

Identifying energy clusters within the gold mining supply chain: Implications for energy policy

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Abstract

An energy supply shortage has caused major disruptions and has become extremely costly for South Africa. The most significant problem constraining economic growth in the country is inadequate energy supply and maintaining the structural reliability of its energy generation network. Energy is crucial for economic growth and a sufficient energy supply is required to sustain economic growth.

The entire country runs on energy in one form or another, either by producing goods or by delivering a service. Gold mining is an important part of South Africa's economy. Once an energy shortage occurs, mining operations are shut down, which requires numerous hours to start operations again. For example, gold mining activities such as smelters and refineries require several hours to start operations again, which results in a major drop in productivity. Gold mining is the most energy intensive form of mining in South Africa. The gold mining industry uses energy directly on site, as well as indirectly through its supply chain. One way in which to identify these high energy-intensive users is to identify energy clusters in the gold mining supply chain.

Once these clusters have been identified, key role-players can engage with these clusters to ensure that energy is used more sparingly and to determine effective ways to reduce energy costs through supply chain engagement. Energy is a necessity in every aspect of the gold mining sector and the gold mining supply chain. Given the complexity of modern supply chains, it is not a trivial task to identify a group of closely connected energy users in the gold mining supply chain, whose interactions largely shape the problem of an energy intensive sector within an environment of energy constraints. An increase in the number of energy intensive sectors has a harmful impact on both the environment and the economy.

The environment is also negatively affected by an increase in the volume of CO₂ emissions. The economy tends to be less profitable and competitive due to the higher costs. Energy policies should focus on promoting and improving energy efficiency in the high-consuming sectors. Therefore, identifying energy-intensive clusters in the gold mining supply chain is essential to design effective energy policies. This paper investigates the energy-intensive clusters in the gold mining supply chain, as well as what the implications of this energy-intensive cluster are on energy policies in South Africa. The focus was to review the energy sector and the policies set out by the Department of Energy. The gold sector performance,

beneficiation, and its supply chain are further analysed. The aim is to decrease South Africa's energy intensity. High-energy intensity leads to high costs and natural resource depletion that affect the entire economy.

The point of departure in this dissertation is to elaborate on the current energy supply predicaments facing the country. It is evident that in this dissertation the emphasis is on the energy intensity of the gold mining supply chain. The gold mining sector and its supply chain form energy clusters with high-energy intensity. Some analyses are performed to provide evidence that these energy-intensive clusters are identified in the empirical analysis through merging the input-output (2011) tables with the network partition approach. Therefore, the empirical analysis consists of three components: a simplified input-output approach, the network partition approach, and a non-systematic matrix approach. From the results, seven energy-intensive clusters are identified, ranking from the highest within cluster effect to the lowest. From the results, the highest energy using sectors in the gold mining supply chain are identified. The energy-intensive clusters within the gold mining supply chain may help to identify the broader economic implications for energy usage, which may be of strategic importance for energy policy.

This dissertation concludes with policy recommendations to not only enhance the use of renewables, but also to implement strategies to assist energy-intensive users to be more energy efficient, which will ultimately reduce energy consumption. These recommendations also seek to inform on the broader economic implications of the Department of Energy and Eskom's current energy policies. Further studies regarding energy intensity in the gold mining supply chain are required. Despite these limitations, the research still aims to make a significant contribution to the knowledge on the topic.

Keywords: Energy intensity, energy clusters, energy sector, energy policies, gold mining supply chain, gold sector

Opsomming

'n Tekort aan energie het groot ontwrigting in Suid-Afrika veroorsaak wat gelei het tot beduidende stygings in die koste van energie. Onvoldoende energievoorsiening is tans een van die grootste probleme wat ekonomiese groei belemmer. Die probleem gaan gepaard met die stryd om strukturele afhanklikheid te handhaaf om die netwerk van energievoorsiening te bekom. Energie is noodsaaklik vir ekonomiese groei en voldoende energievoorsiening is deurslaggewend om ekonomiese groei te handhaaf.

Suid-Afrika is afhanklik van energie in een of 'n ander vorm, hetsy deur die vervaardiging van goedere of die lewering van dienste. Sodra daar 'n energietekort ontstaan, kan dit lei tot 'n langdurige oponthoud in die produksieproses. Dit kan selfs veroorsaak dat die mynboubedryf tot totale stilstand gedryf word, en vereis talle ure om weer met produksie te begin. Byvoorbeeld, in die goudmynbedryf word aktiwiteite soos smelters en raffinaderye hewig beïnvloed omdat die aktiwiteite 'n geruime tyd neem om bedrywigheide weer te begin. Sodoende lei die gebeure tot 'n groot afname in produktiwiteit. Die goudmynbedryf is die mees energie-intensiewe vorm van mynbou in Suid-Afrika. Die goudmynbedryf gebruik energie direk in die eerste fases van produksie, asook indirek deur sy verskaffingsketting.

Om die hoë-energie-intensiewe gebruikers te teiken, is dit belangrik om energiekusters in die goudmynbedryfketting te identifiseer. Sodra hierdie energiekusters geïdentifiseer is, kan die betrokke sleutel in werking tree met die energiekusters om te verseker dat energie meer spaarsamig gebruik word en om effektiewe maniere te identifiseer om die kostes van energie te verminder deur middel van die interaksies van die goudbedryf se verskaffingsketting. Energie is 'n noodsaaklike aspek van al die goudmynbousektor se aktiwiteite en verskaffingsketting. Gegewe die kompleksiteit van die moderne verskaffingsketting, is dit eenvoudig om groepe te identifiseer wat hoë energiegebruikers in die goudmynbedryfverskaffingsketting is. Hierdie verbruikers vorm grootliks deel van die energie-intensiteit in die goudsektor in 'n omgewing van energieverknorsings.

'n Toename in die aantal energie-intensiewe sektore het 'n negatiewe impak op die omgewing en die ekonomie. Die omgewing word negatief beïnvloed as gevolg van 'n toename in die volume van CO₂-uitlaatgasse. Die ekonomie neig om minder winsgewend en mededingend te wees weens die hoër energiekostes. Energiebeleide moet fokus op die bevordering en verbetering van energie-doeltreffendheid in die hoë-verbruikersektore. Dus sal die identifisering van energie-intensiewe klusters in die goudmynbedryfverskaffingsketting noodsaaklik wees om effektiewe energie beleide te formuleer. Hierdie studie ondersoek energie-intensiewe klusters in die goudmynbedryfverskaffingsketting en wat die implikasies vir energiebeleide in Suid-Afrika is. Die fokus was om die huidige energiebeleide van die energie-sektor te hersien wat deur die Departement van Energie opgestel is, asook om die goudsektor se prestasie, verskaffingsketting en veredelings te evalueer.

Ons uitgangspunt in die studie is om meer inligting te verskaf oor die huidige energievoorsiening-struikelblokke wat die land in die gesig staar. Die studie beklemtoon die belangrikheid van die energie-intensiteit van die goudmynsektor. Die goudmynboubedryf en sy verskaffingsketting vorm energiekusters met hoë-energie-intensiteit. Die analise in hierdie studie bewys dat energie-intensiewe klusters geïdentifiseer word in die empiriese analise deur gebruik te maak van die inset-uitset (2011)-tafels wat gekombineer is met die netwerk-partisie-metode. Die empiriese analise bestaan uit drie komponente, naamlik: 'n vereenvoudigde inset-uitset-benadering, die netwerk-partisie-metode en 'n nie-sistematiese matriksmetode. Vanuit die resultate is sewe energie-intensiewe klusters geïdentifiseer wat gerangskik is van die grootste binne-effek tot die laagste binne-effek. Vanuit die resultate is klusters geïdentifiseer met die hoogste energieverbruik in die goudmynbouverskaffingsketting.

Die identifisering van energie-intensiewe klusters binne die goudmynbedryfverskaffingsketting kan help om die breër ekonomiese implikasies vir hoë energieverbruik te identifiseer wat van strategiese belang vir die energiebeleid kan wees. Hierdie studie word afgesluit met energiebeleidsaanbevelings vir die motivering van hernubare energie asook om strategieë te implementeer om hoë-energiegebruikers te help om meer energie-doeltreffend te wees met die oog om energieverbruik te verminder. Hierdie aanbevelings poog om breër ekonomiese implikasies van die Departement van Energie en Eskom se huidige energiebeleid in te lig. Verdere studies rakende energie-intensiteit in die

goudmynsektor word vereis. Ten spyte van hierdie beperkings, poog die navorsing steeds om 'n betekenisvolle bydrae tot die kennis van hierdie onderwerp te maak.

Sleutelwoorde: Energie-intensiteit, energiekusters, enrgiesektor, energiebeleid, goudmynbedryf-verskaffingsketting, goudsektor

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List of abbreviations

ANC	African National Congress
CEF	Central Energy Fund
COSATU	Congress of South African Trade Unions
DME	Department of Minerals and Energy
DMR	Department of Mineral Resources
DOE	Department of Energy
DTI	Department of Trade and Industry
EDI	Electricity Distribution Industry
EIA	Environment Impact Assessment
Eskom	Electricity Supply Commission
GDP	Gross domestic product
GEAR	Growth Employment and Redistribution (policy)
IEP	Integrated Energy Plan
INEP	Integrated National Electrification Programme
IPP	Independent power producer
I-O	Input-Output Tables
IRP	Integrated Resource Plan
ISEP	Integrated Strategic Electricity Planning
MEC	Mineral Energy Complex
NECSA	Nuclear Energy Corporation of South Africa
NEMA	National Environmental Management Act
NEP	National Electrification Programme
NER	National Energy Regulator
NERSA	National Energy Regulator of South Africa
NIRP	National Integrated Resource Planning
NNR	National Nuclear Regulator
NUM	National Union of Mineworkers
PBE	Department of Public Enterprise
SA SAM	South Africa Social Accounting Matrix
SANEDI	South African National Energy Development Institute
Stats SA	Statistics South Africa
UASA	United Association of South Africa

¹Chapter 1: Introduction and problem statement

1.1 Introduction

Energy is an essential factor input to virtually any economic activity. Mining and its associated activities are a case in point, where the gold mining industry uses energy directly on site, as well as indirectly through its supply chain. For example, coal is combusted to produce the electricity, machinery, and equipment purchased by the mining industry and its suppliers. Therefore, inputs to the mining activity are considered to ‘embody’ energy. ‘Embodied energy’ is defined as the sum of the energy consumed, directly and indirectly, to produce a product (Costanza, 1980:1219; Suh, 2009:1; Hertwich, 2011:58). The gold mining sector is an important contributor to South Africa’s economic growth and employment. Correspondingly, the provision of a stable and sufficient supply of energy is crucial to ensuring sustainable economic growth. However, South Africa’s energy sector is currently experiencing supply constraints, while gold mining is an energy intensive sector. Improving energy efficiency can help to combat the current supply constraints.

In supply chain management, collaboration amongst industries within a supply chain is recognised as a significant method to decrease costs and energy consumption collectively (Simpson & Samson, 2008:12; Schliephake *et al.*, 2009:1257-1263). From a policy perspective, supply chain engagement can maximise energy efficiency benefits by targeting the group of mining supply chain partners that are major conduits of embodied factor inputs. For example, identifying the gold supply chain partners with intensive exchanges of embodied energy (i.e. a ‘cluster’) can help to determine effective ways to reduce energy costs through supply chain engagement. A group of closely connected suppliers in a supply chain’s connections creates an energy intensive sector within an environment of energy constraints.

Identifying energy intensive clusters can help to prioritise the relevant supply chain partners to engage and assist in effective energy policy-making. This requires further examination of the key gold mining industry clusters that collectively serve as a conduit for energy-related impacts across the South African economy. From a policy perspective, forming industry consortia around such clusters and encouraging continuous debate with relevant stakeholders (i.e.

Energy in this dissertation is defined as embodied energy, which is energy that is consumed by all of the processes associated with the gold mining supply chain, from the mining and processing of gold to manufacturing, transport and product delivery.

between government and industry) can be an effective strategy to reduce energy use and misuse. Furthermore, it is important to note that changes in a single sector do not happen in isolation, but have flow-on impacts on other related sectors due to the interconnected nature of the economy. According to Davies (2008:5), sectors consume electricity not only directly, but also indirectly through the purchase of inputs from energy consuming sectors within the supply chain. Accordingly, the inter-industry effects that these sectors create will determine the impact on gross domestic product (GDP) for the particular sector (Davies, 2008:5-6).

1.2 Background

Winkler and Marquand (2009:6) argue that the South African economy is extremely energy intensive compared to global standards. Energy intensiveness is defined as a process that utilises energy to the highest demand (Winkler & Marquand, 2009:6). According to Winkler and Marquand (2009:6), South Africa's energy-intensive sectors are predominantly the manufacturing, mining, and industrial sectors. High levels of energy usage create pecuniary spillovers to the supply chains in the sectors mentioned above. An increase in the number of energy intensive sectors has a negative impact on both the environment and the economy. (Winkler & Marquand, 2009:6).

The energy sector can stimulate economic growth and development if the demand for energy declines. If the demand for energy declines, inevitably the energy supply can decrease, resulting in lower energy intensity. South Africa is currently experiencing major energy supply constraints. Fuelling the situation is that the country is a net exporter of electricity to neighbouring countries such as Namibia, Mozambique, Zimbabwe, and Botswana. The other major concern is the lack of infrastructure. No new capacity had been added for decades (Winkler & Marquand, 2009:6). Moreover, South Africa is predominantly dependent on coal as the main resource for electricity energy generation. Coal is a non-renewable resource and significantly energy intensive to exploit. The Department of Energy (DoE) has only recently explored the options of using renewable energy resources such as wind, solar and nuclear capacities. Energy policies aim to expand nuclear power generation by 9 600 MW by 2030. Eskom is currently constructing a major coal-fired power plant (Medupi) aiming to provide approximately 25% of South Africa's existing power generation capacity for electricity power generation. A lack of appropriate planning, political and labour constraints delayed construction until projected completion in 2022 (Winkler & Marquand, 2009:6).

