of data collection and/or quotations in subsequent publications.
   o I do not wish to be recorded and instead, agree to the taking of hand-written notes during the interview.

4. I understand that every effort will be made to maintain the confidentiality of the data now and in the future. The data may also be published in professional journals or presented at conferences. In terms of personal confidentiality (please check the option you are most comfortable with regarding the level of confidentiality you agree to for the purpose of this research):
   
   o I give consent to use my full name and title when cited in any related publications or conference presentations on the current research findings. I understand that my comments provided during the interview will be treated as ‘on the record’.
   o I wish to have my name withheld from any information used in any related publications or conference presentations on the current research findings ad my identity kept confidential to the best of the researcher’s ability. The researcher and I will agree on how I will be referred to, by a general identification of my position or occupation, or by a pseudonym. Although every effort will be made to choose an identifier that preserves confidentiality, I am aware that given the nature of my position/title/occupation, it may still be possible to identify me.

4. I am aware that if I have any general questions, concerns, or complaints regarding the research being conducted, I may contact Melanie Jansen (01) (819) 962-0625; l3mbj1@queensu.ca or project supervisor, Dr. Allison Goebel (01) (613) 533-6000 ext. 77660; goebela@queensu.ca. For inquiries regarding the ethics of the research I may contact the Chair of the General Research Ethics Board (01) (613) 533-6081; Chair.GREB@queensu.ca at Queen’s University.

I have read the above statements and freely consent to participate in this research:

Signature: ________________________________________ Date: _______________________

104
Appendix B: Sample Email Interview Request

Sample Email for Potential Interviewees

Dear Sir/Madam/Dr.

My name is Melanie Jansen and I am a current student at Queen’s University in Canada, pursuing a Master’s in Environmental Studies. My research is focused on the South African platinum mining industry and the social and environmental implications of the role platinum has in emerging sustainable technologies. This research project seeks to explore South Africa’s opportunity to move from a resource-based economy to a knowledge-based economy in light of its platinum resources and their applications in emerging sustainable technologies.

Given your expertise and knowledge on (insert topic here), I would love the opportunity to interview you in order to gain further insight into (insert research area here). Should you agree to participate, the interview should last approximately one hour in length, at a time and location that is most convenient for you.

Thank you for your time and consideration. I look forward to your response.

Regards,
Melanie Jansen
Appendix C: Interviewee Discussion Topics & Sample Questions

Interview Topics and Sample Questions

a) Each interview will be tailored to the particular expert participant. Topics are likely to include the following areas:

- The implications of historical structures of racial inequality in mining policies both pre and post-apartheid
- Power dynamics within structural organisation of mining companies and the effects of Black Economic Empowerment policies
- Accountability of both the government and mining companies in regards to social service provisions and subsequent access to such services by surrounding impoverished communities
- Impacts on surrounding impoverished communities given the increased dependency on platinum for sustainable technologies (employment, health, educational, environmental concerns, etc.)
- Equitable distribution of platinum mining benefits and detriments
- Role of sustainable technologies for South Africa’s development, particularly in regards to environmental and energy concerns
- Impacts of transitioning to a knowledge-based economy amongst broader South African population, particularly surrounding communities

b) Interviews will be open ended and conversational. For example, I will engage participants in ways like the following:

- “In what ways has South Africa’s political history shaped the platinum mining industry?”
- “To what extent has Black Economic Empowerment impacted the platinum mining industry?”
- “In your opinion, what are the major social implications of the platinum mining industry? How are these addressed and by whom?”
- "Please tell me what you know about the environmental impacts of the platinum industry in South Africa"
- “What impacts do you foresee in transitioning to a knowledge-based economy of the platinum mining sector?”
- “What role do you foresee for the South African development of sustainable technologies in both the national and international contexts?”
- “What are the opportunities and challenges in linking the resource-based and knowledge-based economies of the platinum mining industry?”
Appendix D: General Research Ethics Board Clearance

July 14, 2015

Miss Melanie Jansen
Master's Student
School of Environmental Studies
Queen's University
Kingston, ON, K7L 3N6

GREB Ref #: GNSC-071-15; Romeo # 6015930
Title: "GNSC-071-15 South Africa's Participation in the Future of Sustainable Technologies – Moving Beyond its Platinum Reserves"

Dear Miss Jansen:

The General Research Ethics Board (GREB), by means of a delegated board review, has cleared your proposal entitled "GNSC-071-15 South Africa's Participation in the Future of Sustainable Technologies – Moving Beyond its Platinum Reserves" for ethical compliance with the Tri-Council Guidelines (TCPS) and Queen's ethics policies. In accordance with the Tri-Council Guidelines (article D.1.6) and Senate Terms of Reference (article G), your project has been cleared for one year. At the end of each year, the GREB will ask if your project has been completed and if not, what changes have occurred or will occur in the next year.

You are reminded of your obligation to advise the GREB, with a copy to your unit REB, of any adverse event(s) that occur during this one-year period (access this form at https://eservices.queensu.ca/romeo_researcher/ and click Events - GREB Adverse Event Report). An adverse event includes, but is not limited to, a complaint, a change or unexpected event that alters the level of risk for the researcher or participants or situation that requires a substantial change in approach to a participant(s). You are also advised that all adverse events must be reported to the GREB within 48 hours.

You are also reminded that all changes that might affect human participants must be cleared by the GREB. For example, you must report changes to the level of risk, applicant characteristics, and implementation of new procedures. To make an amendment, access the application at https://eservices.queensu.ca/romeo_researcher/ and click Events - GREB Amendment to Approved Study Form. These changes will automatically be sent to the Ethics Coordinator, Gail Irving, at the Office of Research Services or irvingg@queensu.ca for further review and clearance by the GREB or GREB Chair.

On behalf of the General Research Ethics Board, I wish you continued success in your research.

Yours sincerely,

Joan Stevenson, Ph.D.
Chair
General Research Ethics Board

c: Dr. Allison Goebel, Faculty Supervisor
Appendix E: General Research Ethics Board Amendment Clearance

July 23, 2015

Miss Melanie Jansen
Maser’s Student
School of Environmental Studies
Queen’s University
Kingston, ON, K7L 3N6

Dear Miss Jansen:

RE: Amendment for your study entitled: GENSC-071-15 South Africa’s Participation in the Future of Sustainable Technologies – Moving Beyond its Platinum Reserves; ROMEO#: 6015939

Thank you for submitting your amendment requesting the following changes:

1) To conduct some interviews via Skype or telephone due to location issues;
2) Sample E-mail for Potential Interviewee (v. 2015/07/22);
3) Instructions for Skype/Telephone Interview (v. 2015/07/22);
4) Revised Letter of Information / Consent Form (v. 2015/07/23).

By this letter you have ethics clearance for these changes.

Good luck with your research.

Sincerely,

Joan Stevenson, Ph.D.
Chair
General Research Ethics Board

c.: Dr. Allison Goebel, Supervisor