

SOUTH AFRICAN PLATINUM GROUP METALS: POSSIBILITY OF BENEFICIATION

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This research report was submitted to the Faculty of Engineering and the Built Environment, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Science in Engineering.

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DECLARATION

I declare that this Research Report is my own, unaided work. Where use has been made of the work of others, it has been duly acknowledged. It is being submitted for the Degree of Master of Science in Engineering in the University of the Witwatersrand, Johannesburg. It has not been submitted before in any form for any degree or examination in any other University

Signed:

Gary William Skinner

This _____ day of _____ 2018

ABSTRACT

South Africa has an immense Platinum Group Metals (PGM) resource and with such a mineral rich comparative advantage, as opposed to other nations, it would be expected that this windfall could be manipulated to create substantial economic benefit. Sheer comparative advantage does contribute to the economy but added revenue and job creation could be achieved by further processing the metals into higher saleable products by using beneficiation. As the resource is located, close in proximity to the manufacturing industry, the movement of metals from the PGM refineries to the manufacturing facilities should be an advantage. However, circumstances and nuances, related to PGMs, make this sequence irrelevant due to the low transport costs of refined PGMs to processing facilities outside of South Africa. The global auto catalyst industry was, by far, the largest consumer of PGMs in 2016. This single industry consumed 12 million ounces and this aspect of a dominant downstream application makes PGMs unique.

The Beneficiation Strategy for the Mineral Industry of South Africa from the Department of Mineral Resources (DMR) main value proposition was to translate the comparative advantage of the country's mineral wealth into a related industrial competitive advantage and also to create employment. This mechanism was to be achieved through industrial diversification to produce upgraded, higher value products from raw or semi processed mineral products. Fundamentally, this notion is flawed with the downstream PGM industry as the location of the deposit compared to the processing zone has no bearing on the position of the auto catalyst manufacturer. The stimulus for this industry does not have the same drivers as compared to the extractive industry. The auto catalyst industry is dominated by a handful of multinational catalytic converter companies. These companies base their strategy on locality of competitive advantage, incentive policies are a major consideration as to the position of manufacturing facilities.

The South African catalytic converter manufacturing industry has a global reach and is considered a trade policy success story. South Africa has an incentive policy which attracted these companies, but South Africa is not geographically located near to major automotive manufacturing hubs. In 2016, South Africa accounted for 1% of the global passenger car and commercial vehicle production and remarkably, produced 15% of the world's auto catalysts. The incentive policy which drives the local auto catalyst industry uses local content addition to qualify for 65% export rebate certificates. Refined PGMs form part of the local content addition and South African refined PGMs are used in local auto catalyst manufacturing facilities. The driver for the auto catalyst industry is to qualify for the export

rebate, local PGMs add to this qualification but the reality is that there is no real other advantage to use local PGMs.

The South African auto catalyst sector is a R 20 billion South African industry, however, the primary PGM source, or the extractors, are struggling to maintain financial stability. The downstream beneficiation value chain is loaded in favour of the auto catalyst manufacturer and not advantageous to the extractor. South Africa supplied 56% of the global PGM demand in 2016 but this was overshadowed by the poor financial health of the PGM extraction industry which was subjected to a 47% platinum price plunge from 2010-2017.

To leverage the maximum financial advantage through downstream beneficiation of the South African PGM supply is not possible. This would be a considerable risk to the multi-national auto catalyst manufacturers who would have all of their investment in South Africa. Considering the remarkable progress of the South African auto catalyst industry, opportunities exist to re-evaluate the PGM value chain to benefit all stakeholders.

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Lastly, the opinions expressed in this research report are those of the author and may not necessarily represent the policies of the companies and institutions mentioned in this report.

DEDICATION

To my wife and son who have been my pillar of support in life.

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LIST OF ABBREVIATIONS

AGOA	African Growth Opportunity Act
AIEC	Automotive Industrial Export Council
AIS	.....	Automotive Incentive Scheme
APDP	.....	Automotive Product and Development Programme
CCIG	.....	Catalytic Converter Interest Group
CID	.....	Center for International Development at Harvard University
DOC	.....	Diesel Oxidation Catalyst
DPF	.....	Diesel Particulate Filter
DPME	.....	Department: Planning, Monitoring and Evaluation
EFTA	.....	European Free Trade Association
EGR	.....	Extractable Global Resource
ETF	.....	Exchange Traded Fund
Fe – SCR	.....	Iron - Selective Catalytic Reduction
GATT	.....	General Agreement on Tariff and Trade
GCIS	.....	Government Communication Information System
GHG	.....	Greenhouse Gases
HC	.....	Hydrocarbons
IDC	.....	Industrial Development Corporation
IPA	.....	International Platinum Association
IPAP2	.....	Industrial Policy Action Plan
JORC	.....	Joint Ore Reserves Committee

JSE	..... Johannesburg Stock Exchange
KPMG	..... Klynveld Peat Marwick Goerdeler
LBMA	..... London Bullion Market Association
LNT	..... Lean NO _x Traps
MIDP	..... Motor Industry Development Plan
MIP	..... Manufacturing Investment Programme
MPRDA	..... Mineral and Petroleum Resources Development Act
NAACAM	..... National Association of Automotive Component and Allied Manufacturers
OEM	..... Original Equipment Manufacturer
PBC	..... Platinum Beneficiation Committee
PGM	..... Platinum Group Metals
PI	..... Production Incentive
PwC	..... Price Waterhouse Cooper
SACU	..... Southern African Customs Union
SAMREC	..... South African Minerals Reporting Code
SCR	..... Selective Catalytic Reduction
SETA	..... Skills Education Training Authorities
TWC	..... Three-Way-Converter
UNEP	..... United Nations Environmental Programme
USGS	..... United States Geological Survey
V – SCR	..... Vanadium - Selective Catalytic Reduction
VAA	..... Vehicle Assembly Allowance

1 INTRODUCTION

This research report focuses on the viability of downstream beneficiation for Platinum Group Metals (PGMs) mined in South Africa. The mineral endowment in South Africa is subject to some speculation and several estimates exist. The Department of Mineral Resources (DMR) states the estimated resource, per Citi Bank, at USD 2.5 trillion (DMR, 2011a). Eco-partners have a higher estimate at USD 4.7 trillion (Baartjes & Gouden, 2011). Though figures are estimates of the endowment, the ability to mine these resources could be brought into question. However, as an aggregated quantification of the wealth in the ground in South Africa, it illustrates the potential of the mineral endowment in the country.

The research aims to determine, through analysis, where the global supply of PGMs are located and where the markets exist. Furthermore, the aim is to explore the nuances that pertain to the PGM manufacturing industry. Amongst the primary tasks, the research determines the global supply volumes and the related demand outlets. Further to this research, the study contextualises the size of the South African supply position and the local manufacturing capability offtake.

This research report also aims to identify, understand and compile definitive stakeholder requirements. It seeks to comprehend, via economic analysis, comparative mineral asset benefits and competitive manufacturing advantages within the domain of the Platinum Group Metals.

1.1 Background

South Africa has its own set of social and economic problems as do many other nations (DPME, 2017). Although, South Africa remains a mining powerhouse in Africa, that is just not enough to alleviate poverty issues within the country. As a mineral endowed nation, the belief would be that the economic benefit from the endowment would be the driver for human development and economic health of the nation. However, there is risk associated with mineral wealth in that the natural resource will eventually be depleted. If the extraction of the non-renewable resource is not exploited to its full potential, then the maximum benefit cannot not be realised.

Usually the mineral endowment of a country belongs to the state and essentially to the people of that country. As per the vision of the DMR, the right to mine that wealth is controlled by the government who are the elected custodians of the mineral endowment (DMR, 2016).

As a world-wide phenomenon, South Africa does not stand alone in its attempts to maximise the benefits of the exploitation of its natural mineral endowments. Typically, most nations, including South Africa have channels in which the revenues generated from the extraction of minerals can translate to the social and economic development of the nation. These channels seek to assist the national advancement by various methods including, increasing industrial manufacturing capabilities and job creation. The Bill and Melinda Gates Foundation, (2015) views four such channels for extractive industries as conduits from localised benefits to government revenues. Apart from the jobs created directly by the extraction industry, additional jobs are created by the downstream beneficiation industry, thus leading to the social betterment of the nation. The comparative magnitude of South Africa's PGM resources is often seen as an advantage for locally manufactured PGM goods (DMR, 2011a). The characteristic of the comparative global resource advantage separates PGMs from other minerals in South Africa and this characteristic is at the forefront of this discussion.

South Africa has 95% of the world's PGM reserves and is one of a few nations that concentrate on PGMs as the primary mining target (USGS, 2013). In most other countries, PGMs are produced as a by-product to other mineral extraction processes, apart from Zimbabwe and one or two other operations in Canada and Australia (USGS, 2013). South Africa dominates the sector as the largest primary source producer, but even with the extraordinary PGM resource, sustainability and the health of PGM mining operations is questionable.

As a key factor, understanding the magnitude of the reserve within South Africa will undoubtedly define the comparative advantage available over other nations. The fundamental economics of supply and demand of PGMs needs to be understood, firstly, in terms of sustainability for mining operations and secondly for the value addition of local beneficiation for these minerals.

Of the six Platinum Group Metals (platinum, palladium, rhodium, osmium, ruthenium and iridium) the focus of the report is on the three main commercial products (platinum, palladium and rhodium). Although osmium, ruthenium and iridium have value, their contribution has a lesser influence on the overall PGM industry. The global production of the three main PGMs over recent times has had a noticeable upsurge in production from the middle 1970's through to 2016 (Johnson Matthey, 2017b).

The supply and demand characteristics for PGMs are such that the larger portion of the supply of PGMs is from South Africa, however the demand characteristics are controlled by global events, trends and essentially by environmental policy greenhouse gas (GHG) emissions. These influencing factors occur outside of the control of the South African mining and manufacturing industry and beyond the scope of the South African government.

South Africa already conducts local platinum beneficiation in the form of catalytic converter production, however, this industry appears to be struggling to maintain full capacity. It has, and still is, propped up by export/import incentives to give the local industry a competitive edge against other global manufacturers. Many countries use similar incentives to protect and sustain local industries, but even with this incentive plan, it is questionable as to why local auto catalytic manufacturers struggle to maintain capacity (Dewar, 2012). With the comparative advantage of the world largest reserves of PGMs, and an established manufacturing industry, in place, it would be appropriate to have the world's largest catalytic converter manufacturing industry in the country. However, this is not the case and the research report explains these issues.

PGMs are traded via several methods and in a depressed market, or otherwise, the PGM mining sector will seek the best possible advantage to leverage their own business. When these minerals are, and can be traded freely on the open market, what clear economic or other benefits, within the South African PGM value chain, is there for extractive industries supplying the auto catalyst manufacturing business? Varying views and arguments exist within the subject of downstream beneficiation and although some of these views are generic, this research report is specific to PGMs in South Africa. The current state of knowledge and understanding of the PGM value chain is vast in subject matter. However, the following chapters, narrow the topic to stakeholder's involvement, global supply and demand and what opportunities exist in South Africa.

1.2 Problem Statement

Arising from the background of the problem the question is, why does the comparative advantage of the world's largest reserves of PGMs not relate into a world dominating PGM component manufacturing industry? The Beneficiation Strategy of 2011 has been in the public domain for several years (DMR, 2011a). Research has shown that the PGM market is dominated by auto catalyst production, driven by ever tightening restrictions on greenhouse gas emissions from both stationary and automobile engines. South Africa already has an existing auto catalyst industry, but does the government, the mining industry or the catalytic converter manufacturers benefit from downstream PGM beneficiation?

In addition, certain factors and overlaps occur within the boundaries of such a beneficiation strategy and these are in the form of government requirements, sustainable mineral production and the manufacturing industry's capability. The blurred areas require investigation to define where the value proposition lies within the chain. The research will contribute to the gap in knowledge and give a

clearer understanding of the subject to both mining and the industrial sectors, with particular insight for PGM producers.

1.3 Aim and Objective of the Study

The Aim of the study is qualitative and involves a literature review on the aspects of the PGM value chain from the extractive industry through to the South African catalytic converter industry. In addition, the purpose is to identify the advantages of using locally extracted PGMs in the South African catalytic converter manufacturing industry. This research report aims to identify, understand and compile definitive stakeholder needs and seeks to comprehend, via economic analysis, comparative mineral asset benefits versus competitive manufacturing advantage within the domain of the PGMs. The research aims to determine, through analysis, where the global supply of PGMs are located and where the markets exist. Furthermore, the aim is to explore the nuances that pertain to the PGM manufacturing industry. Amongst the primary tasks, the research determines the global supply volumes and the related demand outlets. Further to this research, the study contextualises the size of the South African supply position and the local manufacturing capability.

The research project aims to deliver the following aspects:

- Determine if the downstream beneficiation of PGMs has a significant influence, economically or otherwise to enrich South African society;
- Deliver recent characteristics for the global supply and demand of PGMs with relevance to 2016;
- Deliver a study on production characteristics of the South African PGM operations;
- Deliver an understanding of the global demand for catalytic converters and how large is South Africa's market share; and
- Determine what, if any, significant opportunity creation can be derived from additional production of locally manufactured auto catalytic converters.

1.4 Significance of the Study

The significance of the study is to determine the links in the PGM value chain that exist between the resource in the ground through to the salable end-product. The findings of this research will address the gap in knowledge that exists between government, the extractive industry and the manufacturing industry. (Those industries, related to the manufacture of components, that comprise of high concentrations of PGMs). The findings of this research will contribute to the body of knowledge associated with the possibilities of maximizing financial or other opportunities, associated with the process.

The government and associated policy makers will be able to access the information to make informed decisions and further develop society within South Africa. The mining industry may be able to use the knowledge to better their business model and prospects such as forward integration into downstream manufacturing. Finally, the catalytic converter industry will access the information to understand the nuances and processes involved with the supply of PGMs from the extractive industry in South Africa. Furthermore, new data will advance the collective body of knowledge surrounding the PGM value chain and align the thinking and understanding of the interaction between each stakeholder that will be of benefit to all.

1.5 Primary Research Questions

The research indicates that there are varying views with respect to the downstream mineral value addition in South Africa. As part of the process of sustainable PGM beneficiation, economic rewards are expected. The key questions to be addressed are:

- *Is leveraging the maximum financial advantage, for South African produced PGMs, a viable option for sustainable downstream beneficiation?*

The second question being asked is an extension of the first question. It seeks to deal with how metals are traded and at which point in the PGM value chain, these metals are sold. Furthermore, it seeks to highlight the reality of the nature of the value chain between the mining and manufacturing industry.

- *If PGMs are traded freely on an open market, what advantage does the locality of the deposit bear upon the downstream manufacturing industry? Visa versa, what advantage is created in the process for the Platinum Group Metal extractors, suppling local manufacturers?*

The third question deals with the aspect of opportunity creation in the downstream PGM beneficiation process.

- *What other potential opportunities are created, with downstream beneficiation of PGMs?*

The report seeks to identify the core uses of PGMs and what potential could be derived from local manufacturing of these products. In addition, an auto catalyst business already exists in South Africa and the report offers an insight to the production characteristics of the industry and the policies and strategies surrounding the industry. Essentially, reverting to the question of whether, in South Africa, there are any real advantages, economic or otherwise, in PGM miners supporting the local manufacturing downstream beneficiation industry.

1.6 Hypothesis

The premise of the report is to determine how the PGM value chain functions. Where the boundaries of extractors and manufacturers converge to form a competitive advantage for all stakeholders.

The hypothesis then, is an argument that if the infrastructure exists, or could be implemented and other limiting factors make clear economic sense for local beneficiation, then, will beneficiation support social economic development, promote employment and will it have a positive influence on the economy of South Africa? If not, then would the investment in infrastructure, skills and the hope of employment be made in blind faith? Although, downstream PGM beneficiation may be a popular concept, it may be detrimental to the mining sector and to the economy.

1.7 Methodology

The methodology to be used for the report is a literature review. The literature review analyses a variety of perspectives and opinions from:

- Online journal databases such as Resource Policy, The South African Institute of Mining and Metallurgy and The World Trade Organisation. Whereby, information was researched to determine the PGMs value chain and associated peripheral linkages;
- South African government websites, explicitly, The Department of Mineral Resources and The Department of Trade and Industry with reference to (A Beneficiation Strategy for the Mineral Industry of South Africa) with various other references to acts and policies such as (The

Manufacturing and Investment Programme) and the (Mineral and Petroleum Resources Development Act). The use of the information from these acts and policies surrounded the governance of the PGMs value chain in South Africa;

- Various papers, journal articles and conference proceedings provided information as the basis for the chapters of the research report. The Bill and Melinda Gates Foundation provided some such information as guidance to leveraging natural resources;
- Data for the research report was also provided from professional organisations such as The Chamber of Mines and was heavily reliant on The Catalytic Converter Interest Group, The International Platinum Group Metals Association and The Automotive Export Industry Council;
- Mining data and reports for the research report were provided by Anglo American Platinum Limited, Lonmin Plc, Northam Platinum Limited and Impala Platinum Holdings Limited. Where compliance and reporting references were required, reliance was placed on the SAMREC code along with the Australian JORC code and the Canadian NI 43-101 code; and
- Additional, source information was derived from the Savings and Loan Metal and Mining Data Base (SNL) hosted by Sachs and Poors Global. The companies, Johnson Matthey and BASF provided a large source of information for the downstream section of the PGMs value chain.

Chapter 2 is an appreciation of the Beneficiation Strategy for the Mineral Industry of South Africa. The aim is to achieve an understanding of the government of South Africa's strategy for mineral beneficiation. This chapter is the foundation of the research work and forms a platform for the balance of the chapters in the research report. The strategy may be noble in its intent but other factors may make it difficult to implement tactically. These outcomes are explored in greater detail throughout the report.

Chapter 3 is an overview of the "Resource Curse", understanding that the phenomenon is a major driver to the global fear of wasting non-renewable resources. These resources, if managed correctly, could be used for current and future social development. As part of the overview, this chapter analyses what other countries have done to try to curb the effect of the resource curse. Furthermore, the chapter investigates other channels available for resource rents and what of these are open to governments for sustainable development derived from non-renewable resources. Understanding the concerns and identifying other revenue options are also covered in Chapter 3.

Chapter 4 covers the rarity of minerals and their trading framework. The aim of the chapter is to define the essential difference between resources and reserves and the monetary inferences related to the in-situ mineral wealth estimate. Accessing the mineral wealth and expanding the value, was one of the key drivers for the governments beneficiation strategy. This chapter covers the importance of

understanding the effect of mineral price volatility on such estimates. Further to this understanding the scarcity of minerals is put into perspective. The chapter attempts to highlight that future generations may not be able to benefit from South Africa's sovereign windfall. In addition, a further aim of the chapter is to explore the way minerals are traded. With the understanding that, the market price and production volumes are generally, not in the hands of the producer, but moreover, determined by international supply and demand tactics. Fragile markets and price volatility are often based on conditions and circumstances beyond the control of local intervention. As these variants have a major impact on the viability of the mineral trade, Chapter 4 seeks to highlight and outline these factors.

Chapter 5 seeks to narrow the wider research of the previous chapters and focuses on the 2016 PGM supply and demand characteristics. Initially, the chapter provides an overview to the supply and value chain associated with PGMs. It provides information with respect to the quantification of South African production capability compared to the rest of the world. Furthermore, the chapter defines the supply of these metals, where they are situated and the magnitude of the production capabilities. This information is derived from various data bases, reports and company results from 2016.

The objective is to qualify South Africa's supply capabilities, global position and the viability of sustainable production. Chapter 5, defines global demand factors for PGMs. The world demand is broken down into, where PGMs are used in industry as well as investment potential. The research seeks to unpack the 2016 global demand for these products and services, essential to understand the dynamics of the PGM market. The objective of the chapter is to quantify firstly, the size of the PGM demand market. Secondly, to understand economic use, and thirdly to identify which industrial products may be, or are, produced in South Africa. This leads towards Chapter 6 as the forerunner to understanding global demand and where the South African industry may have the opportunity to conduct downstream beneficiation with PGMs.

Chapter 6 makes use of the threads of information from the previous chapters on supply and demand of PGMs. It aligns to the potential for downstream PGM beneficiation in South Africa. The nuances are defined with the objective of determining where, or if, South Africa can trade locally manufactured PGM products. The initial research indicates that auto catalyts dominate the PGM demand sector. This chapter makes use of South African, 2016, automotive export data to determine where and how many units are produced in South Africa, and to where they are exported. A local incentive policy exists to facilitate sales of auto catalyts, but this too has nuances that are identified in Chapter 6.

Chapter 7, the conclusion, is an overall collation of information and recommendations, bringing together the expectations of government, mining companies and the manufacturing industry. Objectively, this chapter portrays the reality of trading these metals in a global market.

1.8 Assumptions and Limitations

The assumptions involved with the research are based on other study literature being factual. Due to the volatile environment of the mining industry and the cyclic nature of mineral supply and demand, this data is relevant for current global conditions. Future changes in greenhouse gas emissions policies, especially in China or India may drastically sway demand. This may change the current dynamics and make certain information irrelevant.

2 REVIEW OF THE BENEFICIATION STRATEGY OF 2011

2.1 Introduction

The aim of Chapter 2 is to understand the concept and purpose of the South African Beneficiation programme from the point of view of the government and what this process is expected to achieve. The government of South Africa is the custodian of the country's mineral resources, elected by the people of South Africa. This chapter forms the basis for all the following chapters. The viability of sustainable local PGM downstream beneficiation needs a regulatory framework to promote and protect the country's PGM mineral resources.

In June 2011, the DMR released a document entitled "A Beneficiation Strategy for the Mineral Industry of South Africa". The intent and vision of the document was to advance development in South Africa from the mineral wealth generated in the country. Various methods and channels were proposed and this research report seeks to explore these options to understand the rationale behind the DMR's strategic document. In May 2010, a Citibank report, via an independent evaluation, stated that the in-situ mineral wealth in South Africa was estimated at USD 2.5 Trillion, thus, making South Africa the wealthiest global mining jurisdiction (DMR, 2011a). The DMR's main driver was to access this estimated wealth and transition in-situ resources to up-graded products thus creating jobs and additional revenue (DMR, 2011b). The strategic intent of the document sort to make the best possible use of the windfall to support the socio-economic development of South Africa.

The argument put forward by the DMR was that USD 20 billion of South Africa's exports are mining and mineral products and that the South African mining and minerals industry employed half of a million people (Chamber of Mines, 2016a; Chamber of Mines, 2016b). The contribution could be much greater if these mining and mineral products were processed further into transitional and finished products (DMR, 2011b). Thus, by adding additional downstream activities to raw and semi processed products, the value of the goods would increase. This increase in value was expected to contribute to the economy of South Africa. Downstream activities or processes were identified as key objectives for the value addition. Some of these objectives were already entrenched in the legislation of the country (Dewar, 2012).

This strategy recognises and categorises several instruments that would be used to achieve the objectives of the document. These were policies, legislation and incentive plans, that would therefore encourage the downstream processes to add value to the economy.

2.2 Classifications of Terminology, Aim and Intent

Beneficiate in the mining sense of the word is the basics of mineral processing or ore dressing, where the processes involved increasing the concentration of an ore to a higher or more saleable state (Dryzymala, 2007). The Oxford Living Dictionary (2017) defines “beneficiate” as the treatment of a raw material to improve its properties. The DMR uses the term beneficiation in “A Beneficiation Strategy for the Mineral Industry of South Africa”, as the transformation of a mineral (or a combination of minerals) to a higher value product, which can either be consumed locally or exported. The term is used interchangeably with “value-addition” (DMR, 2011a).

In the case of this document from the DMR the strategy is a political plan to create an enabling environment for mining and mineral products to be upgrade to a more valuable asset. This could be monetary value, job creation, skills upliftment or a host of other possibilities.

The intention, in the DMR’s Beneficiation Strategy for the Mineral Industry of South Africa was clear and concise, in that the aim of the policy is to develop South Africa’s mineral wealth to its full potential and to the maximum benefit of the entire population (DMR, 2011a). The vision set out in the document was to create an environment that increased the extent of, or enabled new channels for the beneficiation of mineral products that:

- Have a greater contribution to export revenue;
- Enable economic diversification through industrial opportunities;
- Accelerate development towards a knowledge based economy; and
- Develop enterprise creation and create decent jobs that will support poverty alleviation.

2.3 Beneficiation Value Proposition

Figure 2.1 indicates the potential of beneficiation in the iron and steel industry. It is notable that from the raw material, the value increases with each process step. The process from raw iron ore to steel requires infrastructure and skilled personnel to take the product to a more valuable state. The raw material price compared to the finished steel article is significant. The concept for the DMR (2011a) Beneficiation Strategy was that value could be achieved if finished articles were sold as opposed to raw or semi processed minerals.

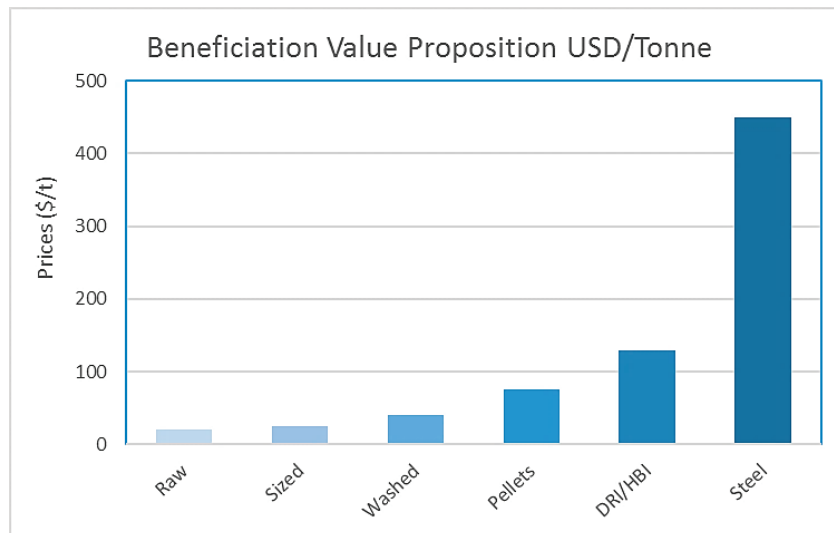


Figure 2.1: Beneficiation Value Proposition Example 1 (Adapted from DMR, 2011b).

A second example, Figure 2.2 shows the value add generated from the mineral extractor, to the mineral processor, to industry and through to the final end-user product. In this case both employment and contribution to Gross Domestic Product (GDP) are indicated. Again, a notable difference on both GDP contribution and employment numbers are indicated with rapid increase in both GDP contribution and employment numbers in the manufacturing/end-user portion of the graph. This massive incremental difference was a driver behind the concept of the DMR's Beneficiation Strategy. This indicates that both the employment numbers and the GDP contribution are highly elevated by producing end-user products (African Development Bank, Development Centre of the Organisation for Economic Co-operation and Development, United Nations Development Programme, 2014; DMR, 2011a).

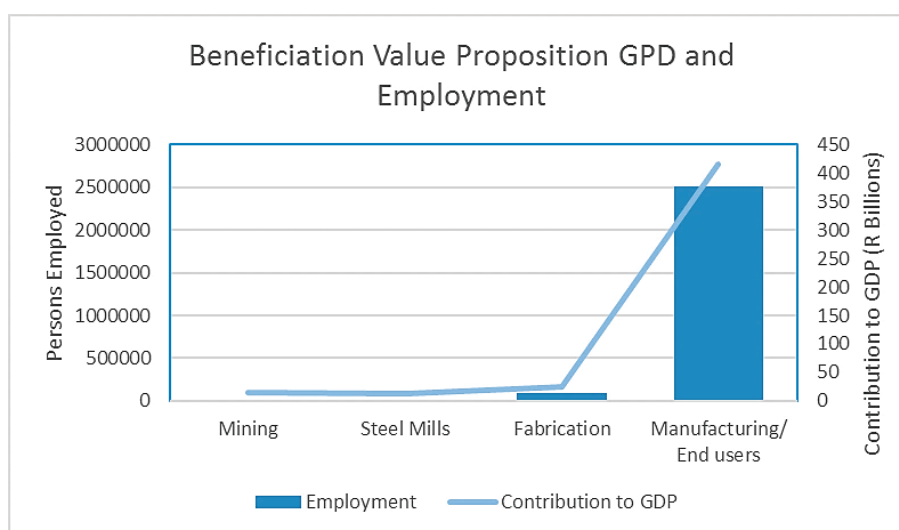


Figure 2.2: Beneficiation Value Proposition Example 2 (Adapted from DMR, 2011b).

The DMR's argument on beneficiation was that if South Africa was exporting non-renewable resources to other countries before developing the full potential to maximise the reward, then the countries to which the under processed products were exported, would reap the benefit.

2.4 Comparative Translation to Competitive Advantage

South Africa contains a host of minerals that offer a comparative advantage versus other nations but most of South Africa's minerals are exported as raw materials or semi-processed products (DMR, 2011a). This leads to the argument that if this has been the traditional trend, then how would this strategy coerce industry to create opportunities to competitively process minerals to products.

Figure 2.3, illustrates the 2008 South African reserves for key minerals and notable from the figure were the reserves of PGMs, manganese and chromium that ranked far above the rest of the world. In fact, these figures almost show complete world dominance in reserve capacity for the top three key minerals. Chapter 5 of this research report expands on the comparative advantage of PGM's in South Africa.

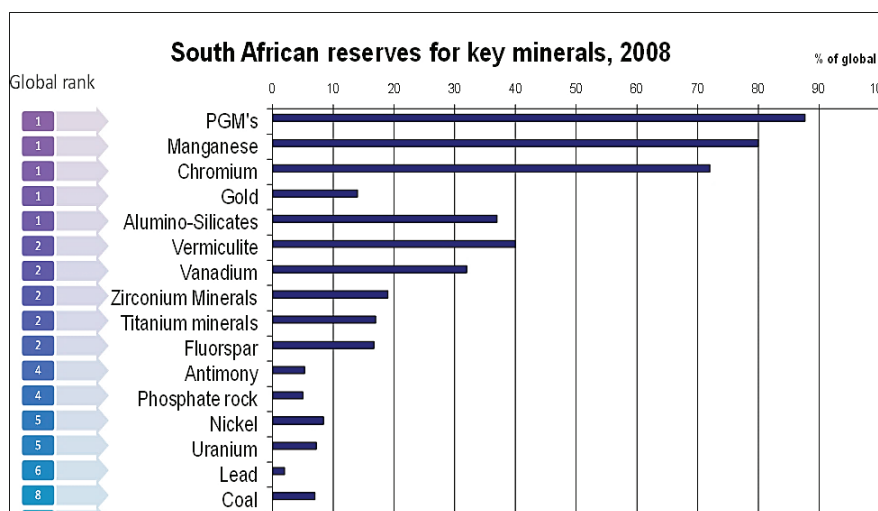


Figure 2.3: South African Reserves as a Percentage of Global Reserves (DMR, 2011b).

It is well understood that South Africa has substantial mineral wealth as indicated in Figure 2.3. The Beneficiation Strategy set out to provide a framework, to enable the massive comparative advantage of the country's mineral wealth and translate that into a national competitive mineral processing advantage (DMR, 2011a). This strategy sort to provide a competitive environment through several pillars such as:

- A legislative framework, where government legislation provided the foundation for expediting the process;
- The use of multi-stakeholder forums, government, mineral extractors and processors, industry and institutions;
- International trade agreements; and
- Beneficiation strategic interventions.

Figure 2.4 illustrates the transition of the comparative advantage of the in-situ value of South Africa’s mineral resources, through to a competitive advantage. The transition was supported by strategic pillars that function as enablers to provide a competitive environment for industry (DMR, 2011a). The DMR also argued that the mineral endowment in South Africa and the comparative advantage that this provided, was the feeder for downstream beneficiation (DMR, 2011a). Further to this reasoning, the increase in economic development would benefit and strengthen the South African knowledge base as a whole (DMR, 2011a).

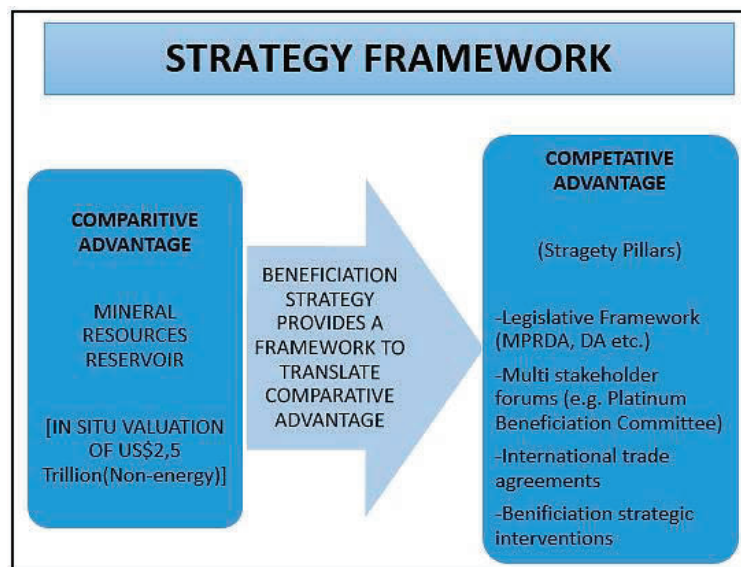


Figure 2.4: DMR’s Strategy Framework (Adapted from DMR, 2011a).

Competitive access to locally produced minerals was another key success factor for the industrialisation initiative (DMR, 2011a). The point that the DMR was attempting to make was that mining companies and mineral producers may already be contractually obligated to supply products to other global manufacturing facilities. The local downstream beneficiation initiative may be

strangled for supply or subject to uncompetitive pricing even though the minerals are derived from the South African mining fraternity.

The DMR suggested that South Africa has a competitive advantage in existing and potentially upgrading infrastructure, along with several large-scale resource-based investment projects. There would be a need to create further essential infrastructure such as roads, rail, ports and pipelines (DMR, 2011a). Clear opportunities for local processing existed in cases where capacity and know-how were available (DMR, 2011a).

The bulk of South Africa's electricity is generated from coal fired power stations. At the time that the DMR's document was created, more than 50% of the annual production of coal was consumed by electricity generation (DMR, 2011a). The production of electricity at a competitive globally cost was thought to have already fuelled the country's economy and created employment. Maintaining globally economic electricity prices was seen to be a value proposition for beneficiation and a competitive advantage (DMR, 2011a).

Comparative mineral advantage did not clearly convert into a competitive advantage for South Africa, so the strategy document had outlined the enablers that were seen fit to provide a pathway. These high-level enablers were seen to be the levers to translate comparative advantage into competitive advantage. The high-level enablers were alterations in legislation to facilitate change, multi-stakeholder forums incorporating all value/supply chain participants, international trade agreements and beneficiation strategy interventions.

2.5 Constraints

The beneficiation strategy articulated that although South Africa had been a prolific mineral producer for more than 100 years, the amount of downstream beneficiation that had occurred during that time had not been significant (DMR, 2011a). It went further to state that with such a mineral endowment, South Africa had not naturally created a significant downstream beneficiation industry. The perception in the report was that dedicated interventions were required to enable the process. Several constraints had been identified and possible mitigating actions had been documented. It was believed that these constraints were inhibiting factors and would impede the progress of implementation and the expansion of the beneficiation industry (DMR, 2011a). The following aspects were identified as major constraints:

- Limited access to raw materials;

- Infrastructure shortages;
- Limited research and development for the beneficiation industry;
- Skills capacity; and
- International market access.

The DMR deduced that the mineral industry's configuration was such that the mining industry was equipped to export raw materials and little consideration had been placed on infrastructure to further beneficiate mineral products. Further to this, mineral suppliers, traders and consumers had bulk supply, long term contracts in place. These obligations were because of mineral producers ensuring sales and consumers securing supply (DMR, 2011a). Other pricing mechanisms used by some raw ore and intermediate produces would also hamper beneficiation progress.

An example of the steel sector was put forward, in which, import parity pricing had rendered steel beneficiation as uncompetitive (DMR, 2011a). International pricing structures for raw and intermediate mineral products did not account for distance to market. South Africa is geographically located too far from international markets. This was thought to have further inhibited the beneficiation process by rendering beneficiated products uncompetitive. Another example was given whereby legislation was created for the diamonds and precious metals industry. This was created to provide local access to products but, per the report, the downstream value addition became uncompetitive due to unfavourable pricing mechanisms (DMR, 2011a).

It was noted by the DMR, that in the 1990's a beneficiation programme for the chemical and metals industry did not create sustainable employment and stimulate downstream fabrication. This was due to a combination of factors that was thought to have attributed to the failure. These factors were cited as, anti-competitive parity pricing, partly due to an absence of supportive infrastructure and the lack of an established commercial supply association (DMR, 2011a). Minerals for local consumption were considered as a vital input to accelerate South Africa's industrialisation programme. Competitive access to these minerals for local beneficiation was a key driver for the countries industrialisation initiative (DMR, 2011a).