In 1998, the Department of Minerals and Energy released the White Paper on Energy, emphasising that the increase in energy demand will exceed the energy supply capacities. The Paper highlighted that investments into energy supply infrastructure were essential to expand the electricity generating capacity. In other words, infrastructure interventions are critical to meet the growing demand for energy (Erero, 2010:3). However, by 2008, the expected higher demand was not complemented by an adequate expansion of electricity generation capacity. This resulted in a series of electricity blackouts and load shedding in all regions of South Africa. Consequently, in 2009, the state-owned electricity utility provider in South Africa, the Electricity Supply Commission (Eskom), experienced a significant financial loss of approximately R9.2 billion. Since 2008, Eskom has urged energy intensive sectors to cut their consumption of energy by 10% (Erero, 2010:3).

A short-term solution was implemented to conserve energy by engaging with energy intensive users. The aim is to promote energy saving strategies and to reduce energy wastage. Energy-intensive industries, such as the gold mining and surrounding interconnected sectors, form clusters that are associated with high-energy intensity. These connections exercise an important role in the decision-making of energy policy in South Africa.

1.2.1 Energy policy in South Africa

Energy policies formulate how an energy development path can obtain long-term sustainability. Consequently, policies provide insight into how the near future might develop. Considering the economic significance of South Africa's energy intensive gold mining sector, it is important to improve policies that would promote energy efficiency in this sector.

Eskom is the primary supplier of electricity in South Africa, generating approximately 95% of electricity and is a key driver of economic success, contributing, in general, to job creation, growth, and quality of life. Eskom's focus is to produce, transmit, and distribute electricity to consumers around the country and, therefore, has a significant impact on every sector in South Africa (Koen, 2012:2).

Figure 1.1 illustrates the hierarchy of the energy policy and planning documentation in South Africa. The Department of Minerals and Energy (DME), Eskom and the National Energy Regulator of South Africa (NERSA) are all responsible for the implementation of the national energy policy's strategies.

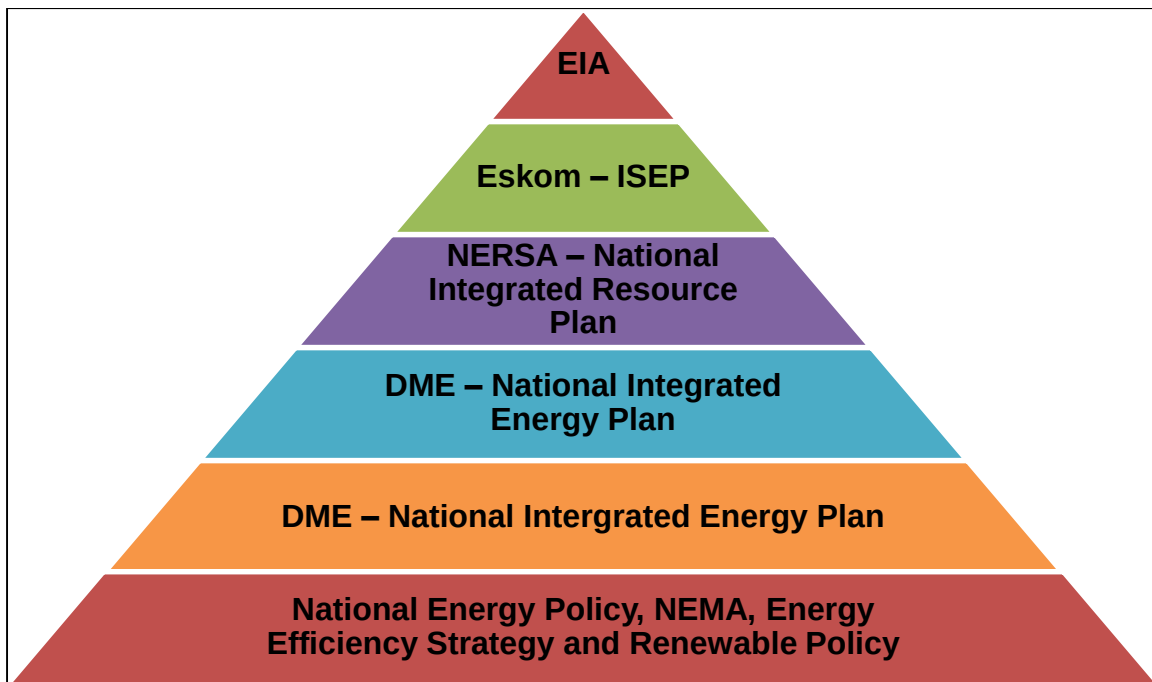


Figure 1-1: Hierarchy of policy and planning documentation in South Africa

Source: Eskom (2006:1)

The energy policy hierarchy outlines the development of energy policy throughout time. Notably, energy policy evolved more towards renewable energy as time progressed, stressing the issue of energy supply shortages and high-energy users such as the gold mining sector.

The first stage of energy policy was implemented through the National Energy Policy, National Environmental Management Act (NEMA), Energy Efficiency Strategy, and Renewable Policy. The White Paper on Energy (1998) is the blueprint for South Africa's energy policy. This Paper identified five main objectives as a focus point for the energy sector. These objectives are as follows:

- Increasing access to affordable energy services;
- Improving energy governance;
- Develop energy strategies to stimulate economic growth;
- Managing energy-related environmental and health effects; and
- Securing supply through diversity (Eskom, 2006:2).

The second stage of policy is formed by the DME, which developed the National Integrated Energy Plan. The National Integrated Energy Plan identifies the need to attain a balance between the energy demanded and resources available to formulate a structure with detailed energy policies, development assessment, and energy supply trade-offs. One of the policy objectives is to promote energy efficiency in the economy, thereby focusing on energy-intensive sectors to cut consumption to create the correct balance between resource availability and energy demand.

The third stage of the policy hierarchy was formed by NERSA. The National Integrated Resource Plan was structured based on the White Paper's objectives on low-cost energy service (Eskom, 2006:3). Energy policy's aim was to sell energy at a low rate to the high-energy consumers such as the gold mining and manufacturing sectors, thereby creating spiralling effects for other consumers.

The fourth stage is based on Eskom's Integrated Strategic Electricity Planning (ISEP), which presents a supply-and-demand-side enquiry into long-term energy supply projections. The final phase of the hierarchy is Eskom's Environment Impact Assessment (EIA) (Eskom, 2006:4). The majority of electricity supply is generated by the extraction of coal; however, the exploitation of coal is not an environmentally friendly activity. Therefore, Eskom's new focus is on strategies to employ renewable energy resources to minimise the depletion of resources and the environmental impact (Eskom, 2007:2).

According to Eskom (2007:2), their energy policy strives to create a foundation for sustainable growth and development with the purpose to add value to the private and public sector. In 2010, Eskom implemented policies for sustainable strategies to improve and manage the electricity value chain with the aim of supplying first-class, inexpensive electricity in a constantly changing economic and political environment. The implementation of the policy is evaluated on a regular basis to foresee sustainability of quality in the supply of electricity (Eskom, 2007:2).

The government has identified the significance of infrastructure in supporting and facilitating economic growth. Infrastructure investments are expanding rapidly, however concerns was raised over the efficiency, scale and timing of these investments and operations (Newbury &

Eberhard, 2008:13). It is vital to expand electricity infrastructure in order to meet the current electricity supply.

On the back of the five objectives of the White Paper on Energy, numerous policies, reports, and strategy documents have been released. The Integrated Energy Planning (IEP) report enables energy decision-makers to maintain a balance between the energy demanded and the energy supplied. When implementing the IEP, one should also consider environmental, safety and health concerns.

In 2004, the National Integrated Resource Planning (NIRP) policy was implemented to enable a long-term cost efficient resource plan that meets future electricity demand (Eskom, 2006:1-2). Therefore, the aim of the NIRP was to promote energy efficiency. One of the major issues post- and pre-Apartheid is the lack of accessibility to electricity (Nkomo & Winkler, 2006:73). As noted, Eskom provides the majority of electricity in South Africa, and therefore, the government should align energy policy to allow for the opportunity of privatisation in electricity supply. In the long term, great policy reforms can change the energy economy (Nkomo & Winkler, 2006:73). For example, Sasol is an integrated energy and chemical company that supplies its own energy.

If policy promotes energy infrastructure investments in the sectors with high-energy usage, Nkomo and Winkler (2006:77) argued that it would further contribute to the energy intensiveness of the economy in the long term, however promote investments in the short run. Once energy infrastructure investments are concluded, there are minor opportunities to improve the production process and energy efficiency (Nkomo & Winkler, 2006:77).

Eskom and the DOE will require several years to restore the required energy supply to reach the demand of consumers. Therefore, the challenge that policy-makers face is to find methods to decrease demand while still enforcing minimum cost on the economy regarding projected energy output, cheap labour and increased social disorder (Nkomo & Winkler, 2006:77).

The most effective policy is not always necessarily an optimal policy. Therefore, it is essential for energy policies to support vulnerable industries that contribute significantly to the economy. These vulnerable industries referred to are mostly the high-energy users such as the gold mining and manufacturing sectors. The government should intervene and subsidise the high-

energy users to maintain a competitive advantage in the global markets (Deloitte, 2012:15-18). The effect that the gold mining sector has on the economy creates awareness for the government to align policy to support vulnerabilities in the mining sector.

1.2.2 The role of the gold mining in South Africa

The role of the gold mining industry is vital to the South African economy. The gold mining industry, as well as the upstream and downstream linkages that form in the sector, is a significant driver of the economy and is essential for job creation. For example, if the gold share price declines, a major capital loss occurs. It is vital for the DOE to explore sustainable solutions to maintain and sustain gold mining operations

According to the annual Chamber of Mines report (2013:4), the gold mining sector plays an instrumental role in the South African economy. Gold mining forms a challenging part of South Africa's economy, contributing profoundly to foreign exchange reserves and accounts for more than one-third of exports (Chamber of Mines, 2012b:3, 4).

The mining sector and more specifically gold mining shared a significant percentage of shares on the Johannesburg Securities Exchange (JSE), responsible for approximately 43% of the total value of the JSE (Chamber of Mines, 2012b:5). South Africa is the second largest producer of gold in the world. Most of the gold mining companies in the world have their origins in South African. Considering all 50 industries in South Africa, gold mining is the most dependent on electricity for production (Deloitte, 2012:14). Other forms of mining are less energy intensive compared to gold mining. Gold mining, followed by platinum mining, is the most dependent on energy as an input to production, which accounts for 22% of the overall costs (Deloitte, 2012:14-15). In general, the mining activities that consume the most energy are cooling, pumping, and ventilation. These activities account for approximately 50% of energy consumption (Deloitte, 2012:14-15). There is a notable difference in added costs when different types of mining operations are compared. For example, underground gold mining has a higher production cost compared to opencast mining such as coal and platinum mining (Deloitte, 2012:14-15). Therefore, underground mining is the most energy intensive form of mining.

The gold mining sector generates significant foreign exchange income while having substantial employment and GDP multipliers. Gold mining is, therefore, essential for the growth, development, and transformation of the South Africa economy. It is essential to identify ways to decrease energy intensity in the sector to help steer the economy forward.

1.2.3 Gold mining supply chain

The gold mining supply chain is a significant linkage of the gold mining sector. A supply chain is defined as the flow of goods from suppliers through transformation and transportation to the consumers. The main objective of a supply chain is to enhance the quality of production, services delivered, and client satisfaction as well as reducing the cost of the final product (Mathu, 2010:50-51).

Numerous phases transpire in a gold mining supply chain. Each of these phases is a crucial element in ensuring the delivery of top-class service and productivity to the final consumer. Promoting energy efficiency strategies throughout the gold mining supply chain will inevitably lead to a decrease in energy usage. As discussed in section 1.2.2, there are strong linkages between the gold mining supply chain and the economic performance of the sector (Accenture, 2007:2, 4).

A gold mining supply chain evolves from the exploration of the mineral and concludes with either export or transportation to the local and foreign consumers, respectively. As part of the gold sector, numerous upstream and downstream activities form linkages to other sectors and unavoidably create the gold mining supply chain. The creation of these intra-industry linkages results in spillovers to other sectors forming energy intensive clusters (Mathu, 2010:136).

1.3 Problem statement

South Africa is one of the most energy-intensive countries in the world, resulting in high costs to society and numerous energy supply complications. Energy is crucial for economic growth. South Africa has an important electricity supply shortage and, therefore, needs to improve efficiency, inevitably reducing the cost for society and combating supply problems. Gold mining is a crucial element of the South African economy, but is also an energy intensive sector. South Africa's energy policy should focus on targeting energy-intensive clusters, specifically within the gold mining sector to decrease energy consumption. Gold mining and its supply chain can engage with the DOE and each other to become more energy conscious and ultimately more energy efficient.

1.3.1 Motivation

Energy is a necessity in every aspect of the gold mining sector and the gold mining supply chain, with links to many other sectors within the South African economy. The entire country runs on energy in one form or another, either by producing goods or by delivering a service. Sufficient energy supply is required to sustain economic growth. Poor energy policy implementation in the past is a key cause of the availability of infrastructure and energy supply shortages. Energy policies should focus on promoting and improving energy efficiency in the high-consuming sectors to reduce energy consumption. Therefore, identifying energy-intensive clusters in the gold mining supply chain is essential to design effective energy policies.

1.3.2 Research question

The research question of this study is as follows: Which sectors form energy-intensive clusters in South Africa's gold mining supply chain and what are the implications for energy policy?

1.3.3 Objectives

The objectives of this study are fourfold:

- Firstly, to provide a review of the DOE's current energy policies through an analysis of the current policy and strategy documentation to determine which policies fulfilled their expectation.
- Secondly to review the related approaches and methods to identify supply chain clusters in the literature.

- Thirdly, to apply a new method to combine a simplified input-output approach with the network partition approach to determine the strength of the relation matrix.
- Fourth, to validate the effectiveness of the method by means of a case study to identify energy-intensive industry clusters in the South African gold mining supply chain.
- Finally, to inform on the broader economic implications of the DOE and Eskom's current energy policies with specific reference to the gold mining sector and related clusters.

1.3.4 Hypothesis

The hypothesis underlying this dissertation is that the identification of energy-intensive clusters within a particular industry (gold mining) supply chain may help to identify the broader economic implications of energy usage, which is of strategic importance for energy policy formulation in South Africa.

1.4 Method

The research problem as presented in section 1.3 will be addressed by means of a thorough overview of the DOE's current energy policies through an analysis of the current policy and strategy documentation to determine which policies fulfilled their expectation and review the related approaches and methods to identify supply chain clusters in the literature.

After that, in Chapter 3, the gold mining sector is reviewed and the gold mining supply chain is identified. The focus is on the impact of energy intensity on the gold industry as well as on the economy. This literature review will focus mainly on recent publications ranging from 2006 until 2013.

To provide a general picture of the energy intensity of the gold mining supply chain, qualitative analyses are undertaken using the 2011 input-output tables (I-O tables) of South Africa obtained from Statistics South Africa (Stats SA). The empirical analysis consists of three components: a simplified input-output approach, the network partition approach, and a non-systematic matrix approach.

The main constraint of this study is the significance of energy intensity within the gold mining supply chain. There is limited research on the subject, and therefore, integrating the I-O tables with the network partition approach analysis can be performed, conclusions can be drawn and policy recommendations based on the study can be formulated. Further studies regarding energy intensity in the gold mining sector are required. Despite these limitations, the research still aims to make a significant contribution to the knowledge on the topic. The key is to inform on the broader economic implications of the DOE and Eskom's current energy policies with specific reference to the gold mining sector and related clusters.

1.5 Outline of the study

This study is presented in five chapters, which are structured as follows: Chapter 1 provides an overview of the study as well as what is to follow in the remaining chapters. Chapter 2 is a summary of the energy policies in South Africa that are relevant to the gold mining sector.

Chapter 3 provides an overview of the gold mining supply chain. Chapter 4 explains the empirical methodology, which connects the input-output analysis and the network partition analysis and identifies the energy clusters, subsequently formulating the results. Chapter 5 concludes with a summary of the study's key findings, as well as relevant policy recommendations.

Chapter 2: Energy policy in South Africa

2.1 Introduction

Energy policy has always been at the centre of policy development in South Africa (DOE, 2013:1). South Africa's energy sector has numerous shortcomings, which are mainly associated with energy supply shortages. For example, energy consumption is exceeding energy supply. The economic and political influences have been one the key driver for energy policy formulation (Davidson and Winkler, 2006:5).

According to Pickering (2011:3), historically, energy policy has never been correctly implemented, thereby creating major shortcomings in the sector. Pickering (2011:3) argues that the shortcomings associated with energy policies occur in the generation capacity and policy planning, as well as an imbalance in supply and demand side management. It is essential for South Africa to develop a comprehensive energy policy system to diversify energy supply.

Furthermore, it is important for the DOE to formulate energy policy that promotes renewable energy strategies. The World Energy Council director, Christoph Frei (2014:1), stated that it is crucial for South Africa to create a single energy policy that captures the broader elements of energy supply. Frei (2014:1) indicated that the country could not provide access to energy for the poor while experimenting with expensive technologies as well as constructing coal power stations all at the same time (Frei, 2014:1).

Davidson and Winkler (2006:8) stated that the key objective of energy governance should be to provide affordable access to energy for all citizens in South Africa (Davidson & Winkler, 2006:8). However, focusing on energy intensity can inevitably lead to affordable access to energy. The current supply constrained economic growth in South Africa.

Given these issues, more emphasis on the implementation of energy policies is needed by congregating the various role players to ensure sustainable supply. These role players, who govern South Africa's energy policy, include the DOE, the Department of Public Enterprise (DPE), the Department of Trade and Industry (DTI), the National Treasury, Cabinet, Parliament, and the public sector (Pickering, 2011:3).

The primary purpose of this chapter is to provide an overview of the energy sector in South Africa (Section 2.2) as well as to identify the role players in the sector. Section 2.3 provides an overview of the role of the DOE and Eskom in the energy sector. Once all energy policies are revealed, it will be significant to see where these policies fit into this study and what policies failed to be implemented that caused the current energy supply shortage.

2.2 Overview of South Africa's energy sector

The South African energy sector is embedded with neglected infrastructure, supply shortages and increasing energy demand (Deloitte, 2013:1). The number of high-energy users in the economy fuels the energy supply situation.

Pickering (2011:3) found that an energy-intensive cluster is formed within the linked sector with high-energy consumption such as the gold mining and manufacturing sectors. The major driving force behind energy intensive sectors was the availability of cheap energy throughout decades. As the demand for energy increased, more energy was supplied, thereby contributing further to the growth of energy intensiveness in the gold sector (Pickering, 2011:3).

Davidson and Winkler (2003:2) found that, in comparison with developing nations, South Africa consumes the highest volume of energy per unit. Furthermore, regarding the total value of energy consumption in Africa, South Africa consumes approximately 42% of the continent's energy (Davidson & Winkler, 2003:2). However, the DOE has indicated that the energy intensive industries are a result of the economic structure of South Africa and not a lack of energy policy implementation (DOE, 2013:1). The DOE has financed and supported the energy intensive industries to help gain a comparative advantage in the global markets (Davidson & Winkler, 2003:2). The high-energy users create strong linkages with one another. For example, the gold mining sector, and its supply chain (note: the manufacturing sector forms part of the mining supply chain.) create an energy-intensive environment, which depends heavily on coal as a source for electricity generation. (Davidson & Winkler, 2003:1). Figure 2.1 illustrates the final share of energy consumption in 2000.

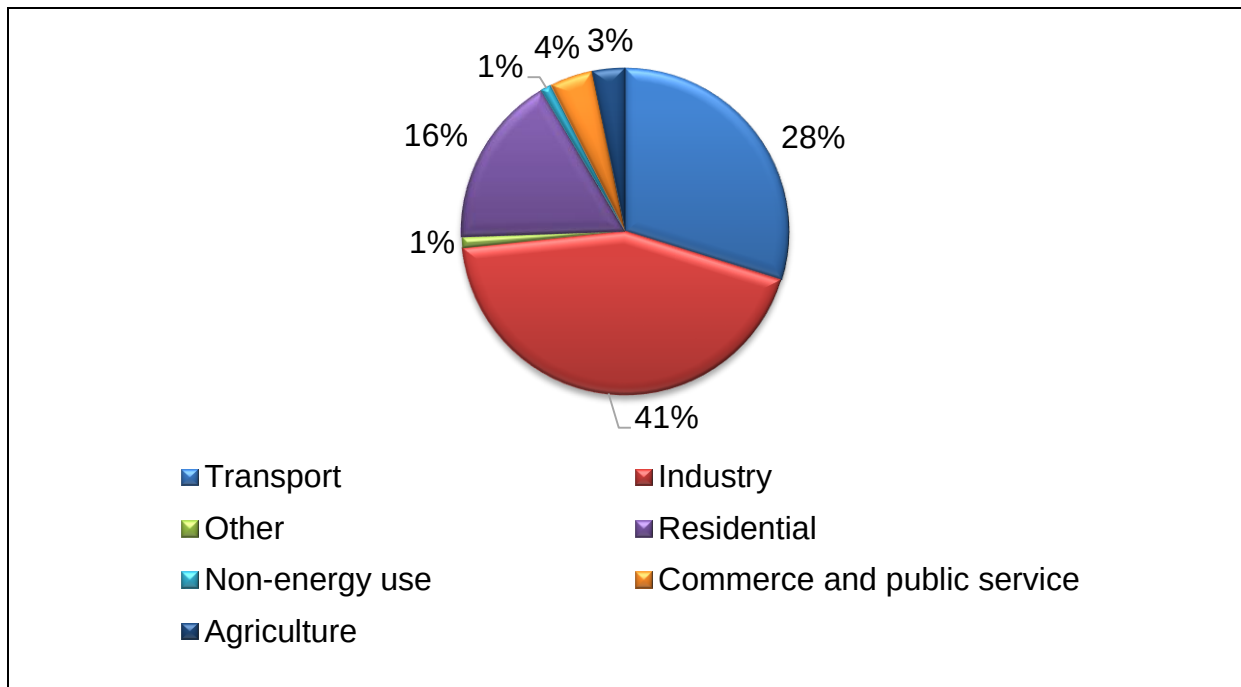


Figure 2-1: Final Share of Electricity Consumption (2000)

Source: Davidson and Winkler (2003:3)

Figure 2.1 illustrates the highest energy consumers. The industrial sector accounts for 41% of the total electricity consumption, verifying the energy intensiveness of the sector. The transport sector (28%), followed by the residential sector (16%) are the second and third highest consumers of energy, respectively. Those industries that consume the least energy are the public services (4%), agriculture (3%), other (1%), and non-energy use (1%) sectors (Davidson & Winkler, 2003:3).

In recent times, the electricity sector evolved from having an abundant supply to a supply shortage. South Africa will suffer substantial financial losses and costs to reconstruct and expand the electricity infrastructure to secure current and future supply (Pickering, 2011:4). South Africa generates power from energy sources such as coal, nuclear, liquid fuels, wind turbines, hydrocarbons and oil and gas (Department of Energy, 2013:1). Figure 2.2 illustrates the primary sources of energy supplied in 2013, indicating the reliance of the energy sector on coal. Coal is accountable for approximately 72% of the total energy supplied, verifying that South Africa depends heavily on coal as a source for energy generation. Coal is associated with a high level of pollution and is regarded as an increasingly depleted resource. Oil (22%) is the second largest contributor, followed by natural gas (3%) and nuclear (3%). Renewable energy contributed less than 1%. Evidently, previous policies on renewable energy failed to be

implemented. This can be seen as a window of opportunity for the DOE (Department of Energy, 2013:1).

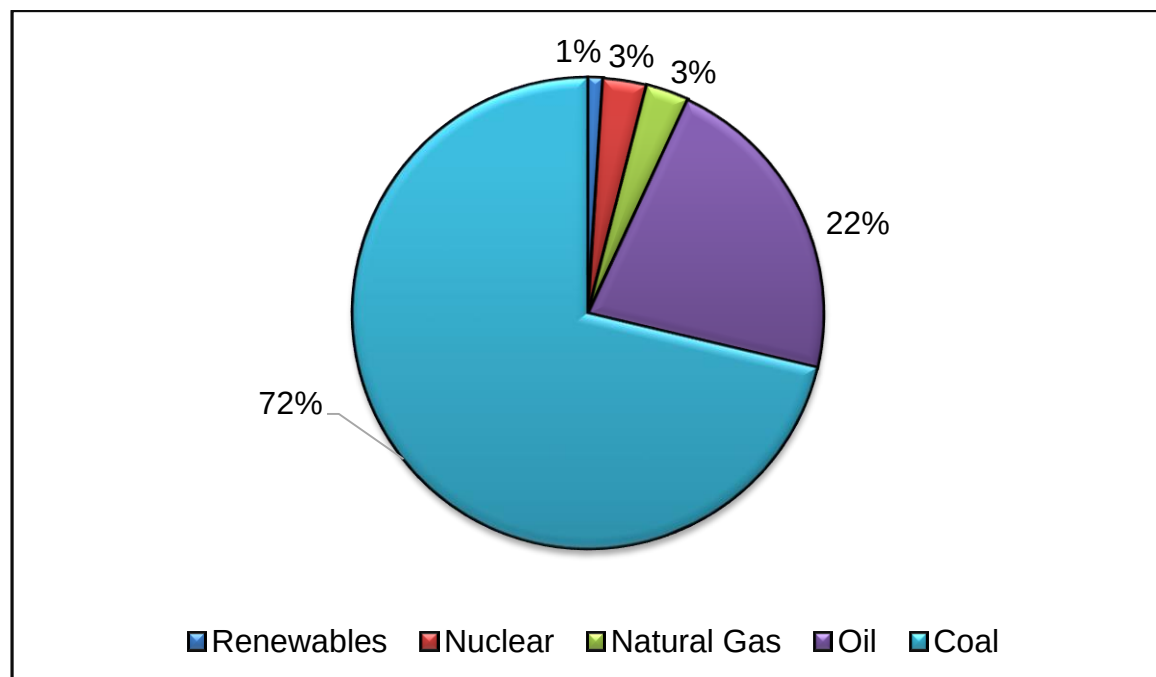


Figure 2-2: Primary sources of energy supplied (2013)

Source: Department of Energy (2013:1)

In South Africa, coal is predominately used as a resource to generate electricity due to the abundance and availability of the resource. The volume of energy input per unit of economic output, and the energy efficiency of a particular sector are relatively high; therefore, an energy-intensive environment is created. These environments referred to can be called an energy cluster. Through the implementation of new, different technologies, the energy intensity levels can decrease in the mining sector. Most of these sectors contribute significantly to exports, economic growth, and job creation (Davidson & Winkler, 2003:4).

Although energy prices have increased over recent years, the DOE has ensured that prices will be kept reasonably low with the intention of implementing an energy policy that promotes the energy efficient strategies as well as accessibility of energy for disadvantaged groups (Davidson & Winkler, 2003:4). Davidson and Winkler (2003:4) argue that inexpensive electricity tariffs have enabled South Africa to gain a comparative advantage attributable to inexpensive and low-grade coal as well as initial investments in energy infrastructure. These aspects remain crucial elements to attract new investments (Davidson & Winkler, 2003:4).

To summarise, the South African energy sector has a dismal outlook. The availability of inexpensive coal and electricity in the past decades has affected the energy sector not to explore /invest in energy-efficient technologies. This lack of development put further strain on the high-energy intensive sectors (Davidson & Winkler, 2003:4). To refer to the research question in this study, it is evident that the availability of inexpensive energy contributed to the energy intensity of the country. This is where intervention from the DOE is required. The DOE will be covered in the next section, mainly focusing on energy policies and the role that the Department has in the energy sector.

2.3 Department of Energy (DOE)

The following section provides an overview of the structure and key policy documentation of the DOE. In 2009, the DME was divided into two different departments, namely the DOE and the Department of Mineral Recourses (DMR). The aim of the restructuring of the DME was to sustain energy supply (Department of Energy, 2012:9).

The mandate of the DOE is to sustain and guarantee secure energy supply in support of socio-economic expansion (Department of Energy, 2011:4). The DOE aims to achieve an energy sector with 30% clean energy before 2025 (Department of Energy, 2012:9). The DOE is responsible for the improvement, operation, and management of all energy resources and to secure and ensure energy supply throughout South Africa. Energy is attracting more interest, as the country continues to maintain growth. In 2011, the DOE transformed their organisational structure into a macro-type structure with the intention of assuring improved performance from the Department. Once again, the focus was to supply the necessary energy to meet South Africa's energy demand, growth, and economic development (Pickering, 2011:3).