The document suggests that the government had the following potential mechanisms at its disposal to mitigate the limited access to raw materials for local beneficiation.

- Leveraging the state's custodianship of the countries minerals to facilitate downstream beneficiation. As the South African government is the custodian of the minerals in the country,

pressure could be applied to mineral producers to avail minerals or mineral products for the local beneficiation process. This was outlined to some extent in the *Mineral and Petroleum Resource Development Act, 2002 (MPRDA): Section 26*, which gave the minister explicit powers to determine the incentives for encouraging beneficiation projects (DMR, 2011a);

- Leveraging the beneficiation “offset element” of the Mining Charter. This was a mining right holder’s option to offset a portion of their black ownership requirements, if the right holder subscribed to financially supporting the beneficiation process (DMR, 2011a);
- Strengthening and supplementing provisions which existed in other legislation. An example given was a diamond export levy, which was said to promote reliable and competitive access to raw materials (DMR, 2011a); and
- Addressing import parity pricing, included the possibility of export taxes on raw ores and intermediate mineral products. Conditions would be attached to the provision of benefits such as loans, debt relief and aid for infrastructure (DMR, 2011a).
- It was suggested that the business fraternity would take advantage of the value proposition proposed and that this would be a channel to expand local demand for mineral ores (DMR, 2011a).

Infrastructure was listed as a constraint and a threat to potential growth in the mineral value chain. Infrastructure such as rail, water, ports and electricity supply were listed as having the largest impact. The strategy determined that the following potential aspects needed attention:

- The location of mineral deposits and efficient connections to the manufacturing industry’s major production facilities was cited as a beneficiation inhibiting factor;
- There was a need to classify specific infrastructure requirements over the next 10 to 20 years;
- In addition, infrastructure planning mechanisms such as the Critical Infrastructure Programme were required to take cognisance of the beneficiation industry;
- The government had released the National Growth Path which was set to rapidly expand the country’s infrastructure through substantial developments in transport, energy, water and communication capability; and
- State infrastructure was to be used for beneficiation promotion.

- The actions required by business were to bring into line, product arrangements with national programmes, embrace effective energy use and electricity co-generation scenarios (DMR, 2011a).

The next limitation which the DMR noted was research and development. It was suggested that beneficiation research and development commitments be aligned to the National Plan for Science and Technology. South Africa's lack of technology in ground breaking research and the inability to create innovative new products was cited as a restricting factor to the progression of beneficiation (DMR, 2011a). Furthermore, it was suggested that business should encourage and advance competitive technologies.

National skills levels were also cited as a prospective constraint in that the country did not have the skilled personnel to feed the beneficiation industry (DMR, 2011a). This skill deficit was to be addressed by the following plans:

- By using the National Skills Development Strategy and the Sector Skills Plan, the approach suggested that, by alignment, the beneficiation programme skill requirement could be facilitated through these initiatives; and
- Further to the suggestion, the proposed method to mitigate the skills inadequacy was to promote skills progression. This was to happen through the Skills Education Training Authorities (SETA), institutes of higher education and training to develop the labour requirement.
- Business was expected to co-operate with government to support the Sector Skills Plans and the National Skills Development Strategy (DMR, 2011a).

Access to international markets was seen to be a constraint to the beneficiation process. The following actions were recommended to open the channels of trade (DMR, 2011a).

- Re-assessment of trade agreements with emphasis on beneficiated products, guidance with foreign direct investment opportunities and market access; and
- Taking advantage of the relationship with Chinese trade was advised as a channel through the Comprehensive Strategic Partnership with China, both with inbound investment and outbound product.

- Business was to take advantage of these conduits to broaden trade and grow the beneficiation industry (DMR, 2011a).

2.6 Downstream and Side-Stream Linkages

As indicated before, this research report investigates downstream opportunities for domestic value addition associated with the PGMs value chain. It focuses, in particular, on the trends in downstream application markets associated with major PGMs, specifically platinum, palladium and rhodium (IDC, 2013).

In the DMR's beneficiation strategy document, references are made to linkages, both downstream and side-stream. Essentially, these were opportunities that came about from associated relationships with a process. These value or supply chain events were only possible if the mining industry was stable and sustainable (DMR, 2011a). Side-stream linkages refer to other inputs that are required to make the process occur. Examples were attributes such as electricity, skills, consumables and services (DMR, 2011a).

The Beneficiation Strategy for the Mineral Industry of South Africa pointed out that downstream value addition required an array of activities inclusive of significant capital expenditure. Smelters and refineries were examples given (DMR, 2011a). The DMR (2011a) also suggested that further value addition investigations were required to fully understand and implement the maximum possible mineral exploitation. These investigations were required to identify the opportunities and challenges in downstream beneficiation (DMR, 2011a).

Linkages in the South African PGM value chain also occur in the form of:

- Backward or upstream linkages. Input suppliers, original equipment supplies and engineering services fell into the group (Montmasson-Clair, 2016);
- In the case of PGMs, fabricators and auto catalytic converter manufacturers were categorised as forward or downstream linkages (Montmasson-Clair, 2016); and
- Side-stream linkages refer to inputs such as electricity supply, roads and rail services, utilities and research and development needed to power the industry (Montmasson-Clair, 2016).

The special qualities of PGM's minerals are desirable for a variety of applications. These range from medical treatment devices to fuel cell technology, with greenhouse gas emission controls topping the list in the form of auto catalytic converters (IDC, 2013).

Figure 2.5 illustrates the downstream PGMs value chain. The process has been categorised from inputs to basic fabricated products, semi-manufactured products and manufactured products. Each step in the process is a downstream beneficiation action and adds value to the saleable product. These manufacturing process steps were what, the Beneficiation Strategy for the Mineral Industry of South Africa, was attempting to create. By delivering an enabling environment for mining and mineral products, higher value commodities could be produced (DMR, 2011a).

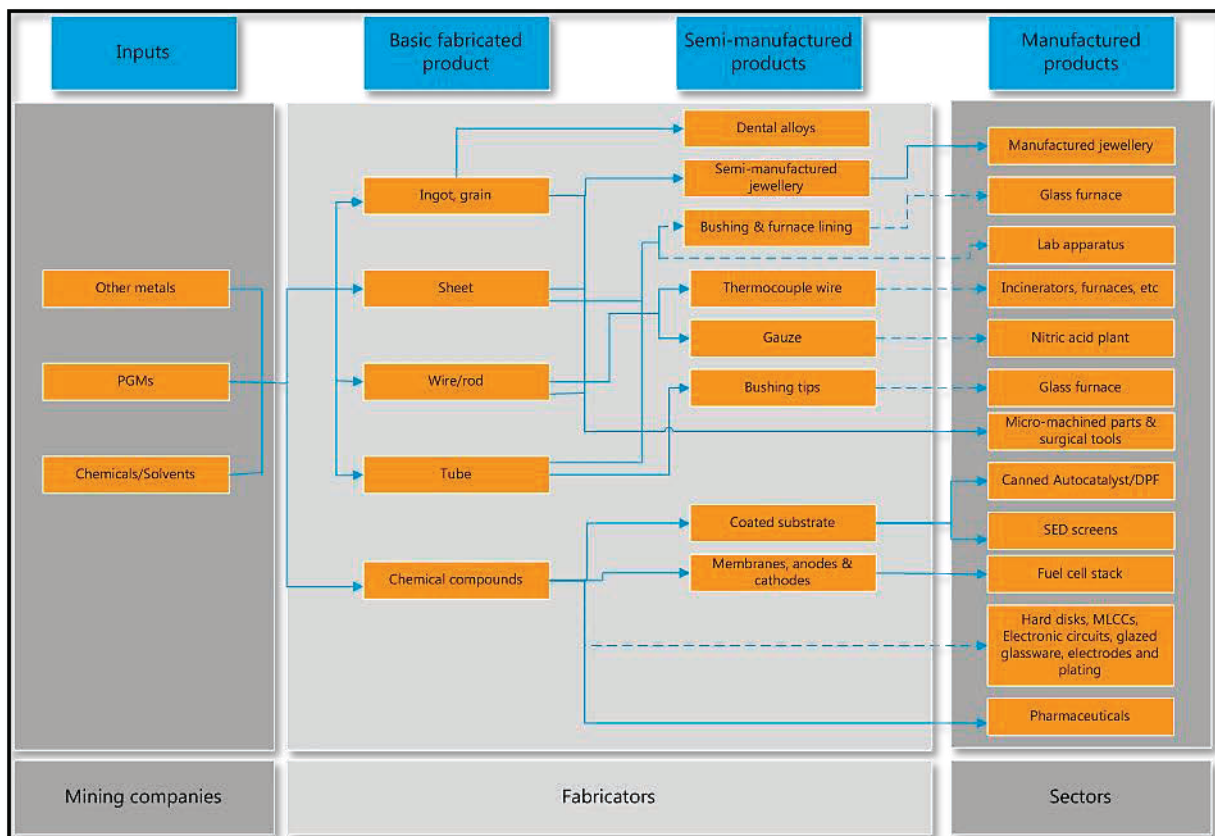


Figure 2.5: Downstream PGM Value Chain (Adapted from IDC, 2013).

Table 2.1, indicates some of the practical downstream applications of PGMs. Notably, Table 2.1 illustrates the diverse applications in which PGMs are used. The beneficiation strategy argues that the maximum value of mineral beneficiation is achieved when both downstream and side-stream linkages are optimised to the greatest potential (DMR, 2011a).

Table 2.1: Downstream Applications for PGMs (Adapted from IDC, 2013).

Application	Platinum	Palladium	Rhodium
Electrical	Electrical contacts and electrodes Hard disk drives	Consumer electronics Ceramic capacitors Spark plugs (aircraft) Electrical contacts	Thermocouples Electrical contacts Spark plugs (aircraft) Hard disk drives
Medical	Chemo-therapy Micro-machined implants		Menthol production
High Performance Alloys	Glass making Resistance thermometers	Surgical instruments	Optical instruments Glass fibre production Alloying agent
Catalysts	Auto catalysts Fuel cells Nitric acid production Silicon production Petroleum refining	Auto catalysts Petroleum cracking Hydrogenation Hydrogen gas purification	Silicon rubbers Auto catalysts Acetic acid production
Other	Jewellery Investment bars	Jewellery White gold production Carbon monoxide detection	Jewellery

2.7 The Beneficiation Strategy for the Mineral Industry of South Africa

The Beneficiation Strategy for the Mineral Industry of South Africa is best quoted by the DMR as “a framework that will enable an orderly development of the country’s mineral value chains, thus ensuring South Africa’s mineral wealth is developed to its full potential and to the benefit of the entire population” (DMR, 2011a, p. V). This was a common thread throughout the document that essentially said that there is much more that could be done to the minerals and mineral products produced in South Africa. It also mentioned that the mineral wealth had not translated into a direct benefit for all South Africans. The so-called “Resource Curse” covered in Chapter 3 better explains the fundamentals of non-renewable resources and the industrial diversification theory.

The beneficiation strategy implementation framework focused on ten strategic minerals or mineral groups, of which one of the groups are PGMs. Figure 2.6, illustrates the Beneficiation Strategy Implementation Framework which was supported by an enabling policy framework, supporting structures, bilateral and multi-lateral agreements and beneficiation strategic interventions. In turn, each of the support functions are sustained by policies, task teams, strategic partnerships and essential input factors.

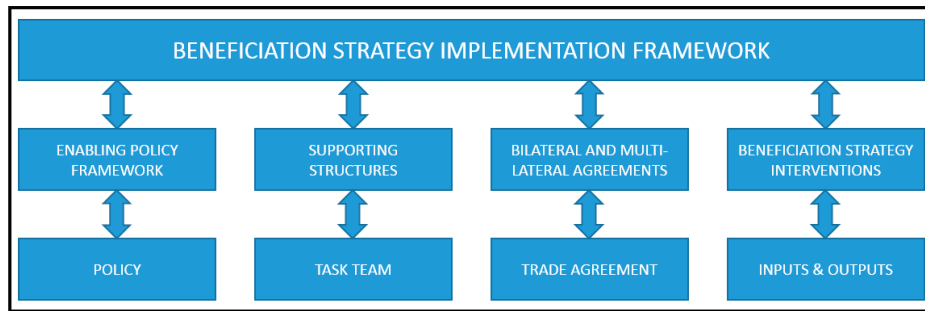


Figure 2.6: The Beneficiation Strategy Implementation Framework (Adapted from DMR, 2011a).

2.8 The Enabling Policy and Regulatory Framework

The DMR’s task team suggested that the principles of the beneficiation strategy were already embedded in policy provisions and the regulatory framework of government. It further intimated that these provisions should be further strengthened to support the enactment of the beneficiation strategy (DMR, 2011a). The provisions noted were:

- The *Minerals and Mining Policy for South Africa (1998)*: which had identified the need to create a policy for favourable conditions to progress the mineral wealth in South Africa (DMR, 2011a). It also identified that the government was to encourage investment in mineral beneficiation through competitive costs for public services and goods such as electricity and transport. Other measures included an incentive system that would insure competitive supply, through a reduction in royalties, to the supply source (DMR, 2011a). Decisions on mineral beneficiation would need to be based on sound economic principles (DMR, 1998). This point about sound economic principles was documented in the White Paper: Minerals and Mining Policy for SA. 1998, but was not a provision in the beneficiation strategy;
- Further provisions in the *Mineral and Petroleum Resource Development Act. 2002 (MRPDA)*: *Section 26*, gives the Minister of Mineral Resources prescriptive powers to determine the incentives for encouraging beneficiation projects. In addition, any person that desired to beneficiate South African minerals outside of the country would require written permission from the Minister of Mineral Resources. This would also include a consultation process with stakeholders, including the Minister of Trade and Industry. The Minister of Mineral Resources could determine the levels of terms and conditions in order to promote the beneficiation of a particular mineral. *Section 23 of the Act* – Granting and duration of mining right, the minister

has the option to refer to Section 26, and invoke those powers with the granting and duration of mining rights (MPRDA, 2002);

- *Broad-Based Black Socio-economic Empowerment Charter for the South African Mining and Minerals Industry, 2017: Section 2.1.4 (a)* which allows the right holder to offset 11% of Black Ownership if they financially subscribe to mineral beneficiation (DMR, 2011a);
- *Precious Metals Act, 2005: Section 6.1* which is in consideration of applications and principles of administrative justice. The regulator must be satisfied with fair access to local beneficiation when considering licences, permits and certificates (Precious Metals Act, 2005). *Section 12.2* of the same act says that, without written permission from the Minister of Mineral Resources, unwrought or semi-fabricated PGMs may not be exported without consideration for local beneficiation (Precious Metals Act, 2005). Further to these provisions, an additional upstream beneficiation provision is contained within the mining charter which provides for local content consideration (Precious Metals Act, 2005), this is explained further in Chapter 3;
- *The Manufacturing Investment Programme (MIP): Section 2.1 to 2.3* from the Department of Trade and Industry (DTI) was an investment intensified plan. The plan acted as an enabler to promote sustainable small enterprise and large-to-medium sized investment projects, with a grant of up to 30%. This was applicable, only when specific terms and conditions were met based on development impact criteria (DTI, 2017); and
- The provisions of the *Tax Act. No 58 of 1962*, also provided certain enabling incentives in the form of accelerated depreciation on investment assets; graduated tax rates for small enterprises and tax incentives applicable to research and development capital expenditure (DTI, 2011).

Through platforms such as the MIP system, in conjunction with the government's National Policy Framework, it was thought that the incentivisation would drive growth (DMR, 2011a). The MIP was formulated to inspire and stimulate investment in the manufacturing industry.

Another such industrial enabling investment scheme was the Industrial Development Corporation (IDC) which was a national development finance institution owned by the South African government. This was set up to promote growth in industrial development (IDC, 2017). This institution was aligned to the governments New Growth Path and the Industrial Policy Action Plan (IPAP2).

2.9 Integrated Approach

It was a recognised fact that constraints existed to implement beneficiation projects. The strategy outlined that, in order to progress, an integrated approach was required. This integrated approach would require the involvement of key mining stakeholders, business and labour as well as various government departments (DMR, 2011a). On a more granular level the document identified the following aspects:

- Access to raw materials at developmental prices, so prices would not retard the growth of beneficiation projects with the support and commitment from local mineral producers (DMR, 2011a);
- Infrastructure development such as railways and telecommunication networks. In addition, a plant which could be made available to clients other than the owners (DMR, 2011a);
- A Research and Development programme that could expedite the requirement of critical skills with well-established and reputable institutions. This was to meet the demand for advanced technology and skills development for industrialisation (DMR, 2011a). These initiatives would also be directed at finding new products and technologies that could reveal the inherent worth of South Africa's minerals (DMR, 2011a); and
- A strategy of alignment of national infrastructure programmes and the New Growth Path framework to mitigate constraints (DMR, 2011a).

Outside of the realm of the government arrangement criteria, mineral producers, business and the government would need to consult and align to create interventions that would form positive outcomes for all stakeholders (DMR, 2011a).

2.10 Global Perspective

The government acknowledged that global markets are required for the beneficiated products produced in South Africa. Since 1970, the quantity and quality of those products had steadily improved (DMR, 2011a). The growth of beneficiated products compared to the South African mineral resource endowment had by no means reached the full feasible potential (DMR, 2011b). The document's strategy was not designed to target a specific value chain of a particular mineral or mineral product. It was an enabling structure that would target specific areas or value chains and create suitable

interventions. These interventions would allow for successful beneficiation programmes (DMR, 2011b).

The strategic document also broadly defined the South African economy as one with low levels of mineral beneficiation and that minerals were mostly exported as ores or semi processed products (DMR, 2011a). This detracted from the potential value that could be achieved by rather exporting superior high value intermediate and finished goods (DMR, 2011a). Typically, the arrangement of import and export trade in South Africa was such that there was an unacceptable balance in the export of raw materials versus the import of finished goods (DMR, 2011a).

The perspective, at the time of the document creation, was that the global economy had entered a new growth phase principally driven by developing economies. The concept at the time was that, this growth would spur the need for finished goods and mineral commodities for infrastructure and development. It was suggested at the time, that South African beneficiated goods would mainly be consumed by these developing markets (DMR, 2011b).

In order to capitalise on the developing market economy proposition, the government would expand and develop the South African economic policy framework to ensure entry to international markets for South African beneficiated goods (DMR, 2011a). The government would then endorse the development of secondary and tertiary mineral based industries. This would be focused at creating the maximum value to mineral based raw materials, derived from the mineral industry of South Africa.

The industrialisation policy of the South African government suggested that there should be a paradigm shift in mineral development. This shift was to enhance the value of exports by strategic investment in assets that maximised the permanent sustainable growth of the beneficiation industry (DMR, 2011a). The Mineral and Petroleum Resource Development Act stated that there was significance in proposing supportive pricing mechanisms to sustain the beneficiation industry. Favourable trading conditions would be crafted in such a way as to benefit the industry. These would be in the form of export/import levies to protect and enhance the industry, local mineral access for local consumption as well as additional incentivisation (DMR, 2011a).

The DMR (2011a) recommended that in order to attract foreign direct investment and to funnel South African beneficiated goods, international trade agreements would be a viable option. Further to this thinking the concept proposed was to leverage optimal benefit from current multi-lateral and bi-lateral agreements and create opportunities from future such agreements.

The paper further listed a number of trade agreements such as:

- The Beijing Declaration on the establishment of a Comprehensive Strategic Partnership between the Republic of South Africa and the Peoples Republic of China;
- The African Growth and Opportunity Act (AGOA);
- Trade agreement between the European Union (EU) and South Africa;
- The Southern African Development Community (SADC);
- The General Systems of Preference;
- Trade Agreement between Zimbabwe and South Africa;
- Trade agreement between Southern Africa Customs Union (SACU) and European Free Trade Association (EFTA); and
- Rules of Origin guides/ Trade Agreement (DMR, 2011a).

2.11 Strategic Interventions

The perception that the process would be a smooth transaction is not portrayed by the DMR (2011a) and a number of constraints had been identified by the DMR's task team. At a high level, the strategy outlines a number of areas of risk and these are listed as:

- Security of raw material supply;
- Regulatory strength;
- Infrastructure development;
- Skills development;
- Research and development interventions; and
- International market access (DMR, 2011a).

2.12 Value Proposition

Considering the previous paragraphs of the chapter, a picture of intent has been painted but intent is unsubstantiated without value. Facts emerged that a considerable quantity of South African minerals were exported in the form of raw ores or only partially processed mineral products (DMR, 2011a). With the strong heritage of mining in South Africa and the understanding that mineral resources were limited, the strategy document intimated that the timing for beneficiation of locally produced minerals had never been better (DMR, 2011a).

On the various minerals and mineral products produced in South Africa, the DMR selected ten minerals and five value chains to demonstrate the inherent value that could be generated for South Africa through the beneficiation channel. These included Coal, Uranium and Thorium, Iron and Steel, Pigment and Titanium metal production and Platinum Group Metals (DMR, 2011a). This research report focuses on the PGM value chain.

According to the strategy document, these suggested value chains would require fiscal and regulatory support to cultivate the value proposition and to ensure that implementation was successful. Further, it made mention of relevant legislative policies that would need to be finalised to ensure the strategy implementation was successful (DMR, 2011a). Coordination was proposed as critical, particularly at the latter stages of the value chain, as this was the zone that harboured the largest employment and diversification gains. The strategic interventions were expected to create direct and indirect benefits for South Africa (DMR, 2011a).

Additional value was sort through export revenue and employment creation. The export of finished consumer goods was set to be the driver for significant adsorption of labour through the increase in industrial capacity (DMR, 2011a). Focused investment was also suggested to be key, to take advantage of the value addition programmes (DMR, 2011a).

Focused investment into critical parts of the value chain would fuel the development of the programmes. The value gained would be industrial diversification and employment creation, with all the spin offs associated with a diverse industrial economy.

2.13 Governmental Objectives for PGMs

In so much as the report has been dealing with the government's over-all thinking with respect to downstream mineral beneficiation. The following investigation seeks to narrow down and explore the

value chain associated with PGMs. The intention of this research report is to focus on value proposition for South African produced PGMs for local manufacturing projects.

South Africa had an already existing significant international auto catalyst manufacturing industry, with a then capacity of about 27.1 million units per annum. At the time of documentation, this equated to about 830 000 Oz per year at a then value of R 10 billion. Established in the 1990's, the auto catalyst sector supplied up to 19% of the global requirement. In addition, it had created about 5000 direct jobs and about 30 000 indirect jobs (IDC, 2013).

South Africa has the largest reserve of PGMs and was the largest global producer of PGMs (DMR, 2011a). From the establishment of the auto catalyst sector in the 1990's, a steady increase in the consumption of local PGMs was attributed to the advancements made in industrial technology. Auto catalysts and diesel particulate filters are exhaust components for the control of emissions of carbon dioxide (CO) and nitrogen oxide (NO). The increased demand globally for these products were driven by ever tightening governance of greenhouse gases and particulate matter (DMR, 2011a). Further and more explicit details on auto catalytic converters and diesel particulate filters are documented in Chapter 6.

The then suggested intervention for local platinum beneficiation in the auto catalytic and diesel particulate manufacturing industry was to:

- Ensure security of supply of PGMs to the local industry by soliciting certain provisions of the law to do so. It was also noted that, at the time, the mining industry had a willingness to support this beneficiation process by fully participating in the then Platinum Beneficiation Committee (PBC) (DMR, 2011a);
- Develop an agreed model of local metal access between government and mining houses (DMR, 2011a);
- Unlock value in the PGM sector through research programmes, industry sharing forums and international partnerships (DMR, 2011a);
- Promote careers in related fields as well as capitalising on existing skills (DMR, 2011a); and
- Promote sector investment and the continuation of the Automotive Product and Development Programme (APDP) (DMR, 2011a). (Explained further in Chapter 6).

The strategy considered the jewellery market as a potential outlet for local produced PGMs and although the DMR stated that the jewellery market was not a priority for PGM beneficiation, they intimated that the addition of specialised platinum jewellery to the jewellery hub concept would be an advantage. The document mentioned that as part of the overarching potential for the jewellery trade, that integrated jewellery hubs should be established. These hubs would incorporate locally produced diamonds and gold along with platinum to provide the ingredients for the jewellery trade (DMR, 2011a). Furthermore, it was highlighted that the United States of America (USA), Japan and Europe were considered as markets with potential for platinum based jewellery and the mechanism to promote trade to these regions was through trade agreement such as the Africa Growth and Opportunity Act (AGOA) which provided access to the USA (DMR, 2011a). The following strategic interventions were considered for local value addition:

- Government would investigate the reasons for insufficient access to locally produced gold, (used in conjunction with platinum for jewellery manufacture) (DMR, 2011a);
- A training programme that was industry specific to develop up-to-date trends, aligned with the South African Mining Qualifications Authority and the Skills Education Training Authority (DMR, 2011a); and
- Consideration for a metals advance scheme of local metal access (DMR, 2011a).

Although not stated as a priority, the jewellery business was considered as a participant in the beneficiation of PGMs. As part of the expansion of the PGM value chain, it was reliant on the evolution of jewellery manufacturing hubs. These also incorporated other locally produced gems and precious metals with a cross-pollination of product supply to produce specialised jewellery. Skills were expected to take into consideration current specific demand, and qualification of skills would come through various local institutions. The competitive edge was to be propagated through sufficient access to locally produced precious metals and gems, along with a high level of skilled jewellers and a metal advance initiative to encourage the industry.

2.14 Chapter Summary

The Beneficiation Strategy for the Mineral Industry of South Africa was somewhat baffling with high-level strategy, although the intent was understood, the mechanism for deployment lacked

indisputable argument and hinged on the then current policy and popular programmes. Objectively, it was stated that the document is not a blue print for beneficiation in South Africa but an enabler for certain interventions to the value chain (DMR, 2011a).

The purpose of the document “A Beneficiation Strategy for the Mineral Industry of South Africa” was to provide a globally competitive diverse beneficiation industry in South Africa. This strategy would stimulate economic development, create employment and optimise mineral resource rents. The enablers for the strategy would come from various policies and legislation that could be invoked to pressurise mineral and mineral product producers to comply with local supply needs. The export of finished goods and up-graded semi-finished products were the focus of the strategic document. This was to stimulate the latter sections of the value chain, where it was believed that, the greatest revenue return and employment creation was expected.

However, noble the strategy may seem, tactically, many other variables stand in the way of progress. Where would the money come from for the cost of infrastructure, research and development and training and, if the system failed, would that investment be detrimental to the economy of South Africa. Further to this is that the physical barrier of distance to market is not likely to change. Further research should be conducted to determine the cost.

Several interventions were required in respect of the enablement progression to allow the beneficiation process to function and develop. The driver for the need of specific interventions, was the fact that South Africa had, for several decades, been producing and exporting raw ores and mineral products with little to low beneficiation repetition. This was the governmental and legislative point of view. The ingrained global supply dynamic was assumed to be a historical nuance due to the way the mining industry of South Africa was configured in the past.

Interventions would be the driver seen to change this dynamic along with the infrastructure expansions that would be required to create the beneficiation industry, inclusive of transport and utilities. Access to locally produced minerals and mineral products was seen to be inhibitive due to the way in which global mineral trade had been established. In addition, access was constrained due to the structure of supply with respect to long term contracts. (International trading frameworks are covered in more detail in Chapter 4). Further, it was noted, that the PGM mining industry had been forthcoming with supply of locally produced platinum and were actively involved in promotional entities such as, the now defunct, Platinum Beneficiation Committee.

Support to the beneficiation industry was to be sort from local skills development institutions, to provide the man-power requirement needed to establish and expand the industry. Research and

development in the field of innovation and product potential was highlighted as a prospective constraint. The document sort to look to business and government institutions with an integrated approach to address the shortfall.

Accessing international markets to supply locally beneficiated goods was seen to be restrictive, but a mitigation strategy was to channel foreign direct investment towards the beneficiation industry and incentivising exports for the industry. Leveraging optimal benefits from current trade agreements and the creation of beneficiation opportunities from future agreements was also seen as an international market access enabler.

Specific to the PGM beneficiation value chain, the production of auto catalyts and diesel particulate filters dominated the production capability strategy. Building on the back of an already existing industry, the government sort to secure future supply of locally produced PGMs. This was for locally manufactured auto catalyst and diesel particulate filters for the automation component manufacturing industry of South Africa. To this end, it was proposed that a model be defined between government and the local mining industry. This model was to unlock the intrinsic value of beneficiated PGMs, the strategy looked towards an integrated approach of industry sharing forums and international partnerships along with support from appropriate research and development centres.

PGM jewellery manufacture was not as much of a priority as the auto catalyst and diesel particulate filter industry, however, several government drivers were set to nurture this jewellery industry. This mainly comprised of the creation of jewellery hubs that would rely on both locally produced gold and diamonds which, with PGMs, would form a product integrated jewellery industry. Jeweller training and a metal advance system were also to be employed. In the Statement on Cabinet, meeting of 8 June 2011, section 2.4, the Cabinet approved “A Beneficiation Strategy for the Mineral Industry of South Africa” as the countries policy (GCIS, 2011).

Chapter 3, takes the research into the broader aspect of the channels for non-renewable resources available to governments as possible sources for human development. It seeks to understand what other options are available to government to translate mineral wealth into socio-economic development. Chapter 3 explores the phenomenon of the so called “Resource Curse”. The introduction of the subject to this research report is to appreciate the problems associated with the curse and to understand what has occurred in other countries. Part of the premise of the introduction of the beneficiation strategy is centred around the associated problems created by this phenomenon.

3 THE RESOURCE CURSE AND ALTERNATIVE CHANNELS FOR HUMAN DEVELOPMENT

3.1 Introduction

The aim of Chapter 3 is to understand what had inspired the government to enter the course of downstream mineral beneficiation when a natural path could determine the growth of industry related to secondary inputs. Further to this understanding, other countries have mineral endowments and must have experienced similar issues. Part of the aim of this chapter is to explore the actions that other countries have taken when dealing with the socio-economic factors related to converting mineral wealth into social development. In addition, the review seeks to find the guidelines and direction from other nations when dealing with the conversion of mineral resources into human development. The fear of not getting the full potential out of non-renewable natural resources for current and future social development is a coherent feature that is prevalent in Chapter 2 and continues to be the focus in Chapter 3.

The chapter also explores arguments for alternative channels to beneficiation that may lead to social development. The relevance of this chapter pertains to best practice and offers alternatives to local beneficiation. The premise is that the beneficiation strategy in a buoyant mineral cycle, may be effective. However, in a down-trending cycle survival of the business is at the forefront of the mining company's agenda and parts of the strategy may appear as rent seeking. The status of the PGMs extractors in South Africa, covered in Chapter 5, fits the down-trending cycle argument (Creamer, 2017). Government's stance on prescriptive policy was subject to opinions that a natural path would better determine the growth of industry, related to secondary inputs. It was also thought that prescriptive or uncertain policies would erode current and future investment (PwC, 2012). Global perception of the South African extractive industry fuels foreign direct investment to that sector (Gelb, 2010). The magnitude of the PGM resource may, if extraction is secure and sustainable, have a greater impact on the economy over time, than the effect of incentivised downstream value addition. Alternatively, South Africa has some existing human development channels in place and downstream beneficiation may advocate further value.

Nations with natural resource endowments are cautiously protective when it comes to the exploitation of those assets, especially with non-renewable resources (DMR, 2011a). South Africa is a mineral endowed country and the management of its resources is important to the future well-being of its citizens (DMR, 2011a). Understanding the complexity of managing mineral resources requires attention due to the diverse nature of how best to develop the country.

3.2 Non-Renewable Resources

Natural resources could be categorised into two very basic groups, renewable and non-renewable natural resources. Those that are renewable are sustainable and have the ability, under conditions, to be exploited to perpetuity. Non-renewable resources have finite boundaries and once depleted, the resource has no further income generating capacity. Ultimately, the monies generated from non-renewable mineral endowments cannot be replenished, as depletion of the resource is inevitable. Thus, the gross value of the natural non-renewable resource to a nation constantly diminishes as the resource is consumed. This is opposed to regenerative economic resources such as agriculture, industry and tourism. Nations should be mindful of the revenues accrued from non-renewable resources and how wisely these monies are spent.

The perception exists, with reasonable judgment, that the exploitation of these non-renewable resources in mineral endowed countries should benefit the source nation (DMR, 2011a). However, in some cases, the aggregated wealth derived from such exploitation can have little or a negative effect on an economy (Elbra , 2013). This phenomenon is referred to as the “Resource Curse”. Blurred lines often cloud the hotly debated subject of the curse, however, certain trends appear through works of researchers that revert to the root cause of the problems associated with the resource curse occurrence. This chapter seeks to unpack the history and significance of the resource curse.

Of the many countries with mineral or natural resource endowments, a diverse few have been selected. The good and bad processes of those countries have been outlined in this chapter. The polarity of the selected nations is intentional, as the phenomenon exists on a global basis. This chapter seeks to explore the various aspects of the resource curse occurrence. An objective approach is taken and several differing arguments are considered.

3.3 Resource Curse

South Africa is a mineral based economy and arguments exist that mineral based economies can impede other forms of industry (Smit, 2017). The “Resource Curse” is acclaimed to be the negative economic impact affecting a nation’s economy in a natural resource endowed country. This is compared to their non-natural resource endowed peers (Elbra , 2013). Empirically, research indicated that resource endowed countries are often economically worse off than their non-endowed country equivalents. This is often measured by the Gross Domestic Product (GPD) per capita. This is referred to by the DMR in Chapter 2, Figure 2.2 as a driver for downstream beneficiation. The GPD per capita

is an indicator of the degree of poverty within a country and could be a general indicator of the health of an economy (Gilberthorpe & Papyrakis, 2015).

The paradigm is oddly perpetuated by the windfall gained in the exploitation of the resources and going against conventional thinking, that the windfall would increase the GDP per capita. The expected windfall transformation into the economic environment does not transpire and the consequence of the curse causes the economy to suffer (Mckay, 2012).

The prevalence of the concept is through one, or several, factors that halt or hinder economic development. This occurs by the misplacement of complimentary revenues generated from the natural resource. Thus, those revenues, rents or taxes generated by the sale of natural resources are then misappropriated or poorly allocated and this affects national development. In certain cases, the magnitude of the exploitation of natural resource revenue generation may create significant funds that, when wisely spent, may change the course of a nation (Ross, 2012).

The “Resource Curse” was coined in the 1970’s, later referred to as the “Dutch Disease” (Mckay, 2012). The Netherlands, as a developed country, experienced an unexpected outcome from the discovery and exploitation of massive gas reserves. The concept of real and tangible, substantial national income to the economy was realised and a strange and unforeseen phenomenon occurred (Elbra , 2013). The development of the lucrative natural gas project, over time, negatively affected the national economy.

The human resource requirement to man the gas industry created a demand which was not able to compensate the loss of skills from industry and agriculture. Thus, both industry and agriculture suffered. In addition, the influx of revenue generated from the burgeoning gas industry inflated the national currency, further adding woes to the local economy. The inflation of the Guilder, the local currency at the time, made the imports more affordable and exports less desirable (Bacture, 2013).

This shift had other lesser effects which also contributed to negative economic growth. Overall the exploitation of a natural resource, in a developed country, had an adverse influence on the expected economic benefit. Sachs & Warner (2001) were amongst the first to endorse the concept and this created a flood of academic interest and speculation surrounding the topic. Although years later, the long-term effects of the resource curse in the Netherlands never lead to abject poverty or total dissipation of national wealth. Forbes (2016), suggests that the Netherlands today is both prosperous in the gas industry, manufacturing, agriculture and is a sturdy member of the European Economic Community, which asks the questions as to the substance of the “Resource Curse” phenomenon (Forbes, 2016).

3.3.1 Non-renewable Resource Translation in Other Countries

Figure 3.1, shows an example of the real GDP growth per-capita (1970 - 1989) versus the exports of natural resources, in percent of GDP, 1970. Figure 3.1 shows that from 1970 for the next 20 years, that countries which had copious natural resource did not grow rapidly.