In the final quarter of 2011, the DOE revised their strategic outcome-orientated goals, which is in line with their mandate. These goals include the following (Department of Energy, 2012:9):

- Promote energy efficiency and a diverse energy mix within the energy sector
- Improve energy supply-and-demand-side management
- Enable energy regulation and cooperation; construct an effective, economic and receptive energy infrastructure complex

- Promote clean energy and environmental impact assessments
- Implement policies that promote the effects on climate change
- Improve corporate governance for operational and efficient service provision
(Department of Energy, 2012:9)

The DOE's role in South Africa is becoming increasingly important; therefore, it is vital for government to achieve the objectives formulated in its policies (Department of Energy, 2012:25). The next section will cover the structure of the DOE.

2.3.1 Structure of the DOE

The structure of the DOE is framed in line with current energy policies. The DOE has developed a macro-governmental structure to adapt to the changing environment of the energy sector, as well as global climate changes and supply shortages. The DOE structure is divided into four different operational branches, namely the policy development; operational energy services; integrated energy planning; and nuclear power. Furthermore, the DOE has three support branches: financial, statistics and supply chain management; corporate services; and the chief operating officer (Department of Energy, 2012:31).

The nuclear branch is responsible for the regulation of the nuclear energy industry in South Africa by ensuring total control of the distinctive nuclear resources for nuclear regulation. As a legislative requirement and to comply with international standards, the nuclear energy branch is accountable for the management and implementation of nuclear safety and technology requirements (Maleka, Mashimbye & Goyns, 2010:4).

The policy development branch is responsible for the implementation, development, and evaluation of electrification and hydrocarbon policies. Additionally, the branch is responsible for policies concerning the reformation of the generation capacity industry. The policy development branch has to develop and implement planning structures and ongoing integrated energy policies that correspond with international standards (Maleka *et al.*, 2010:4).

The main objective of the energy operational services branch is to operate and regulate pricing disputes, licencing compliance, as well as the regulation of export and import processes. Furthermore, the branch is responsible for the promotion of consciousness with regard to petroleum products to provide energy-related services and to administer the Integrated National

Electrification Programme (INEP). Lastly, the branch enables the implementation of renewable energy technologies, and standardises and promotes clean energy activities. As a result, the clean development mechanism has a vital role in managing energy efficiency to incorporate renewable energy into the mainstream of energy supply, which is mainly the energy-intensive clusters (Maleka *et al.*, 2010:5).

By approving energy securities, the integrated energy-planning branch helps to develop, implement, and maintain the National Integrated Energy Plan to manage economic factors that influence the energy sector (Maleka *et al.*, 2010:5).

As mentioned, the DOE has further support in the form of support branches. The corporate services branch provides direct assistance to support services, communication and knowledge management services, strategic human resource services as well as the provision of legal guidance. The financial, information, and supply chain management branch manages all related financial activities and enquiries such as budgetary processes, debtors and creditors. Furthermore, the branch ensures a comprehensive supply chain management and information technology service. Lastly, the office of the chief operating officer is responsible for the evaluation of the DOE's influence on processes outside as well as inside the DOE (Maleka *et al.*, 2010:6).

2.3.2 Key energy policies and legislation of the DOE

Over the past three decades, the governance of energy in South Africa made several key policy publications. These publications in energy policy date back to 1984 when the De Villiers Commission investigated the supply of electricity in South Africa (Pickering, 2011:3).

In 1992, the ANC addressed the issue of the affordability and access of electricity. Furthermore, in 1992 and 1993, the National Electrification Forum established the Regional Electricity Distributors (REDs) as well as an independent energy regulator (NER) (Pickering, 2011:3). After the elections in 1994, the Reconstruction and Development Programme (RDP) launched a target to provide 2.5 million households with electricity over six years. The government met this objective. This goal, however, was never met. The relevance of studying energy policy throughout decades is critical to identify where weaknesses arose as well as where these energy supply issues can be identified and rectified.

The policies discussed in this paper can be regarded as the foundation for energy policy in South Africa. Although these policies only form the basis of energy policy, there are other policies not discussed in this paper due to their irrelevance pertaining to this study. Therefore, the energy policies discussed in the dissertation are as follows: White Paper on Energy (1998), National Energy Act, White Paper on Renewable Energy, White Paper on Renewable Energy, Integrated Resource Plan (IRP), National Nuclear Regulator (NNR), National Nuclear Regulatory Act, Nuclear Energy Policy and Strategy and Nuclear Energy Act. These energy policies not only form the foundation for the energy sector, but also frame the future of energy intensive sectors such as mining.

Most of these documents are renewed and reviewed to fill the gaps previously left by poor implementation. It is critical for the DOE to address and overcome the complications of energy supply shortage, implementing renewable energy, and improving energy efficiency. The next section will cover the energy policies relevant to this study (Pickering, 2011:3). As mentioned previously, the White Paper on Energy (1998) is regarded as the blueprint for energy policy in South Africa,

2.3.2.1 White Paper on Energy policy in South Africa

In December 1998, Cabinet approved the White Paper on Energy, which mostly focused on promoting integrated resource planning methodologies. Energy policy in South Africa is administered by the White Paper on Energy. The main goal of this policy was to encourage additional energy supply infrastructure and investments that enable the upgrade of older power stations (Pickering, 2011:3).

The White Paper provides a framework for the energy sector's macroeconomic stability regarding employment rates, taxes, the balance of payments, as well as the total GDP share in South Africa. Furthermore, the White Paper emphasises that it is essential for energy policies to synchronise with social sectors as well as sub-sectors to overcome energy constraints in both energy demand and supply (Department of Minerals and Energy, 1998:8).

As discussed in Chapter 1, the White Paper on Energy has identified five key objectives. These goals form the framework for numerous energy policies that have evolved through time. The

aim of the objectives was to promote renewable energy, aiming to enhance the energy supply.

The objectives are as follows:

- Increasing access to affordable energy services
- Improving energy sector governance
- Stimulating economic development
- Managing energy-related environmental impacts
- Securing supply through diversity

The policy aims to reduce the environmental impact by managing supply and demand. A process to develop an appropriate regulatory framework for non-grid electrification was introduced by the National Electricity Regulator. The White Paper also highlighted the government's intention to promote renewable energy technologies and to reduce emissions. The White Paper's objective, as mentioned above, is discussed in the next paragraph:

Increasing access to affordable energy services: The government aimed at promoting access to inexpensive electricity for disadvantaged households, small firms, and farms as well as to provide excellent public services to the communities in South Africa (Department of Minerals and Energy, 1998:8).

Improving energy sector governance: The second objective of the White Paper on Energy was to improve the governance of energy. The different roles and goals of each department and sub-division should be simplified to ensure improved governance. The aim was to ensure engagements with stakeholders to provide assistance in draughting and implementing innovative energy policies. The synchronisation among government departments was aimed at ensuring greater integration in energy policy draughting and implementation (Department of Minerals and Energy, 1998:8).

Stimulating economic development: Government attempted to intervene where market failures occur to ensure an efficient and sustainable supply of energy services to consumers. Furthermore, the government aimed to sustain a comparative advantage among energy markets by regulating tariffs that enable the energy sector to be cost effective. A key aim of this objective was for the government to create an investor-friendly environment in the energy

sector through sustainability and well-established transparent governing systems (Department of Minerals and Energy, 1998:9).

Managing energy-related environmental impacts: Government has ensured the provision of basic energy services to informal settlements to combat negative health impacts arising from carbon dioxide emissions. Government established policies to neutralise the energy-related emissions, which are dangerous to the environment and society. These policies aim to guarantee a balance among misusing fossil fuels and the preservation of suitable environmental necessities (Department of Minerals and Energy, 1998:9).

Securing supply through diversity: In sub-Saharan Africa, opportunities in energy trade have become more prominent. As stated in the White Paper on Energy, Government has encouraged diversity in both supply sources and primary energy exporters (Department of Minerals and Energy, 1998:9).

The White Paper addressed the need to improve energy policy constantly, discussing the process of energy policy formulation and the expression of strategic objectives (short-term and long-term) in the energy sector. Demand-side management enables government to investigate the various energy supply channels to households, industries, transport, agriculture, and mining. On the supply side, the White Paper focused on utilising resources such as nuclear energy, oil and gas exploration, liquid fuels, coal and renewable energy sources to forecast sustainable energy supply.

The White Paper concludes by stating that government strives to sustain energy supply by ensuring economic growth, a development strategy within the energy sector, energy efficiency programmes, combatting fiscal and pricing issues and the development of human capital (Department of Minerals and Energy, 1998:9).

2.3.2.2 White Paper on Renewable Energy

In 2003, the White Paper on Renewable Energy was released in line with the objectives of the White Paper on Energy, stressing the issue of integrated resource planning. This policy specifically addresses the importance of natural resources in promoting renewable energy. The purpose of this policy was to formulate a framework of the DOE policy ethics, strategic

objectives, and vision to consign the basis of implementation of renewable energy (Maleka *et al.*, 2010:8).

The aim of this policy was to implement 10 000 GWh of renewable energy, which contributes 5% of the final energy demand before 2013. The target was set to be executed during 2004 to 2013 and was examined on a regular basis to govern the efficiency of the processes and technologies implemented. The aim is to produce energy mainly from biomass, solar and small-scale hydro sources as well as to generate electricity by exploiting renewable technologies such as solar water heating and biofuels (Maleka *et al.*, 2010:8). Global warming and international renewable energy markets have created awareness for the development of renewable energy in South Africa. The White Paper on Renewable Energy is reviewed on a regular basis to sustain supply and improve the energy sector's performance (Maleka *et al.*, 2010:8).

2.3.2.3 Integrated Resource Plan (IRP)

The IRP was published in 2010, focusing on regulating energy supply and demand in South Africa. The aim was to identify different resources such as oil, gas, coal, nuclear power, and renewable energies that can co-operate to sustain future supply until 2030 (Maleka *et al.*, 2010:8).

The IRP established a differentiated energy source mixture. The idea was to diversify the energy supply resources to be less dependent on coal. The target was set for new energy generation capacity to consist of coal (14%), nuclear (22.6%), gas (14.8%), hydro (6.1%), wind (19.7 %), solar power (2.4%), and photovoltaic (19.7%). The IRP also focused on numerous constraints and risks, such as decreasing carbon emissions, new technology, water usage, job creation, sub-Saharan integration, and supply provision (GCIS, 2011:172). The objective of the IRP was to establish methods to sustain long- and medium-term energy supply at the lowest possible costs with the intention of reaching future electricity demand, considering economic growth and development.

The IRP also indicated that renewable energy technologies could minimise the risk of environmental impacts (Maleka *et al.*, 2010:8). The policy also aimed to reduce energy-intensive sectors over a period of 20 years in South Africa (Eskom, 2009:2).

2.3.2.4 National Energy Act

The National Energy Act, released in 2008, is legislation that allows the government to control for measures – such as energy securities and policies – such as the Integrated Energy Plan (IEP). The National Energy Act legislation was implemented to fulfil previous gaps in the White Paper on Energy (Maleka *et al.*, 2010:8).

The policy provided an outline in which the implementation of comprehensive energy policies, development assessments, and energy supply exchanges was finalised (Eskom, 2009:15). The purpose of the IEP was to establish a balance between the availability of natural resources and the energy demanded. Therefore, the aim was to deliver cheap energy for economic development, while considering environmental, health and safety impacts. The IEP projected that in 2007 the demand for energy would exceed the energy generation capacity and that South Africa will be dependent on coal for the next two decades, indicating that coal continues to be the primary source of new electricity capacity/generation. Other alternative sources such as natural gas, nuclear capability, and renewable energy were explored (Maleka *et al.*, 2010:8).

Furthermore, the IEP promoted energy efficiency management, access to clean and affordable energy, new technologies as well as the environmental impact of adding additional generation capacity. The IEP introduced the policy, legislation, and regulation to promote renewable and efficient energy strategies (Eskom, 2009:16). As stated in the National Energy Act, government has an obligation to review and develop the IEP on an annual basis. The National Energy Act installed initiatives with the intention of obtaining a target of 15% energy efficiency in the industrial sectors and 12% nationally by 2015, respectively (Stats SA, 2012:1).

These initiatives range from the generation of solar wind energy to the implementation of new construction regulations and standards in which construction efficiency is monitored. Furthermore, there are also projects and programmes such as the Working for Energy Programme, the Carbon Dioxide Geological Storage Atlas, and the Clean Development Mechanism for energy to improve and promote efficiency. The liquid fuels industry introduced a new pipeline between Durban and Johannesburg to allow investment opportunities at the Coega Industrial Development Zone (IDZ) in the Eastern Cape. Consequently, this has resulted in an increase in the transportation of petroleum capacity (Maleka *et al.*, 2010:8; Stats SA, 2012:1).

In 2011, Abrahams argued that the National Energy Act aimed at providing access through a diversity of energy mix and energy services in the energy sector to sustain the constant energy demand by the population of South Africa (Abrahams, 2011:9).

2.3.2.5 National Nuclear Regulator (NNR) and National Nuclear Regulatory Act

The NNR is a public entity, which was established in 1999, and is governed by the National Nuclear Regulatory Act. The primary responsibility of the NNR is to secure the safety of the environment, assets, and the public against nuclear damage through the implementation of policies and safety measurements (NNR, 2012:2).

The National Nuclear Regulatory Act was also established in 1999 and is responsible for the establishment of an NNR. The NNR regulates nuclear installations, vessels as well as any other form of nuclear energy that may cause harm to society. The DOE governs all nuclear technology and safety requirements and is responsible for the management of the Nuclear Energy Corporation of South Africa (NECSA) as well as the NNR (NNR, 2012:2).

The NNR currently controls the facilities and actions of the safety measurements of the following operations: the Pelindaba Research and Production Facilities; the Koeberg Nuclear Power Station; the Vaalputs Nuclear Waste Repository; the exploration of Uranium as well as radioactive ores (NNR, 2012:5). Nuclear energy is extremely cost effective, and can be implemented efficiently in the sectors with high-energy users. Therefore, the Nuclear Regulatory Act has to promote and regulate these possibilities.