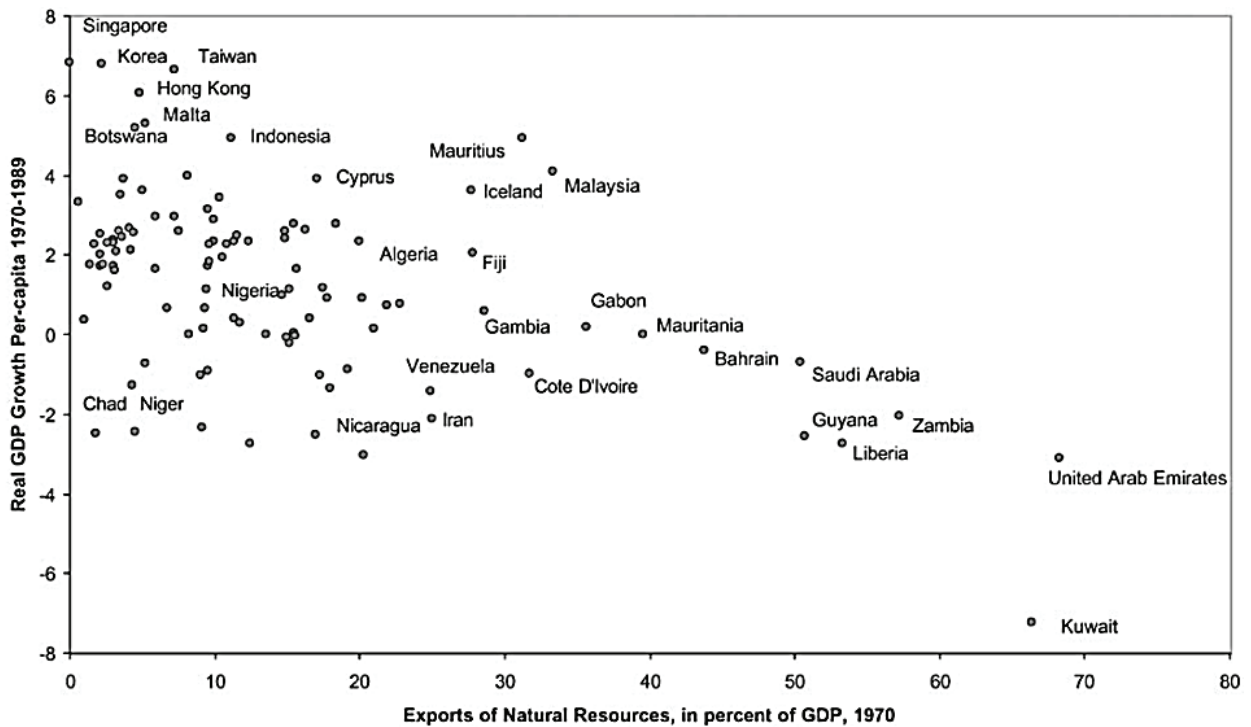


Figure 3.1: Growth and Natural Resource Abundance 1970 -1989 (Sachs & Warner, 2001).

The following series of short subsections highlights the effect on nations of the “resource curse or blessing”. This portrays the outcome of some countries’ exploited non-renewable natural resource revenues.

United States of America

A well-established diverse economy with strong high-quality institutions, where originally the Californian gold rush of 1848 created a movement of the pioneers and settlers that expanded the countries footprint (History Channel, 2017). In the latter years, a social development trust fund was established as a benefit sharing instrument that was fuelled by the mineral industry. The main beneficiaries were in areas that were sparsely populated and highly dependent on natural resources (Fisher, 2007). An example is the Alaska Permanent Fund where the government, primarily, used the resource revenue to support public expenditure and the effects of the resource curse was not prevalent (Mehlum, et al.; 2005 Soderholm & Svahn, 2015).

Canada

Canada had a very similar approach to the United States of America, although the country had a more substantial mineral endowment. Canada had a diverse economy, strong high quality institutions and made use of benefit-sharing trust funds for community development agreements. An example of this was the Alberta Heritage Fund (Fisher, 2007). The government, primarily, used the resource revenue to support public expenditure and, again, the resource curse was not prevalent (Mehlum, et al., 2005; Soderholm & Svahn, 2015).

Australia

Again, like the United States of America and Canada, Australia had a substantial mineral endowment, a diverse economy with strong high quality institutions and made use of benefit-sharing. In Australia's past, mining was conducted on traditional Aboriginal lands with no reward, whereas now, the land rights are returned and benefits from mineral extraction compensate the Aborigines. This was in the form of the Aboriginal Benefits Reserve and the fund serves as a clearing house for stakeholders rather than a saving fund (Fisher, 2007). The government, primarily, used the resource revenue to support public expenditure and the resource curse is not prevalent (Soderholm & Svahn, 2015; Mehlum, et al., 2005).

Papua New Guinea

Eighty percent of the population relied on subsistence farming and despite significant mineral and oil related revenue generation, little difference had been made to the average Papua New Guinean. Revenues had funded non-productive sectors such as federal, provincial and local government institutions. Domestic enterprises had yielded low returns and revenues had been squandered. Institutions are weak and Papua New Guinea is still considered to be a developing country despite decades of mineral revenue income. Papua New Guinea also attempted to make use of benefit-sharing which caused conflict as land rights were in dispute. However, other small scale benefit-sharing initiatives had been partially successful (Fisher, 2007; Gilberthorpe & Papyrakis, 2015; Mckay, 2012).

Norway

Norway had a well-established diverse economy with strong high-quality institutions, where oil resources successfully funded the Norwegian Petroleum Fund. The establishment and use of funds directly benefited the welfare of the citizens and was considered a "best practice model" (Corrigan, 2014; Fisher, 2007; Gylfason, 2001; Mckay, 2012).

Colombia

Colombia had a National Royalties Fund which was highly complicated and allowed for rents to be channelled to affected communities and to municipalities. The government took a lesser share of the wealth. The concept, although complicated, was almost a benefit share system, however, in times of crisis the Colombian government had accessed the fund. The fund faced challenges from corruption and political violence. Colombia was a developing country with weak institutions but overall the fund had a positive effect on the economy (Fisher, 2007; Gilberthorpe & Papyrakis, 2015).

Chile

In Chile, mining companies paid an annual fee for mining rights and revenues. These proceeds were distributed between municipalities and the National Fund for Regional Development. Some benefit sharing systems existed and overall the World Economic Forum considered the programme to be successful. Chile has avoided the resource curse and scores high on the institutional and political indicators (Mehlum, et al., 2005; Soderholm & Svahn, 2015).

Malaysia and Thailand

Both avoided the resource curse by accepting that revenues from resources would take the pressure off the national balance of trade, but continued to be as efficient as possible and pursued competitive industrialisation strategies (Mckay, 2012; Mehlum, et al., 2005).

Botswana

Botswana is a best practice case for developing countries and was thought to have managed the resource curse through prudent fiscal policies. The revenues generated were filtered through a multi-year national development plan, and through strong institutions it channelled the revenue to appropriate receivers. Botswana had, in the past, embraced the World Bank for consultation and mentoring (Corrigan, 2014; Fisher, 2007; Gylfason, 2001; Mckay, 2012; Holder, 2004; Mehlum, et al., 2005).

Chad

Chad is one of the poorest countries in the world. The Chad-Cameroon oil pipeline, monitored and funded by the World Bank, was a 28-year programme intended to economically develop Chad (Fisher, 2007). Failed agreements, weak institutions, outright corruption and racketeering by Chad's president

and the politically elite ended the upliftment programme. This programme, for the poor, was set out by the World Bank and placed oil revenues in the hands of the corrupt government (Pegg, 2009).

Nigeria

Nigeria is a developing country with weak institutions and poor political decision making. It squandered its wealth from non-renewable natural resources. Examples of this are:

- Of significance, the oil in the Niger Delta;
- The Ajakouto steel complex, which had not commercially produced steel; and
- The revenue plundering of successive military dictatorships.

The oil revenues enabled the Nigerian government to increase government spending and provided the opportunity for kickbacks (Mckay, 2012; Mehlum, et al., 2005; Sala-i-Martin & Subramanian, 2003).

Democratic Republic of Congo (DRC)

The Democratic Republic of Congo is a developing nation with weak institutions and is well endowed with non-renewable natural resources. The country is considered to have multiple issues including inefficient economic policies. Acemogulu et al., (2004), exposes a host of issues related to the DRC and the multiplicity of how not to avoid the resource curse (Acemogulu, et al., 2004; Mehlum, et al., 2005).

The cases studies listed in Section 3.3.1 are by no means the full global list of mineral, oil or non-renewable resource rich countries but moreover, illustrate a variety of countries that have either succumbed or defied the resource curse. From the literature, it could be argued that developed countries do not suffer the effects of the resource curse, but the Netherlands and their oil windfall proved such a finding unjustified. It could also be argued that developing nations, in general, are subject to the curse. Botswana, however, is an exception which has avoided the issue.

Mckay (2012, p.5) states that “Out of 65 resource dependant developing countries, only four were able to generate long-term investments of more than 25 per cent GDP”. One strong trend is that diversified industrialised countries such as Canada, Norway, United States of America, Australia, Thailand and Malaysia seem to have avoided the resource curse, although it could be argued that the Netherlands in the 1970’s was considered industrialised.

Another strong, notable trend is that strong institutions have a great influence in preventing the effects of the resource curse. In general, strong institutions orchestrate good practices and those with weak institutions show an affinity to the resource curse. Colombia is an exception, classified as having weak institutions yet the net effect of resource income was positive. There is not a set of specific rules that will prevent natural resource endowed countries from experiencing the effects of the resource curse (Sachs & Warner, 2001).

3.3.2 Resource Curse Root Cause Factors

The following section examines the perpetrators of the resource curse and the effect on nation's economies. From the review in Section 3.3.1, certain trends were established with no exact set of rules to mitigate the resource curse. The effect was more likely to occur under certain circumstances. To understand the issue, the very principle of non-renewable resources for economic benefit must be understood. The fact is that a resource, from a national prospective should be extracted as efficiently as possible to maximise returns. These economic benefits are attained in rents, taxes, share benefits, royalties and any other forms of resource driven revenue generation. This must be optimally used, as once depletion has occurred the resource potential will diminish (Mckay, 2012). The blurred lines occur when theory is put into practice.

There does not seem to be much appetite for arguments that corruption and conflict have direct negative consequences (Corrigan, 2014; Cuvelier, et al., 2014; Elbra , 2013; Le Billon & Levin, 2009; Robbins , 2008). Corruption can occur at government, institution or company level (Soderholm & Svahn, 2015). The following are examples of corrupt processes:

- Corruption was a two-way process, the corrupter (the company or entity) was just as guilty as the government, institution or representative purporting the corrupt activities (Shaxson, 2007);
- Essentially, related to the subject, was the misappropriation of national assets in some manner or form, for personal gain (Kolstad & Soreide, 2009);
- Rent seeking nations and political patronage are often associated with the curse (Elbra , 2013; Kolstad & Soreide, 2009; Mckay, 2012; Mehlum, et al., 2005; Soderholm & Svahn, 2015); and
- Kolstad & Soreide (2009) suggested transparency and accountability, that is, publish what you pay as a form of mitigating the effects of corruption from governments, companies and

institutions. Audited results by neutral parties may also be a means of mitigation (Corrigan, 2014; Mckay, 2012).

In addition to corruption, commodity price volatility and employment instability was a root cause. Market conditions and employment fluctuations occur from industry to the resource sector and vice versa as resource potential diminishes. Price volatility also affects resource revenue generation for governments as stable, long term incomes cannot be guaranteed (Fisher, 2007; Gamu, et al., 2015; Mckay, 2012; Shao & Yang, 2014; van der Ploeg, 2009). Another root cause was lack of political will to diversify, by converting non-renewable resource opportunities into sustainable agricultural, tourism or industrial activities. This was outweighed by the aspirations of political decision makers (Auty, 2001; Gamu, et al., 2015; Mckay, 2012; Sachs & Warner, 2001).

Also common is the mismanagement of public funds and the ineffective allocation of public resources into domestic enterprises yielding low returns (Fisher, 2007; Kolstad & Soreide, 2009; Mckay, 2012; Soderholm & Svahn, 2015). The quality of institutions was one of the most prolific root causes of the resource curse. This occurred in a myriad of poor decision making applications from carelessness and reckless judgements through the spectrum to outright corrupt activities (Bhattacharyya & Holder, 2010; Corrigan, 2014; Fisher, 2007; Mckay, 2012; Mehlum, et al., 2005; Soderholm & Svahn, 2015).

Other institutional failures overlap with corrupt activities and include:

- Lack of accountability for public funds (Corrigan, 2014; Kolstad & Soreide, 2009); and
- Dysfunctional behaviour to benefit political ambitions or corrupt activities (Kolstad & Soreide, 2009);
 - Strange or unclear allocation of licences and concession procedures (Gamu, et al., 2015; Kolstad & Soreide, 2009); and
 - Lack of checks and balances to moderate dysfunctional behaviour (Corrigan, 2014; Soderholm & Svahn, 2015).

The final major root cause was policy uncertainty and unclear economic outcomes from mineral rents (Auty, 2001; Corrigan, 2014; Mckay, 2012).

3.4 Natural Resource Options

3.4.1 South African Context

The mineral endowment in South Africa is subject to some speculation and several estimates exist. DMR states the estimate per Citi Bank research at USD 2.5 trillion (DMR, 2011a). Ecopartners have a higher estimate at USD 4.7 trillion (Baartjes & Gouden, 2011). These figures, although widely different, have some form of technical foundation. Political statements, based on such publications can fuel unsubstantiated expectation of resource delivery (SACSIS, 2014). Notable, are that these claims vary widely. Questions arise as to the interpretation of the source information and the way in which it has been used. Claims of such magnitude need to be in context, Chapter 4 covers this aspect in more detail, with respect to resources and minable reserves.

Although figures are estimates of the endowment, the ability to mine these resources could be brought into question. As an aggregated qualification of the wealth in the ground within South Africa, it illustrates the potential of the mineral endowment within the country. With such figures being bounded about the political landscape, it is questionable as to why South Africa should have issues with poverty?

Sachs & Warner (2001) argued that mineral rich countries experienced slower economic growth than their non-mineral rich peers. In agreement with Sachs and Warner, Auty (2001) found that the GDP per capita growth in mineral rich countries is 2-3 times slower than that of the non-mineral rich peers.

In the South African context Elbra (2013), determined that South Africa was not immune to the resource curse. Elbra (2013), used the 2013 World Bank Figures for upper middle income, 1994 – 2011 to determine the results. Elbra (2013) found that the regional growth of Africa's Sub-Saharan GDP per capita averaged 2.17%, and the world average equated to 3.15%, whilst the average for South Africa was determined to be 1.56%. South Africa's middle income GDP per capita was half that of the world average (Elbra , 2013).

Elbra (2013) advocated that resource extraction failed to recognise the needs of a large portion of the South African society. In addition, Elbra (2013) declares that society has not benefitted from the resource extraction and that most of the wealth generated lay outside of the formal sector. Elbra (2013) went further to say that South Africa should not be mistaken in thinking that they have averted the resource curse, when compared to the lesser mineral rich neighbouring states such as Zambia, DRC and Angola. He concludes that South Africa's mineral wealth has failed to alleviate poverty, or

change the lives of most of the citizens and furthermore that South Africa is facing many of the challenges facing other resource cursed states.

3.4.2 Mineral Beneficiation Advantages and Disadvantages

Within South Africa and many other African countries, poverty alleviation is a common thread. Sub Saharan Africa is one of the poorest but rapidly rising regions in the world (Bicaba, et al., 2015). Poverty exists all over the world and is not only limited to third world countries, some first world countries have not totally addressed the subject of poverty within their domain (Poverty USA, 2016). This aspect is difficult and rather complex to address. Some governments and particularly South Africa have looked towards the mineral wealth of the country to address the transformation from poverty. In South Africa, one of the initiative strategies is the beneficiation of local mined products into goods of higher value and final products. The drive is to capitalise on the wealth from the non-renewable resources and maximise job creation (DMR, 2011a).

Some seek to promote local beneficiation as the route to industrial diversification and the alleviation of poverty through, employment creation and the advantages associated with downstream mineral beneficiation. Other arguments exist, such as the report from the Centre for International Development (CID) at Harvard University, Examining Beneficiation. Hausmann, et al., (2008) suggest that mineral beneficiation may indeed not be the way forward for South Africa and this is evident from their trade-off study to which they refer that:

- Beneficiation strategies are common amongst developing countries that export natural resources. They seek diversity through well-targeted “inducement mechanisms to create employment, create structural transformations within their economies and protect their commodities from volatile markets” (Hausmann, et al., 2008, p. 17);
- Policies advocated proximity to production facilities, and therefore low transport costs of raw materials represent easy pickings given their local presence (Hausmann, et al., 2008);
- Production capabilities broad factor intensity, (the relative importance of beneficiation versus other factors in an industry) have statistically significant relationship with distance, but not an economically significant relationship (Hausmann, et al., 2008); and

- When transport costs are low, production can, more easily, be spread to countries with the lowest factor costs, alternatively with high transport costs, co-location is a greater benefit (Hausmann, et al., 2008).

Hausmann, et al., (2008), went further to advocate that export driven structural transformation occurs, not through production chains, but more with sectors of technological similarity, common factor intensity and other requisite capabilities. Hausmann, et al., (2008) argues that beneficiation is not a good policy. It is evident that professional organisations do not share the same attitude as the DMR and that the argument, may indeed, be totally flawed and this is per the (CID) at Harvard University, who consider, through their research, the fact that downstream beneficiation is not the way forward for South Africa (Hausmann, et al., 2008).

The African Mining Vision states that down-stream beneficiation may also not be most beneficial for Africa and that up-stream and side stream linkages may be better for Africa regionally. “Promoting mineral beneficiation before export. Downstream processing of minerals before export need not be placed at the top of the national agenda for the mineral industry. Beneficiation contributes to growth and diversification only when it generates above average upstream and side-stream linkages, and should not be pursued merely for its own sake” (African Mining Vision, 2017, p. 3).

3.5 Alternative Extractive Industry Channels for Human Development

The Bill and Melinda Gates Foundation (2015) highlights four channels in which mineral wealth can and may influence human development. Figure 3.2, depicts the channels for human development, showing extractive industry activities and how those activities relate through to human development. This is conducted on a national scale through the social sectors and diversification and on a localised scale through employment, procurement and infrastructure as well as local social investment.

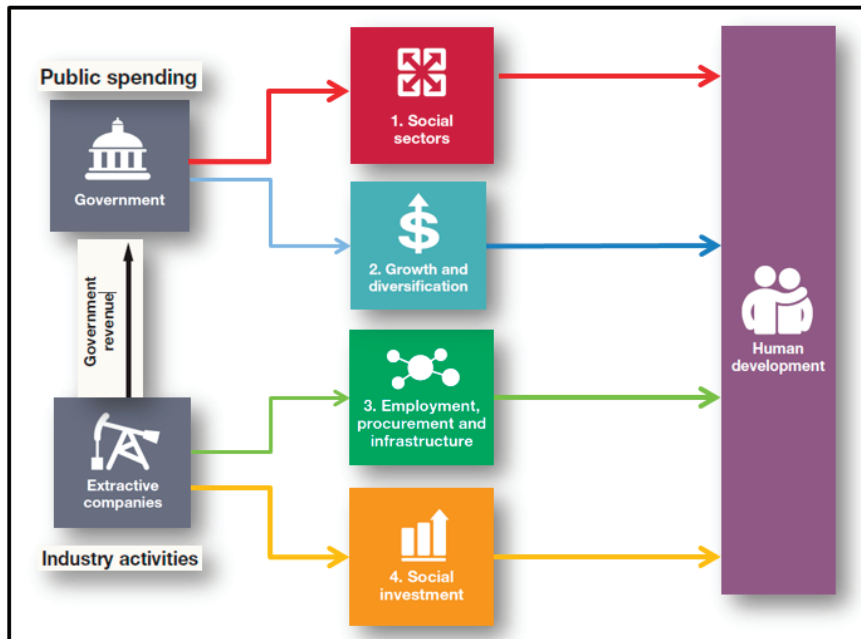


Figure 3.2: Bill and Melinda Gates Foundation’s Four Channels to Human Development (Bill and Melinda Gates Foundation, 2015)

3.6 Quantifying the Mining Spend

The African Mining Vision in the previous paragraph referred to the benefits of upstream and side stream linkages as opposed to promoting beneficiation before export. The following paragraphs seek to unravel these other opportunities. The average distribution of spending in the mining extractive industry provided by the (Bill and Melinda Gates Foundation, 2015).

Figure 3.3, illustrates the average distribution of spending in the extractive industry Bill and Melinda Gates Foundation (2015). The graph indicates the four general sectors of spending for the extractive industry, notably with employment, infrastructure and procurement being the largest at 50-65 % of the total revenue being paid out of mining companies.

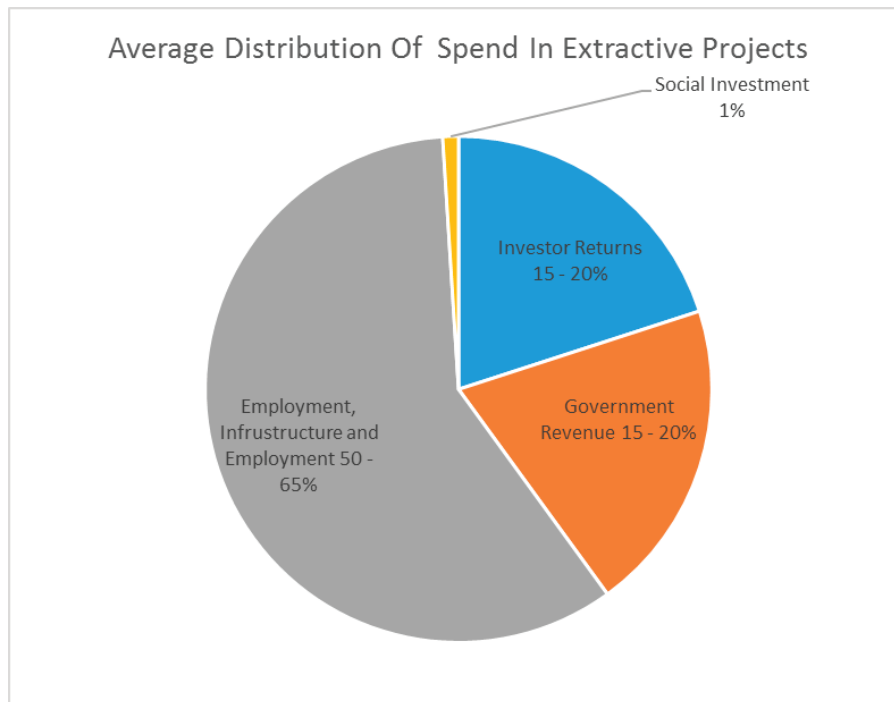


Figure 3.3: Average Distribution of Spending in the Extractive Industry (Adapted from Bill and Melinda Gates Foundation, 2015)

3.6.1 Upstream Linkages in the Mining Industry

As an alternative to down-stream beneficiation, mentioned in Chapter 2, upstream linkage options exist. An alternative upstream beneficiation proposition exists in the form of local goods, services provided to the mining industry and infrastructure provided by mining operations. In the context of South Africa, the aspect of employment, mineral industry consequential infrastructure and procurement, are prospects surrounding mining activities. These prospects open opportunities for delivery of supplies and services from a local perspective. Growth through innovation and skills are linked to human development. These are considered, by the Bill and Melinda Gates Foundation (2015) to be channels for translating non-renewable mineral wealth into sustainable human development, if the channels are soundly managed.

Figure 3.4, illustrates the value chain for sustainable human development by indicating input linkages that show enhanced local contribution as a provision for development. The Mining Charter of South Africa requirements and regulations stipulate conditions for local extractive industry that mandates requirement specifications for local content (MPRDA, 2002).

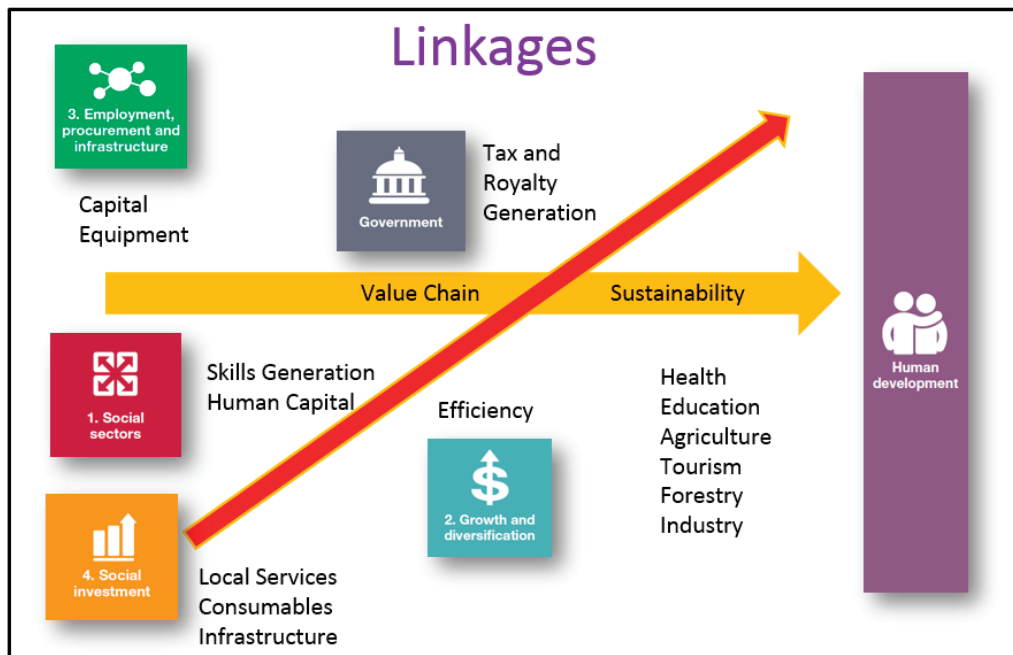


Figure 3.4: Value Chain for Sustainable Human Development (Adapted from Bill and Melinda Gates Foundation, 2015)

These provisions are in place to provide opportunities, related to upstream linkages. Whether these conditions provide a forum for “best in class” excellence in efficiency, will play out in the attritive nature in the global mining environment. The mining industry would welcome a lower input cost pressure (PwC, 2014). The logical argument then exists in that if the cost of local manufactured product is higher than a net imported product, does the mineral industry have to bear the additional cost?

3.6.2 Local Services or Local Content for Job Creation

The Bill and Melinda Gates Foundation (2015) suggested four channels that the extractive industry can contribute to human development as shown in Figure 3.2. Firstly, by rents and taxes that can be used in the social sectors for education and health. This revenue could also be utilised for growth and diversification for job creation activities or for the establishment of sovereign wealth funds. Secondly, on a local level, as a direct input in terms of employment, procurement and infrastructure. Thirdly, for human capital development and skills generation and finally, as social investment with respect to the mining operations internal social plan (Bill and Melinda Gates Foundation, 2015). Social sustainability can only be effective from the position of the extractive industry as long as the industry is viable (International Labour Organisation, 2002). There is no use in implementing policies and strategic

objectives if the core issue of viability of the industry is not correctly addressed. Viability is inherently linked to market competitiveness and a competent and content workforce.

3.6.3 Capital Goods Local Services, Consumables and Infrastructure

The Bill and Melinda Gates Foundation (2015) suggests that the aggregated direct spend from mining companies is inclined to exceed direct government revenue attained from mining activities. In a bid to diversify the employment of capital input, the requirements of the Mining Charter for local content provision attempted to enable accelerated development of locally manufactured capital and consumable goods and services (DMR, 2011a). Infrastructure such as roads, rail service, water and electricity supply required by mining activities add to the countries' structure.

3.6.4 Skills Generation and Human Capital Development

Modern mining requires skill sets such as diesel mechanics, auto electricians, instrument technicians, engineers, communication and information technologists. Common ground exists between the manufacturing and mining industries, as these skills could migrate between the two. Upskilling people through the extractive industry in South Africa could provide skilled labour to the general industry (Griffith, 2015).

3.6.5 Tax and Royalty Generation

The Bill and Melinda Gates Foundation, (2015) suggested that royalties, rents, taxes and other extractive industry generated government revenue be placed into the government treasury for public spend for the social sector as well as for growth and diversification. An alternative suggested, was that where issues of governance prevailed, these revenues should be placed in designated social funds (Bill and Melinda Gates Foundation, 2015).

3.6.6 Growth and Diversification

Through the channels of revenue generated from non-renewable resources, the Bill and Melinda Gates Foundation (2015) suggests that, the rents, taxes and royalties should be spent on health and education. The premise of this argument is such that the short-term benefits for human development are evident, and in the longer term it was expected that this would contribute towards broad based economic development (Bill and Melinda Gates Foundation, 2015).

3.7 Chapter Summary

More equitable societies could be created with well-planned policy commitments and investments. These commitments are expected to translate natural resource revenues to social development for current and future generations. The discussion of this chapter has focused on the problems associated with resource rich mineral states and the negativity associated with the endowment. The objective was to determine the inspiration for the government of South Africa to pursue the beneficiation path. It is evident that there are issues and consequences associated with non-renewable mineral resources and that opportunities exist with sound management of natural resource revenues. Furthermore, getting these choices wrong will see the opportunity evaporate and the source of the revenue is not replaceable. An example given was the lack of political will to diversify, by not converting non-renewable resource opportunities into sustainable economics such as agricultural, tourism or industrial activities.

It was clear from the chapter that there are no hard and fast rules related to the exploitation of natural resources and that the resource curse phenomenon is not only associated to developing countries. It was evident that in most cases; real, stable, diverse, mature economies have systems, policies and accountability in place that prevent the actions of the resource curse. One could argue that there are certain tangible aspects associated with the resource curse that may be beyond the control of nations such as price and labour volatility.

There was a strong trend, with exceptions, that natural resource endowed developing countries with immature national or institutional management, unclear or goal-post-changing policies and corrupt practices are likely to be the recipient of the resource curse. In general, it is economic mismanagement and not a specific phenomenon that causes the "Resource Curse". It is quantifiable that South Africa has a substantial mineral resource and this natural resource should be extracted for the maximum benefit of the people of the state. Whilst the government's stance is clear on the direction chosen for

beneficiation, others dispute the course of action. The location of raw materials with low transport costs could easily be transported to zones that have low factor costs or ultimately have more fortuitous production prospects. Where transport costs were high, co-location or local beneficiation was more advantageous.

Chapter 4, explores the scarcity of minerals and the rarity of economically minable PGM deposits. It seeks to understand international trade of minerals and the basics of supply and demand.

4 SCARCITY OF MINERALS AND METAL TRADING FRAMEWORK

4.1 Introduction

The aim of this chapter is linked to Chapter 2 regarding the mineral wealth statement, where it was estimated that South Africa had, for non-energy related minerals, more than a 100 years of economically exploitable mine life. This translated to an estimated value of USD 2,5 trillion (DMR, 2011a). The policy framework considered this estimate as the basis to leverage the mining value chain to effect mineral beneficiation (DMR, 2011a).

Chen (2010) refers to extreme volatility in short term metal commodity prices and mentions that these prices can change by 50 -100% in one year. The first section of this chapter is to comprehend the scarcity of minerals and the essential differences between resources and reserves. Vital to this understanding is that resources are relevant, but only to a point in time when they are economically viable reserves. Even reserves, are likely to fluctuate considerably due to volatile mineral pricing (Chen, 2010). The second objective of this chapter is to appreciate how minerals are traded and if any control to pricing can be effected at national or producer level. South Africa was blessed with a PGM resource that is globally unrivalled in magnitude (Montmasson-Clair, 2016). If international market economics drives the fate of these minerals, then would comparative advantage be enough to promote downstream beneficiation of PGMs?

4.2 Classification and Scarcity of Minerals

Taking the in-situ monetary estimate of USD2.5 trillion at face value, risks exist, in the cost of infrastructure, skills development and job creation. If the beneficiation investment was to take place based on leveraging the mining value chain and volatile mineral prices weakened by 50-100%, would the value chain advantage still exist (Chen, 2010)? If this scenario turned into reality, the massive capital investment requirement may have dire consequences to the South African economy (Hausmann, et al., 2008; Reynolds, 2013). It is important to understand the classification of resources and reserves in the mining context as there are many minerals in the earth's crust and only a very small portion on these minerals are concentrated enough to be economically mineable (Devarajan & Fisher, 1981; Reynolds, 2013).

To classify resources and reserves certain rules or codes are required. Versions of codes exist such as SAMREC (South African), NI 43 101 (Canadian) and JORC (Australian) (Canadian Institute of Mining, 2011; JORC, 2004; Samcodes, 2016).

As an introduction to the classification of mineral resources and reserves, understanding the distribution of minerals in the earth's crust is a vital foundation to the classification codes. Figure 4.1 illustrates the grade tonnage distribution of major elements.

Figure 4.1 indicates that both common rock and ores contain elements. Common rocks may have very small quantities or traces of elements but due to the large volume of common rock, the amount of mineral is significant. As mineral concentration occurs the grade increases and, under the right conditions, mining may occur. The mineral grade contained in ores compared to common rock may be high, but the volume of rock containing a higher grade is minimal. Henckens et al. (2016), argues that the ores for common elements exist up to a mineralogical barrier and thereafter the element will not occur in the earth's crust at economically mineable quantities. Thus, although minerals occur in the earth's crust in abundance, when distributed across the whole of the crust, there are only minuscule quantities of minerals that are concentrated enough to be economically extractable (Henckens, et al., 2016).

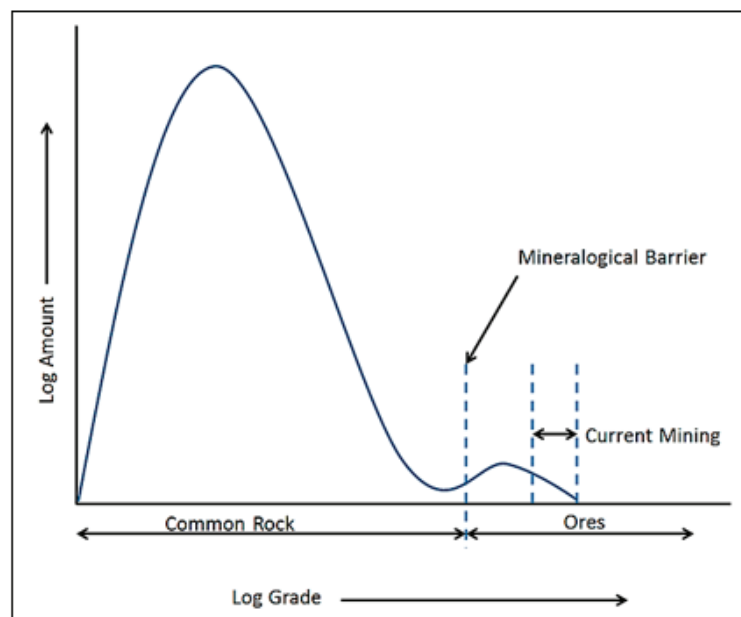


Figure 4.1: Grade Tonnage Distribution of Major Elements in the Earth's Crust (Adapted from Henckens et al., 2016).

Figure 4.2 depicts the reporting relationship between exploration results, mineral resources and mineral reserves. The system was instituted to provide commonality to the way in-situ minerals are reported to provide comparative clarity. What the system does define is the measure of certainty from exploration results to a measured and proven mineral reserve. This is through increasing levels of geoscientific knowledge and confidence. Mineral resources indicate, with various levels of certainty,

the estimates of the volume and grade of the deposit. This has little or no bearing on the mineability or economic extraction of the deposit (Samcodes, 2016).

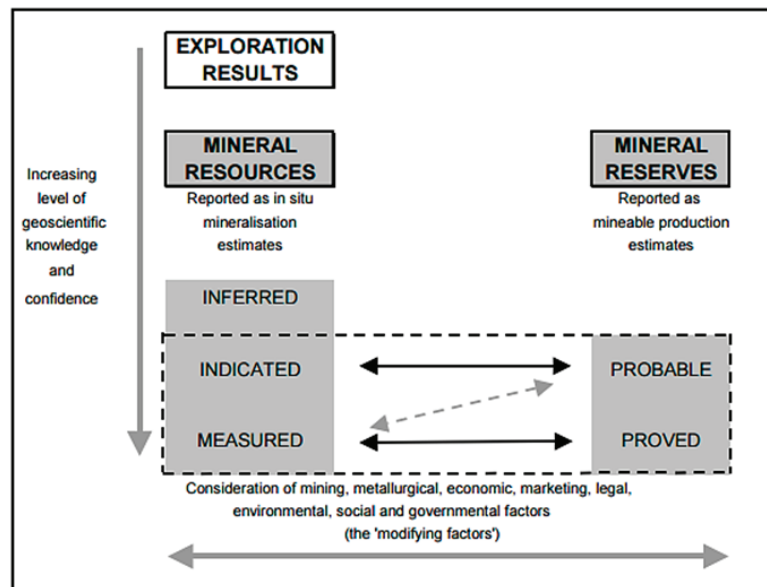


Figure 4.2: SAMREC Code – Mineral Reserve and Resource (Samcodes, 2016)

Mineral Resource

“A ‘Mineral Resource’ is a concentration or occurrence of solid material of economic interest in or on the Earth’s crust in such form, grade or quality and quantity that there are reasonable prospects for eventual economic extraction. The location, quantity, grade, continuity and other geological characteristics of a Mineral Resource are known, estimated or interpreted from specific geological evidence and knowledge, including sampling.” (Samcodes, 2016, p. 18)

Mineral Reserve

“A Mineral Reserve is the economically mineable part of a Measured and/or Indicated Mineral Resource. It includes diluting materials and allowances for losses, which may occur when the material is mined or extracted and is defined by studies at Pre-Feasibility or Feasibility level as appropriate that include application of Modifying Factors. Such studies demonstrate that, at the time of reporting, extraction could reasonably be justified. The reference point at which Mineral Reserves are defined, usually the point where the ore is delivered to the processing plant, must be stated. It is important

that, in all situations where the reference point is different, such as for a saleable product, a clarifying statement is included to ensure that the reader is fully informed as to what is being reported” (Samcodes, 2016, p. 25).