2.3.2.6 Nuclear Energy Act

The DOE also formulated the Nuclear Energy Act in 1999, which led to the establishment of NECSA. NECSA is a state-owned public entity that is responsible for all safety measurements, such as the Safeguards Agreement and protocols under the regulations of the Republic and the International Atomic Energy Agency (Maleka *et al.*, 2010:7).

Furthermore, NECSA, under the regulation of the Nuclear Energy Act, regulates the attainment and possession as well as the import and export of nuclear fuel, equipment, and material that comply with international standards (Maleka *et al.*, 2010:7).

2.3.2.7 Nuclear Energy Policy and Strategy

The Department of Minerals and Energy formulated the Nuclear Energy Policy and Strategy in 2008 to provide a policy framework for nuclear-related activities such as mining exploration, milling, the use of nuclear materials and the improvement and utilisation of nuclear energy (Department of Minerals and Energy, 2008:3).

Furthermore, this policy was formulated from government's vision and commitment as well as downstream and upstream activities of the current nuclear energy sector (Department of Minerals and Energy, 2008:6). The policy aims to cover all uranium ore mining as well as other ore related to nuclear technology for energy generation (Department of Minerals and Energy, 2008:3). The objectives of this policy are to (Maleka *et al.*, 2010:12):

- promote nuclear energy as a source for electricity generation by implementing nuclear power systems;
- ensure governmental structures for a comprehensive nuclear power programme;
- implement an outline for safe and protected exploitation of nuclear energy with a negligible impact on the environmental;
- support national programme in promoting social and economic growth and development;
- monitor, enhance, stimulate, and sustain all engagements in the nuclear energy sector;
- enable the nuclear power sector to sustain long-term global nuclear independence;
- control of all activities regarding uranium ore;
- guarantee the availability of nuclear sites for future electricity generation;
- ensure access for public entities in the uranium value chain;
- reduce greenhouse gas emissions;
- safeguard energy securities in South Africa;
- enhance the quality of life and human well-being through the improvement of science and technology in the field of nuclear studies; and
- Promote skills development associated with nuclear energy operations.

The utilisation of nuclear energy is vital for mining exploration. Nuclear power is a tool to improve energy efficiency, inevitably aiding the high-energy users.

2.3.2.8 Petroleum Products Act

The Petroleum Products Act was established in 1977 to control all petroleum products. The Petroleum Products Act is responsible for the exploitation of petroleum products to be cost

effective and efficient when controlling for price, regulation, and information concerning all petroleum products (Maleka *et al.*, 2010:13).

Additionally, this act enables and promulgates licencing for entities involved in the production and sale of specific petroleum products as well as the enhancement of petroleum and liquid fuel industry in South Africa (Maleka *et al.*, 2010:13).

2.3.2.9 Other policy documentation

Several policy documents evolved from the White Paper on Energy as well as other energy policy documentation through legislation and renewed policies. Numerous established policies were revised over the years and most of these policies are revised on an annual basis. Table 2.1 provides a timeline of all energy Acts and Bills not captured in the above section.

Table 2-1: DOE's Acts and Bills from 1977 to 2008

Energy Policy Acts and Bills	Release Date
The Central Energy Fund Act	1977
The Abolition of the National Energy Council Act	1991
The Coal Act Repeal Act	1991
The Liquid Fuel And Oil Act Repeal Act	1993
South African Energy Policy Discussion Document	1995
Nuclear Energy Act	1999
National Nuclear Regulatory Act	1999
Gas Act	2001
The Gas Regulator Levies Act	2002
The Petroleum Products Amendment Act	2003
The Petroleum Pipelines Bill	2003
Energy Bill	2003
Petroleum Pipelines Money Act	2004
Electricity Distribution Act	2006
Electricity Supply Industry Regulatory Bill	2006
Electricity Supply Industry Restructuring Money Bill	2004
Industry Restructuring Bill	2004
Electricity Distribution Industry Restructuring Money Bill	2004
The National Energy Regulator Act	2004
The Energy Efficiency Strategy of the Republic of South Africa	2005
Energy Security Masterplan for Electricity	2007
The National Radioactive Waste	2008
Disposal Institute Act	2008

Source: Department of Minerals and Energy (2008:14)

The Acts and Bills listed in Table 2.1 were released by the DOE, but are not relevant to this study. Virtually all energy policy documents in South Africa are reviewed and renewed on a regular basis to ensure growth and redistribution to create improvements in the energy sector (Department of Minerals and Energy, 1998:6). It is challenging to provide a comprehensive overview of the policy documentation within the energy sector, and therefore the aforementioned captures a broad framework of energy policy in South Africa (Eskom, 2007:2).

South Africa's most influential energy policies were reviewed in the sections above. The purpose of this review was to highlight the shortcomings in the energy supply sector.

2.3.2 Entities reporting to the DOE

The following section provides a brief introduction into the state-owned entities under the supervision of the DOE. These entities are:

- The Central Energy Fund (CEF)
- National Energy Regulator of South Africa (NERSA)
- South African National Energy Development Institute (SANEDI)

The Central Energy Fund (CEF) is a key role player in the liquid fuel industry of South Africa, focusing mainly on the finance and marketing of purchasing coal, exploration of coal as well as producing different energy sources from coal such as liquid fuels. The CEF comprises four branches namely: South African National Energy Institute, National Energy Efficiency Agency, Petroleum Agency of South Africa, Energy Development Cooperation (Maleka *et al.*, 2010:15). (Maleka *et al.*, 2010:17).

NERSA was established in 2004 as a juristic person. The purpose of NERSA is to regulate the energy, piped gas, and petroleum pipeline industries within South Africa as efficiently and effectively as possible (Maleka *et al.*, 2010:17). The South African National Energy Development Institute (SANEDI) was established to encourage energy research and energy efficiency as well as development in South Africa. The function of the SANEDI is defined in the National Energy Act (Maleka *et al.*, 2010:19).

Eskom reports to the Department of Public Enterprise (DPE) and is only influenced by DOE indirectly through energy and regulatory (NERSA) policies. In the next section, a brief summary of Eskom, South Africa's monopolistic power utility is provided.

2.4 Eskom

The following section presents an overview of Eskom's policy framework as well as the current situation around the Mineral Energy Complex (MEC). Eskom's impact on South Africa's economy has become increasingly important. Energy has been the driver of South Africa's economy, contributing significantly to economic growth and job creation (Eskom, 2011:9).

Eskom was established in 1923 and was first known as the Electricity Supply Commission (ESCOM). In 2002, Eskom transformed into a monopolistic state-owned company (SOC). The utility supplier is Africa's largest electricity provider and generates approximately 95% of electricity consumed in South Africa. Eskom operates under the licenced supervision of NERSA and generates revenue according to approved tariff rates formulated by NERSA (Eskom, 2011:13).

The purpose of Eskom is to supply electricity on a sustainable and efficient level to develop the economy and enhance the living standards of the population of South Africa. Eskom has developed their foundation on strategic pillars to support their policy by means of the following:

- Lead and collaborate to keep the lights on.
- Promote low carbon growth opportunities.
- Ensure future supply and resources requirements.
- Transform coal transportation from road to rail.
- Collaborate with the private sector (Eskom, 2012:8).

Figure 2.3 illustrates Eskom's electricity sales in 2012. Eskom's electricity sales accumulated to 224 785 GWh supplied and electricity revenues contributed to approximately R113 billion. Figure 2.3 illustrates that municipalities (41%) purchased the most electricity from Eskom, followed by industry (26.10%), mining (14.50%), commercial and agriculture (6.40%), foreign (5.90%), residential (4.70%) and rail (1.40%) (Eskom, 2012:7).

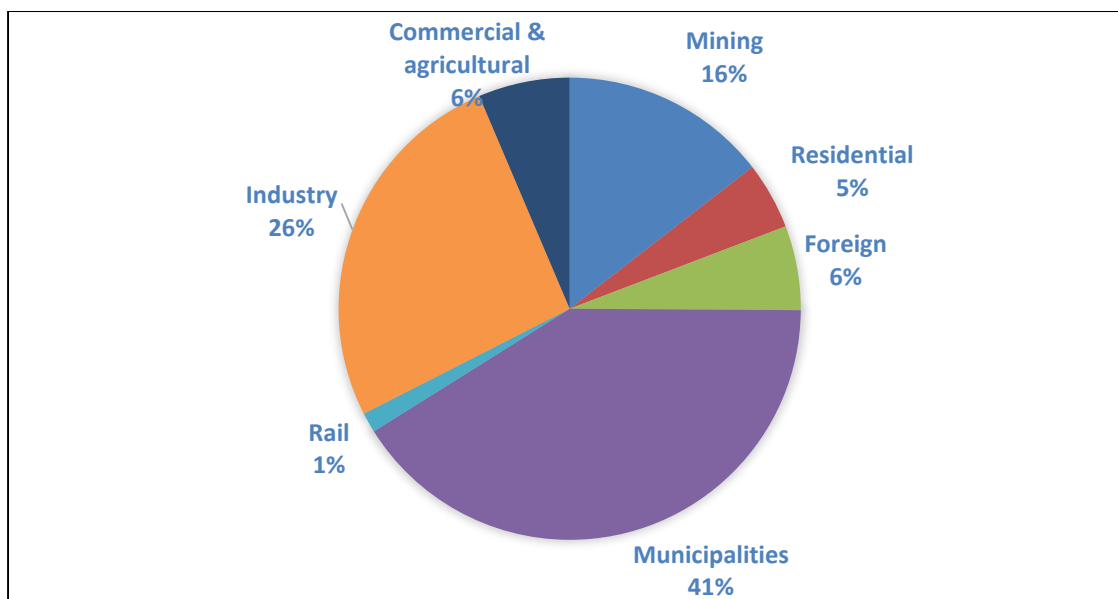


Figure 2-3: Eskom electricity sales by customer in 2012

Source: Eskom (2012:7)

As illustrated in Figure 2.3, several industrial, residential, and mining consumers are supplied through municipalities making this approximation conventional, because municipalities also provide electricity to the industries and mining sector. In South Africa, economic activities such as manufacturing, industrial and mining create relatively high value added outputs for very high inputs of energy consumed (Cameron, 2008:14).

The sectors that consume the highest volumes of energy in South Africa are non-ferrous metals and gold mining. These sectors accounts for 25% of electricity consumption in South Africa. The contribution to GDP is comparatively small (4%), but linkages to other sectors can create larger impacts as it creates spillovers to other sectors. Therefore, the high energy-intensive sectors such as non-ferrous metals and gold mining are indirectly affecting the GDP per unit of energy consumed. (Deloitte, 2012:9-10).

During 2012 and 2013, Eskom endured enormous pressure to withstand the high volumes of energy demanded by the public and private sector (Pienaar & Nakhooda, 2010:2-3). In the first quarter of 2012, Eskom introduced a buy-back programme that would encourage industrial and commercial consumers to cut their electricity consumption. However, in the final quarter of 2012, derelict power station in South Africa and below average grades of coal as well as production interferences in the mining and transport sectors further contributed to Eskom's negative outlook (Pienaar & Nakhooda, 2010:2-3).The shortage in supply forced NERSA to

accept Eskom's proposed tariff increase to facilitate new electricity infrastructure (Pienaar & Nakhooda, 2010:2-3).

Although Eskom controls the distribution of bulk electricity, the utility provider does not have exclusive electricity supply and generation rights. Eskom runs an integrated nationwide high-voltage transmission scheme, which entitles them to supply electricity directly to large consumers such as industries and mines (Pienaar & Nakhooda, 2010:2-3).

Due to the major impact that Eskom has on the South African community and economy, it is vital to align policies to maintain and sustain energy-efficient consumption. These policies will enable the identification of an energy cluster within the venerable sectors.

2.4.1 Eskom's current energy policy

The lack of competition in the energy sector has forced government to implement policies that regulate economic development to benefit all involved parties. Subsequently, in 1994, an Integrated Reporting Document and Environmental Report of Eskom were released with the approval of the DOE and NERSA. In 2002, the DME published the first Integrated Annual Report, which included financial and sustainability information.

After the energy crisis (2008), Eskom initiated proposals to increase their electricity production capacity. Given prevailing new electricity generation infrastructure, the DOE confirmed that Eskom and NERSA are deprived of commencing their respective energy development activities. Instead, the DOE instructed Eskom to develop an IRP process, which provided a draft for resourceful electricity generation infrastructure (Pienaar & Nakhooda, 2010:2, 3). The DOE formulated national energy policy based on decisions to expand Eskom's electricity supply (Eskom, 2012:7).

Eskom's electricity policy resorts under the regulation of the DOE, and therefore Eskom is responsible for the implementation of these policies. The key policy documentation in the electricity sector is summarised Table 2.2 below.

Table 2-2: Eskom's key energy policies

Electricity Regulation Amendment Act:	The Electricity Regulation Act was established in 1987 and later amended in 2007. The Act was formulated to provide a structure under the guidance of NERSA for the electricity supply industry in South Africa (Eskom, 2011:34). The purpose of the Act was to provide a blueprint for future investments. The DOE is authorised to determine which of the Independent Power Producers (IPP) are eligible to generate electricity and to create a competitive environment within the energy sector. To address the supply problem in South Africa, it is essential for Eskom to support the IPP. The IPP enables the diversification of the source of electricity supply as well as the acquisition of skilled labour into the industry (Eskom, 2011:34).
Independent System Operator (ISO) – This policy was withdrawn in 2014.	In 2010, government established an independent system operator in support of the IPP by forming a non-conflicted purchaser of energy. In 2011, the cabinet accepted the Independent System and Market Operator Bill and subsequently established the Bill within the South African energy supply sector, aiming to restructure the electricity supply industry (Eskom, 2011:34).
Integrated Resource Plan for Electricity (2010-2030):	During 2011, cabinet approved the IRP, which formed the foundation of energy generation for the next 20 years. The IRP attempted a strategic approach towards implementing renewable energy with the aim of promoting low carbon emissions for long-term sustainability (Eskom, 2011:34).

Source: Eskom (2011:34)

Eskom's policies strived to increase capacity to combat current supply shortages. Therefore, Eskom's policies must focus on energy-intensive industries such as manufacturing, mining, etc. With reference to the gold mining sector, Eskom's past policies were not sufficient to decrease energy intensiveness in the sector. The MEC to follow in the next section is a reflection of the strong resource base (e.g. gold mining) and energy relationship in South Africa.