Reserve and resource statements are published in company annual reports and form part of the worth of a mining organisation. From time to time these estimates are reviewed and the results are normally published on an annual basis (Anglo American Platinum Limited, 2015). Figure 4.3 indicates Anglo American Platinum Limited’s ore reserves and mineral resource estimate as of 31 December 2015. These are strictly defined figures that are guided by the SAMREC code for reporting.

ORE RESERVES AND MINERAL RESOURCES ESTIMATES									
AS AT 31 DECEMBER 2015									
ORE RESERVES									
By reef (4E)									
The figures in the table below represent Anglo American Platinum Limited's (Amplats) attributable interests:									
Reef	Category	Reserves million tonnes		Grade 4E g/t		Contained 4E tonnes		Contained 4E million troy ounces	
		2015	2014	2015	2014	2015	2014	2015	2014
South Africa									
Merensky Reef	Proved	51.5	58.2	4.78	4.69	246	273	7.9	8.8
	Probable	21.6	18.5	4.54	4.74	98	88	3.1	2.8
	Total	73.1	76.7	4.71	4.70	344	361	11.1	11.6
UG2 Reef	Proved	326.6	328.4	3.96	3.96	1,294	1,301	41.6	41.8
	Probable	81.8	83.3	4.11	4.13	336	344	10.8	11.0
	Total	408.4	411.7	3.99	4.00	1,630	1,645	52.4	52.9
Platreef	Proved	707.3	688.8	2.75	2.72	1,944	1,870	62.5	60.1
	Proved primary ore stockpiles	42.1	38.1	1.81	1.71	76	65	2.5	2.1
	Probable	546.4	847.6	2.91	2.68	1,589	2,268	51.1	72.9
	Total	1,295.8	1,574.5	2.79	2.67	3,609	4,203	116.0	135.2
All reefs	Proved	1,127.5	1,113.5	3.16	3.15	3,560	3,509	114.4	112.8
	Probable	649.7	949.4	3.11	2.84	2,023	2,700	65.0	86.8
	Total	1,777.3	2,062.9	3.14	3.01	5,583	6,209	179.5	199.6
Zimbabwe									
Main Sulphide Zone (MSZ)	Proved	14.5	11.7	3.40	3.56	49	42	1.6	1.3
	Probable	33.1	37.7	3.32	3.52	110	133	3.5	4.3
	Total	47.7	49.5	3.34	3.54	159	175	5.1	5.6
South Africa and Zimbabwe									
All reefs (including MSZ)	Proved	1,142.1	1,125.2	3.16	3.16	3,609	3,552	116.0	114.2
	Probable	682.9	987.1	3.12	2.87	2,133	2,832	68.6	91.1
	Total	1,824.9	2,112.4	3.15	3.02	5,742	6,384	184.6	205.3
South Africa – tailings									
Tailings	Proved								
	Probable	94.4	20.9	1.08	1.06	102	22	3.3	0.7
	Total	94.4	20.9	1.08	1.06	102	22	3.3	0.7

Figure 4.3 Ore Reserve and Mineral Resource Estimates for Anglo American (Anglo American Platinum Limited, 2015).

Factors or costs associated with the economic extraction of the minerals, discount the profitability of a deposit until such time that the deposit is no longer a viable proposition. This point is called the cut-off grade. Portions of the orebody that fall below this determinant are generally not considered in the extraction plan (Devarajan & Fisher, 1981).

Mineral prices are unpredictable (Chen, 2010), and if the unit cost of production remains constant and the sale price of the mineral is high, the cut-off grade will go down and the reserve will expand. If the

unit cost of production remains constant and the sale price of the mineral drops, the cut-off grade will rise and the reserve will shrink (Reynolds, 2013). A real evaluation of this principle in action is the South African platinum industry where costs are rising, grades are diminishing and the platinum price has slumped (Montmasson-Clair, 2016).

Figure 4.4, indicates the platinum daily spot price in USD per troy ounce, from April 2010 to April 2017. Considering the Citi Bank article in May 2010 on South African in-situ estimated in Chapter 2 (DMR, 2011a), Figure 4.4, illustrates the daily spot price for platinum from the time the article was released to current times. The platinum price weakened considerably from 2010 to 2017. These reserve estimates would have been severely impacted with the platinum price deteriorating from USD 1700 per Oz to USD 900 per Oz. This 47% plunge in the price of platinum alone, coupled with rising costs, would have decimated the original estimates of South Africa's mineral resources at USD 2.5 trillion. Chapter 5 contains details of PGM extraction costs. Long term strategic policy decisions made off reserve and resource estimate are also sensitive and subject to volatile mineral prices (Chen, 2010). This case has only considered one mineral group and a very simplified explanation of the effects of price volatility. The sparkle of leveraging, USD 2.5 trillion, may fade in the face of volatility in mineral pricing.

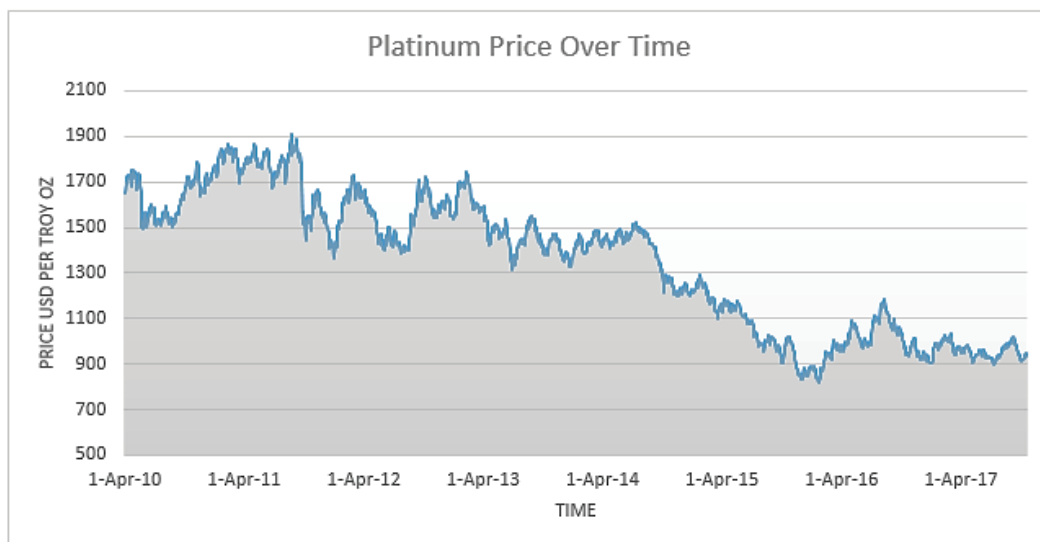


Figure 4.4: Platinum Price per Troy Oz Versus Time (Adapted from Johnson Matthey, 2017a).

The previous section concentrated on mineral price volatility. The next section explores the scarcity and rarity of minerals. With the investment required, for local PGM downstream beneficiation to occur, the source of supply needs to be sustainable.

Table 4.1 derived the exhaustion periods of 60 elements in years after the date 2050. They assumed that the extraction of all the elements mentioned increases annually by 3% until 2050 after which it levels off. Metals and metalloids were classified per geologic scarcity. EGR = extractable global resource as defined by UNEP (Henckens, et al., 2016).

Table 4.1: Exhaustion of Major Minerals (Adapted from Henckens et al., 2016).

2050 Timeline		2150 Timeline		3050 Timeline	
Mineral	EGR	Mineral	EGR	Mineral	EGR
Antimony	-10	Arsenic	400	Aluminum	20,000
Gold	10	Bismuth	200	Barium	1,000
Molybdenum	50	Boron	200	Beryllium	200,000
Rhenium	80	Cadmium	500	Cobalt	2,000
Zinc	50	Chromium	200	Gallium	1,000,000
		Copper	100	Germanium	200,000
		Iron	300	Indium	10,000
		Lead	300	Lithium	9,000
		Nickel	300	Magnesium	30,000
		Sliver	200	Manganese	2,000
		Tin	200	Mercury	400,000
		Tungsten	300	Niobium	2,000
				Platinum Group Metals	1,000
				Rare Earth Metals	20,000
				Selenium	300,000
				Strontium	10,000
				Tantalum	20,000
				Thallium	1,000,000
				Titanium	10,000
				Uranium	2,000
				Vanadium	20,000
				Zirconium	2,000

Figure 4.5, indicates the classification of “Scarce Minerals”, according to Henckens et al., (2016) calculations, with limited availability 100 years after 2050. Antimony is classified as “Very Scarce” and, this mineral will be exhausted before 2050.

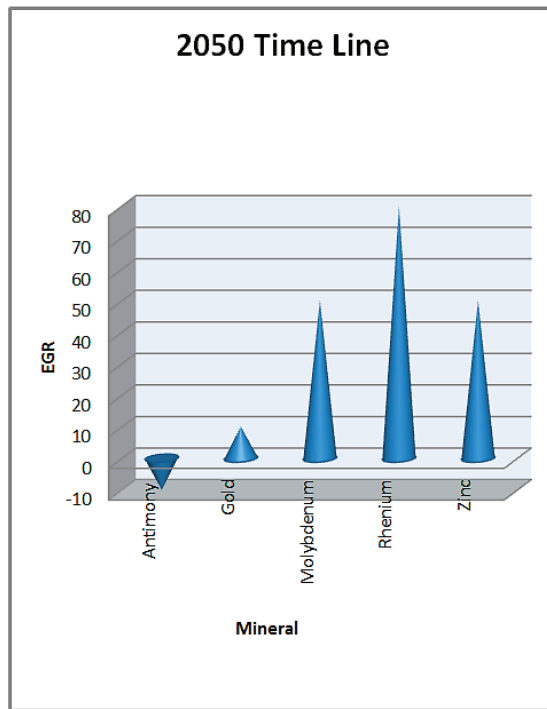


Figure 4.5: Exhaustion Levels of Minerals and Metalloids 100 years after 2050 (Adapted from Henckens et al., 2016).

Figure 4.6, indicates the classification of “Moderately Scarce Minerals”, with limited availability 100 - 1000 years after 2050. The classification of scarce minerals on the left-hand side of the graph (Antimony to Zinc) shows the magnitude difference in extractable global resource as compared to the moderately scarce minerals (Henckens et al., 2016).

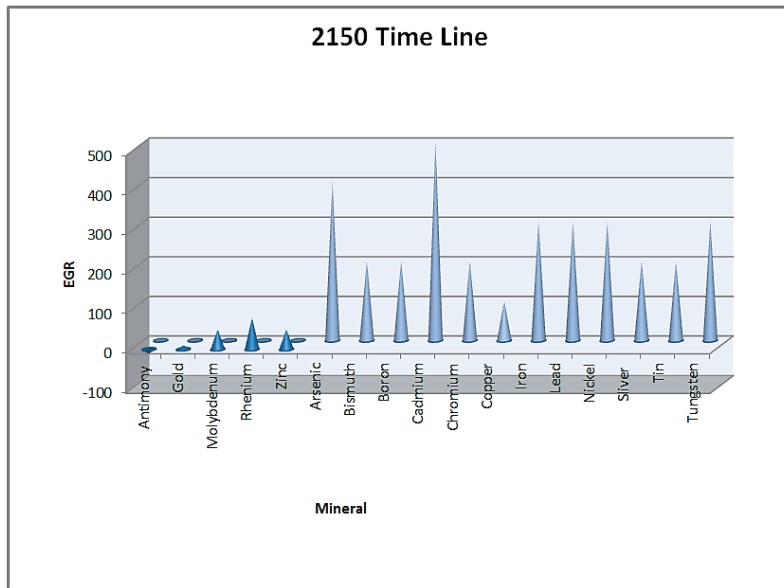


Figure 4.6: Exhaustion Levels of Minerals and Metalloids 100-1000 years after 2050 (Adapted from Henckens et al., 2016).

Figure 4.7 indicates the classification of “Not Scarce Minerals”, with limited availability 1000 plus years after 2050. Disturbing is that, a vast number of minerals and metalloids cease to exist per the UNEP definition of Extractable Global Resources. PGMs are within the “Not Scarce” sector with an estimated exhaustion time of over 1000 years.

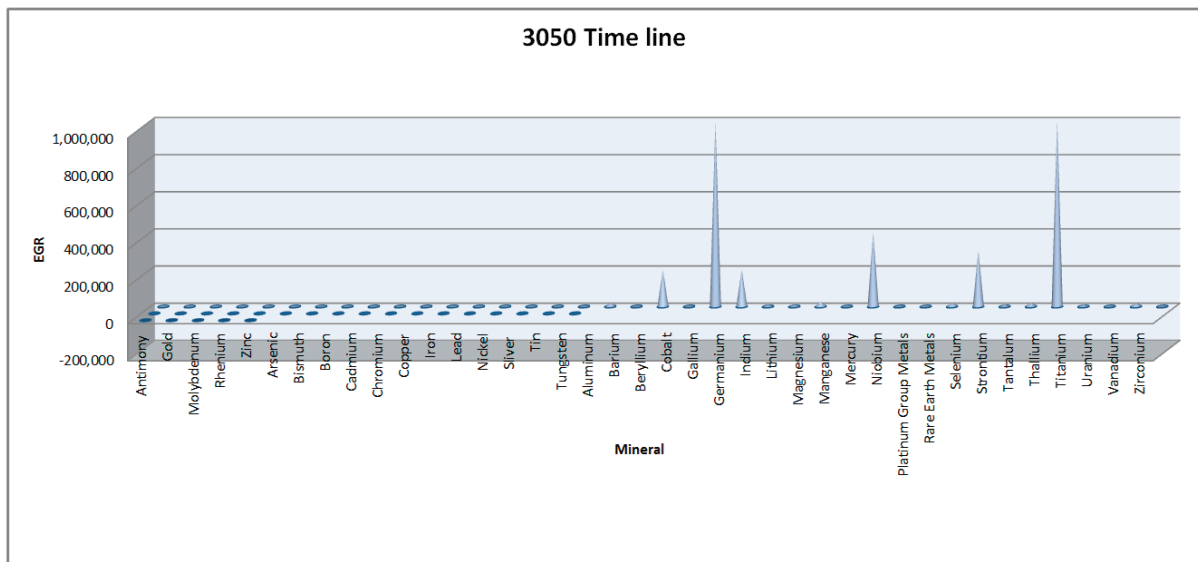


Figure 4.7: Exhaustion Levels of Minerals and Metalloids < 1000 years after 2050 (Adapted from Henckens et al., 2016).

Douce (2016) argues that if neither economic growth nor world population undergo any severe change for the rest of this century, the demand for minerals was expected to be an order of magnitude larger than all the minerals mined from the steam age to present time. Arguably, both Henckens et al (2016) and Douce (2016) put forward points for consideration and some assumptions may very well be skewed by future events, however, what is clear is that some minerals are scarce and, by population growth, global demand will continue to increase. Henckens, et al., (2016) further stated that common rock contains the bulk of the minerals in the earth's crust but only a very small portion has sufficient grade or quantity to be mineable.

Mining activities are depleting these small portions and the world is mining towards the mineralogical barrier. The mineralogical barrier defined by Henckens, et al (2016) was a point at which economic mining can no longer be viable. Minerals are scarce and once a minable asset has been depleted it cannot be replaced. IPA (2013), classified PGMs as very rare metals in the earth's crust. USGS (2013) stated that PGMs are usually a by-product of mining other metals such as Nickel and Copper. PGMs are not scarce but rarely occur in economically minable concentrations. The sovereign windfall of South Africa's mineral endowment may be difficult to value, but if managed correctly it will benefit future generations (Henckens et al., 2016).

4.3 Mineral Price and Trading

There are multiple factors involved in the trading of minerals. The beginning of this chapter focussed on the classification of mineral deposits and the scarcity of minerals. From the classification perspective, a mineral resource is not a mineral reserve. There are distinct differences in the estimate classifications. The significance of the difference is often understated when the mineral endowment of South Africa is quantified. Henckens, et al (2016) evaluation emphasized that resources are not renewable and that there are extraction limitations. This was highlighted by a mineralogical barrier, whereby a mineral could not be economically mined and reserves do not occur in sufficient quantity to allow for extraction. PGMs were classified as not scarce and would be extracted for more than a thousand years. However, economically minable deposit are very rare.

The following subsection focuses on the elements of minerals and metal trade. As the economics of trade for minerals is mainly export driven in South Africa, international metals trading structure needs to be considered (Smit, 2017). According to Chen (2010) prices of mineral commodities are volatile, reflecting unpredictable shifts in the balance between supply and demand. This prevailing balance is not driven by national markets but moreover by the unpredictable global distribution of viable mineral

deposits. This erratic distribution of minerals presents opportunities for metals and minerals to be traded from whichever locality and is not subject to the point of origin of the product (Maxwell, 2006).

Minerals and mineral product transactions can occur at multiple stages of production from concentrated ores to ingots, refined bars or any stage after extraction. Minerals and mineral products are subjected to a myriad of international trade arrangements (WTO, 2010).

Four broad procedures generally determine mineral pricing. These are; producer pricing, independent pricing determination, negotiated price and commodity exchange pricing (Strauss, 1987). The nature of the minerals or mineral products, determines the way in which it is traded. Some commodities can rely on one or several pricing methods based on perceived advantage by the buyer or the seller. Commodities can vary in price between locations and markets, bulky commodities mainly incur different pricing structures dependant on value and locality from the market. Trade quotas and other limiting factors may also influence price determination (Strauss, 1987).

Maxwell (2006), stated that one of the most important factors that influence comparative advantage and the extent of resource trade is the mineral commodities value to weight ratio. Maxwell (2006) goes further to say that moving Australian gold is relatively inexpensive and apart from the security issues, the process is straight forward. The gold from Australia could be delivered and sold in London, Mumbai, Hong Kong or New York. The cost for the transport of gold to any of the trading hubs is comparatively small versus the value of the product. Maxwell (2006)'s mineral value and transport cost to value ratio curve, (Figure 4.8), places gold and PGMs in the same category.

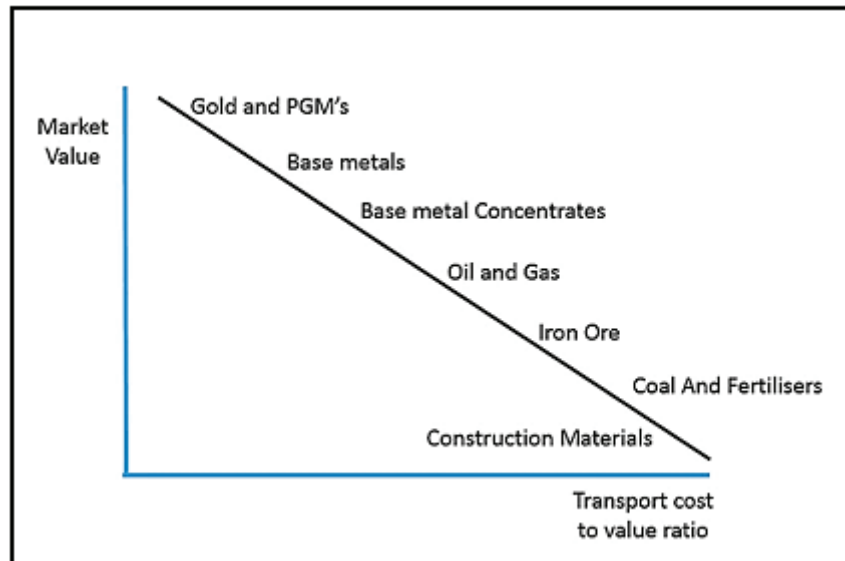


Figure 4.8: Mineral Commodity Values and Transport Costs (Adapted from Maxwell, 2006).

It could be deduced that gold and PGMs have similar value to weight ratios and therefore the global movement of PGMs has little influence on the commodity price. Maxwell (2006) demonstrates the opposite effect where iron ore, being extracted from the Pilbara region of Australia, was subject to several limiting factors. Factors such as the extraction of iron ore occurred on-site in the Pilbara, the iron ore producer had to undertake the expense of moving the product from the mine to the local port. The producer then incurred the cost to shipping the ore to a foreign port, thereafter the onward costs were borne by the buyer. Before iron ore prices rose, steel makers in America and China, favoured local poor quality iron ore over the imported high quality product due to the cost of transport. Maxwell (2006) also noted that during the period of low iron ore pricing, that the cost of the iron ore transportation had the potential to be higher than the sale price of the commodity (Maxwell, 2006; WTO, 2010).

4.3.1 Producer Pricing

Producer pricing was determined by the seller where the seller had a particular advantage over their competitors. This allowed suppliers to dictate the price of their goods. Due to the diverse location of mineral deposits, this does not occur very often especially for mineral products that exhibit a high value to transport cost ratio (Maxwell, 2006). The producer considers, the cost of production, potential markets, their market share and competitive position advantage. The competitive factor

should be heavily weighted in favour of the producer to command producer pricing conditions (Strauss, 1987).

Two examples of this occurred, firstly with the Chilean nitrate of soda industry, prior to World War I and secondly with the Greenland cryolite industry prior to World War II. In both instances the producers were competitively positioned in such way that they had the ability to command their own prices. These monopolies ended with synthetic substitutions (Strauss, 1987). According to Strauss (1987) producer pricing occurs in what economists call oligopolies, where a few dominant sellers control most of the market. Through a collaborative forum, the sellers, controlled the price of the mineral or mineral product by controlling the major share of the global supply.

The comparative advantage of the South African PGM suppliers, may possibly fit the category to form an oligopolistic regime. History has shown that competition for market share by the producers, was one of the major downfalls of such structures (Strauss, 1987). The risk also occurs where, profitability drives new mines to come-on-line and will affect the mineral supply pipeline. According to Strauss (1987), by nature, the majority of the world's PGMs were supplied out of South Africa and Russia and that in the past producer pricing mechanisms had been in place. However, these markets became increasingly influenced by commodity exchange trading. Strauss (1987), suggested that supply contracts for PGMs are linked to or inclined to follow the trends of the commodity exchange.

4.3.2 Independent Pricing Determination

Independent pricing determination relies on frequently published prices from an authentic trade periodical. The independent pricing is not a function of the seller unilaterally determining the price at which the commodity will be sold. A recognised trade institution fixes the price of the commodity for a certain repeatable period. This may be daily, weekly or monthly. The fixed price in many cases is not influenced by the buyer or the seller, but more over by an institution that canvasses producers, sellers and merchants and fixes an average price for a fixed period. The contracts that occur around independent price determination are agreed upon by the parties and the price for a set tonnage of metal or mineral is determined by the fixed publication price (Strauss, 1987).

4.3.3 Negotiated Price

Negotiated prices, as the name suggests is a price determined in the interest of both the seller and the buyer as opposed to the price determined by the seller or that which occurred in a publication. A community of interests is created with specific supply terms, for example, frequency of delivery and quality of raw materials. Negotiated price contracts are generally for long term contracts and are common in the base metal industry. Each party is cognisant of the other party's requirements and the negotiated contract takes these considerations into context. Examples of the considerations may be adjustments or provision for price escalation such as labour cost or inflationary adjustments over time. The nature of the long-term contract structure should be flexible enough to accommodate the producers' needs as well as the buyers' needs so that both parties prosper (Strauss, 1987; WTO, 2010).

4.3.4 Commodity Exchange Pricing

Commodity exchanges exist in a variety of places around the world, the most famous metal exchanges are the London Metal Exchange (LME) and the New York Mercantile Exchange (NYMEX). Trading at these exchanges are conducted as an auction for contracts for a given commodity within defined hours of trade. Trading is conducted through a firm or individuals that are bona fide members of the exchange. Exchange contracts specify standard quantities and qualities for given commodities. Offerings for these given commodities are traded for future delivery dates. Sellers may deliver to an accepting warehouse of their choice. Furthermore, the buyer may collect from an alternative, more suitably positioned warehouse that may be closer to the buyer's location. Central to the trend of prices on commodities exchange, is the perceived balance between supply and demand (Strauss, 1987).

If the demand exceeds supply, inventories in the exchange will diminish and the price of the commodity will rise. When the opposite occurs and inventory rises, the perceived price falls. In principle, this is how a commodity exchange functions, however, according to Strauss (1987), the majority of exchange transactions are never delivered. The buyers may sell their contract prior to collection and the sellers may buy back the quantity tendered prior to the effective date of transaction. The manipulation of the exchange or hedging tactic, is merely to determine a known price to protect the buyers raw-material input costs or cover the sellers output. Other cost drivers are event driven speculative buying and selling through traders using the future delivery as a mechanism to generate revenue.

Commodity exchanges are agnostic to the origin of the mineral or mineral product and consider the quality and quantity to be the criteria of sale. Prices are mainly linked to the United States Dollars as a common currency and no contract negotiation occurs through the sale. Increased input costs, labour costs and energy costs have no bearing on the sale price of the mineral or mineral product (Strauss, 1987; WTO, 2010).

The London Bullion Market Association (LBMA), part of the LME sets the PGM prices twice per day. Due to the limited number of refiners and suppliers of PGMs, the prices are generally set by the sales offices of the major producers (Bell, 2016; JSE, 2017).

The South African PGM supply market is dominated by long term contracts but influenced by the spot price from the commodities market (DMR, 2011a). Evidence for this is tied to the poor commodity price and lack of producer pricing (England, 2012).

4.4 Supply and Demand Fundamentals

The chapter thus far has dealt with classification of mineral deposits, scarcity of minerals and mineral trading frameworks. Each of the preceding sections had an element of supply and demand characteristic related to minerals and mineral products. As a precursor to Chapter 5, which is a detailed supply and demand characteristic for PGMs, the following section covers the basic fundamentals of supply and demand. With the price of metals and minerals typically beyond the control of the producer, the markets perception of value controls the price of these commodities (Strauss, 1987; WTO, 2010). This perception of value creates an environment subject to volatile pricing (Chen, 2010).

Mineral export attributed R221.5 billion to the total merchandise exports in 2016, this equated to 20.1%. PGM mineral exports were 22% of this (Chamber of Mines, 2016a). Volatility with metal prices in periods of sustained premium market pricing leads to prosperity. Governments should be cognisant that this same volatility, in a depressed mineral market, can cause poverty if the economy is reliant on a mineral based income (Chen, 2010).

Price volatility occurs with long lead times for supply to come-on-line, high capital requirements and other conditions related to mining operations. This, coupled with external markets determining demand, drives price volatility (Chen, 2010). The long lead time endured with bringing new projects to production to fill a deficit in supply causes shortfalls in global supply and drives the price upwards. If too many new sources come-on-line or the market shrinks, the opposite occurs and oversupply

causes a depressed market. As mining operations take years to become established, this phenomenon becomes cyclic and extended periods of prosperity occur along with protracted periods of depressed markets (Douce, 2016; Kesler, 2013; Tilton, 1985).

With the availability of costing information through advancements in public information and media, the mineral trade cost curve soon became the primary tool for benchmarking, cost management, market traders, financial and government institutions (Latoff, 2009). In Figure 4.9, demand is basically centred on the ability to consume, such that in a perfect environment if nothing changes, apart from price, the capacity to purchase will increase with lower prices and decrease with higher prices. This is an inverse relationship between price and quantity demanded (Haworth, 2016).

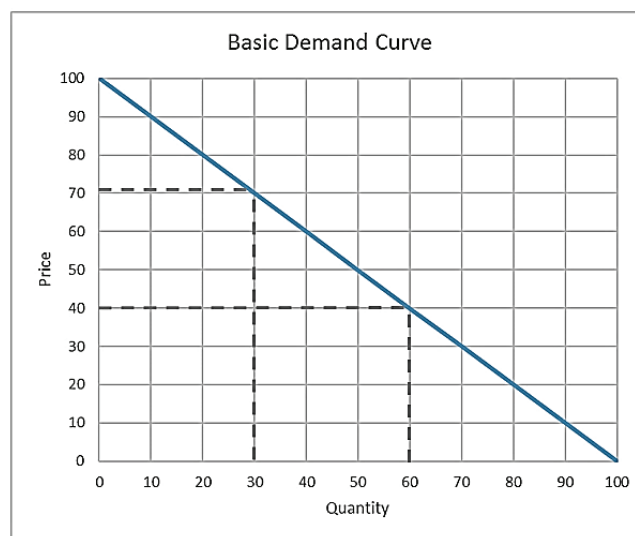


Figure 4.9: Basic Demand Curve (Adapted from Haworth, 2016).

In Figure 4.10 supply is basically centred on price, such that in a perfect environment if nothing changes, the price incentivises suppliers to produce. A supplier will produce fewer units if prices fall and more units if the price increases. Maximising revenue is the basis for supply (Haworth, 2016).

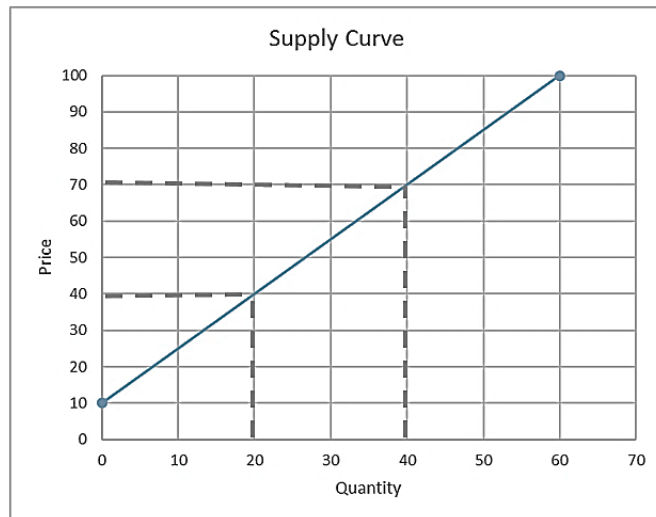


Figure 4.10: Basic Supply Curve (Adapted from Haworth, 2016).

In Figure 4.11 where the supply curve and the demand curve meet, an equilibrium point is defined as the market-clearing point. This is the point in a perfect market where the price of the product is such that the consumer is willing to pay for total supply (Haworth, 2016).

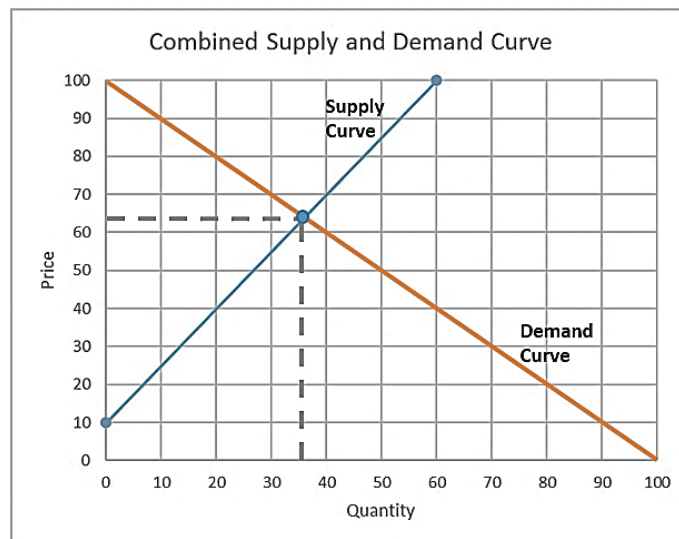


Figure 4.11: Combined Supply and Demand Curve (Adapted from Haworth, 2016).

4.5 The Foundation of the Cost Curve

Harold Hotelling and Lewis Gray were probably the fore fathers of modern mineral economics. Works on the economics of exhaustible resources inspired and spurred interest in non-renewable resources. As the extraction of minerals is finite, the scarcity of the mineral will increase with each unit extracted. If the mineral is in demand, then scarcity of supply would, under normal circumstances, increase the price of the mineral in use. Eventually, the cost of the mineral would be infinitely expensive as the reserve is depleted to exhaustion (Crabbe, 1983; Hotelling, 1931).

In very broad terms, exhaustible mineral resource outputs can theoretically, through mining operations, increase and decrease capacity to meet demand as long as they exist. This could be achieved by expanding operations or opening new mines. However, once the global resource becomes depleted it cannot be replenished, unlike renewable resources where regeneration is possible. Therefore, non-renewable resources have special peculiarity in the world of economics (Crabbe, 1983; Devarajan & Fisher, 1981; Reynolds, 2013).

Industry cost curves are strategic tools and are no more than standard micro-economic graphs that show, at a given cost per unit, how much output a supplier can produce. The curves are used when commodities are fungible. Sugar, for example may be produced by a number of suppliers at a variety of prices per unit. Therefore, sugar may be used in an industry cost curve. Minerals are fungible and much the same, in that PGM extractors produce a similar product yet, each mine's cost of production varies (Watters, 1981).

Industrial cost curves are used for a multitude of applications for various outcomes. Determinants of inputs are aggregated from economic and production data. The simplicity and intricacy of the curves vary considerably and highly complicated mathematical equations can be applied to forecast future prices and supply and demand capacity (Harvey, 2006).

So far in Chapter 4 the fundamentals and basics of cost curves have been highlighted. The curves, although simple thus far, are completely dependent on the input data, and the accuracy of that data. Of concern are, aggregated input costs and company specific cost allocations, where they come from and how they were allocated (Imbs, et al., 2008). Furthermore, when forecasting, the future cannot be told. Therefore, the cost curve is an indicator rather than an exacting tool.

4.6 Mineral Trade Cost Curves

Mining companies, ultimately, are required to provide economic value to shareholders in return for the monies invested (Tholana, 2012). In the mineral trade the commodity price is not normally dictated by the supplier, but moreover, the price is dictated by the market and the demand for the associated mineral product. The price of the mineral produced is dictated by value of the product perceived by the buyer (Ajam & Padia, 2014; Chen, 2010). For the most part purchases or the demand for minerals including PGMs are conducted in international markets and therefore, the price willing to be paid is in the domain of the international markets. By and large, mineral and metal producers are price takers and have little influence in price determination (Chen, 2010).

The demand for minerals is limited to market capacity, for industrial minerals such as, iron ore, copper, and coal. Precious metals such as gold, platinum and silver behave slightly differently in terms of total market demand but prices are affected in the same way when the supply exceeds demand. The massive holdings of bullion, jewellery, coins and works of art from historical mining totally overshadows the current, newly mined stocks and plays a commanding role in price determination (Strauss, 1987). PGMs to a lesser degree are subject to a similar phenomenon, driven by inventory in investment funds, jewellery and recovered scrap metal (Strauss, 1987). Chapter 5 clarifies the source of these stocks. It is vital for mineral suppliers and buyers to understand, available capacity, total market demand and price. In addition, decisions need to be made for future expected demand and expected pricing.

The “unit cost of production” is the bear minimum sale price for producers of mineral commodities (PwC, 2016). Operating below the minimum unit cost of production would signify a loss to the producer. With mineral price volatility determined on supply and demand characteristics, market swings can deviate and correct quickly. By attrition, those producers who do not have enough liquidity to carry them through downturns will become insolvent and will no longer be a market supplier (PwC, 2016). As mines get deeper and grade becomes lower the operational output is subject to higher and higher unit production costs (IPA, 2013). With a fixed market demand off-take, new mines with lower unit production costs, come-on-stream and the mineral supply pipeline forces the high cost producers out of the market (Douce, 2016; Kesler, 2013; Tilton, 1985).

Pricing dynamics are determined by a cost curve which charts the products’ available capacity, incrementally, in order of increasing cost. Theoretically, the market demand capacity sets the market price by the next available supply capacity as seen in Figure 4.12 (Latoff, 2009).

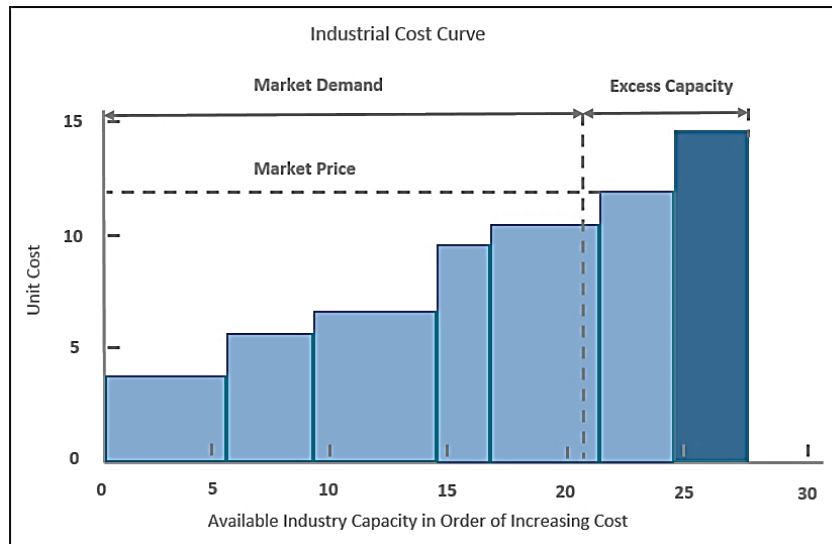


Figure 4.12: Example of an Industrial Cost Curve (Adapted from Latoff, 2009).

The curve shows the impact that capacity can have and is also able to highlight shifts in demand which influence market pricing. Before the 1980's, many mineral suppliers and buyers relied on "gut feel" approach to pricing (Latoff, 2009). With the introduction and popularity of this type of curve, the minerals industry has used, manipulated and displayed the graph in many forms. The reliability of the graph is only as good as the input data. As the complexity grows, the outcomes derived can increase in ambiguity (Imbs, et al., 2008). This section is a fore runner to the cost curves in Chapter 5, which signifies the health of the South African PGM extractor industry.

4.7 Chapter Summary

The aim at the beginning of the chapter was to demonstrate that mineral resources are an asset, but these resources are subject to a rigorous process to convert them to mineral reserves. Mineral resource valuation, used in the context of financially viable mineral extraction propositions are "time and conditions based". Therefore, relying on the evaluation information for future planning may create false expectations of the capability of extraction industries. Volatility in mineral prices can have devastating effects and decision makers should be aware of this with policy judgements. Minerals based economies such as South Africa are subject to price volatility which is beyond the control of the producer.

Minerals are scarce and once a minable asset has been depleted, it cannot be replaced. Future generations may not benefit from the sovereign windfall. Governments and mining companies need to act, commercially responsibly, when extracting non-renewable mineral resources.

Supply and demand characteristics control the price of minerals and mineral products. Very seldom, is the price in the control of the producer. Prices of minerals are determined at an international demand related level and not at a nation level. Therefore, preferential pricing required in the DMR's beneficiation strategy document, for PGMs, would be very difficult to maintain.

Fragile markets and price volatility are generated by conditions and circumstances beyond the control of local intervention. Government institutions do not have a direct influence on the price of PGMs or other commodities. Given that South Africa has a major comparative advantage in the supply of PGMs and this could favour an oligopolistic forum, history has shown that this is not a satisfactory concept. South Africa has a comparative advantage with reserves of PGMs, however, this mineral group is not scarce, but rarely occurs in economically minable conditions.

Comparative advantage has little, to no effect in the value chain to the point of sale for refined PGMs as transport cost to value ratio is extremely low. The price of PGMs are basically the same in London, New York or Johannesburg. Supply price manipulation in one form or another, for downstream competitive advantage, is the only logical direction that makes clear economic sense for downstream PGM value addition. However, this would be very difficult to achieve and maintain.

Chapter 5 narrows down the focus of the research report to understand the supply and demand characteristic of PGMs, where they are produced, competition in this market and how much of the market share is owned by South Africa. Understanding the supply capacity, market demand and the financial health of the extractive industry may leave un-answered questions as to why South Africa continues to supply PGMs into a depressed market.

5 PGM SUPPLY AND DEMAND CHARACTERISTICS

5.1 Introduction

Chapter 4 dealt with the classification and scarcity of PGMs, how minerals are sold and the basics of supply and demand. This chapter takes the 2016 production results and defines the supply market and the demand for that year. The objective of this chapter is to understand South Africa's potential to dominate the world PGM market and to indicate comparative advantage. The research also covers the history of PGM supply in South Africa, explores the global supply and defines the uses and demand characteristics of the industry. The objective is also to understand competition in the PGM industry as far as supply characteristics are concerned. Further objectives are to understand where, in the world, PGM are consumed and what are the major uses for the metals.

5.2 History of PGMs in South Africa

The history of platinum began in the 18th century, prior to which it was thought that the metal had no value. Platina, a native alloy of platinum, was used as a means of counterfeiting silver coins (Whitburn, 2012). In 1924 a geologist, Hans Merensky, was credited with the discovery of two platinum deposits that ran for approximately 100km. Combined, these deposits produce three quarters of the world's platinum supply, now known as the Bushveld Complex of South Africa. The two reefs became known as the Merensky and the Upper Group 2 (UG2) reefs (Jones, 2000). The Merensky and UG2 reefs are located adjacent to each other and the UG2 reef occurs, in the range of 20 to 330 meters below the Merensky reef. Reef thicknesses varies from 15 centimetres to 2.5 meters (Jones, 2000).

The Merensky reef was first mined in 1926, followed sometime later by the UG2 reef which was first commercially mined in 1980. The payload of the Merensky was comparatively high and easier to recover than the difficulties experienced with recovery of UG2 ores (Whitburn, 2012). South African PGMs almost exclusively were derived from the Bushveld Complex with a comparative miniscule percentage, being generated from the gold and copper extraction around the country (Jones, 2000). Hans Merensky's discovery in 1924, of economic deposits of platinum in South Africa, led to the commencement of a number of platinum operations. Some operations closed and others merely changed names (Jones, 2000). From 1971, these platinum mining operations positioned South Africa as the world's principal PGM producer (Jones, 2000).

PGMs consist of the six platinum group metals which are platinum, palladium, rhodium, ruthenium, iridium and osmium (Whitburn, 2012). These deposits of PGMs are rarely mined as a primary supply,

in significant quantities, anywhere outside of South Africa, apart from Zimbabwe (SNL Data Base, 2017). The annual production of PGMs is significantly lower than common metals and PGMs are classified as precious metals. PGMs may also occur along with copper, nickel, gold and silver. Platinum, Palladium and Rhodium are the most commercially targeted metals with ruthenium iridium and osmium as co-products (IPA, 2013). Platinum, palladium and rhodium, are the most economically significant PGMs and they also occur in the largest quantities (Impala Platinum, 2017).

Figure 5.1 is a block diagram of the South African Bushveld Complex. This was a result of a colossal ejection of metal rich magma from deep within the earth. The outflow of an estimated 1 million cubic kilometres of magma occurred over a very short geological time scale and the lateral extent of this flow was thought to cover a diameter of at least 300km (Cawthorn, 2010). Geologists estimated the magma ocean to be in the region of 8 km thick. As the enormous out pouring cooled very slowly, minerals began to solidify in thin parallel deposits at the bottom of the epic magma ocean (Cawthorn, 2010). The first economically important platinum discovery by Hans Merensky, was found in one of these single parallel deposits and the reef bears his name (Cawthorn, 2010).

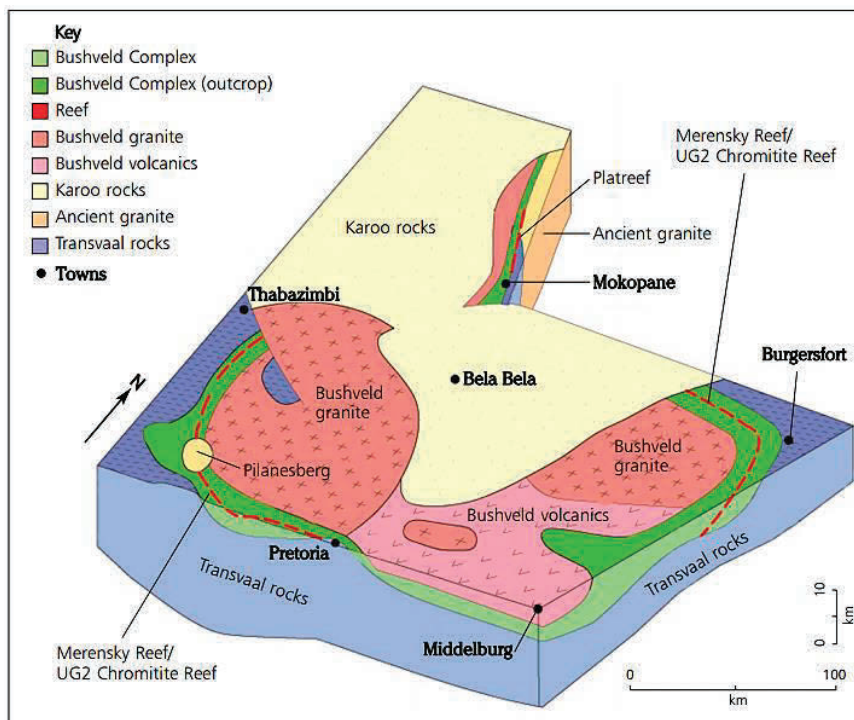


Figure 5.1: Block Diagram of the Bushveld Complex of South Africa (Cawthorn, 2010).

The currently exploitable reserves of PGMs in the Bushveld Complex occur in three mineralogically distinctive layers. These are concentrated in narrow but extensive strata formations now formally known as the Merensky, the UG2 Chromitite layer and the Platreef (Jones, 2000). The Platreef is mined

in the Mokopane area of South Africa while the Merensky and UG2 formations are mined in several locations in the Bushveld Complex (Jones, 2000). The Merensky ore has higher sulphide content and is contained in a silicate substrate as opposed the UG2 ore that is contained in a chromite matrix.

The chromite matrix, Cr_2O_3 is said to require a different and challenging approach to ore processing (Jones, 2000). Platreef ore is considered to be similar in nature to the Merensky reef with an enhanced palladium content (Jones, 2000). Before the Merensky reef was discovered, knowledge existed about the occurrence of platinum in the chromite rich layers of the Bushveld complex, but at the time, economic exploitation was not possible (Cawthorn, 2010).

South Africa had four major primary platinum producers, namely Anglo American Platinum, Impala Platinum, Lonmin Platinum and Northam Platinum, with Sibanye Stillwater, a fifth recently joining the major producers (Jones, 2000). The range of their operations covers open pit and underground mining, milling, flotation, drying, smelting, converting, refining and marketing (Jones, 2000).

Mining, primarily occurs underground and to a lesser extent in open pit operations. Most underground mining is conducted by conventional methods with hand held rock drills and to a lesser degree by mechanised mining methods (IPA, 2013).

Primary source PGMs extraction, in South African operations, consumes considerable amounts of energy and has a high capital and labour intensity (IPA, 2013). More than 90% of South Africa's electricity generation is via thermal power stations fuelled by coal. This intense energy consumption by the PGM extractors and processors poses a second element into the equation of depletion of non-renewable resources. In order to concentrate PGMs to a saleable form, two national non-renewable resources, coal and PGMs, are being exploited (IPA, 2013).

The three reefs, Merensky, UG2 and Platreef of the South African Bushveld Complex combined form the single largest global platinum resource (Cawthorn, 2010). Estimates abound when determining the reserve capacity of PGMs in the Bushveld Complex. These estimates of global reserves in South Africa range from 75% to 90%. (Chapter 4, explains how reserve calculation are determined). Qualitatively, the comparative advantage of the South African global reserve of PGMs, at any time, is larger than three quarters of the world minable assets (IPA, 2013; Jones, 2000; van der Lith, 2015). Grades suggested by the IPA (2013) puts the range of minable grade at 2-6g/t. Cawthorn (2010) puts the grade of the chromitite layers at up to 3.0g/t. Both grade ranges are extremely low in comparison to common and other precious metals.

Cawthorn (2010) suggests, at the date of publication, that probably nearly half the estimated in-situ reserve capacity contained in the first km from surface had already been mined. Cawthorn (2010) also suggests that 200 million ounces of PGMs remained in the upper 1km and 350 million ounces in the second km. Other figures suggested that the Merensky reef contained 547 million ounces of PGMs and the UG2 reef had between 800 and 1000 million ounces of PGMs. To understand the enormity of these statements van der Lith (2015) states that “There is no other commodity or substance that is so geologically concentrated” (van der Lith, 2015, p. 3).

South Africa dominates the global supply of PGMs, with the exception of palladium. This command of upstream PGM production is not duplicated in the value-added PGM manufacturing base of South Africa (DMR, 2011a). According to findings of the IDC (2013), less than 3% (as a percentage of export sales) of platinum, palladium and rhodium are sold on the domestic market. This figure would have changed over time.

5.3 Processing PGMs in South Africa

In the early 1930s, the weak platinum price, led to extensive mine closures and amalgamations. The resultant factor of this upheaval was the formation, in 1931, of a single dominant company, Rustenburg Platinum Mines. In that era, bulk concentrates derived from oxide ores were shipped from South Africa to the UK for refining. During these early phases platinum ores were mainly recovered by traditional milling and gravity table concentration (Jones, 2000).

By 1936 throughput had expanded and oxidized ore was nearly exhausted. To reduce transport costs, it became necessary to commission a local flotation plant, a small blast furnace and a converter unit to produce platinum-rich copper-nickel matte. This matte was cheaper to ship than the former bulk concentrates. In 1953 a second blast furnace was commissioned. Blast furnace smelting was not economical and not as environmentally friendly as the electric furnaces that dominated PGM smelting thereafter (Jones, 2000).

Figure 5.2, depicts the mineral processing procedure for concentration and refining of PGMs. The process is described by the following steps:

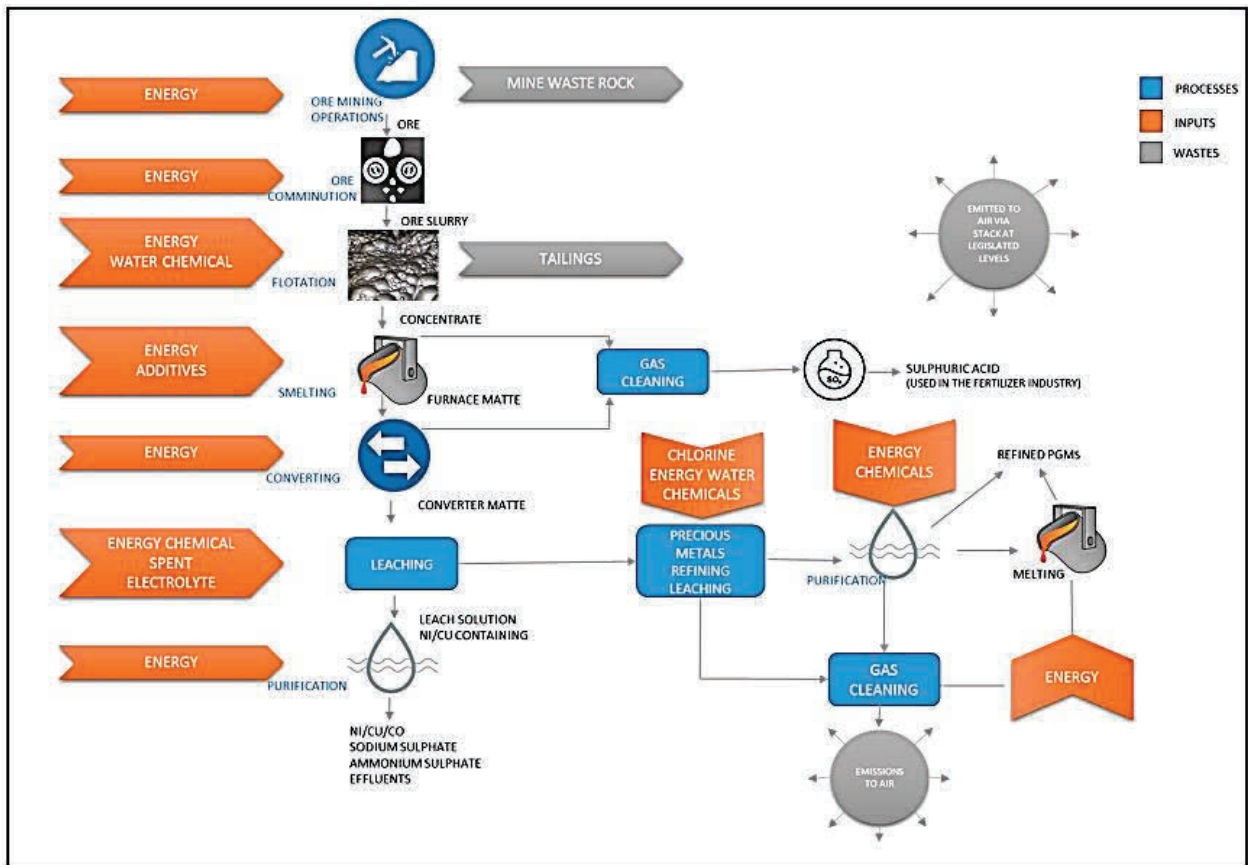


Figure 5.2: PGM Primary Production Process (Adapted from IPA, 2013).

- Comminution - To liberate the PGM minerals from the ore, fine milling is required. UG2 concentrates requires a finer grind (about 80% less than 75 micron), than that of the Merensky (about 55% less than 75 micron). During concentration recoveries range from 80 to 87 %;
- Gravity Separation – Gravity concentrates are extracted prior to sulphides separation;
- Flotation Concentration – Gangue is separated from the PGM sulphides;
- Concentrates Drying – This process, for smelter preparation, is conducted by spray or flash drying to reduce energy consumption and smelter blowbacks or explosions in the furnace;
- Smelting – At temperatures ranging from 1350°C – 1600°C, to further reduce the gangue content from sulphide materials forming a matte. Gangue is disregarded in the slag, however the slag is reprocessed and matte droplets are recovered;
- Converting – Air is blown through the molten matte for several hours to oxidise the iron and sulphur constituents. The reaction is exothermic and the process is controlled and cooled to 1250°C. Some valuable minerals such as cobalt and nickel may be lost in this oxidation

process. It was not unusual to reprocess slag and up to 30% of the matte is reintroduce into the converting process to obtain an optimal product; and

- Refining – Converted matte is either cast and crushed or granulated prior to refining. Crushed or granulated material is milled and chemically treated to remove base metals. The residue is then further processed at a precious metals refinery to produce pure precious metals (Jones, 2000).

Each concentration step in the process further improves the value of the product: Ore 0.0005% (5g/t), Flotation concentrates 0.0150% (100-400g/t), Converter matte 0.2%, PGM concentrate 30-65% and refined metals 99.90 – 99.95% purity (Jones, 2000). Jones (2000) estimates the cost structure of a South African PGM operation at: mining 72%, concentrating 10%, smelting 9% and refining 9%.

Figure 5.3, indicates the secondary production process, which occurs in the form of recycling of end-of-life products as well as reprocessing residue from the primary process.

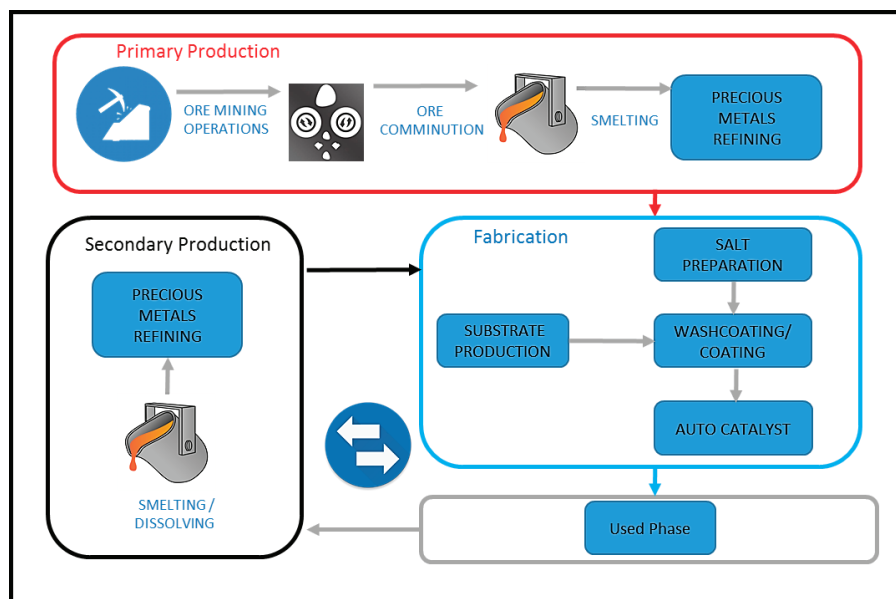


Figure 5.3: PGM Secondary Production Process (Adapted from IPA, 2013).

The aim of the following section is to explore the 2016 PGM supply characteristics and to determine South Africa’s position of dominance in the global supply market. This relates to the comparative advantage statements used in previous chapters. Further to these findings this section explores the actual source of these PGMs and the health of the PGM industry in South Africa.

5.4 PGM Supply

If primary supply is economically affected by depressed commodity prices, then there is limited scope for discounted or transfer pricing for downstream beneficiation. In addition, the appetite for PGMs producers to support such an initiative will diminish as survival in the industry becomes a primary concern. A selected sample of South African producers was analysed to understand the effect of the current depressed commodity pricing and the present cost of production. Below are several graphical representations of 2016's production of the three main commercial PGMs. The primary purpose was to determine South Africa's position in the global supply chain. Figure 5.4, shows the total 2016 production of primary or co-produced source platinum pegged at 6.1 million ounces. Of this figure of just over 6 million ounces, South Africa supplied 4.4 million ounces, 72% of the global production. Russia produced 723 000 ounces, 12 %, followed by Zimbabwe at 498 000 ounces which was 8% of world production. Canada and the United States of America produced 338 000 ounces, 5% and the rest of the world produced 3%.

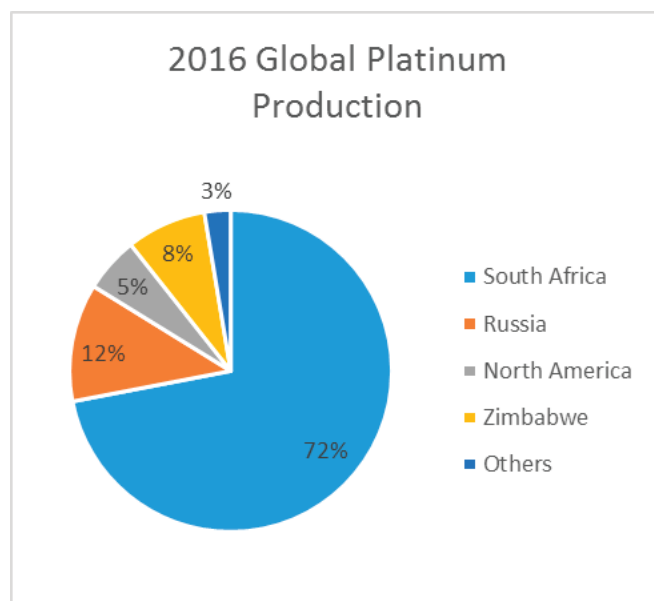


Figure 5.4: 2016 Global Platinum Supply Primary Source or Co-produced (Adapted from Johnson Matthey, 2017a).

Figure 5.5, shows the total 2016 production of primary or co-produced source palladium pegged at 6.7 million ounces. Of this figure of just over 6.7 million ounces, South Africa supplied 2.6 million ounces, 38% of the global production. Russia produced 2.7 million ounces, 41%, followed by North America at 894 000 ounces, 13% of world production. Zimbabwe produced 392 000 ounces, 6% and the rest of the world produced 129 000 ounces or 2% (Johnson Matthey, 2017a).

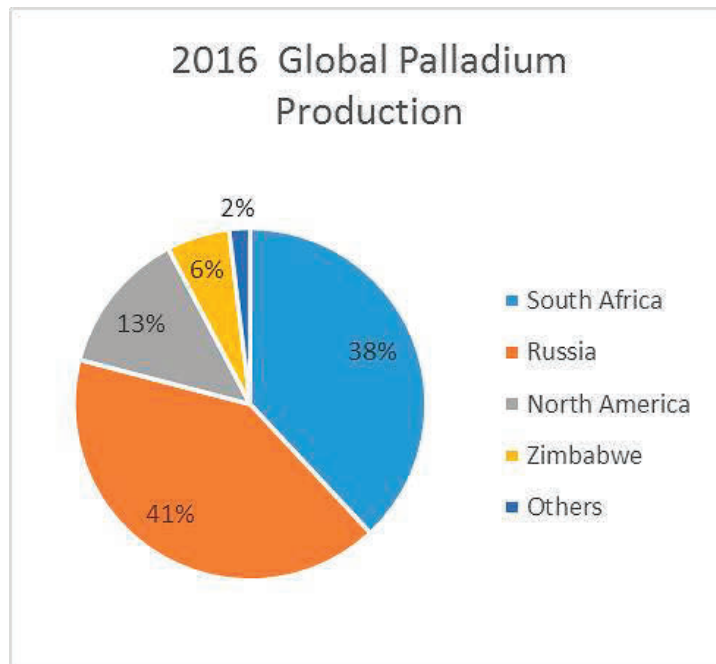


Figure 5.5: 2016 Global Palladium Supply Primary Source or Co-produced (Adapted from Johnson Matthey, 2017a).

Figure 5.6, shows the total 2016 production of primary or co-produced source rhodium pegged at 774 000 ounces. Of this figure, South Africa dominated supply at 615 000 ounces, 79% of the global production. Russia produced 85 000 ounces, 11%, followed by Zimbabwe at 43 000 ounces and 6%, of world production. North America produced 24 000 ounces 3% and the rest of the world accounted for 1% (Johnson Matthey, 2017a).

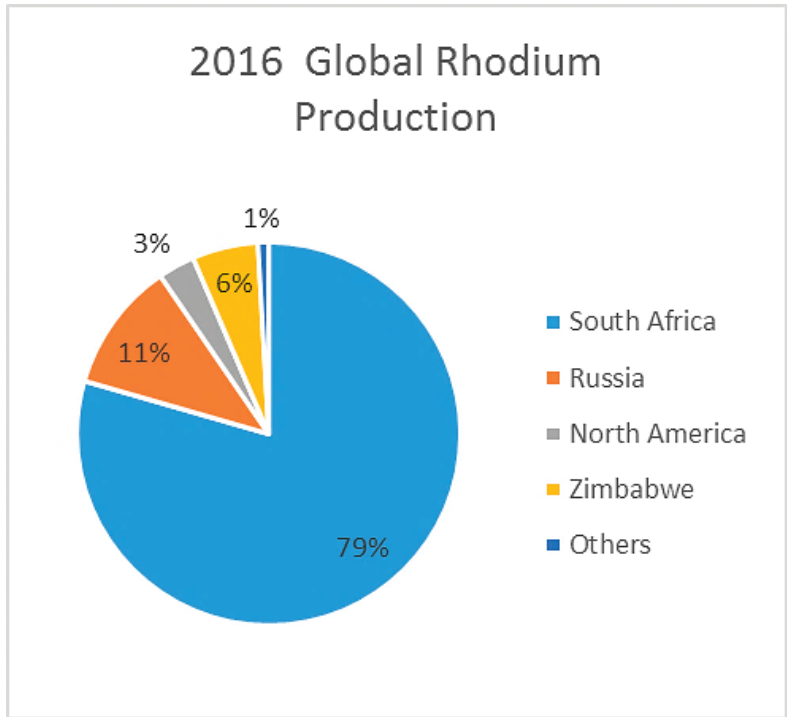


Figure 5.6: 2016 Global Rhodium Supply Primary Source or Co-produced (Adapted from Johnson Matthey, 2017a).

Figure 5.7, shows the total 2016 production of primary source or co-produced platinum, palladium and rhodium combined, pegged at 13.6 million ounces. Of this figure of just over 13.6 million ounces, South Africa supplied 7.6 million ounces, 56% of the global production. Russia produced 3.5 million ounces, 26 %, followed by North America at 1.3 million ounces, 9% of world production. Zimbabwe produced 924 000 ounces, and accounted for 7% of global production. The rest of the world accounted for 297 000 ounces and 2% of the global production (Johnson Matthey, 2017a).

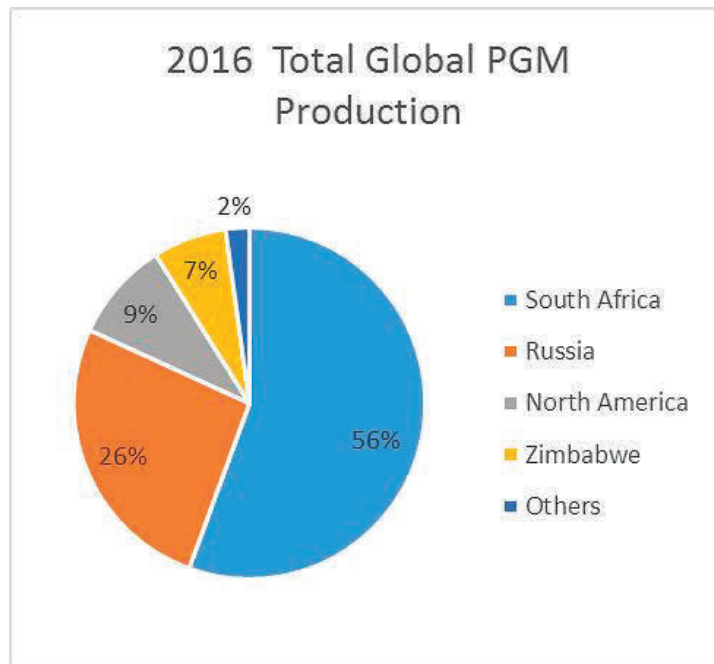


Figure 5.7: 2016 Global PGM Combined Supply Primary Source or Co-produced (Adapted from Johnson Matthey, 2017a).

The primary or co-produced production output is dominated by South Africa both in platinum and rhodium production at 72% and 79% respectively. Russian primary production of palladium only just outweighed that of South Africa at 41% and 38% respectively. On a global combined PGM primary or co-produced production, South Africa accounted for 56% of world's production followed by Russia at 26%. The rest of the world's primary production rate for 2016 made up the balance. In comparative nature, South Africa dominates the PGM global supply (Johnson Matthey, 2017a).

South Africa's PGM production comes from open pit and underground mining operations as well as some retreatment plants. Some primary producers have both open pit and underground operations, although this is not common. The following section is based on SNL Data Base, (2017) information relating to South Africa and the costs involved with the supply of PGMs. The cost information was aggregated for the year and cut off at 31st December 2016.

The premise of the exercise was to understand the health of South Africa's PGM mining industry in 2016. Beneficiation demands such as preferential pricing, transfer pricing, export levies and guaranteed supply can only occur if the industry is productive and sustainable. In a stressed environment, survival of the operations may out-weigh the appetite to support local downstream manufacture.

Figure 5.8 is a cost curve for the major South African PGMs mining companies showing the 2016 average producer costs for platinum. The average market price for platinum in 2016, according to SNL Data Base, (2017), was USD 985/Oz. The graph displays, the total-cash-cost in USD/Oz, to produce platinum in 2016. The graph indicates that the total-cash-cost for most producers had almost met the average platinum price for 2016. African Rainbow Metals Ltd performed the best with a total-cash-cost of USD 710/Oz. Royal Bafokeng Platinum Ltd attained a total-cash-cost of USD 743/Oz. Anglo American Platinum Ltd attained a cost of USD 803/Oz. The rest, Incwala Resources, Lonmin Plc, Sibanye Gold Ltd, Northam Platinum Ltd and Impala Platinum Holdings Ltd range from USD 922–982/Oz. (Sibanye gold was renamed Sibanye Stillwater). (Through equity stakes, Incwala Resources and Lonmin Plc are one and the same in this data base information). The original, total-cash-cost USD/Oz, cost curve for 2016 South African platinum production, is available in Appendix A.

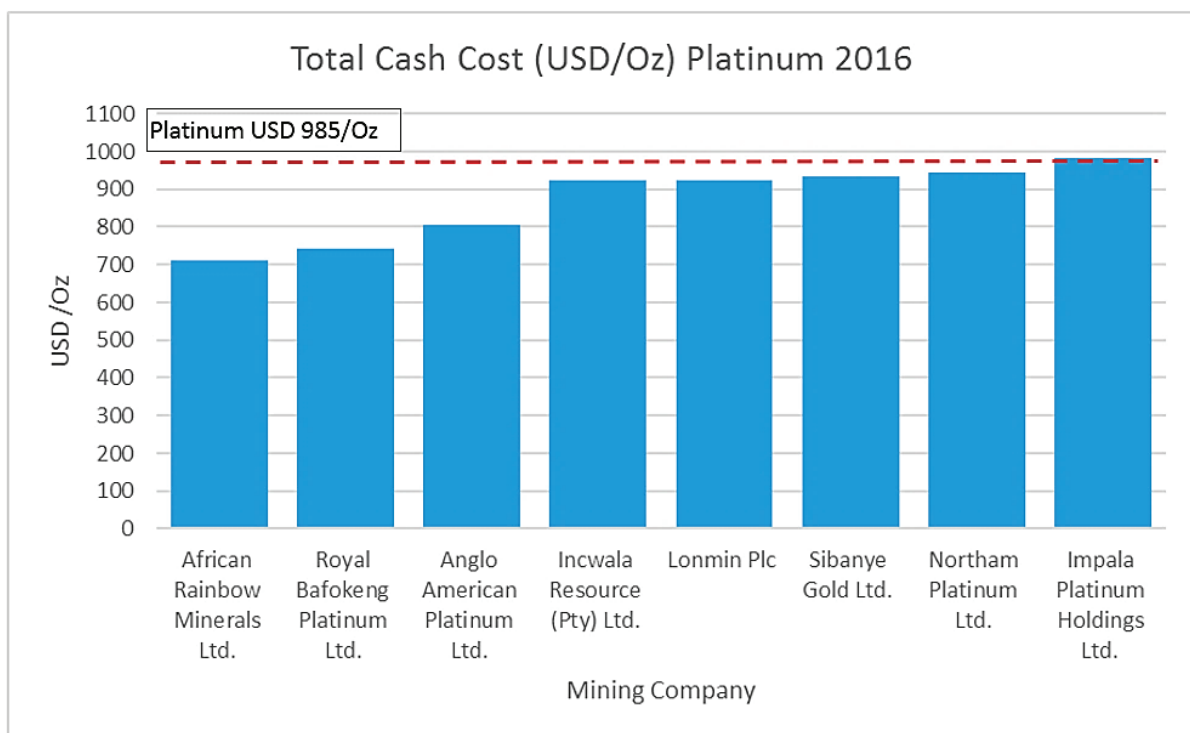


Figure 5.8: Platinum 2016 Cash Cost per Oz for Major Extractors (Adapted from SNL Data Base, 2017).

Considering that most of the world’s platinum, (72%) in 2016, was extracted from these operations, the prosperity of the platinum industry in South Africa is truly in distress. The total-cash-cost is the price paid to extract and process the metal, all-in-sustaining costs or all-in-cost would put the price of production well above the average selling price of USD 985/Oz. Under these conditions most of the platinum operations are not sustainable. “Chamber of Mines CEO Roger Baxter wrote in the Chamber’s most recent quarterly update that several parts of the mining industry are continuing to

struggle with the effects of weak commodity prices on revenues and profits. For example, about 60% of the platinum sector remains loss-making with the attendant danger that unprofitable and labour-intensive mines might face closure” (Peyper, 2017, p. 1).

Figure 5.9 is a cost curve for the major South African PGM mining companies showing the 2016 average producer costs for palladium. The average market price for palladium in 2016, according to SNL Data Base, (2017), was USD 612/Oz. The graph displays the total-cash-cost in USD/Oz, to produce palladium, in 2016. Anglo American Platinum Ltd had the lowest total-cash-cost at USD 462/Oz followed by Royal Bafokeng Platinum Ltd and African Rainbow Minerals Ltd at USD 469 and 491/Oz respectively. Incwala Resources (Pty) Ltd, Lonmin Plc, Northam Platinum Ltd, Sibanye Gold Ltd and Impala Platinum Holdings ranged from USD 575 to 602/Oz. Impala Platinum holding was, again, just below the 2016 average price. The original, total-cash-cost USD/Oz, cost curve for 2016 South African palladium production, is available in Appendix B. Although, palladium is mined along with platinum there is no real respite for extractors through palladium sales. South Africa produced 38% of the world palladium in 2016.