2.4.2 The mineral-energy complex

South Africa's primary source of electricity generation is coal. Previously, policies were formulated to ensure efficient supply and well-graded coal. Coal is a significant driver of South Africa's energy intensive problem due to the availability and access to inexpensive coal. The MEC is created through resource extraction and the development of linkages among economic activities (Eskom, 2011:4).

Eskom's dependency on coal has formed the foundation for the MEC, which plays a vital role in the South African economy. The MEC consists of all activities within the energy sector, i.e. minerals processing, mining, as well as linkages among the energy sector. The MEC focus areas are mining and mining beneficiation. These activities are supported by the endowment of inexpensive electricity costs (Eskom, 2011:4). The MEC has consumed the highest volume of energy supplied over the past few decades (Eskom, 2011:5).

Regarding energy policy formulation in South Africa, Eskom influences the decision-making of government departments, policy-makers, and legislative organisations. Compared to global standards, South Africa's energy efficiency is considerably low. The industrial and mining sectors consume approximately 60% of electricity generated in South Africa. Furthermore, the MEC has promoted the use of coal as a source for power generation, making it the highest in the world (Eskom, 2011:5).

The lack of accountability in the governance of Eskom has limited the control over the MEC. Eskom plays a crucial role in the MEC by exploiting resources, as well as social and environmental expenditure to maximise profits for local and international organisations. The

dominance of coal usage within the MEC for electricity generation must switch towards renewable energy. It is vital for Eskom to engage in improved organisational structures to encourage renewable energy (Eskom, 2011:5).

2.5 Conclusion

The purpose of this chapter was to provide an overview of the energy policies relevant to this study and to highlight the gaps in these policies, which may be addressed through supply chain management, focusing on the energy-intensive users in identified supply chains.

South Africa is currently in the midst of an energy supply crisis. A lack of infrastructure and derelict power stations has forced the issue to draft a comprehensive, integrated energy policy system across all sources of electricity generation. Numerous energy policies were discussed in this chapter and it is evident that there are not necessarily insufficient policies, but rather a lack in the implementation of existing energy policy. This has fuelled the current energy supply shortage. South Africa's energy demand is projected to double by 2030. Therefore, the need for new energy infrastructure, technology, and renewable energy is becoming increasingly important. The DOE, in cooperation with Eskom, has framed a comprehensive programme to stabilise the electricity supply and distribution structure.

Energy policy should promote the forming of industry consortia around energy-intensive clusters and encourage continuous debate with relevant stakeholders (i.e. between government and industry) as an effective strategy to reduce energy use and misuse. South Africa's energy sector relies mostly on coal as a source for electricity generation, creating limited diversification within the energy sector. The MEC has contributed to the energy-intensive industries within the economy, which comes at the expense of all South Africans. To enforce a sustainable future in the supply of electricity, it is essential for the DOE and Eskom to be held accountable for all activities within the energy sector. The energy policy implemented by the DOE has numerous shortcomings. The White Paper on the Energy Policy (1998), which was regarded as the foundation of all energy policies, failed to deliver its objectives. For example, a lack of comprehensive planning for future energy supply along with inexpensive energy has resulted in high-energy consumption in the gold mining sector.

Only after the energy crisis in 2008, Eskom forced the issue of additional electricity production capacities. Eskom implemented an Integrated Resource Planning Policy to promote renewable energy, which also failed its objectives. The construction of the new power station, Medupi,

has taken longer than projected due to political interferences as well as labour strikes. As a result, South Africa could face a second energy crisis, which will have further implication on an already dismal economic future. The gold mining industry will be largely affected, attributable to its energy intensity. These negative occurrences will spill over to other linked sectors.

It is evident that an appropriate policy document does not guarantee implementation. Energy policy role-players need to provide a more sound understanding of the importance of implementing the policy. Support must come in the form of the following:

- Supporting legislation with clearly defined policy instruments
- Established measurements for policy implementations
- Sources of finance must be regulated and monitored
- Co-operative governance

The following chapter will review the main role players forming the gold mining supply chain.

Chapter 3: South African gold mining sector

3.1 Introduction

South Africa is one of the most energy-intensive countries worldwide, with high costs to the gold mining sector and serious energy supply shortages. Recent economic conditions in the gold mining sector have caused the global demand for mining products to decrease, which remains a crucial element of the South African economy. As previously, discussed, gold mining is the most energy-intensive form of mining.

Considering the linkages between energy-intensive suppliers in the gold mining supply chain, energy policy should be drafted to target these energy-intensive clusters. These clusters can be a dominant force for sustainable energy development in South Africa. Therefore, the gold mining supply chain can engage with the DOE to become more energy conscious and energy efficient (KPMG, 2012:1).

The manufacturing sector is the most energy-intensive industry in South Africa. The mining sector and manufacturing sector are linked through the beneficiation of the raw products such as gold, forming energy-intensive clusters in the gold mining supply chain. South Africa's economy will be heavily affected if the energy sector's policy is not aligned with energy-intensive users. The energy-intensive sectors are the backbone of South Africa's economy and with constant price increases and decreased energy efficiency, production levels have dropped. As a result, South Africa's global competitiveness has declined (Ruffini, 2013:1). The gold mining sector should focus on restructuring technologies for mining-related waste with the purpose of reducing energy use (DST, 2012:9).

This chapter provides an overview of the gold mining sector itself, laying the foundation for the empirical analysis in Chapter 4. Other focus points in Chapter 3 are the key role players in the gold mining supply chain as well as gold mining policy related to energy policy in South Africa. Once the structure of the gold sector and its supply chain has been identified, it will be significant to analyse the sectors closely connected to one another that may form energy-intensive clusters the gold mining supply chain

3.2 Overview of the South African gold mining sector

The following section will provide an overview of the South African gold mining industry by discussing the current structure and performance of the gold mineral, the economic linkages within the mining sector as well as the beneficiation in gold mining.

3.2.1 Structure and performance

The gold sector is under serious pressure due to an increase in the depletion of the mineral as well as a drop in the standards of gold grades and ageing mines. However, the industry's contribution to the South African economy remains positive. In the back end of 2012, the gold industry suffered a setback, as approximately 40% of the mines were considered non-profitable, purely based on the constant decline in the price of gold and the rising costs for the sector, especially labour and input costs such as energy (Chamber of Mines, 2013:1).

To maintain constant production, the gold mines exploit capital expenditure to generated marginal profit, which is considered as an industry predicament to profits will decrease. Therefore, with the increase in input costs such as energy, the influence on marginal profit will be significant (Chamber of Mines, 2013:1-2). Statistics released by the Chamber of Mines (2013c) indicated that the total income in the South African mining sector was R447 billion. Of this accumulated income, R437 billion accounted for the total expenditure of which R251 billion was spent on input costs such as energy, water, logistics and steel (Chamber of Mines, 2013:2). In 2012, the estimated revenue of South African gold mines was approximately R76.9 billion and the total profit was calculated at R39.8 billion. The most significant revenue generator is the export of gold and in 2011 gold was ranked second in export earnings after platinum and before, iron ore and coal (Chamber of Mines, 2012a:3).

The mining sector is dependent on gold to boost the industry's performance. Gold is a net exporter. The contribution of the gold sector in 2011 was estimated at R45 billion to GDP, accounting for 1.5% of the total GDP in South Africa (Chamber of Mines, 2012b:3). Approximately 89% of all income generated by the gold sector locally is spent on input costs such as salaries and wages, capital expenditure, direct corporate taxation, interest on loans at banks, and dividends paid out to shareholders. The majority income generated by the gold sector is spent directly back into the economy, signifying the importance of the industry (Chamber of Mines, 2012a:3).

The gold sector is vital for growth in numerous sectors within the South Africa economy. In 2012, the Industrial Development Corporation (IDC) conducted a study and found that the mining sector created approximately 1.3 million jobs which explain its importance to the South African economy (Chamber of Mines, 2012a:3). The gold mining industry consumes approximately 25% of energy in South Africa, and in 2011, 95% of electricity generated in South Africa was supplied by 125 million tonnes of coal. Gold mining consumes 15% of all electricity generated in South Africa (Chamber of Mines, 2012a:1). South Africa produces 50% of the world's gold reserves and the Witwatersrand gold reef is the world's largest gold deposit. However, in recent times, China and Australia have surpassed South Africa in producing more gold (Chamber of Mines, 2012a:1).

Between 2012 and 2014, government intended to spend R845 billion on mining-associated infrastructure, such as energy and logistics. The logistics infrastructure referred to is mainly rail transport. During this period, Eskom aimed to upgrade power stations as well as enhance energy supply networks and distribution infrastructure to the mines. Transnet aimed to exercise major upgrades in export lines for coal, iron ore and steel as well as substantial improvements in the freight rail network (Chamber of Mines, 2012a:3).

For the purpose of the empirical analysis, which will be discussed in Chapter 4, gold is defined as metal ores. Gold represent 80% of metal ores and, therefore, will be used as the substitute for gold in the empirical analysis.

3.2.2 Economic linkages

Economic linkages are defined as economic activities in one industry that create spillover effects in another industry in the form of economic growth (Leeuw, 2012:14). Therefore, economic linkages can further be defined as the emergence of new clusters. By improving the various channels in production efficiency, logistic, management, etc., the economic linkages throughout the supply chain tend to be stronger (Leeuw, 2012:14).

Leeuw (2012:14) stated that economic linkages in the primary sector are dependent on further beneficiation for a significant impact on a nation's economy. Industries with significant impact create new clusters in the economy. Therefore, industries act as suppliers and buyers of outputs, creating linkages from the flow of expenditure between consumers and producers. Furthermore, Leeuw (2012:14) hypothesised that mining, especially the gold mining sector, is

the foundation of the economy in South Africa, creating strong linkages among sectors. The significant representation of the gold sector among foreign exchanges and the economy support this hypothesis. South Africa's gold mining industry has the capability to strengthen backwards and forward linkages (Leeuw, 2012:14).

Figure 3.1 is an illustration of the economic linkages (backwards, forward, and lateral linkages) within the gold mining supply chain, illustrating the flow of production to final consumer as well as inputs such as financial instruments and human resources.

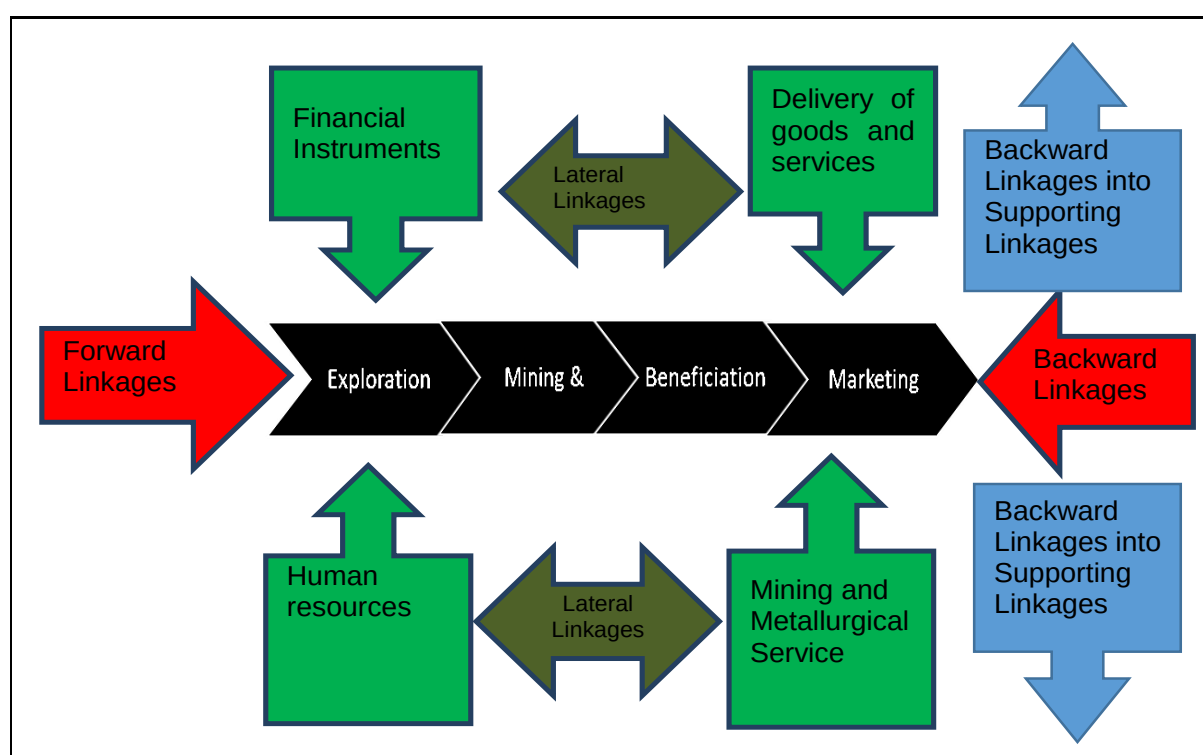


Figure 3-1: Illustration of economic linkages within the gold mining supply chain

Source: Leeuw (2012:16-17)

As indicated in Figure 3.1, the gold sector creates backwards linkages, forward linkages, and lateral linkages (African National Congress, 2012:47). Forward and backwards linkages can be defined as downstream linkage and upstream linkage, respectively. Upstream linkages represent the beneficiation and value adding of downstream industries. Downstream industries in the gold sector originate in the industrial sector in the form of chemical and steel beneficiation (Leeuw, 2012:14).

Mining-associated backwards linkages comprise services, consumables, and capital goods of suppliers. Backwards linkages are regarded as the most significant linkage, connecting the raw materials to the economy (African National Congress, 2012:47). Within the context of gold mining, backwards linkages are the procurement of goods and services that fuel production in the manufacturing sector, and enhance the delivery of services. For example, 15% of energy in South Africa is consumed by gold mines, which indicates the high-energy consumption of the industry (Chamber of Mines, 2013:3).