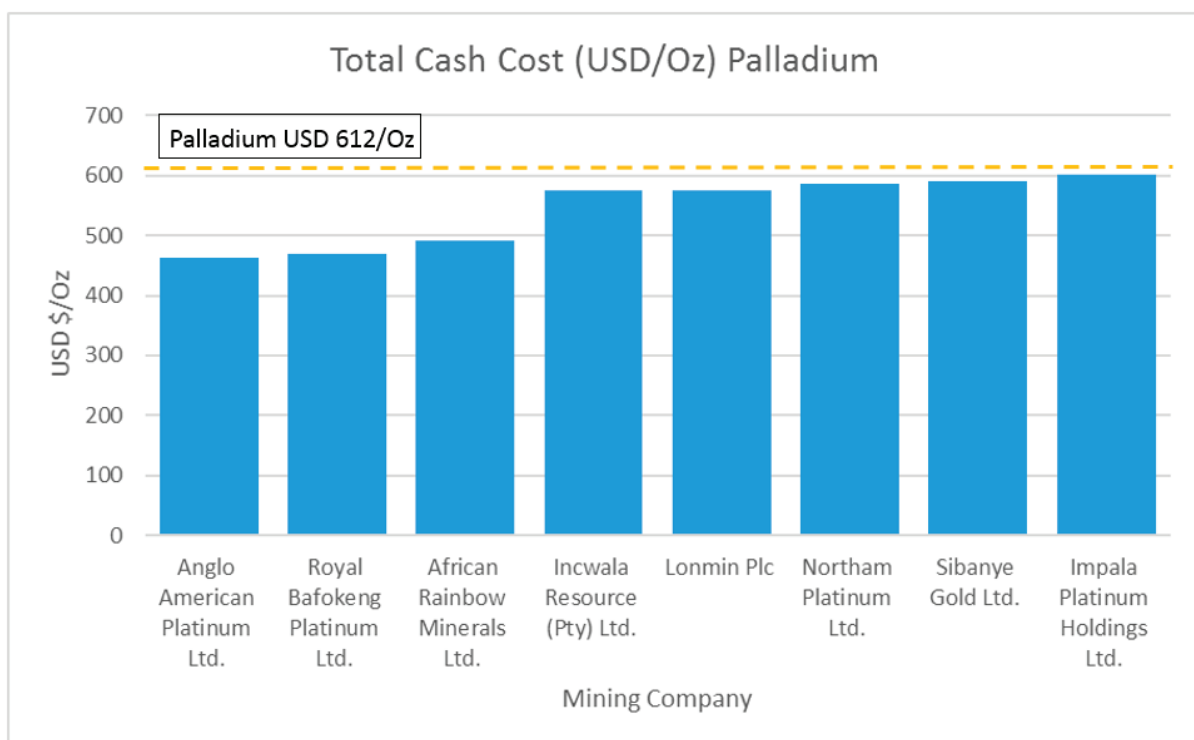


Figure 5.9: Palladium 2016 Cash Cost per Oz for Major Extractors (Adapted from SNL Data Base, 2017).

Figure 5.10 is a cost curve for the major South African PGMs mining companies showing the 2016 average producer costs for rhodium. The average market price for rhodium in 2016, according to SNL Data Base (2017), was USD 624/Oz. The graph displays the total-cash-cost in USD/Oz, to produce

rhodium, in 2016. African Rainbow Minerals Ltd had a total-cash-cost in 2016, of USD 501/Oz, followed by Anglo American Platinum Ltd at USD 608/Oz. All the rest of the company's total-cash-costs exceeded the average selling price of rhodium in 2016. The original, total-cash-cost USD/Oz, cost curve for 2016 South African rhodium production, is available in Appendix C. Considering that South Africa, in 2016, produced 79% of the world's rhodium, the low metal price would have eroded some of the PGMs extractors' profits.

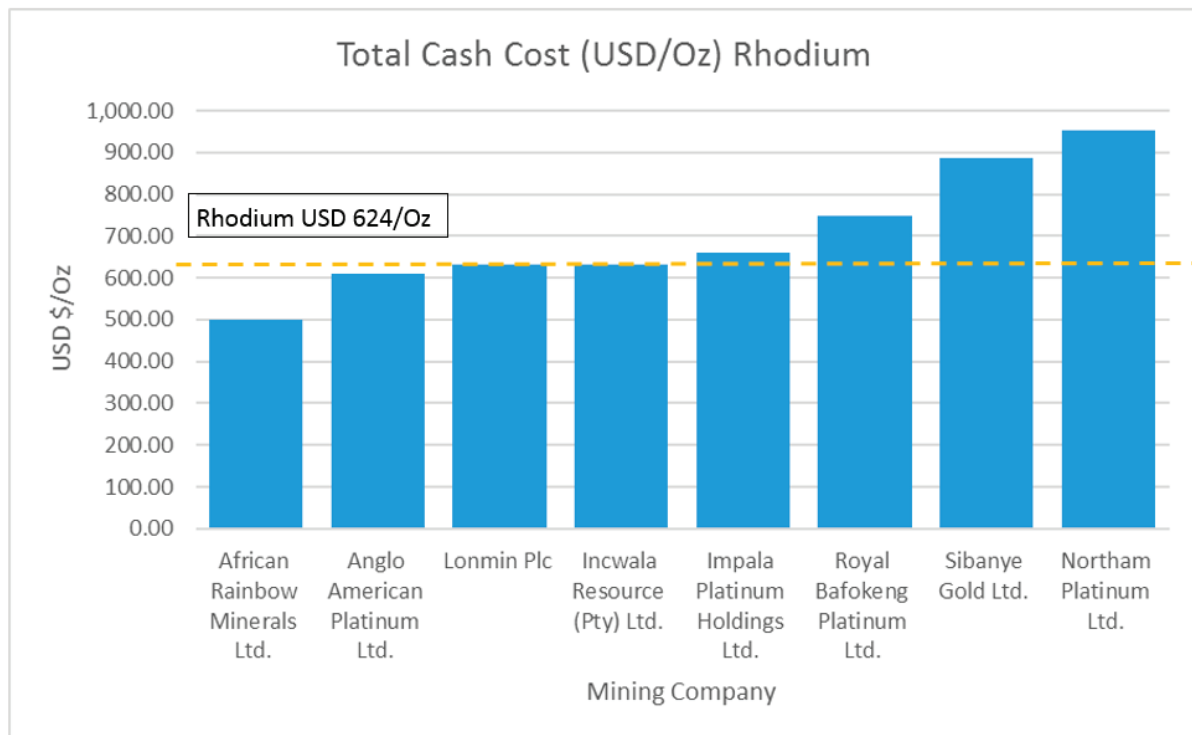


Figure 5.10: Rhodium 2016 Cash Cost per Oz for Major Extractors (Adapted from SNL Data Base, 2017).

Overall, apart from African Rainbow Minerals Ltd and Anglo American Platinum Ltd, the sustainability of the PGM industry is in a dire position. If the unit cost of production continues to rise and the pricing of PGMs remains, as it was in 2016, some of these large producers will not have the liquidity to continue to function and operations will close.

One of the costs mentioned earlier in Chapter 4, is the labour cost associated with the mining of PGMs in South Africa as it is a labour-intensive extraction process. The most significant mine site cost was the cost of mining labour at an average of USD 46/tonne. This was extracted for the underground operations and graphically is represented in Figure 5.11. Figure 5.11, indicates the average mine labour cost in 2016 was 78% of the total cost of mining (SNL Data Base, 2017).

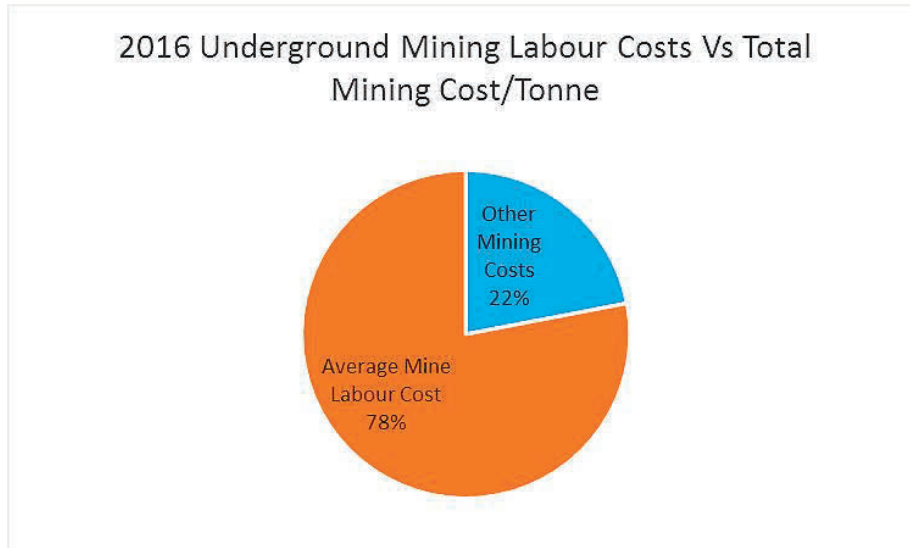


Figure 5.11: 2016 Average Underground Mining Labour Cost Vs Total Mining Cost/Tonne (Adapted from SNL Data Base, 2017).

Figure 5.12, indicates the average underground mining labour cost/tonne versus the total mine site costs, inclusive of processing costs, 67% of the total mine site costs are adsorbed by mining labour costs. The single most expensive line item, in 2016, for South African underground PGM extraction, was the labour complement required for extraction (SNL Data Base, 2017).

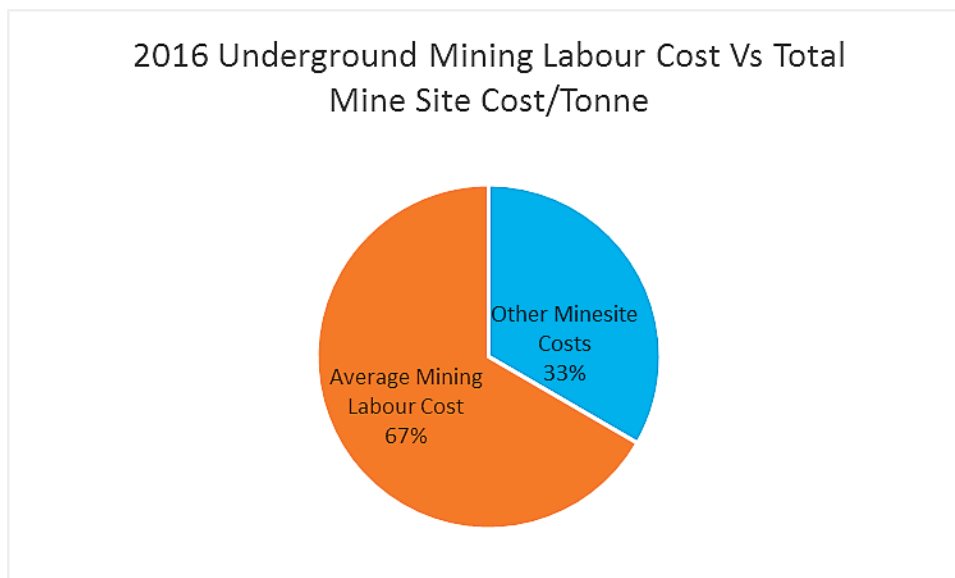


Figure 5.12: 2016 Average Underground Mining Labour Cost Vs Total Mine Site Cost/Tonne (Adapted from SNL Data Base, 2017).

Caution should be applied with data base information and even with such an upstanding entity such as the SNL Data Base as, aggregated company annual report information is subject to the interpretation of the analyst. For this reason, a spread of mining operations was used to deduce the 2016 state of the South African PGM industry. Rather than precise quantification, qualitative recognition should be applied to the data base outputs.

5.5 Source of Supply of PGMs

The following section and tables refer to primary source production on a global basis. These mines or mining companies (44 in total), are divided per the country of origin. The table is further sub-divided into the property name and the primary commodity mined. The primary commodity columns, within the tables, consider both primary source, as those operations that primarily target PGMs and those where co-production is prevalent. The PGMs production figures are then further subdivided into platinum, palladium and rhodium production. Finally, the PGMs production was combined, totalled and a world ranking applied purely on aggregated PGM production. This information was adopted from the SNL Data Base, (2017), who in turn, compiled the information from 2016 company reports. China's figures were regarded as incomplete, as insufficient data was available. The table aggregates underground, open pit and reclamation operations and no differentiation is considered.

Table 5.1, indicates 26 South African mines and that these operations form the bulk of the world's supply of platinum and rhodium. The world ranking has Impala as the 3rd largest global supplier to Smokey Hills as the 43rd largest global supplier. The largest, Impala, produced just under 1 000 000 Oz of combined PGMs and was indicated as 2016's highest producer of platinum (SNL Data Base, 2017).

Table 5.1: South African PGM Production 2016 (Adapted from SNL Data Base, 2017).

Property Name	Primary Commodity	Country Name	Platinum Production - Oz	Palladium Production - Oz	Rhodium Production - Oz	Combined Pt, Pd,Rh	PGM Combined world ranking
Impala	Platinum	South Africa	619700	292900	78800	991400	3
Marikana	Platinum	South Africa	618403	285041	87715	991159	4
Mogalakwena	Platinum	South Africa	401100	425900	28000	855000	5
Amandelbult Section	Platinum	South Africa	456500	200600	72000	729100	6
Rustenburg	Platinum	South Africa	381866	205157	55495	642518	7
Kroondal	Platinum	South Africa	276223	144864	51876	472963	9
Two Rivers	Platinum	South Africa	190800	113500	33600	337900	11
Bafokeng-Rasimone	Platinum	South Africa	196000	82800	17900	296700	13
Zondereinde	Platinum	South Africa	163679	79058	26010	268747	14
Modikwa	Platinum	South Africa	113300	107300	22700	243300	15
Union Section	Platinum	South Africa	147500	65200	25800	238500	16
Mototolo	Platinum	South Africa	116200	68800	19500	204500	19
Booyendal North	Platinum	South Africa	113138	54399	18615	186152	20
Marula	Platinum	South Africa	79000	81100	16500	176600	22
Pilanesberg	Platinum	South Africa	97744	45614	16291	159649	23
Bokoni	Platinum	South Africa	77372	54337	8000	139709	25
Tharisa	Platinum	South Africa	81000	23441	13579	118020	28
Nkomati	Nickel	South Africa	31579	84211	1128	116918	29
Western Limb Tailings	Platinum	South Africa	63827	21348	3399	88574	30
Sylvania Dump Operations	Platinum	South Africa	41035	15771	9863	66669	32
Pandora	Platinum	South Africa	31700	14884	5227	51811	34
Platinum Mile	Platinum	South Africa	8951	5693	1637	16281	37
Maseve	Platinum	South Africa	9942	2684	107	12733	39
Phoenix	Platinum	South Africa	4774	2273	1347	8394	40
Twickenham	Platinum	South Africa	3000	3200	700	6900	42
Smokey Hills	Platinum	South Africa	1517	1551	345	3413	43

Table 5.2 is Russian production and has Norilsk's Polar division as a co-producer and produces PGMs in conjunction with Nickel. The data indicates that this mine, in 2016, was the world's largest PGM producer. The world ranking indicated that the Polar Division produced just over 2.22 million Oz in combination with the largest palladium production at just over 1.7 million Oz. The Norilsk Kola division produced 815 000 Oz of palladium, the second largest palladium producer and ranked as the second largest, combined, PGM producer (SNL Data Base, 2017).

Table 5.2: Russian Production of PGMs 2016 (Adapted from SNL Data Base, 2017).

Property Name	Primary Commodity	Country Name	Platinum Production - Oz	Palladium Production - Oz	Rhodium Production - Oz	Combined Pt, Pd,Rh	PGM Combined world ranking
Polar Division	Nickel	Russia	451000	1711000	62639	2224639	1
Kola Division	Nickel	Russia	161000	815000	22361	998361	2
Conder	Platinum	Russia	49049			49049	35
Koryakgeoldobycha	Platinum	Russia	8000			8000	41
West Kytlim	Platinum	Russia	363			363	44

Table 5.3 shows Zimbabwean PGM production culminating from three major operations ranked from 8th to 26th, the most prevalent was Zimplats who produced just under 300 000 Oz of platinum and just under 250 000 Oz of palladium (SNL Data Base, 2017).

Table 5.3: Zimbabwean Production of PGMs 2016 (Adapted from SNL Data Base, 2017).

Property Name	Primary Commodity	Country Name	Platinum Production - Oz	Palladium Production - Oz	Rhodium Production - Oz	Combined Pt, Pd,Rh	PGM Combined world ranking
Zimplats	Platinum	Zimbabwe	295892	241560	26004	563456	8
Mimosa	Platinum	Zimbabwe	120600	95700	10100	226400	17
Unki	Platinum	Zimbabwe	71700	56500	6600	134800	26

Table 5.4 shows Canada's PGM production for 2016. Canada's production was dominated by co-producers, with 4 producers ranked from 10th to 27th in global production, along with a strong supply of palladium (SNL Data Base, 2017).

Table 5.4: Canadian Production of PGMs 2016 (Adapted from SNL Data Base, 2017).

Property Name	Primary Commodity	Country Name	Platinum Production - Oz	Palladium Production - Oz	Rhodium Production - Oz	Combined Pt, Pd,Rh	PGM Combined world ranking
Ontario Division	Nickel	Canada	169181	238462	9965	417608	10
Lac des Iles	Palladium	Canada	11367	165263		176630	21
Sudbury Operations	Nickel	Canada	58460	87212	3565	149237	24
Raglan	Nickel	Canada	36363	94793	3009	134165	27

Table 5.5 shows USA's PGM production for 2016. The USA has three producers with the main supply coming from Stillwater, the country's mines ranked from 12th to 36th with a strong supply of palladium (SNL Data Base, 2017).

Table 5.5: United States of America Production of PGMs 2016 (Adapted from SNL Data Base, 2017).

Property Name	Primary Commodity	Country Name	Platinum Production - Oz	Palladium Production - Oz	Rhodium Production - Oz	Combined Pt, Pd,Rh	PGM Combined world ranking
Stillwater	Palladium	USA	76500	250500	2042	329042	12
East Boulder	Palladium	USA	48600	169700	1259	219559	18
Eagle	Nickel	USA	9860	6854		16714	36

The rest of the producers mentioned in Table 5.6, are from Botswana, China and Finland and are not major suppliers. These countries are ranked from 31st to 38th in the global ranking. Although mentioned previously in this section, figures from Chinese PGM production could not be validated.

Table 5.6: Rest of the World's Production of PGMs 2016 (Adapted from SNL Data Base, 2017).

Property Name	Primary Commodity	Country Name	Platinum Production - Oz	Palladium Production - Oz	Rhodium Production - Oz	Combined Pt, Pd,Rh	PGM Combined world ranking
Jinchuan	Nickel	China	64302	18000	4000	86302	31
Kevitsa	Nickel	Finland	37109	24700		61809	33
Phoenix	Nickel	Botswana	4000	10000		14000	38

Two other sources of PGMs occur that affect the international markets. These occur in the form of recycled end-of-life products and above ground stocks.

Figure 5.13 indicates that the production of recycled PGMs, re-entering the market was categorised by Johnson Matthey (2017a), in 2016, as:

- Recycled platinum stock at 1.92 million Oz or 24% of global supply;
- Recycled palladium stock at 2,5 million Oz or 27% of global supply; and
- Recycled rhodium stock at 0.3 million Oz or 26% of global supply.

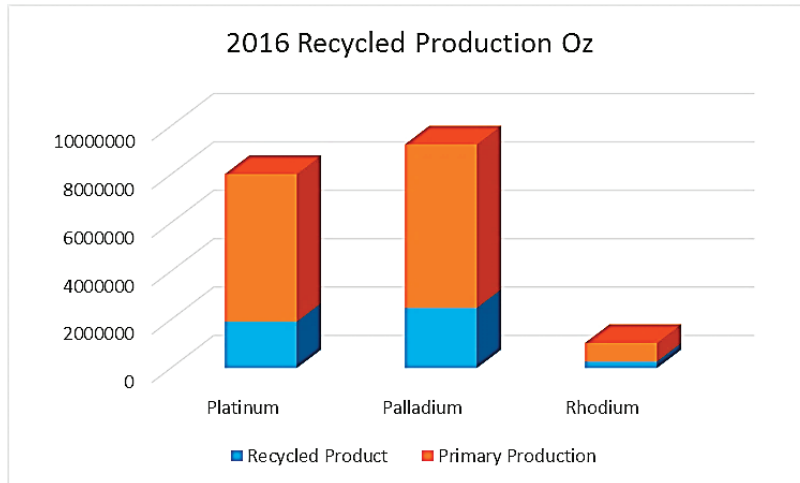


Figure 5.13: Recycled PGM Global Production 2016 (Adapted from Johnson Matthey, 2017a).

Above ground stocks consisted of PGMs held in investment portfolios that are traded on a speculative or strategic basis. According to the World Platinum Council, above ground stock at the end of 2015 was 2.4 million ounces and EFT platinum holding was at 2.5 million ounces. Both recycling and above ground stocks have a significant influence on commodity trading (PwC, 2016).

5.6 Forecast for Supply for PGMs

Figure 5.14 is the forecasted supply of PGMs to world markets and will remain mostly flat into 2017 and anticipated global supply of platinum at 6.0 million Oz, palladium at 6.6 million Oz and rhodium at 754 000 Oz (Johnson Matthey, 2017a).

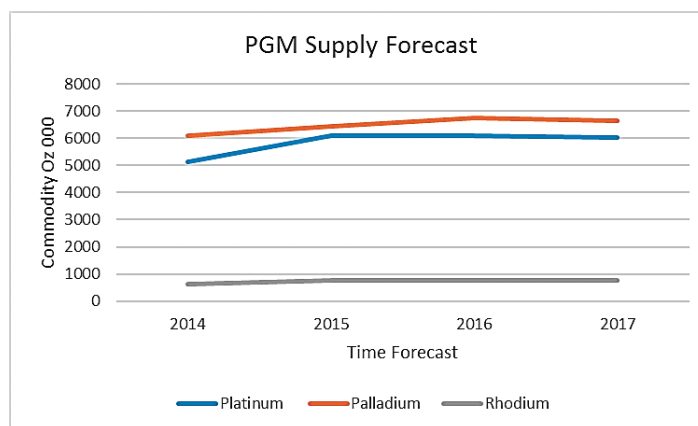


Figure 5.14: PGM Supply Forecast 2017 (Adapted from Johnson Matthey, 2017a).

Figure 5.15 estimated a slight rise in platinum pricing from 2016 at USD 985/Oz to a maximum of USD 1064/Oz in 2018 and a fall to USD 1035/Oz in 2019. Palladium was expected to rise from 2016, at USD 612/Oz to USD 873 in 2019. Rhodium was expected to rise from 2016, at USD 648 in 2016, to match the platinum price in 2019 at USD 1025/Oz.

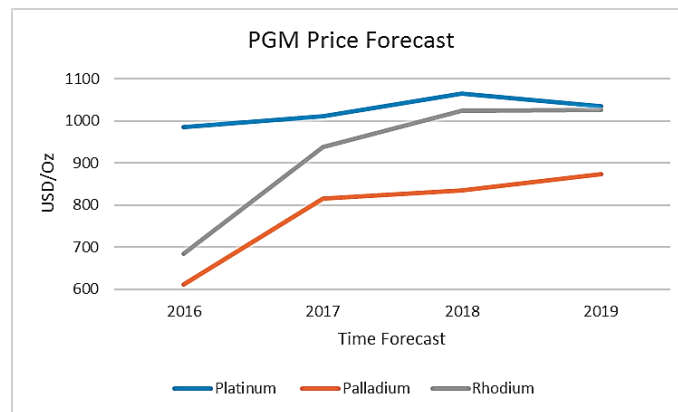


Figure 5.15: PGM Price Forecast for 2017 (Adapted from SNL Data Base, 2017).

5.7 PGM Demand

PGMs demand is driven by distinct markets, which separate PGMs from other precious metals by their physical and chemical properties. These markets include auto catalysts, jewellery, industrial applications and investment. As noted, earlier in this chapter, a significant proportion of primary supply was concentrated in South Africa and the largest portion of demand was driven by emission controls and clean air policies that are beyond the borders of South Africa (Johnson Matthey, 2017a).

The primary supply of PGMs, in 2016, was dominated by South Africa in the form of platinum and rhodium and to a lesser extent palladium. Demand for PGMs, in South Africa is not matched in equal significance to the supply capability.

5.7.1 Auto Catalysts

The climatic change agenda is an unavoidable public policy, driven mainly by clean air emission control legislation for automobiles and stationary engines (Montmasson-Clair, 2016). These stringent controls on vehicle emissions has sustained the demand of the three major PGMs; platinum, palladium and rhodium (Montmasson-Clair, 2016). Europe, North America, Japan and China are geographical regions that lead the demand for PGMs through these emission control regulations. Further progressive

emission control regulations in China and India could advance the demand for PGMs (Montmasson-Clair, 2016).

The driver behind the global auto catalyst market was progressively tightening emission control regulations and the growth of vehicle sales (PwC, 2016). When confronted with the global economic crisis, vehicle sales stagnated or dropped, so the demand for auto catalysts dropped substantially, affecting demand (Lonmin, 2017).

As the global population is set to increase, there could be an expected increase in the demand for motor vehicles. Apart from electric cars, almost all vehicles are fitted with auto catalysts and the demand for PGMs would be expected to rise proportionately (IDC, 2013). This relationship is not directly proportional, as thrifting (using less metal, in typically thinner coatings, to achieve the same effect), recycling and PGM substitution affect the primary source demand (Perrott-Humphrey, 2006). Platinum may also, to some extent be substituted, within the realm of the PGMs, by the cheaper PGMs such as palladium and rhodium (PwC, 2016).

5.7.2 Jewellery

The physical properties of PGMs make the metals very suitable for jewellery manufacture. PGMs do not oxidise, fade or tarnish and they exhibit non-allergenic properties which makes them an ideal material to produce jewellery (Impala Platinum, 2017). When alloyed, certain physical property changes occur. When alloyed with iridium, brilliance is enhanced. When platinum and palladium are alloyed, the blend of metals has an improved softness and ductility which is beneficial for chain making. When platinum is alloyed with ruthenium the machinability of the metal is enhanced and high volume production can occur (Impala Platinum, 2017). The Chinese jewellery market is the largest since taking over from Japan in 2000 (Perrott-Humphrey, 2006). Jewellery demand was dominated by China and in 2011. China made up almost three quarters of the global demand (Lonmin, 2017). Much of the Chinese demand hinged on the liquidity of the middle-income consumer. Difficult trading conditions, fewer wedding registrations and lower stocking quantities have impacted the market (Lonmin, 2017).

The jewellery market is complex and follows short term trends which are difficult to grasp. Demand was affected by manufacturing metal offtake and final consumer offtake. In times of price volatility, margins were eroded (Perrott-Humphrey, 2006). As a fashion product, short term trends affect offtake, one such example is the return of gold jewellery as the preferable choice by consumers (IDC,

2013). China, Japan, North America and Europe are the main consumers of PGM jewellery, although current markets are shrinking or flat. China and India are stated as having the best growth prospect (IDC, 2013).

5.7.3 Industry

The largest consumer of PGMs in the chemical industry was platinum-based catalysts especially for the manufacture of nitric acid used in the production of nitrogen fertiliser. The electronics industry was a major user of palladium for coatings in multi-layer ceramic capacitors and connectors in hybrid integrated circuits. These are used in mobile phones, computers, electronic lighting and high voltage circuits. Magnetic platinum-cobalt alloys are used in computer hard disks, enabling increased storage capacity. Extreme high temperature crucibles use alloys of platinum and palladium with exceptional hardness and durability. The petroleum industry uses platinum catalysts to upgrade octane levels in gasoline and palladium in the hydro fracking process (Impala Platinum, 2017). PGMs are also used in high specification glass and LCD screen manufacture as well as in the fiberglass production industry (Perrott-Humphrey, 2006). PGMs are used in the medical and dental industry, where crowns, inlays and bridges are comprised of PGMs alloyed with gold and silver (Impala Platinum, 2017).

5.7.4 Investment

In the past, PGM investment was sparked by the growth of China where demand for metals drove prices upward. The increased presence of financial players in the metal markets, combined with strong global GDP allowed for sustainable growth. Traditional supply and demand equations were impacted when financial buyers liquidated inventories. This could be accredited by fund flows directly into commodities from the financial markets (Perrott-Humphrey, 2006). These flows came not only from short term hedge fund players but also from fixed percentage fund assets which were allocated long term so-called “alternative investments” (Perrott-Humphrey, 2006). Investment demand was in the form of platinum bars and physically-backed exchange traded funds (ETFs).

Tight supply of PGMs fuelled investment demand (IDC, 2013). Contributing factors, mainly global economic concerns, slowed the demand. These worrying factors saw the re-emergence of gold as the precious metal of choice and became the investors safe-haven. PGM investment portfolios still play a

major role in the supply and demand characteristics where above ground stocks substitute primary production opportunities (Johnson Matthey, 2017a).

5.8 Summary of Demand for PGMs 2016

The demand for PGM in 2016 was, for the purpose of this report, divided into two sections. Firstly, the total global demand for platinum, palladium and rhodium was analysed by demand sector and secondly, by the geographical destination for the demand. Primarily, the demand breakdown was to establish the major users of PGMs and secondly to determine where, geographically, they are consumed. Viable local downstream manufactures of PGM related goods would require the knowledge of the downstream market demand.

From Table 5.7, four major off-take channels have been established. These are the auto catalyst industry, the jewellery industry, industrial usage and investment. “Other” denotes lesser insignificant markets. Industrial usage covers a host of purposes, some of which were mentioned earlier in this chapter and included chemical industry catalytic converters. The enormity of the auto catalyst market allowed for this sector to be separated from industrial use. Jewellery and investment market sectors are differentiated enough to have clear boundaries (Johnson Matthey, 2017a).

Table 5.7: 2016 Market Demand for Platinum, Palladium and Rhodium (Adapted from Johnson Matthey, 2017a).

2016	Platinum Oz -000	Palladium Oz- 000	Rhodium Oz - 000	Total Combined PGM Demand
Auto Catalyst	3,318	7,935	795	12,048
Jewellery	2,446	189		2,635
Industrial	1,382	1,791	155	3,228
Investment	620	(646)		(26)
Other	461	147	40	648
Total Demand	8,227	9,416	990	18,633

Figure 5.16, indicates the metal demand per sector, the auto catalyst sector’s demand adsorbed most PGM supply. The most prominent metal consumed was palladium, in the auto catalyst industry at, 7.9 million ounces, followed by platinum at 3.3 million ounces. The auto catalytic sector also consumed most of the world’s rhodium production in 2016. Figure 5.16 placed the auto catalyst rhodium demand

at 80% of total demand. Jewellery was dominated by platinum at just under 2.5 million ounces. Investments show negative result for palladium and this indicates that funds are purchasing palladium (Johnson Matthey, 2017a). This is in line with Figure 5.15, where the price is expected to rise over the next few years.

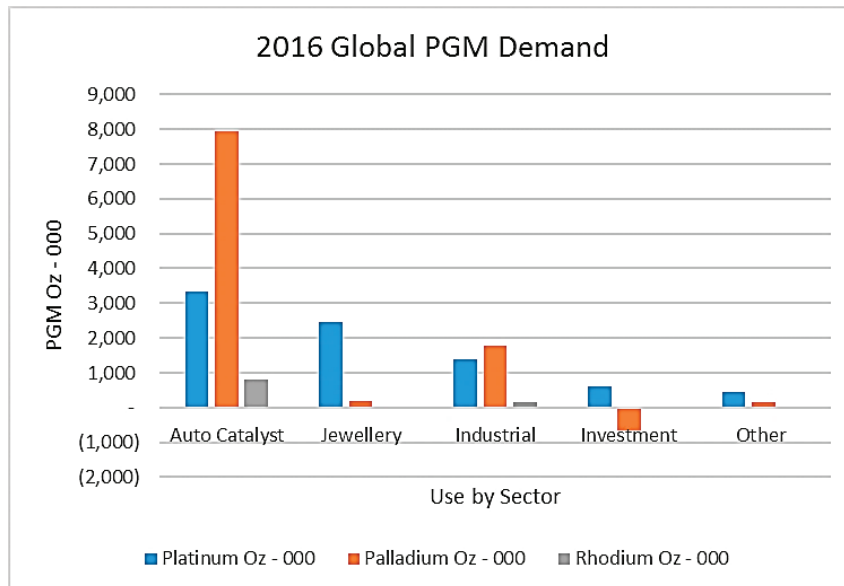


Figure 5.16: 2016 Global PGM Demand by Sector of Use (Adapted from Johnson Matthey, 2017a).

Figure 5.17, indicates the total demand per sector, with the aggregated stacked metal demand. At just over 12 million ounces, the auto catalytic sector is at the forefront of the demand criteria at 65% of the PGM consumption for 2016. This is followed by industrial usage at 18% and jewellery at 14.1% (Johnson Matthey, 2017a).

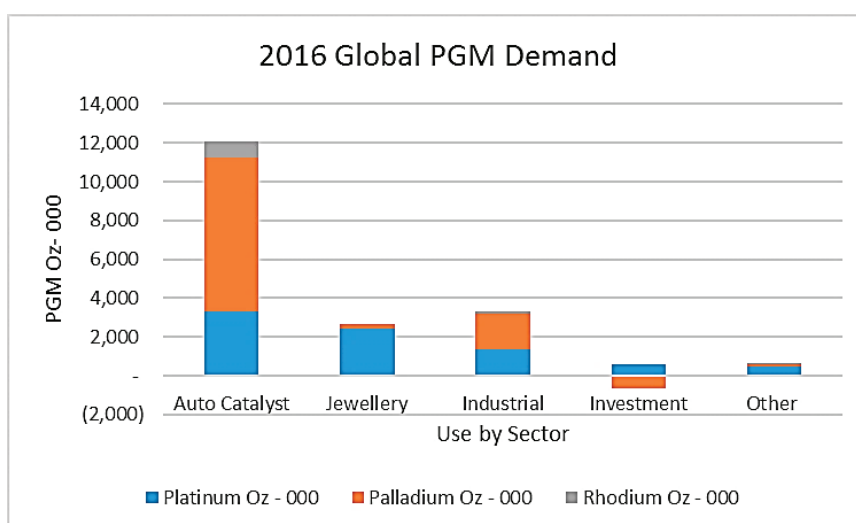


Figure 5.17: 2016 Stacked PGM Demand Sector (Adapted from Johnson Matthey, 2017a).

Geographical market volumes indicated where the consumption of PGMs occurred during 2016. The consumption of these metals, by region, are indicated in Figure 5.18 and Figure 5.19 being platinum and palladium respectively. Data on the lesser PGM, rhodium, was not available.

Figure 5.18 indicates that Europe’s auto catalyst demand for platinum in 2016, surmounted other global locations and equated to 54% of the demand in this sector. Japan and North America’s demand was 12% and 13% respectively and China equated to 5% of the platinum auto catalytic demand (Johnson Matthey, 2017a).

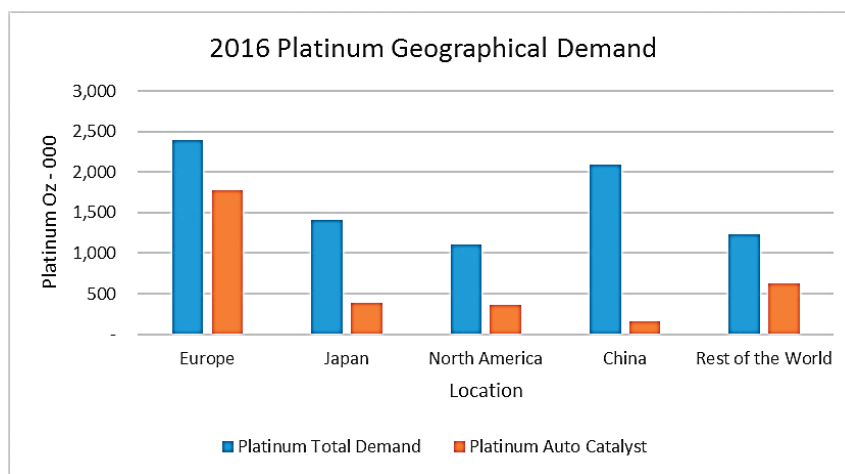


Figure 5.18: 2016 Platinum Geographical Demand (Adapted from Johnson Matthey, 2017a).

Figure 5.19, indicates global palladium geographical demand with China having the greatest demand at 26% closely followed by North America at 25%, Europe at 18%, the rest of the world at 18% and Japan at 14%. The auto catalyst demand for palladium is led by China at 25%, closely followed by North America, also at 25%. Europe’s demand was 20% closely followed by the rest of the world at 20% and Japans demand was 10% (Johnson Matthey, 2017a).

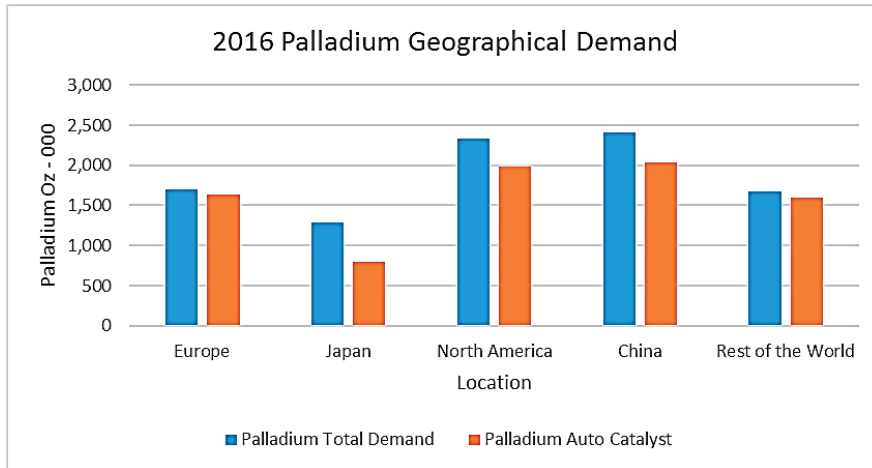


Figure 5.19: 2016 Palladium Geographical Demand (Adapted from Johnson Matthey, 2017a).

5.9 Chapter Summary

South Africa has by far, the greatest amount of operations in the global PGM supply market. In 2016, this translated into the largest portion of the PGM global supply at 56%. In addition, South Africa was, globally, the largest supplier of platinum and rhodium at 72% and 79% respectively. Russia was the largest global supplier of palladium at 41%, South Africa was a close second at 38%. South African mines are dominated, almost in entirety, by mines that specifically target PGMs. Zimbabwe and a handful of other mines also specifically target PGMs, but the trend is almost unique to Southern Africa. Russian and other mines around the world co-produce PGMs, mainly with nickel.

South Africa supplies more than half the world's PGM demand and had the largest comparative advantage. The health of the South African PGM suppliers is truly worrying. Although the research does not extend over a multi-year scenario, the grim analysis of 2016's total-cash-cost of producing PGMs in South Africa, was in numerous cases, not sustainable based on the global average price for the metals. The main contributor to this was the cost of the labour to mine the metals, for this reason, it can be expected that retrenchments will continue to plague this industry. Producer pricing power related through comparative advantage had little influence.

Prolonged, downturned commodity prices will result in mine closures through natural attrition. Little appetite, or scope exists for preferential or transfer pricing to the downstream value addition PGM industry. Under the 2016 market conditions, access to metal supply with preferential local pricing, transfer pricing or additional taxations would have dire consequences on the primary PGM suppliers in South Africa.

If the PGM extractive industry were obligated to supply PGMs with preferential local pricing, transfer pricing or additional taxations to support value addition projects, under the 2016 conditions, the net effect would cause the industry to constrict. National employment would be affected and the economy would feel the pressure. Perhaps government actions to reign in South African PGM supply may help the industry and save resources for future generations.

In 2016 most of the global PGM's supply was consumed by China, Europe, North America and Japan. By far, the highest sectorial use for PGMs are auto catalysts. Geographical demand location is, not surprisingly, related to vehicle manufacturing hubs. China's platinum jewellery demand is also significant. In relation to South Africa, global demand was dominated by a handful of, distant, foreign consumers. The catalytic converters sector drove the PGM demand. Increasing global population numbers, the need to travel and emission control regulations, forecast long-term demand for PGMs.

Chapter 6 seeks to understand the South African auto catalyst industry and how all the stakeholders are connected. The chapter introduces the types of and uses for auto catalysts and provides facts and figures about automobile and auto catalyst production. The constraints of the industry are highlighted with distance to market as an issue. Employment opportunities are explored along with incentive plans and the value chain process.

6 LOCAL BENEFICIATION INDUSTRY

6.1 Introduction

From the previous chapter, it was evident that auto catalysts dominate PGMs demand followed by the jewellery market, industrial applications and investment options. For South Africa to take advantage of the value add component of downstream PGM beneficiation, auto catalysts would be the largest market. Jewellery should not be discounted, but as mentioned in Chapter 5, complexity and short term trends contribute to uncertainty of demand. Industrial application covers a host of smaller opportunities for niche markets.

6.2 Auto Catalysts

The company Engelhard Corporation pioneered the development of the first automotive catalytic converters in 1975. A year later they introduced the Three-Way-Catalyst (TWC) which, in one form or another, is still in production today. The modern version of the TWC has the capability, in vehicle exhaust systems, to destroy over 90% of hydrocarbons (HC), carbon monoxide (CO) and nitrogen oxides (NO_x) (BASF, 2012).

Figure 6.1, illustrates the internal sections of an auto catalytic converter. Catalytic converters are, honey comb-like structures, made up internally, of a substrate of a ceramic material of metal. Externally, the substrate is usually wrapped with a stainless-steel covering. The substrate is constructed of hundreds of channels coated with platinum, palladium or rhodium. The structure allows the maximum amount of exhaust gas to be exposed to the catalyst whilst exiting the engine (Impala Platinum, 2017). The greenhouse gasses auto emission policy's around the globe dominated the rapid expansion of the industry (Dewar, 2012).

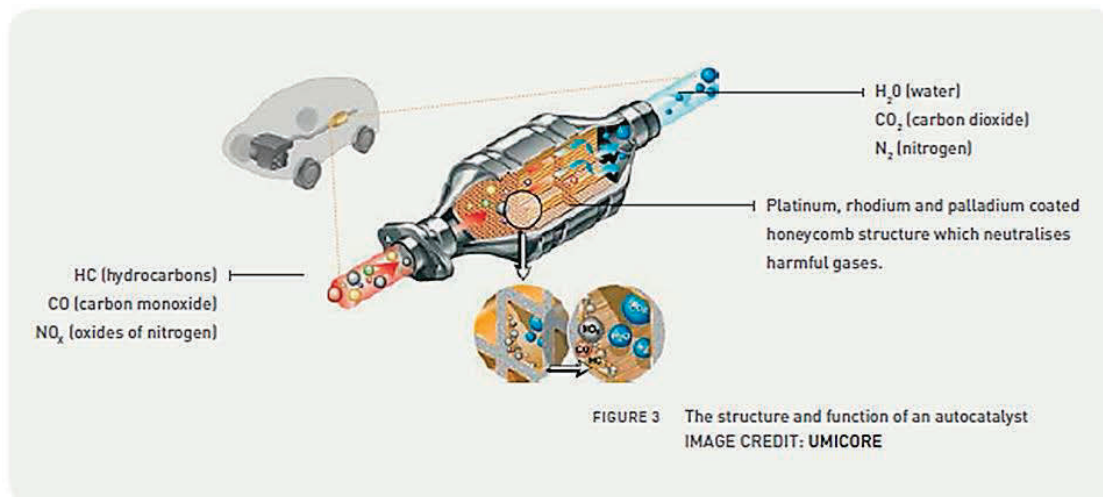


Figure 6.1: Simple Auto Catalyst Diagram (IPA, 2013).

At the request of the original equipment manufacturers (OEMs), local facilities were established in the early 1990s. Since then, the auto catalytic industry in South Africa has achieved remarkable growth. The industry was the highest contributor to component export revenue and in addition, had the highest local content (Dewar, 2012). The South African auto catalytic industry was vertically integrated and relied on over 50 manufacturing plants (NAACAM, 2017).

The average diesel catalytic converter system consists of a 7-8g PGM loading. Petrol engine units have an average of 2-3g PGM content in their catalytic converter system (IPA, 2013). To comprehend the advancement of these products, an average automobile's emission in the 1960's, equates to the emissions of more than 100 vehicles today (IPA, 2013). In 2016, the South African auto catalyst business remained, with significance, one of very few down-stream manufacturing industries that maintained a global footprint. Investment in economy of scale, technology, state-of-the-art production equipment and facilities, matched those of the overseas operations (NAACAM, 2017).

Auto catalysts are produced in a variety of forms and sizes, fit for purpose for the application. These are categorised as Three-Way-Converters (TWC), Diesel Oxidation Catalysts (DOC), Diesel Particulate Filters (DPF), Selective Catalytic Reduction, (SCR), and Lean NOx Traps (LNT). Supply companies also have a host of other acronyms for their individual products (Johnson Matthey, 2017a). Fe - SCR's (iron based) and V-SCR (vanadium based) systems are making their way onto the market, claiming some of the PGM market share. Euro 6, Tier 3, China 5 and China 6 are some of the emission control standards that drive the auto catalyst business (Johnson Matthey, 2017a). IPA (2017) advocates that "the auto

catalyst is the most important pollution abatement device ever invented” (IPA, 2017, p. 1), most new vehicles are fitted with these devices.

6.3 South Africa’s Auto Catalyst Industry

The relevance of this section is to understand the magnitude of the South African catalytic converter industry. The global production of passenger and commercial vehicles is relevant to understand the geographical location of manufacture as seen in Figure 6.2. Of the 88.5 million vehicles produced in 2016, 56% were produced in Asia, inclusive of India, China, South Korea, Japan, Thailand and Indonesia. North America, inclusive of Canada and Mexico produced 21% and Europe produced 19%. South Africa’s manufacturing capacity only amount to 1% of the global production (AIEC, 2017).

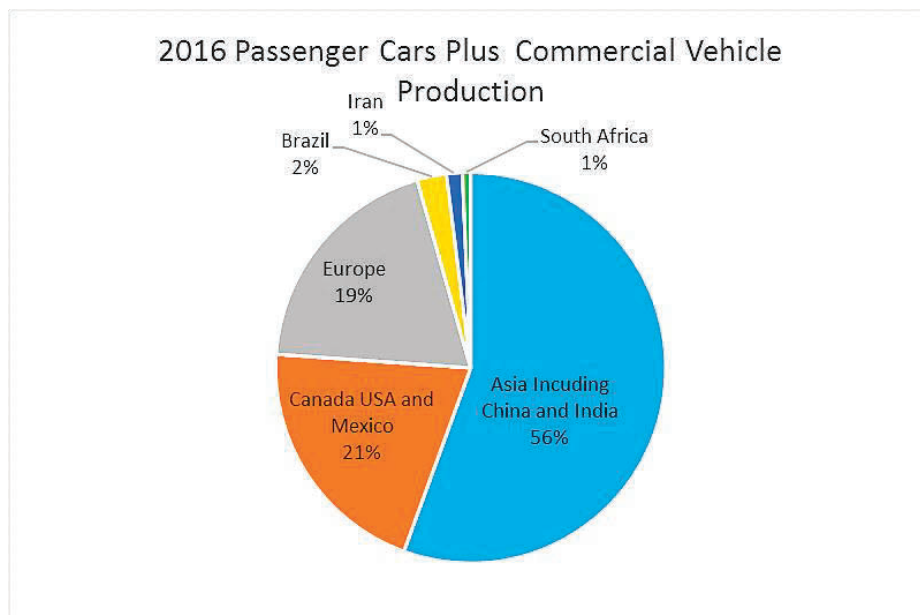


Figure 6.2: 2016 Global Passenger Car and Commercial Vehicle Production (Adapted from AIEC, 2017).

Figure 6.3 indicates the sales by region of South African manufactured catalytic converters. Europe was the largest receiver at 71% followed by North America at 21% and Asia at 7%. China’s purchases of catalytic converters from South Africa only equated to R2 million (AIEC, 2017).

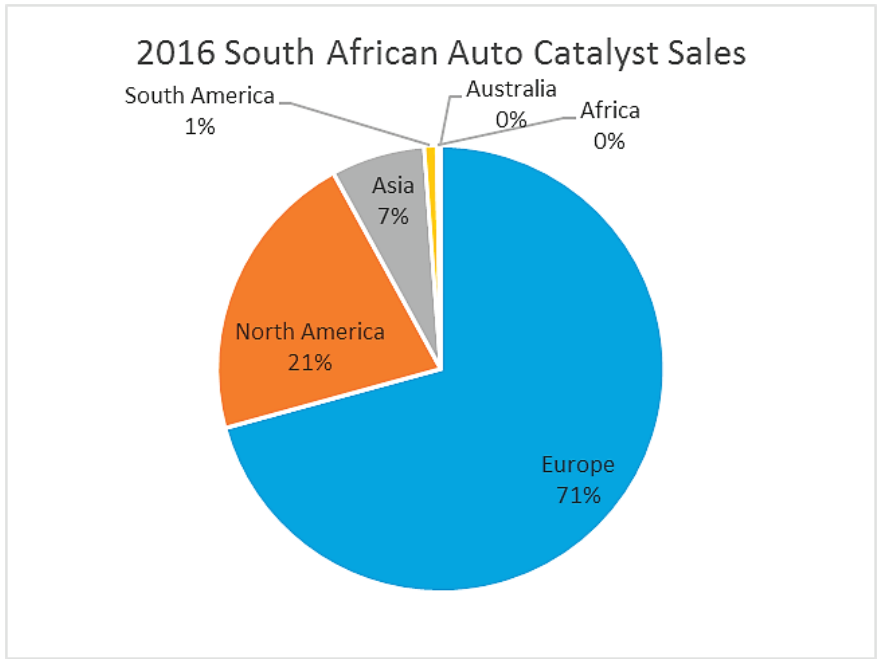


Figure 6.3: 2016 South African Auto Catalyst Sales (Adapted from AIEC, 2017).

Figure 6.4 indicates total market net export value for the catalytic converter industry in South Africa in 2016. This equated to R21.9 Billion and was up from 2012 at R16.3 Billion. This is not a fledgling industry in terms of export revenue generation. This figure peaked in 2008 at R 24.3 Billion (AIEC, 2017; Montmasson-Clair, 2016).

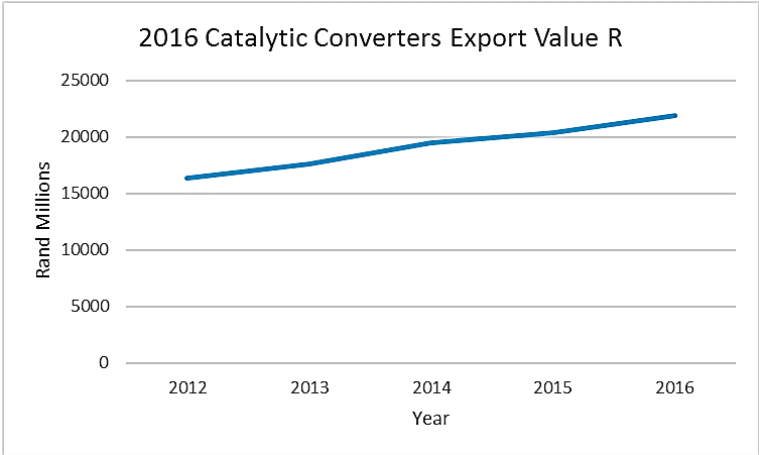


Figure 6.4: 2016 South African Auto Catalyst Export Sales (Adapted from AIEC, 2017).

Figure 6.4, indicates a gradual increase in export revenue generation, however inflation and currency devaluation are not considered. Figure 6.5, compares the catalytic converter export revenue generated over time, versus the total component export revenue generation. The result is almost flat and indicates that share is neither increasing nor falling (AIEC, 2017).

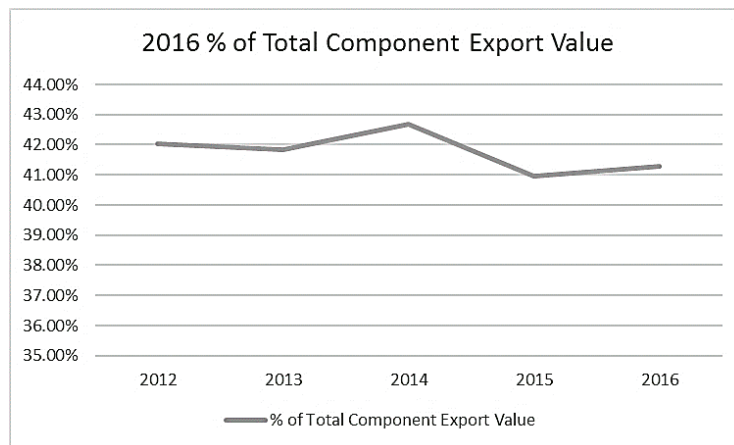


Figure 6.5: 2016, Catalytic Converter Export Revenue Vs Total Component Export Revenue (Adapted from AIEC, 2017).

6.4 Fabrication Opportunities and Obstacles

The catalytic converter industry in South Africa was reported as one of the success stories of South African industrial policy. The success has found global reach for the industry (CCIG, 2014). CCIG (2014) further mentions that, at that time, the industry was under threat of decline as the Automotive Production and Development Programme's (APDP) incentive was diminishing. This decline was to levels which could no longer cover risk factors, such as, the distance to market. Different opinions exist pertaining to the industry.

The general manager of Magneti Marelli South Africa, told Engineering News Online that under the government's new APDA incentive plan, the company was no longer able to be competitive enough to receive any further European contracts and that they could not cover their export transport costs. Magneti Marelli has since closed (Venter, 2014). The Catalytic Converters Interest Group (CCIG) had been seeking assistance for shipping costs because of South Africa's geographic disadvantage of being so far from major markets. Furthermore, Mr Dewar, of the CCIG advocated that South Africa was in

danger of losing market share stating that platinum was easily shipped by air, intimating that, catalytic converter manufacturers do not have to rely on proximity to the source of platinum (England, 2012).

South Africa is isolated in relation to demand markets and transportation of catalytic converters was costly in comparison to catalytic converter producers near to vehicle manufacturing hubs (Cokayne, 2013). Also noted, was that Europe was seen as being a major destination for catalytic converter exports. Trouble within the South African catalytic converter industry had caused new production programmes to be placed elsewhere. Furthermore, substantial catalytic converter investment was not being seen in South Africa (Cokayne, 2013). Others had a positive approach, the President and General Manager of General Motors Africa, commented on General Motors approval, ahead of a clear legislative framework by government to support export growth. At that stage a 12-year relationship between General Motors South Africa and Tenneco SA, resulted in exports totalling 2.6 million units per year. This meant that 17% of General Motor's vehicle production were fitted with South African catalytic converters (Cokayne, 2013).

Commenting on the export position of South Africa, AIEC (2017) maintained that under the APDA, catalytic converter exports had sustained their market share by value. Figure 6.5 supports this comment even through to 2016. The auto catalyst industry was said to have the highest local value addition compared to all other automotive categories (Dewar, 2012).

6.5 Incentivisation Initiative

The Automotive Production and Development Programme (APDP) is an automotive industry government incentive plan. This programme was preceded by the Motor Industry Development Plan (MIDP) which started export incentive programmes in 1961. This eventually fell foul to the World Trade Organisations (WTO), General Agreement on Tariff and Trade (GATT), obligations (Barnes & Black, 2013). In January 2013, after substantial negotiations, the MIDP was replaced by the APDP (Barnes & Black, 2013).

The APDP consists of four pillars, Import Duty (tariff structure), Vehicle Assembly Allowance (VAA) (rebate mechanism), Production Incentive (PI) (rebate mechanism) and the Automotive Incentive Scheme (AIS) (cash grant). Catalytic converters were mostly affected by the PI, as provisions in the APDA make exceptions for this sector. The PI is engaged in promoting local value addition by offering, qualifying companies local value addition duty rebate certificates. Qualification for this duty rebate certificate, for catalytic converters, in particular, is calculated at 65% of designated local value

addition. Local value addition is calculated on the selling price, less the value of non-qualifying material and imported components (AIEC, 2017).

Under the APDP, the rebate focused on local value addition and from 2017 the rebate was frozen at 65% (AIEC, 2017). The incentive plan was designed to encourage local value addition and create employment as a spin-off (AIEC, 2017). The South African automotive industry's exports, under the APDP in 2016, amounted to R171.1 billion, 15.6 % of South Africa's total exports of R1099,9 billion (AIEC, 2016). Although, near record exports were achieved, in some sectors evidence exists that the South African catalytic converter manufacturers relied on high levels of state assistance in the form of the APDP (AIEC, 2017).

6.6 Industrial Application

With the introduction of the former MIDP and the latter APDP, an incentive structure was born into the automotive industry. According to AIEC (2016), part of the global OEMs strategy was to source their business partially on the offer of country incentives.

The Government of South Africa required investment for the business sector to stimulate economic growth. At that time, business required the government to provide an enabling and conducive environment for investment. The inter alia arrangement occurred through stakeholder engagements, and the incentive plan was formulated (AIEC, 2016). The APDP programme is targeted at the automotive industry in South Africa and not specifically aligned to the catalytic converter industry. The driver behind the programme was to promote local value addition and as an offshoot this would encourage employment.

Economies of scale was a criteria and value driver for the initial MIPD programme as incentives were high to encourage investment into the South African catalytic converter industry. Thereafter as production increased the objective was to gradually reduce the incentive (Barnes & Black, 2013). The APDP, as from January 2017, had frozen the incentive to 65% of local content value addition (AIEC, 2017). The economies of scale meant that producers were under pressure to increase production as a way of reducing costs (Barnes & Black, 2013).

Automotive development programme incentives are intended to grow all sectors of the automotive industry to reach global scales and international price competitiveness. According to Dewar (2012), the South African auto catalyst industry had met those criteria of global sales and competitiveness. Volumes of 20 million units and costs, ex-factory, were equal to or below most competitive regions

(Barnes & Black, 2013). Investment in the beginning of the programme involved infrastructure development such as establishing plants that imported ceramic substrates and coated and canned them in South Africa. Several very large deals were signed and the pace of expansion increased to a point where South Africa was supplying nearly 14% of global production. Supposed critical mass had been achieved to orchestrate backward integration in the form of local ceramic substrate manufacture.

Two large international companies undertook the process of establishing substrate manufacturing plants, however due to the high investment required for substrate production, this did not occur (Barnes & Black, 2013). It may be argued that the investment was too much of a risk for the manufacturers. Alternatively, the risk of incentivised duty rebate certificates used on imported substrates would have eroded the local manufacture profitability.

6.7 Employment Opportunity Profile

The APDP's programme was structured to promote business through several channels, one of which was the incentive plan. Crucial to the objective was the spin-off factor of job creation. Complexity and speculation abound with actual job creation numbers, however, opportunities do exist and the following section qualifies these prospects. The figures obtained were relevant to, timing of publications, and the speculative nature of forecasts. The numbers were based on opinions from several sources and are objective indicators.

Figures from (CCIG, 2014; Cokayne, 2013; Dewar, 2012; Doneva, 2009; Montmasson-Clair, 2016) indicate that the catalytic converter industry in South Africa employed between:

- 5 000 – 6 500 direct workers; and
- 20 000 – 35 000 indirect workers.

BASF (2012) quoted that their Port Elizabeth facility was equipped with state-of-the-art, high speed technologically advanced equipment that produced DOC, DPF and TWC catalytic converters. The companies involved in this process are global leaders in their respective areas and have invested in production facilities that match both size and technology to their overseas counterparts (NAACAM, 2017).

In 2016, the industry exported R21.9 Billion with an estimated workforce of 6 500 persons, which equated to just under R4.5 million per person employed. The catalytic converter industry is a high volume low labour industry, unlike the PGM extractor industry where mining labour is the highest single cost. According to the Chamber of Mines (2017), PGMs extraction in 2016, contributed R66.8 billion and directly employed 172 124 persons. This equated to just over R338 000 per person employed.

The ratio of jobs to GPD contribution is 13 mining jobs to 1 in the catalytic converter industry. Therefore, the PGM mining industry had a far larger employment capacity than did the catalytic converter industry. Based on GPD contribution per head, PGMs mining is labour intensive and the catalytic converter industry is not by comparison. Dewar (2012) believed that at full capacity, the catalytic converter industry could triple export revenue and increase employment levels to 50 000 direct and indirect jobs.

6.8 Competitive Nature of Catalytic Converters

South Africa's automotive industry's performance was founded on the cooperation of OEMs and government. Globally automotive supply chains are strong and competitive, not only do they compete on end products, but also for industry benefits (AIEC, 2016). PGMs are integral to the production process and partly because of their high value, the catalytic converter industry is capital intensive (Barnes & Black, 2013).

In the 1990's the South African motor industry was widely regarded as inefficient and uncompetitive. South Africa was far from major markets and showed little sign of growth (Barnes & Black, 2013). In the latter years from 1995 onwards, rapid change occurred and the industry was re-considered to be globally competitive but still hampered by distance to the market (Barnes & Black, 2013; Dewar, 2012). Strong global linkages, supplier development and competitive improvement accounted for the rapid change and remain crucial to the sustainability of the industry. Critical to the competitiveness of the industry was supplier development, localisation, competitive logistics and economies of scale (Dewar, 2012).

Since the 1990's, the international automotive landscape changed and economies such as China, India and Thailand have emerged with large domestic markets, major regional markets, cheap production and growing technological capabilities (Barnes & Black, 2013). Based on Barnes & Black (2013),

automotive component manufacturers in Thailand had lower factor costs and had a 14% operating cost advantage over similar components manufactured in South Africa.

6.9 Location of Manufacturing Facilities

A large amount of South Africa's PGMs are exported without beneficiation due to the global nature of the automotive industry (Montmasson-Clair, 2016). BASF, a major global auto catalyst producer has manufacturing plants in the United States of America, Brazil, Germany, Poland, South Africa, China, India and Thailand plus joint ventures in Japan and Korea. Their research and development sites are located in the United States of America, Germany, China, Japan and Korea (BASF, 2016).

The auto catalytic business is highly competitive and the South African industry is part of the global array. A handful of very large producers dominate the production of catalytic converters in South Africa. As global entities, these companies have the capability to determine the top locations for their production facilities and focus investment in these zones. Barnes & Black (2013) argued that mid and high cost production locations have lost out in this process. If profitability in the South African catalytic converter industry plummets, there is a clear risk of investment reduction leading eventually to plant closures (Barnes & Black, 2013).

Factors that drive the international catalytic converter industry are profitability, timeous delivery, quality products and international price competitiveness. Failure to meet these criteria will force multi-national catalytic converter producers in South Africa to locate elsewhere. AIEC (2016) and Cokayne (2013) argued that in the five years of policy uncertainty, during the transition from the MIDP to the APDP, new catalytic converter platforms were set up in Eastern Europe, Mexico and other low cost countries. Cokayne (2013) went further to note that if the price of catalytic converters out of South Africa, inclusive of incentives and logistics, was not advantageous, then supply would simply relocate.

6.10 Distance to Market

Outside of the APDP's domain, there is an inclination to move production of catalytic converters out of South Africa. Extra external global capacity, closer to major vehicle assembly hubs and logistic costs are the motivators (Venter, 2014). The CCIG had been advocating the production of catalytic

converters in South Africa and had been seeking support for shipping costs, financial costs and cargo duties to alleviate some of these pressures (IPA, 2013).

South Africa as a preferred location to produce catalytic converters would be at risk if the support from the APDP was to diminish. The associated benefits from the APDP were needed to offset the risk and costs associated with the distance to export markets (Dewar, 2012).

According to Dewar (2012) the essential factors effecting distance to market are:

- Logistic costs equalled 3% of total cost;
- Destination plus 5000kms;
- Delivery period of South African catalytic converters is approximately six weeks; and
- Other suppliers were located internationally closer to their customers and in low cost countries.

The realism was that catalytic converter customers would source products from South Africa only if the total cost, inclusive of transport and perceived risk was less than the cost from their sister plants. Barnes & Black (2013) indicated that South African firms were “swing” producers, occupying a peripheral position and were a contingency to low cost capacity in Central Europe. This was due to high transport costs, long distances to market and high levels of input costs. Barnes & Black (2013) related factors such as the volumetric profile of components making them expensive to trade over long distances. Just-in-time or just-in-sequence was the methodology used in the automotive assembly industry. Long delivery times and delays in supply, renders the process ineffective. To exemplify the issue, Figure 6.6, is a picture, with dimensions, of an average catalytic converter.

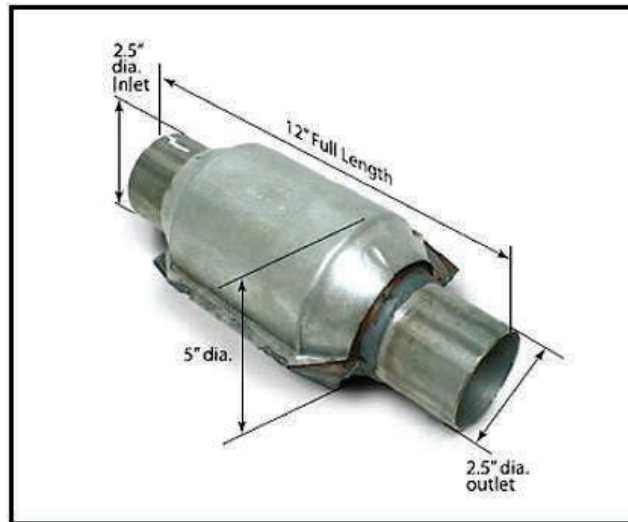


Figure 6.6: Middle-of-the-Range 5-inch Catalytic Converter (SLP, 2017).

Calculating the effect of the transport to value ratio would be as follows:

Assumptions

- The packing box would need to be a minimum of 310mm x 130mm x 130mm;
- All internal and external catalytic converter component costs were considered equal in value at any global location;
- Only the platinum content and volumetric profile was considered;
- Average platinum loading on a petrol engine catalytic converter is 2.5g; and
- Specific Gravity of platinum is 21.45.

The packing box would occupy a volume of 5 239 cm³.

2.5g of pure platinum occupies a volume of 0.117 cm³.

The volume of 2.5g of pure platinum compared to the end-product packaging volume, increased 45 000 times. The transport to value ratio, only considering the platinum, would increase by a factor of 45 000.

Only considering platinum and no other components or spin-offs, the most economical option would be to send the refined platinum to the catalytic converter plant closest to the automotive manufacturer. Therefore, under these conditions, there is a negative economic effect on logistic costs

by manufacturing catalytic converters locally. Without the APDP, there is limited economic advantage in beneficiating locally refined PGMs in South Africa unless preferential pricing is employed.

With the support of the former MIDP and the APDP the South African catalytic converter industry became ultra-export orientated and South Africa exported a high share of its output considering its remote location (Barnes & Black, 2013). Export rebate certificates allow for a reduction of import duty, directly related, with conditions, to the volume of exports generated. Essentially, the more local content provided in the exported goods, the higher the value of the rebate. The process was directed at the stimulation of local content value addition, which was to the betterment of South Africa. The rebate's financial reach needed to exceed the cost associated with risk and distance to market to make the product competitive.

A conundrum exists whereby import duties are a form of taxation, which ultimately funds the national treasury. The trade-off lies with the benefit of South African consumers being able to purchase new cars or automotive related purchases at better prices, as opposed to retaining the tax component in the national treasury. Essentially, if export rebate certificates were removed, automotive imports would generate greater revenue for the national treasury. This complex trade-off situation would involve further research. This would require quantifying the possible fiscal revenue that would be generated from automotive import duty versus the benefits generated by the catalytic converter industry. The reality is that the South African catalytic converter industry, in 2016, contributed exports of almost R22 billion to GDP, the negative and alarming side would be, that tax payers were funding the industry.

6.11 PGM Mineral Extractors Benefit

The PGMs' value chain as seen in Figure 6.7 comprises of three primary sectors namely mineral extraction, manufacturing industry and the recycling industry. Each of these zones are distinct and independent of each other, apart from the supply chain aspect. For the South African mineral extractors to support the South African PGM manufacturing industry there needs to be benefit. Off take can be classed as a benefit, but if the APDP incentives did not exist, the distance to market aspect would, result in the catalytic converter manufacturers relocation out of South Africa. This relocation would be closer to the major automotive manufacturing hubs. The effect on the mineral extractor would be negligible as the cost of PGMs are independent of locality.

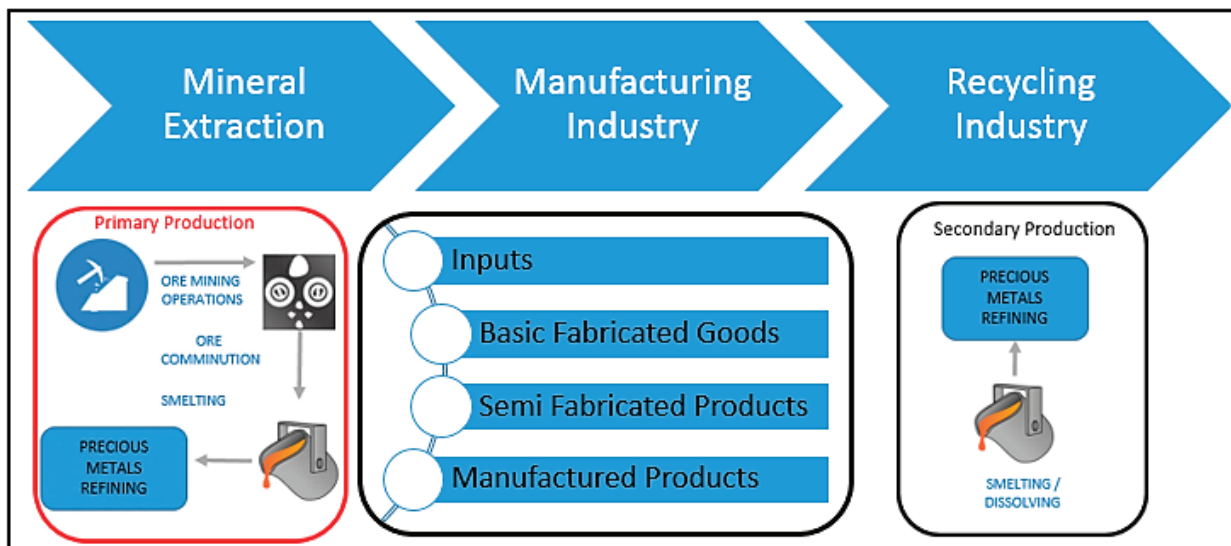


Figure 6.7: The PGM Value Chain (Adapted from IPA, 2013).

Transportation of refined PGMs incur a minuscule cost in comparison to the price of the metals. The majority of South African produced PGMs were exported compared to the PGM offtake of the South African catalytic converter industry. Barnes & Black (2013) suggested that a handful of multinational vehicle producers dominate the global production and economies of scale is important. These multinational vehicle producers have considerable influence over the location of new investments.

Comparative advantage of endowments was an insignificant factor in this environment and complex forces exist, such as, global strategies of multinational companies, host countries policy and domestic and regional market conditions. Catalytic converters, for the automotive industry, are by far, the greatest global consumers of PGMs. The automotive industry was driven by dynamics that do not consider comparative advantage of PGM endowments to be of any consequence. There is no real advantage in using South African produced PGMs in the South African catalytic converter industry except if preferential pricing was implored.

The advantage of additional supply, on a global basis, for local PGM mineral extractors does not exist, however, additional market share for local PGM extractors may be attractive. This, for local PGMs extractors, may apply in the form of maintaining existing international contracts and increasing market share by preferential supply to the local industry.

Ideas abound with taxation, in one form or another, on the PGM extractors to promote local downstream value addition. In Chapter 5, the results for the 2016 performance of the South African PGM miners placed the existence of the industry on a knives edge. Additional pressure on the industry could see further job losses and mine closures. Ian Farmer, Chief Executive of Lonmin said that caution

should be considered when trying to get the platinum industry to subsidise local beneficiation, effectively this would relate to applying another tax on the industry (England, 2012). CCIG (2014) proposed preferential discounted pricing as a structure to accelerate local beneficiation in the PGMs industry. Ian Farmer also thought, that by looking at current prices and the state of the PGM extractors industry, the industry did not have producer power (England, 2012).

Venter (2014) suggested that others advocated production or export taxes for PGM extractors as a means of incentivising local beneficiation of PGMs. Production taxes would be applied on exported PGMs and not to the local PGM beneficiation industry. Robert Houdet, National Association of Automotive Component and Allied Manufacturers, executive director, suggested that the mining companies add this tax at invoice level when they charge their customers (Venter, 2014). It was suggested that this had occurred with the Middle East oil industry in the 1970's. Venter (2014) advocated that South Africa had platinum, and that a once in a lifetime opportunity existed for government to implement the tax. PGMs extractors are supplying PGMs to specialised refineries in South Africa. These refineries then manufacture PGM sponge for local auto catalyst industry (Northam Platinum Limited, 2007). Under the APDP incentive plan, this is the mechanism to achieve the local content parameters required for the export rebate. The APDP supports the automotive industry in South Africa and not the extractive industry. The research has shown that no real or dramatic changes have occurred to the auto catalyst industry in South Africa by using locally produced PGMs. The function of the APDP promotes local content to achieve export rebate incentives. If the APDP's plan was fixed on other objectives to achieve the export rebate, then the auto catalyst industry would focus on those other objectives to obtain the certificates. Therefore, it can be said that it is the rebate incentive is a significant driver for the local auto catalyst industry and not locally produced PGMs.

The global PGMs value chain as seen in Figure 6.8, comprises of three primary sectors namely mineral extraction, manufacturing industry and the recycling industry. Excluding the recycling industry, PGM extractors and catalytic converter manufacturers are not reliant on each other. If the South African PGM mineral extractors ceased to exist, apart from the global PGM deficit, the South African catalytic converter industry would still survive. The supply of PGMs would be sourced from the rest of the world. Vice versa, if the South African catalytic converter industry were to collapse, demand would relocate and the South African PGM extractors would continue to supply the new locations.