Through the exploration of gold, the upstream linkage occurs due to the economic connections concerning the primary sector and its suppliers. Therefore, backward linkages supply forward linkages in the economic chain of gold mining. Leeuw (2012:14) as well as the ANC's (2102) report on maximising the growing impact of mineral assets found that backwards linkages tend to be capital intensive which is an indication of lateral mitigation. The lateral linkage is known as the production of improved generic technologies. Consequently, the multiplier effect of lateral linkages is the foundation of the application of modified generic technologies in mining-associated sectors. Technology is vital for mining, especially regarding backwards linkages to create strong relations with suppliers and clients (Leeuw, 2012:14).

Forward linkages (downstream linkages) can be defined as the beneficiation process of minerals. The Chamber of Mines (2013:3) indicated that nations with effective forward linkages are countries that utilise the beneficiation of raw minerals. Therefore, the key is to add value to the raw product to optimise economic potential. The major focus of the downstream industry is job creation through inputs such as energy, manufacturing, agriculture, and infrastructure (ANC, 2012:40). Gold mining-related forward linkages are the manufacturing of gold in industries, such as jewellery fabrication and the production of refined gold (Chamber of Mines, 2013:3).

Due to the export and net import nature of the economy, local economies do not always benefit from the export of raw material. For example, gold products are mainly exported to and beneficiated in a foreign country. Leeuw (2012:18) argues that an increase in the production of gold can stimulate the financial sector and encourage supply and demand for gold, as well as creating spillover effects to other sectors such as the service, logistic, agriculture, and manufacturing sectors. These sectors will require further inputs to meet their responsibilities

towards one another. Therefore, the impact of mines on the local economy is determined by the inputs into the mines by the organisations and firms (Leeuw, 2012:18).

Through the analysis of the economic performance and the linkages of the mining sector, it is increasingly notable that the gold mining sector plays a pivotal role in the South African economy (Anglo Gold, 2012:1-5). The next section will discuss the beneficiation of gold.

3.2.3 Beneficiation in gold mining

The beneficiation of gold is a costly affair with various input costs as well as different sectors linked to the beneficiation process. Beneficiation of minerals can be defined as the process of adding value to the raw mineral, thereby transforming the mineral into the final product. Numerous energy-intensive activities are involved in the beneficiation process of gold. Other activities include refining plants and labour intensive processes such as artisanship of jewellery. Each process of beneficiation adds value to the final product and subsequently increases the final selling price (Department of Mineral Resources, 2014:1).

In South Africa, there has been continued debate on adding value to minerals before they are exported. There is still an enormous gap in beneficiated gold output, especially in the production of finished goods such as jewellery (Department of Mineral Resources, 2014:1). Only 2% of all gold mined is beneficiated in South Africa. This figure is extremely concerning and indicates that the most significant natural resource in South Africa has a weak comparative advantage. The gold jewellery manufacturing industry controls most downstream industries associated with gold mining and contributes approximately 80% of the country's gold consumption. (Mogotsi, 2004:17).

Throughout time, the beneficiation of gold has evolved outside mineral-rich countries. Therefore, the majority of value added to the final product occurs when the product is highly concentrated. Since 1990, South Africa's gold beneficiation increased slightly and during the nineties exports transformed more from primary commodity-orientated to processed minerals (Department of Mineral Resources, 2014:1).

South Africa is a recourse-based economy and, in 2010, the economy produced approximately US\$2.5 trillion revenue in mineral resources. The country is among the biggest exporters of

gold and platinum in the world, even though the majority of minerals exported are not high value intermediate to finished goods (Deloitte, 2011:3). Figure 3.1 is an illustration of the beneficiation process of gold in South Africa.

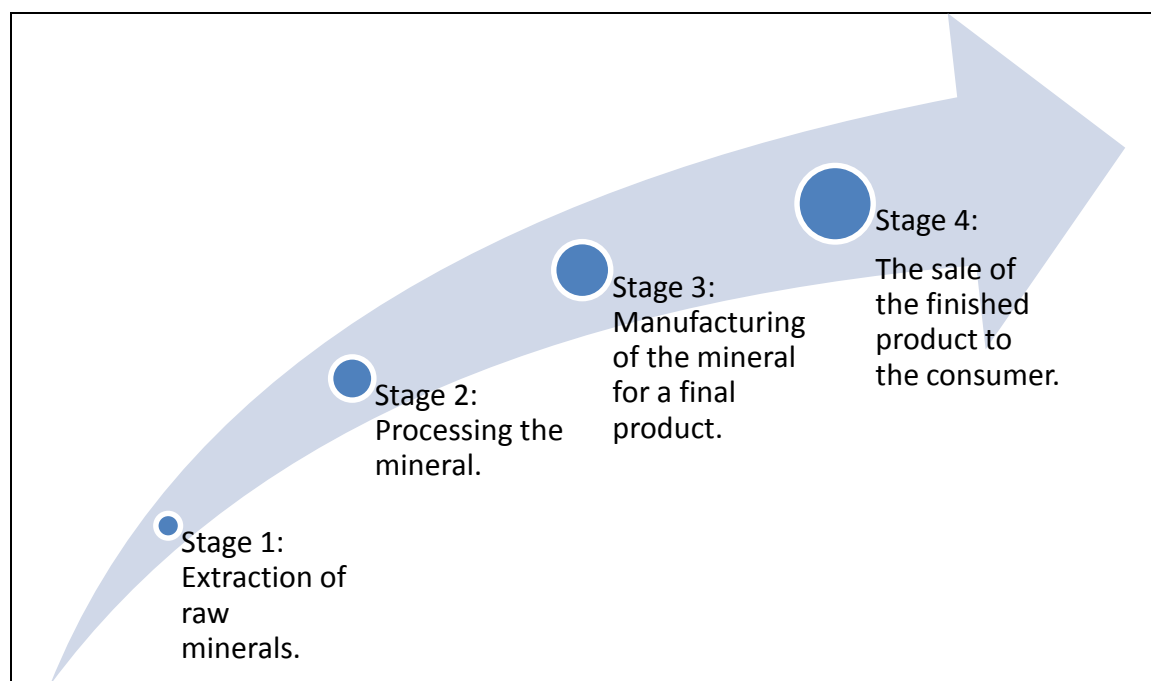


Figure 3-2: Stages of gold mineral beneficiation

Source: Deloitte (2011:6)

The beneficiation process can be broken down into four stages. The first stage of the process starts with the extraction of raw minerals. The raw minerals are transformed into a concentrated form and are further beneficiated to a certain standard required for manufacturing. The second stage enhances the mineral to acquire specific industry criteria. The third stage consists of the mineral in the manufacturing process for a final product. Therefore, various value-adding processes take place during this stage, for example jewellery design and manufacturing. The final stage includes the sale of the finished product to the consumer for a profit (Deloitte, 2011:6).

For efficient and effective gold beneficiation, South Africa requires integrated jewellery hubs and manufacturing firms to enable the process. A significant share of gold is being exported to markets in Europe, Japan, and the United States of America. The effect of gold exports is twofold. In the case of South Africa, gold is mostly beneficiated in foreign countries, and subsequently being exported to that country. Gold exports provide access to foreign markets

for domestic firms to develop their markets internationally (Deloitte, 2011:5). A contributing factor why the gold beneficiation has experienced stagnant growth is due to the way the industry is structured (Deloitte, 2011:5).

South Africa faces considerable challenges in beneficiating minerals. These challenges are not new to the industry and government. Government must create a framework that will enable policy to promote the beneficiation of gold and inevitably increase the country's comparative advantage (Deloitte, 2011:5). The gold mining supply chain should be the focus point in building a sustainable beneficiation process; therefore, the next section will concentrate more on the supply chain itself.

3.3 Gold mining supply chain

The following section will discuss the gold mining supply chain in South Africa as well as the energy clusters created within the sector and the energy intensity of the mining sector.

3.3.1 Gold Mining Supply Chain in South Africa

Mathu (2010:136) defines the gold supply chain as the linkage of the flow of goods from the point of exploration through transformation via beneficiation to the distribution of finished products (Mathu, 2010:136). Mathu (2010:136) found that there is a strong link between the gold supply chain and the financial performance of the industry (Mathu, 2010:136).

Numerous gold mining companies in South Africa focus on enhancing operational efficiency to enable optimisation in overall performance to the final consumer (Accenture, 2007:2, 4). Improved and innovative technology, as well as high-quality information, will enable the gold mining supply chain to adjust to production and environmental changes to cooperate and synchronise with the clusters within the supply chain. Numerous mining supply chains in South Africa operate under derelict infrastructure. Thus, the need for effective management in electricity infrastructure is important to achieve the given production outputs (Mathu, 2010:136). Figure 3.3 is an illustration of a gold mining supply chain.

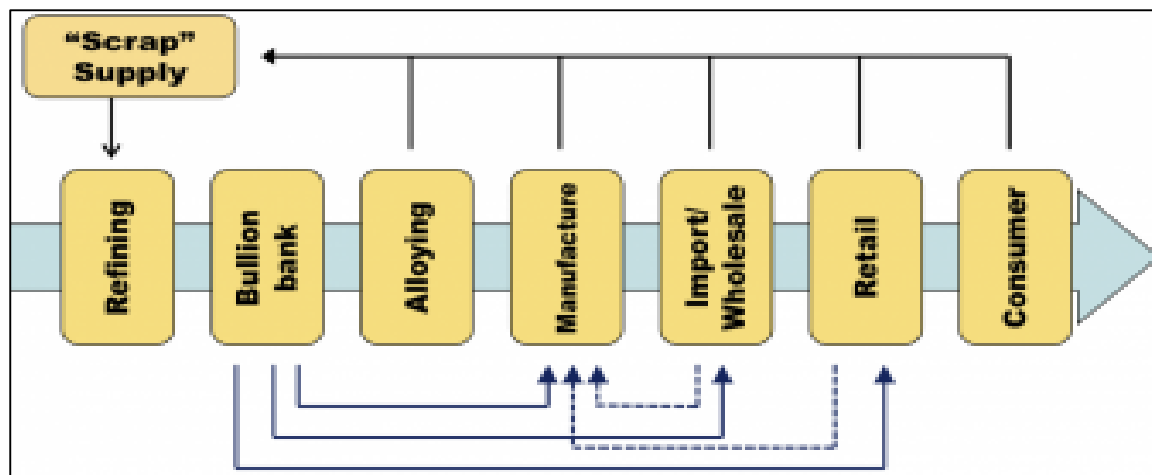


Figure 3-3: Gold Mining Supply Chain

Source: Verite. (2016:1)

As illustrated in Figure 3.3, a gold mining supply chain in South Africa consists of the following attributes and processes: raw materials to suppliers (extraction), manufacturers (processing), supply centres (logistics), and delivery of final goods (consumer). These actions signify the overall manufacturing capacity as well as the downstream flow to the consumers. Within the process of exploration of the raw material to the export of the processed mineral, numerous sectors are involved. These sectors form clusters within the gold mining supply chain.

Concerning Figure 3.3, the first step is the extraction of the mineral; after that, the exploited mineral will either be disposed of as waste or processed, as it needs to be separated from the surrounding ore. The second step in the gold mining supply chain is when gold is then separated from the chemical solution, melted and poured into bars, which is the refinery of the extracted gold into pure gold (Verite, 2016:1). Therefore, these processes are conducted on an industrial scale. The majority of gold mines in South Africa process their gold-bearing ore on site to produce ‘doré’ bars of up to 92% clarity. Once gold is mined and processed, it can be mixed with stronger metals to produce an alloy. Jewellery and other goods are produced from the gold, which is sold, to manufacturers and retailers (Verite, 2016:1).

The processing of the gold-bearing ore requires intensive, high technology, which is highly energy intensive. Throughout every step in the supply chain, transportation of the mineral from the supplier to the local consumer as well as foreign consumers for exports is being executed. Every process in the gold supply chain forms linkages with other sectors of the economy, and

these linkages not only create spillovers to other sectors, but also develop energy clusters along the processes (Pooe & Mathu, 2011:13).

As mentioned, gold mining is the most energy intensive form of mining and by applying energy-efficiency strategies, energy consumption can decline. It is vital for the gold sector to find strong linkages to collaborate between the supply chain and the linked clusters (Pooe & Mathu, 2011:13). The next section seeks to determine the energy cluster in the gold mining supply chain. The section will always provide a brief definition of an energy cluster.

3.3.2 Energy clusters in the gold mining supply chain

The concept of clusters can be defined as the collaboration of various proficiencies among inter-linked industries to create a specialised product. The establishment of linkages is due to the interactions between sectors, institutions, and firms (Statistics South Africa, 2005:2).

Therefore, clusters are formed through linked sectors with product information flow between sectors, institutions, and firms. The clustering of manufacturers, consumers and competitors, established in the same geographical area or connected through similar activities, stimulates proficiency and increases specialisation. Therefore, the level of advanced activities enhances competitiveness among firms as well as creating innovative functions and activities that fuel technological spillovers in sectors (Statistics South Africa, 2005:2).

Within the context of the energy sector, every process in the linked industries of the gold mining sector consumes energy in one form or another. These linked industries are energy intensive and subsequently create an energy cluster in the gold mining supply chain. A widespread and specialised resource-based economy sustains the growth of the mining sector, which has been the foundation of South Africa's economy. As mentioned, the gold sector is the most energy intensive and, therefore, the gold sector has a significant impact on productivity, sustainability, and energy efficiency in South Africa (Nkosi, 2008:4). Gold mining companies attempt to be more energy efficient in their production processes (Govender, 2008:11-12).

However, as mentioned in this chapter, every process in the gold mining supply chain consumes significant volumes of energy. It is fundamental to identify energy-intensive clusters objectively within the gold mining supply chains to enable efficiency (Kagawa, Nansai, &

Kondo, 2012:4). Due to the lack of research on the subject, energy-intensive clusters in the gold mining supply chain will be identified in the empirical analysis.

3.3.3 Energy intensity of the gold sector

The gold sector is linked to numerous sectors of the economy and accounts for approximately 45% of energy consumption (Winkler, Nkomo, 2006:79). Therefore, the industry is regarded as extremely energy intensive with gold being the major contributor to the energy-intensive predicament (Winkler, Howells & Alfstad., 2006:104).

Gold mining has high-energy demands due to deteriorating ore grades and the following prerequisite to deep mining activities (Winkler *et al.*, 2006:104). The energy required increases to mine the same grade of gold, as the exploration of gold has to mine deeper.