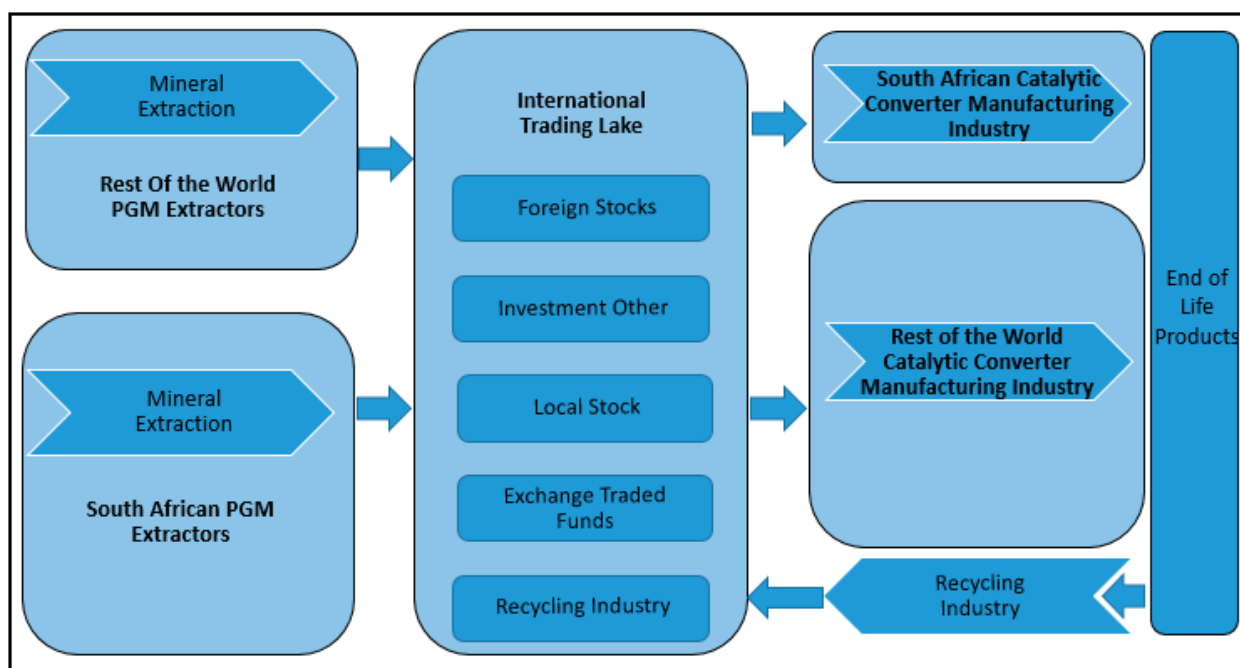


Figure 6.8 Global PGM Value Chain.

Comparative advantage of endowments was an insignificant factor in this environment. The catalytic converter business is not driven by locality of supply, but more by complex forces such as global strategies of multinationals, host countries policy and market conditions. The DRM estimated the production of South African auto catalytic converters equated, in 2011, to 19% of global supply (DMR, 2011a). Recent estimates put this figure at 15% of global supply (BASF, 2017). Going against the ideology of the DMRs strategy, the auto catalyst industry was controlled by dynamics that do not consider, comparative advantage of PGM endowments. The advantage for using South African produced refined PGMs in the South African catalytic converter industry is reliant on the APDP rebate system.

The disconnected relationship that occurs in the PGMs value chain leads to the conclusion that downstream beneficiation, in the case of PGMs, is weighted in support of the auto catalyst manufacturers. There is no particular viable or real leverage attained by using South African produced refined PGMs in support of local downstream beneficiation.

6.12 Chapter Summary

South Africa has an auto catalyst industry that has prospered since the 1990's. It was cited as a success story for South African industrial policy. The South African auto catalyst producers have a substantial industry that was created from a number of factors, one of which was the MIDP/APDP incentive plan.

The APDP incentive plan prescribed local content input to qualify for the export rebate certificates to stimulate local industry. This advantage was sectorial and benefited the automotive industry but does not assist the PGM mining industry.

In 2016, South Africa manufactured 1% of the global production of passenger cars. Multinational automotive producers, for several reasons, prefer component manufacturers to be close to vehicle manufacturing hubs. South Africa is not, geographically, located near to any of these hubs and is disadvantaged by distance to market. An export rebate system was introduced to compensate for this factor, without the incentive plan the industry would struggle to be competitive.

The industry has specialised up-to-date equipment and is highly mechanised and thus, is not employment intensive. Factors that drive the international catalytic converter industry are profitability, timeous delivery, quality products and international price competitiveness. Comparative advantage of endowments is an insignificant factor in this environment. Other complex forces drive the industry such as global strategy of multinationals, host countries policy and domestic and regional market conditions.

The auto catalyst industry was driven by dynamics that do not consider comparative advantage of PGM endowments to be of any consequence. There is no advantage in using South African produced PGMs in the South African catalytic converter industry except if preferential pricing was implored. If preferential pricing were to be implemented in any form, this would result in the PGM extractors funding the South African catalytic converter industry.

Refined PGMs incur minimal costs for transportation in comparison to the cost of the product and they can be bought, sold or processed anywhere in the world. This unique feature of PGMs separates the PGM extractors and the catalytic converter industry as neither are reliant on each other. The positive and remarkable aspect of this industry is that South Africa manufactures 1% of the global passenger plus commercial vehicle production while it produces 15% of the world's auto catalysts.

7 CONCLUSION AND RECOMMENDATIONS

7.1 Conclusion

This research report aimed to determine if downstream beneficiation could leverage maximum financial advantage from South African produced PGMs and if this would be viable and sustainable. The objective was to identify, understand and compile definitive stakeholder requirements. Further objectives were to comprehend comparative mineral and competitive manufacturing advantages within the domain of PGMs in South Africa. Certain factors conflicted and overlapped within the value chain and these were in the form of government requirements, sustainable mineral production and the manufacturing industry's capability.

A further objective was to determine how the PGMs value chain functioned and where the boundaries of extractors and manufacturers converged to create competitive advantage. The argument was that if the infrastructure existed or could be implemented and other limiting factors make clear economic sense, would this encourage the beneficiation of PGMs. This strategy, would then support social economic development, promote employment and should have a positive influence on the economy of South Africa.

The strategic intent of the DMR policy was to make the maximum use of the country's mineral endowment to support the socio-economic development of South Africa. This document, a Beneficiation Strategy for the Mineral Industry of South Africa from the DMR, was a political plan. The plan was to create an enabling environment for mining and mineral products to be upgraded to more valuable products. The objective was to create a greater contribution to export revenue, enabling economic diversification through industrial opportunities and accelerate development towards a knowledge based economy. In addition, it was to develop enterprise creation and create decent jobs that would support poverty alleviation.

South Africa is exporting non-renewable mining products to other countries before developing the product's full potential. The argument from the DMR was that the countries to which, the under processed products were exported, would reap the benefit from upgrading the materials.

The DMR suggested the use of a legislative framework, where the government provided the foundation for expediting the process. They contemplated the use of multi-stakeholder forums including; government, mineral extractors and processors, industry and institutions. International trade agreements and beneficiation strategic interventions were also considered. A key success factor for the industrialisation initiative was competitive access to locally produced minerals. The reason was

that the local downstream beneficiation initiative may have been strangled for supply, or subject to uncompetitive pricing, even though the minerals are derived from the South African mining industry.

According to the DMR, the mineral industry's configuration was such that it was equipped to export raw materials and little consideration had been placed on infrastructure to further develop mineral products. As the South African government is the custodian of the minerals in South Africa, pressure could be applied to mineral producers to avail product for the local beneficiation process. Some actions that could be used to lever beneficiation were the "offset element" of the Mining Charter, export levies and the possibility of export taxes on raw ores and intermediate mineral products.

To promote the PGM process of downstream beneficiation, access to raw materials at developmental prices, was suggested, so price would not retard the growth of beneficiation projects. Other measures included an incentive system that would insure competitive supply, through a reduction in royalties, to the supply source. Typically, the arrangement of import and export trade in South Africa was such that there was an unacceptable balance in the export of raw materials versus the import of finished goods. Favourable trading conditions would be crafted in such a way as to benefit the industry. These would be in the form of export/import levies to protect and enhance the industry, local mineral access for local consumption as well as additional incentivisation. The export of finished consumer goods was set to translate into and to be the driver for significant adsorption of labour through the increase in industrial capacity. The value addition would be mostly generated at the latter end of the value chain where the greatest export revenue and employment opportunities could be sort.

Government's stance on prescriptive policy was subject to opinions such as a natural path would better determine the growth of industry, related to secondary inputs. It was also thought that prescriptive or uncertain policies would erode current and future investment. Decisions on mineral beneficiation would need to be based on sound economic and market principles.

The "Resource Curse" was introduced to the research as an associated phenomenon related to beneficiation through the exploitation of minerals and the economy. The curse is acclaimed to be the negative economic impact forced upon a nation's economy in a natural resource endowed country. This is not a supernatural phenomenon, but more an insight, to the issues around the sound management of natural resources. The South African landscape is not immune to the symptoms and recognisable patterns occur with corruption, maladministration, and financial mismanagement, perceived or otherwise. It was clear from the study that there are no hard and fast rules related to the exploitation of natural resources and that this phenomenon is not only associated with developing countries. It was evident that in most cases; real, stable, diverse, and mature economies have systems,

policies and accountability in place that prevent the consequences of the resource curse. One could argue that there are certain tangible aspects associated with the resource curse that may be beyond the control of nations such as price and labour volatility. However, with policy making decisions, strong considerations for price volatility and sound management are crucial for economic stability.

PGMs were classified as very rare metals in the earth's crust. PGMs often occur as by-products of mining other metals such as Nickel and Copper. However, it was very rare to find a primary source PGM reserve. These significant deposits of PGMs are seldom mined anywhere outside of South Africa, apart from Zimbabwe. PGMs are not scarce but rarely occur in economically minable concentrations. South Africa's PGM extractor industry is not as robust as perceived and price volatility has seriously impacted the economics of these minable deposits.

Mineral resource valuations, used in the context of financially viable mineral extraction propositions are "time and conditions based". The use of these valuations, in the future, may not be accurate. Relying on time and conditions based information for future planning may create false expectations of the capability of extraction industries.

Volatility of metal prices in periods of sustained premium market pricing leads to prosperity. All stakeholders should be cognisant that, this same volatility, in a depressed mineral market can cause poverty. This phenomenon becomes cyclic and extended periods of prosperity occur along with protracted periods of market stagnation.

The driver for the beneficiation strategy was centred on a report availing USD 2.5 trillion as a value for the mineral resource base in South Africa. This made South Africa the world's wealthiest mineral jurisdiction. It may have been a reasonable valuation, in 2011, however this is not the case today. The 47% plunge in the price between 2010 and 2017, of platinum alone, coupled with rising costs, has most likely decimated the original estimates of South Africa's mineral resources. Long term strategic policy decisions made from reserve and resource estimates are sensitive and subject to volatile mineral prices.

Most of the world's PGMs were supplied from South Africa and Russia and in the past, producer pricing mechanisms had been in place. However, these markets are increasingly influenced by commodity exchange pricing. The South African PGM supply market is dominated by long term contracts but influenced by the spot price from the commodities market. Supply contracts for PGMs are linked to, or inclined to, follow the trends of the commodity exchange. Central to the trend of prices on the commodity exchanges, is the perceived balance between supply and demand. The price of mineral

products is dictated by the value perceived by the buyer. This perception of value creates an environment subject to volatile pricing.

Commodity exchanges are agnostic to the origin of the mineral or mineral product and consider the quality and quantity to be the criteria of sale. Fluctuations in input costs, labour costs and energy costs have no bearing on the sale price of the mineral or mineral product. With the price of metals and minerals typically beyond the control of the producer, the market's perception of value, controls the price of these commodities. For the most part, purchases or the demand for minerals, including PGMs, are conducted in international markets and therefore the price, willing to be paid, is in the domain of international markets. Mineral and metal producers are price takers and have little influence in price determination.

Commodities can vary in price between locations and markets, bulky commodities many incur different pricing structures dependant on value and locality to market. Trade quotas and other limiting factors may also influence price determination. One of the most important factors that influences comparative advantage and the extent of resource trade is the mineral commodity's value to weight ratio. PGMs are traded freely, anywhere in the world, and with minuscule costs for the transportation compared to their value. The local PGM downstream manufacturing industry achieves no advantage by proximity to the PGM deposits. Similarly, local South African PGM extractors attain no real advantage by supplying the local industry.

South Africa has by far, the greatest number of operations in the global PGM supply market. In 2016, this translated into the largest portion of the PGM global supply at 56%. In addition, South Africa was, globally, the largest supplier of platinum and rhodium at 72% and 79% respectively. Russia was the largest global supplier of palladium at 41%, South Africa was a close second at 38%. South Africa supplied more than half of the world's PGM demand and had the largest comparative advantage. However, producer pricing power for PGMs, related through comparative advantage had no influence on commodity price.

In 2016, the total-cash-cost of producing PGMs in South Africa, in numerous cases, was not sustainable against the global average price for the metals. The main contributor to this was the cost of the labour to mine the metals. Under these condition, access to metal supply with preferential local pricing, transfer pricing or additional taxations would have dire consequences on the primary PGM supply in South Africa. Under the current conditions, leveraging the maximum financial advantage from PGM downstream beneficiation is not a possible option.

PGMs are fungible and extractors produce a similar product yet, each mine's cost-of-production varies. By attrition, those producers who do not have enough liquidity to carry them through pricing downturns will become insolvent and will no longer be a market supplier. If the PGM extractive industry were obligated to support downstream value addition projects with preferential pricing, under the current conditions, the net effect would cause the industry to constrict. National employment would be affected and the economy would feel the pressure.

With regards to the other potential opportunities that are created by downstream PGMs beneficiation, the research revealed that, mostly, this opportunity is in place and successful. Protection and nurturing of this outstanding business are all that is required to sustain and grow the industry. At the request of the OEMs, local catalytic converter facilities were established in the early 1990s. Since then, the auto catalytic industry has achieved remarkable growth. The catalytic converter industry was reported as one of the success stories of South African industrial policy. In the automotive industry, catalytic converters were the highest contributor to component export revenue and attained the highest local content. The South African auto catalyst business remained, with significance, one of very few downstream manufacturing industries that sustained a global footprint. Investment in economies of scale, technology, state-of-the-art production equipment and facilities, matched those of the overseas operations.

South Africa is isolated in relation to demand markets and transportation of catalytic converters is costly in comparison to producers near to vehicle manufacturing hubs. Of the 88.5 million vehicles produced in 2016, 56% were produced in Asia, inclusive of India, China, South Korea, Japan, Thailand and Indonesia. North America, inclusive of Canada and Mexico produced 21% and Europe produced 19%. Only 1% were produced in South Africa, however, 15% of the world's auto catalysts business stems from South Africa, a truly remarkable achievement.

South African catalytic converter manufacturing was in danger of losing market share by the fact that platinum was easily shipped by air. This fact intimated that, catalytic converter manufacturers do not have to rely on proximity to the source of PGMs. The use of South African refined PGMs in the local auto catalyst industry has no real advantage to either the extractor or the auto catalyst manufacturer. The advantage of using local PGMs in the auto catalyst industry lies purely with the benefits from the APDP incentive.

The APDP is an automotive industry government incentive plan. Part of the APDP was a production/duty rebate incentive. Qualification for this duty rebate certificate, for catalytic converters was calculated at 65% of designated local value addition. Although competitive, evidence existed that

the South African catalytic converter manufacturers relied heavily on state assistance in the form of the APDP incentive. The driver behind the programme promotes local value addition and as an offshoot it should encourage employment. If the support from the APDP was to diminish, advantages for companies to produce catalytic converters in South Africa would dwindle. The associated APDP benefits were needed to offset the risk and costs associated with the distance to export markets.

Global automotive supply chains are strong and competitive, not only do they compete on end products, but also for industry benefits such as the South African APDP. Strong global linkages, supplier development and competitive improvement remain crucial to the sustainability of the industry. Critical to the industry was competitive logistics and economies of scales. Factors that drive the international catalytic converter industry are profitability, timeous delivery, quality products and international price competitiveness. Failure to meet these criteria would force multi-national catalytic converter producers in South Africa to locate elsewhere. If the price out of South Africa, for catalytic converters, inclusive of incentives and logistics, was not advantageous, then manufacturing companies would simply relocate. The realism was that catalytic converter customers would source products from South Africa only if the total cost, inclusive of transport and perceived risk was less than the cost from their sister plants. The APDP incentive plan uses local content as the driver, multi-national catalytic converter producers would be agnostic to the qualifying reasoning as their interests lay with competitive advantage.

The catalytic converter industry in South Africa employed between 5 000 – 6 500 direct workers. The ratio of jobs to GPD contribution, when comparing industries, is 13 mining jobs to 1 in the catalytic converter industry. The PGM mining industry had a far larger employment capacity than did the catalytic converter industry. Based on GPD contribution per head, PGM mining is labour intensive and the catalytic converter industry is not by comparison. Although any employment opportunities would be welcomed, the highly mechanised auto catalyst business is not employment intensive. Although South African refined PGMs are being used by local auto catalyst producers, no significant adsorption of labour through industrial capacity has occurred.

Can the maximum financial leverage be attained, for South African produced PGMs through downstream beneficiation? This is simply not possible, 56% of the global production of PGMs come from South Africa and the diversification required to consume that amount of product would be a pipe dream. However, accomplishing the best possible returns, under the circumstances, is a far better target to achieve.

The global greenhouse gas clean air policies are real and increasing in reach and intensity. Both the PGM extractive and catalytic converter industries possess positive, long and prosperous futures if soundly managed with innovative ideas.

7.2 Recommendations

7.2.1 Policy Review

The research found gaps in the original DMR policy, specific to PGMs. A review of the policy should consider the entire value chain from extraction all the way through to point of sale. Policy capability should be able to cope with price volatility, provide fair opportunities for all stakeholders, and make clear economic sense.

7.2.2 Support for Extractors

With the DMR's 2011 beneficiation strategy, little concern was assigned to the extractive industry. The expectations projected the impression that the extractive industry was some sort of "golden goose" that could supply all the demands to create these expectations. PGMs were particularly hard hit by down trending mineral prices and continue to be affected. It is essential that support for the PGM extractive industry be considered. Without the primary source, downstream beneficiation is a fantasy.

7.2.3 Value Add for Extractors

The incentive for South African PGM extractors to participate in the beneficiation programme appear to be one sided with very little incentive for them. The good intentions of the DMR's 2011 beneficiation strategy have been diminished by rent seeking overtones, with such statements as "Invoke relevant provisions of the law to ensure security of PGM supply." (DMR, 2011a, p. 18). A far better position to have taken would have been to incentivise local mineral producers to support the downstream industry without implying force. Long term supply agreements hold little risk for the PGM extractors and coalition agreements should be sort.

7.2.4 Forward Integration Mechanism

The forward integration mechanism is one such coalition instrument that, if well prepared, may incentivise future collaboration between PGM extractors and industry. As pragmatic as this proposal is at face value, intellectual property and many other aspects would require far greater research to prove practical.

Capacity exists within the South African catalytic converter industry to perhaps triple output and South African PGM suppliers are struggling with poor commodity pricing. A possible workable scenario exists in the form of forward integration.

If this is the case, then an opportunity exists to benefit all parties. The major suppliers of the PGM extractive industry and the catalytic converter industry are made up of reputable companies. Government wanted greater local content value additions to improve the national economy and create employment. A theoretical, possible, scenario exists that could benefit all parties with a joint concerted effort. An opportunity framework showing benefits, for all, may be required to entice local PGMs extractors and auto catalyst manufacturers to collaborate. A re-work of the DMR's beneficiation strategy, specific to the PGMs value chain would be a reasonable starting point.

Figure 7.1 depicts the PGMs value chain. The industry exists in such a way that the local South African PGM mineral extractors are subject to low commodity pricing, high unit production costs and limited profitability. The local PGM manufacturing industry suffered from distance to market issues but had positives such as the APDP incentive plan, spare capacity and multi-national distribution channels. According to conventional trade theory, the finished product supplier enjoys a higher profitability on manufactured goods than does the mineral extractor on refined metals.

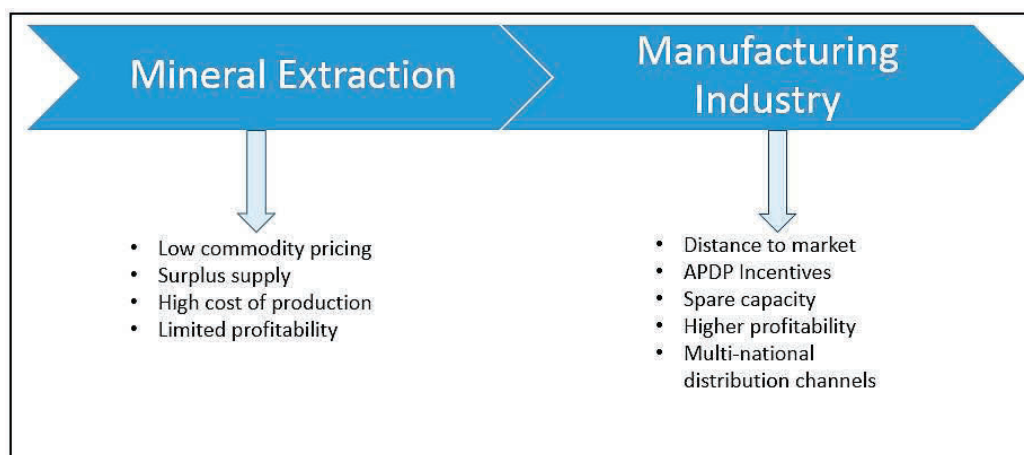


Figure 7.1: Existing Non-Collaborating Supply System.

Figure 7.2 shows forward integration, or bundling, that would involve a coalition between local PGM mineral extractors and the local PGMs manufacturers. The local catalytic converter industry has spare capacity and the industry is founded on economies of scale. With the theoretical financial profit margin belonging to the manufacturing industry, collaborative integration should benefit the mineral extractor.

If the PGM mineral extractor supplied PGMs at lower than commodity market pricing, the manufacturer would have a competitive advantage for supply of catalytic converters. Highly advantageous competitive pricing should increase throughput and absorb excess capacity. If indeed the profit margin lies with the manufacturer, the local producer would realise an overall increase in profit, through the increase in volume. Part of this forward integration would require the increased profit to be shared with the mineral extractor. The PGM manufacturer would succumb to a lower overall profit percentage, but would realise a higher overall profit through capacity absorption. The profit share would also revert to the mineral extractor and offer a higher than market related return.

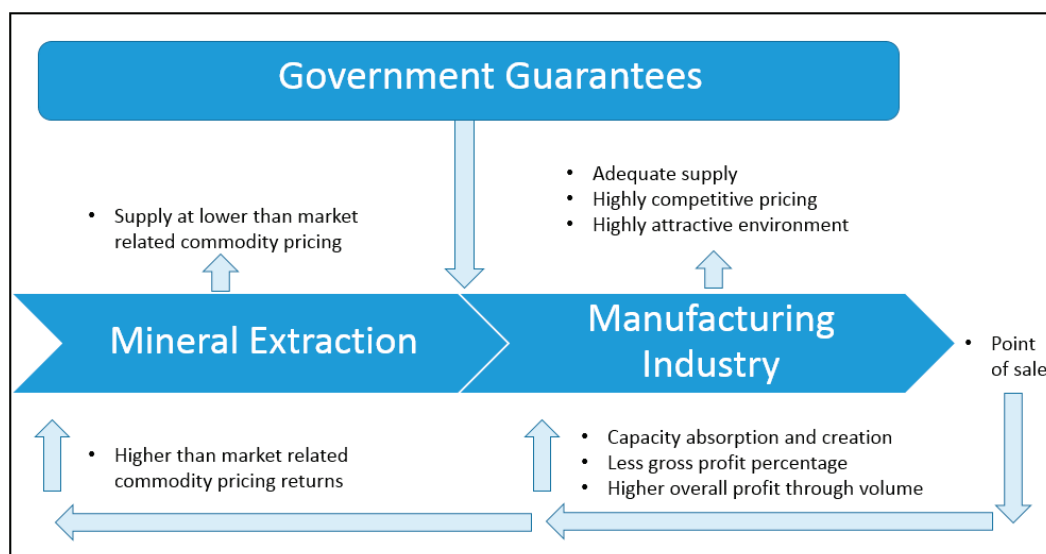


Figure 7.2: Forward Integration Theory.

The mineral extractor supplying the catalytic converter manufacturer with PGMs would incur risk in the form of not being paid for product. The extractive industry and the catalytic converter industry are dominated by a handful of reputable international companies. Perhaps, if the government stood guarantor to the process, all stakeholders would benefit. As pragmatic as this proposal is at face value, it would require far greater research to prove practical.

7.2.5 Enticement of Peripheral Business

The catalytic converter industry is a mature substantial income generator. The enticement of peripheral support industries such as substrate manufacturers, speciality PGM additive chemical producers, rare earth suppliers and other inputs should be encouraged with dependable investor support.

7.3 Future Research Work

Following on from the findings, the issues listed below constitute possible future areas of research:

- A study into the associated costs to implement the DMR's beneficiation strategy. In particular, for requirements such as infrastructure, research and development, training and distance to market influences and what effect this investment would have on South Africa's economy;
- Research into the support offered by the APDP's catalytic converter incentive programme of export rebate certificates. Does this programme benefit South Africa or just the automotive industry?
- Research into the collaborative forward integration mechanism of supply from PGM extractors to the auto catalyst industry and both parties benefiting from the final sale; and
- A review, under current market conditions, of the Beneficiation Strategy for the Mineral Industry of South Africa of 2011. Extending, along the value chain from PGM extractors right the way to point of sale, considering mineral price volatility, exploring fair opportunities for all stakeholders and a clear path to economic sense.

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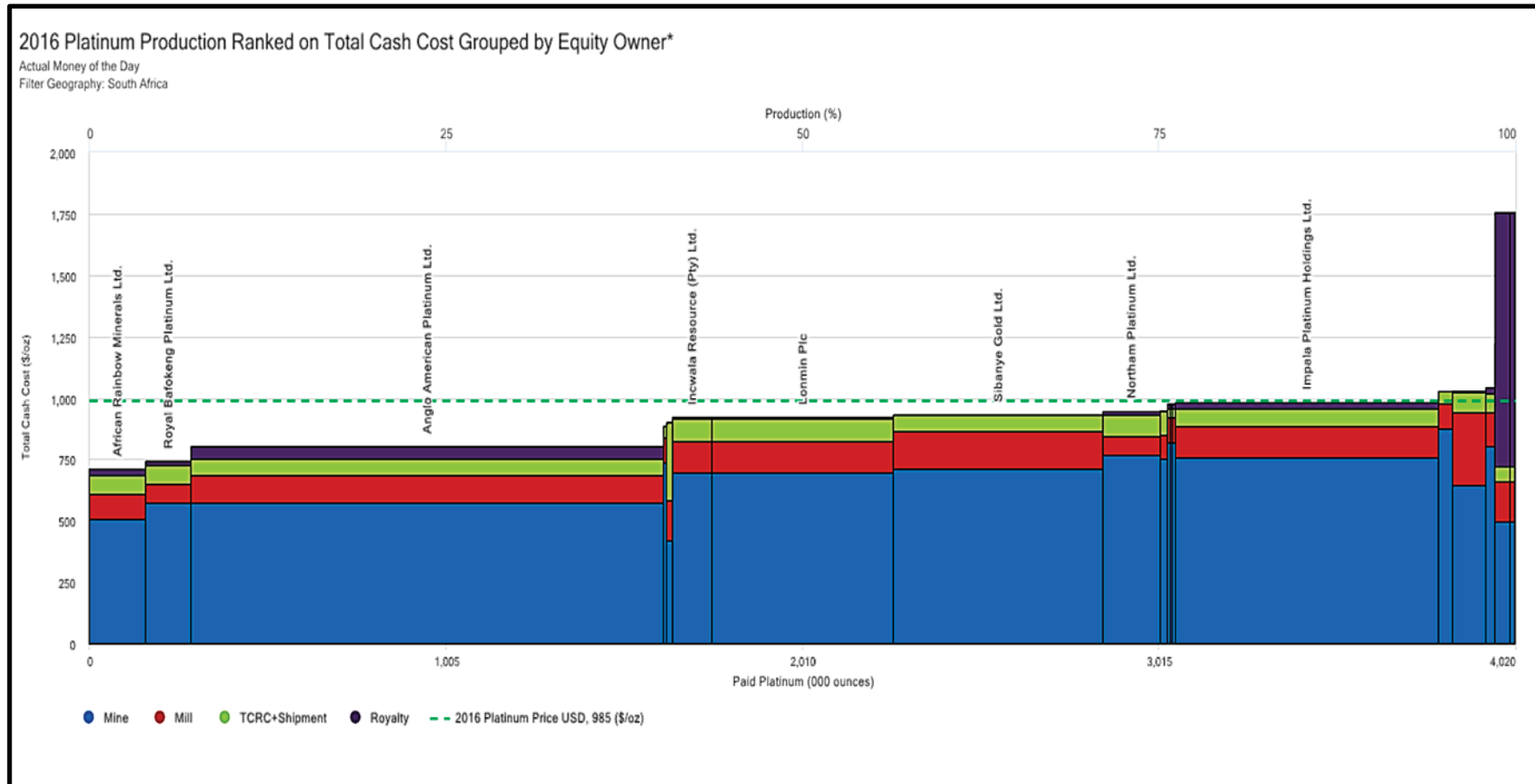
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APPENDIX A

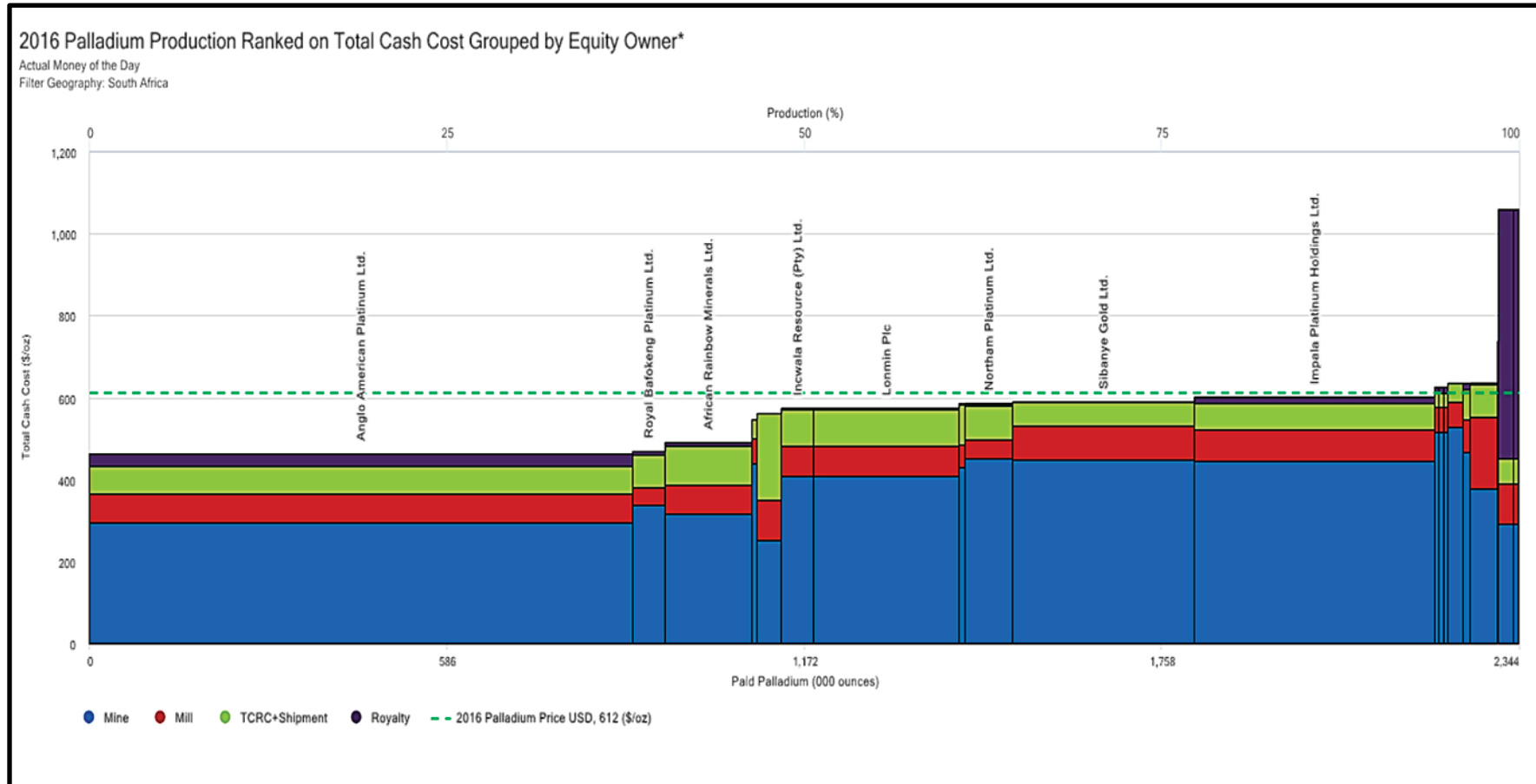
Appendix A: - 2016 South African Platinum Production Figures Total Cash Cost Grouped by Equity Owner.



(SNL Data Base, 2017)

APPENDIX B

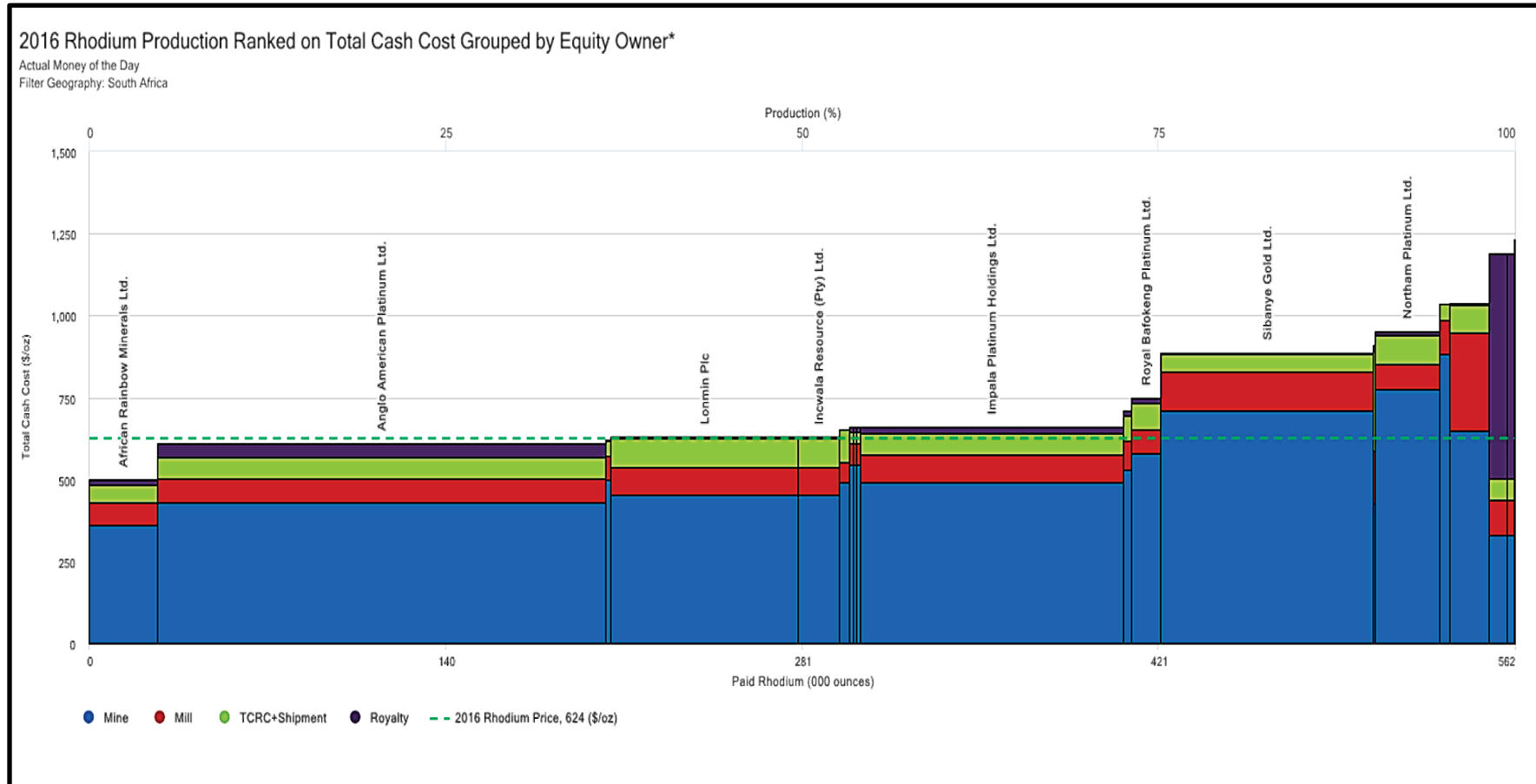
Appendix B: - 2016 South African Palladium Production Figures Total Cash Cost Grouped by Equity Owner.



(SNL Data Base, 2017)

APPENDIX C

Appendix C: - 2016 South African Rhodium Production Figures Total Cash Cost Grouped by Equity Owner.



(SNL Data Base, 2017)