Across all sectors of South Africa, gold mining is the single most energy-intensive sector. Gold mining only consumes slightly less energy in comparison to the entire mining sector's energy usage (Winkler *et al.*, 2006:104). Figure 3.4 is an illustration of the energy intensity of the various types of mining resources (Winkler *et al.*, 2006:104). Approximately 90% of the energy consumed is consumed by gold mines. Other forms of mining consist of approximately 75% of energy. This also indicates that gold mining is the most energy intensive form of mining (Winkler *et al.*, 2006:104).

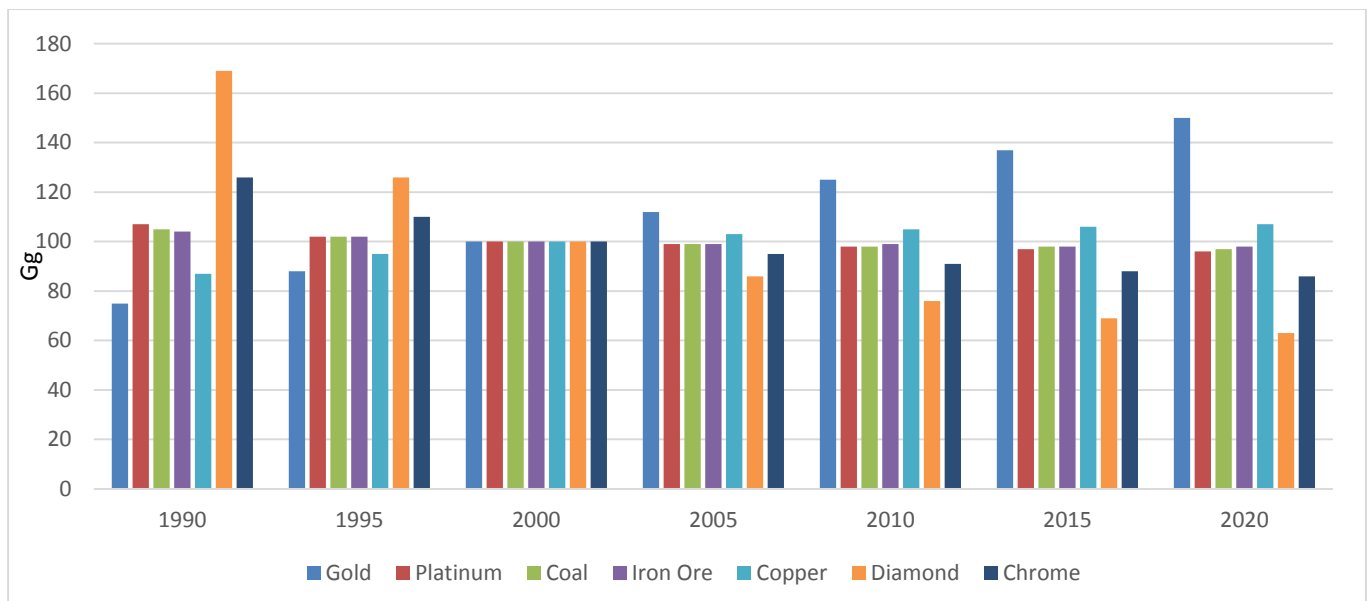


Figure 3-4: Energy Intensity in the mining sector

Source: Winkler *et al.* (2006:108)

From Figure 3.4, gold mining's energy intensity has rapidly increased throughout time. These findings are consistent with deteriorated ore and the deeper mining processes (Winkler *et al.*, 2006:108). The challenge is for the gold sector to decrease energy consumption; however, with ore deteriorating at a significant speed, gold mining's energy usages can only become higher.

Policies should focus on more energy-efficient strategies to promote renewable energy in the gold mining sector. It is vital for the role players in the industry to execute policies and processes to support the gold sector.

3.4 Key role players in the South African gold industry supply chain

The role players in the gold sector form an instrumental part in the industry and economic growth. In South Africa, the major companies that influence the gold mining industry are AngloGold Ashanti, Gold Fields, Harmony Gold, and Sibanye Gold.

As discussed earlier, the Chamber of Mines in South Africa was established in 1889, with the aim of protecting the constitutional rights of the mining companies as well as to promote the interests of the committee members of mining companies in South Africa. The Chamber examines all policies related to mining. Therefore, the Chamber plays a pivotal role in the mining supply chain concerning policy-making and opinion forming (Mathu, 2010:53-54).

Other important role players include NERSA, DMR, Eskom, and Transnet. Eskom in collaboration with the DOE is instrumental concerning output costs in the gold sector. As mentioned, Eskom is a monopoly in the industry and supplies energy through 13 coal-fired power plants in South Africa. Within the context of mining, gold consumes 43% (2009) of Eskom's energy supply. Eskom is continuously encouraging the gold mining industry to cut consumption with the intention of decreasing the energy intensity in the sector (Mathu, 2010:53-54).

Transnet, a state-owned corporation, is liable for all the main transport infrastructures such as pipelines, rail, and ports. Transnet aims to ensure that all methods of transportation are consistent with international standards. The railway service is vital for the transportation of gold throughout the beneficiation process to exports (Mathu, 2010:53-57). NERSA, formed in 2005, is a regulatory authority established as a juristic person that is responsible for the regulation of energy, gas, and petroleum in the energy sector. NERSA's mandate is to regulate the three industries in the energy sector, namely the electricity, piped-gas and petroleum pipeline industries (Mathu, 2010:53-54).

Other role players in the industry include unions. Unions mainly support the employees. In contrast, the South African Mining Development Association (SAMDA) supports the employers. Additional unions include the National Union of Mineworkers (NUM), Congress of South African Trade Unions (COSATU), the United Association of South Africa (UASA), and the Chamber of Mines of South Africa. NUM was established in 1892 and is the leading recognised co-operative negotiating representation for workers in the mining, manufacturing and energy sectors in the country. Furthermore, NUM is also recognised as a principal associate of COSATU. UASA is an international representation of workers. The focus area for UASA is to protect workers against economic globalisation as well as to co-ordinate with various other international federations (Mathu, 2010:53-54).

The role players in the industry must engage with policy-makers to find effective ways to overcome energy supply shortages. Bearing in mind the role players mentioned above, it is vital for these entities to act under legislation that would incorporate efficient processes in the gold mining supply chain.

3.5 Gold mining legislation in South Africa

The legislation covered in the following section provides insight into gold mining legislation.

3.5.1 Mining Rights Act No. 20 of 1967

In 1967, the Mining Rights Act No. 20 of 1967, as well as the Precious Metals Act No. 35 of 2005, was released. The Mining Rights Act No. 20 of 1967 has had a positive impact in the past on the gold sector. The Mining Rights Act No. 20 of 1967 banned private companies and organisations from possessing gold in any form other than bullion coins or jewellery. The Mining Rights Act No. 20 of 1967 controls any business activity, including the trade of gold, which is in possession of the gold raw material, such as refining and jewellery manufacturing (Gold in South Africa, 2007:116).

The Precious Metals Act No. 35 of 2005 replaced the Mining Rights Act No. 20 of 1967 in 2006. The key focus area for the Precious Metals Act No. 35 of 2005 was to decrease the administrative processes concerning the control and trade of gold as a raw mineral. The Bill distinguishes between wrought and raw metals clarified in the Mining Rights Act No. 20 of 1967. The Precious Metals Act No. 35 of 2005 will further differentiate among classifications of permits for users of valuable metals. The Precious Metals Act No. 35 of 2005 categorises gold as a raw metal if the mineral is unrefined or if the purity of gold is not refined to up to 99.95% (Gold in South Africa, 2007:116). The Precious Metals Act No. 35 of 2005 comprises three categories of licencing, namely the attainment, control, and removal of valuable metals in its raw and semi-fabricated form. The three classes of licencing are:

1. Refining licences: This permit allows the possessor of unwrought valuable metals to purchase, obtain, refine, or dispose of the metals above. Refining licences are valid for 25 years and can be renewed afterwards (Gold in South Africa, 2007:116).
2. Beneficiation licences: The beneficiation licence allows the holder of semi-fabricated metal to purchase, obtain, refine, or dispose of the metals. The beneficiation licence is valid for ten years and can be renewed for another ten years after that (Gold in South Africa, 2007:116).
3. Jewellers' permits: This licence entitles the same rights as beneficiation licences; however, the licence is only valid for five years (Gold in South Africa, 2007:117).

To summarise, the Mining Rights Act No. 20 of 1967 and the Precious Metals Act No. 35 of 2005 were formulated to ensure protection against illegal mining and to maintain high-quality production (Gold in South Africa, 2007:117).

3.5.2 Charter for the mining industry

The Charter of the mining industry is mainly concerned with social, economic, as well as historical inequalities in South Africa's mineral sector and plays an integral part in regulating the governing framework of the mining sector. A focus area for the Mining Charter is to ensure impartial access to all mineral resources in South Africa (Gold in South Africa, 2007:119).

3.5.3 Energy intensive user group (EIUG)

The Energy Intensive User Group of Southern Africa consists of 31 major energy users such as Harmony Gold Mine Company Ltd, Sibanye Gold Ltd, AngloGold Ashanti, Richards Bay Minerals, Transnet Ltd, Exxaro Resources, etc. (EIUG, 2015:1).

The EIUG accounts for approximately 44% of South Africa's energy. The group was established in 1999 and aims to confront supply shortages, energy generation and efficiency as well as energy regulation and pricing. The EIUG conducts business directly with government entities such as NERSA, Eskom, DoE, etc. The group's focus point is to establish a sustainable and competitive South African industry (EIUG, 2015:1). The EIUG advises on and provides energy policy insights, and additionally delivers technical leadership to government entities and external stakeholders.

Therefore, they create a platform for energy management and assist smaller role-players that do not form part of the EIUG. The EIUG has a significant influence on mining in Southern Africa and therefore the group will play a pivotal role in the energy sector (EIUG, 2015:1).

3.6 Summary

The purpose of this chapter was to provide an overview of the gold mining industry in South Africa. The chapter outlined the sector's performance and structure as well as the economic linkages within the sector.

The performance of the gold sector is currently under question. However, the sector remains one of South Africa's most significant contributors to the economy. The most significant revenue generator compared to all other mineral resources is the exportation of gold. The gold sector is also ranked second in export revenue after platinum. Gold mining is a major contributor to the mining sector's performance. A significant percentage of all income generated by the gold sector is spent directly back into the economy, indicating the importance of the industry. The mining industry consumes approximately 25% (2011) of energy consumption in South Africa; however, the industry only contributes 1.5% (2011) of total GDP. The gold sector produces 50% of the world's gold reserves and has the world's largest gold deposit (Witwatersrand gold reef).

The gold sector creates spillover effects to other sectors linked to its supply chain. The gold sector creates backward linkages, forward linkages, and lateral linkages. The upstream and downstream industries are vital for beneficiation and value adding as well as economic connections concerning the primary sector and its suppliers. The gold mining supply chain explained the process from exploration to the final consumer, indicating the importance of every stage of beneficiation and the effect on efficiency, especially energy consumption. According to the Chamber of Mines (2013), only 2% of all gold mined is beneficiated in South Africa, which is an extremely low figure. The gold sector has the potential to contribute far more to the South African economy because currently the sector has a weak comparative advantage. South Africa faces considerable challenges in beneficiating this mineral.

Within the context of the energy sector, every process in the linked industries of the gold mining sector consumes energy in one form or another. As mentioned, gold mining is regarded as the most energy intensive sector in South Africa and has a significant impact on productivity, sustainability, and energy efficiency. These linked industries are energy intensive and subsequently create energy clusters in the gold mining supply chain. However, due to the insufficient theory on the subject, assumptions are mainly based on these statistics.

Gold mining's energy intensity has rapidly increased over time due to deteriorated ore grades and deeper mining processes. The challenge is for the gold sector to decrease energy consumption; however, with ore deteriorating at a significant speed, gold mining's energy usages can only become higher.

These energy clusters in the gold mining supply chain will be identified in the empirical analysis to follow. The key role players in the gold mining supply chain have a significant impact on productivity and efficiency in the gold industry. These role players consist mainly of unions, companies, and government institutions. The role players are primarily responsible for interactions with industry as well as other industry stakeholders.

For the purpose of the empirical analysis, which will be discussed in Chapter 4, gold is defined as metal ores. Gold represent 80% of metal ores and, therefore, will be used as the substitute for gold in the empirical analysis. The following chapter outlines the input-output, network partition, and K-means methods that can be used to analyse clusters and identify energy-intensive clusters.

Chapter 4: Methodology: Clustering approach

4.1 Introduction

South Africa has a persistent energy supply constraint. Gold mining is the most energy intensive sector in South Africa and is an important role player in the economy. Thus, energy policy must target energy-intensive users in the gold mining sector as well as its supply chains to enhance energy efficiency. Therefore, we need to identify the energy-intensive clusters in gold mining and its supply chain.

The aim of the empirical analysis is to determine energy-intensive clusters in the gold mining supply chain. The identification of these clusters will be useful to inform South Africa's energy policy, especially when considering the importance of gold mining to the economy. Therefore, energy policy should be aligned to focus on the energy intensity of gold mining and the current energy supply constraints facing the country. Based on a previous study conducted by Kagawa *et al.* (2012), key economic sectors were identified. The input-output (I-O) table could be used to determine the industry clusters, which are strongly connected by extracting inter-industry networks based on exceeding a certain threshold value.

The first step in the empirical analysis is to determine which sectors in the industry is part of the gold mining supply chain. As mentioned, the gold mining sector is part of the metal ores sector in the industry. A 2011 I-O table of South Africa forms the underlying database for the empirical analysis. By using the I-O tables, one can determine which sectors form part of the value chain. The rest of this chapter explains how I-O analysis is integrated with network partition analysis to identify clusters.

Once the sector is identified, the 2011 South Africa Social Accounting Matrix (SA SAM) is used to determine the networks of the sectors in that cluster linked together. Furthermore, once industry clusters are identified, the K-means method is used to determine energy-intensive clusters. The networks will not always be directly connected as it may be indirectly connected through another sector. This information is required to draw the cluster diagram in NodeXL. To identify the gold mining industry itself as metal ores, SPA (structural path analysis) was used to determine the networks of metal ores with all other sectors in this particular cluster.

4.1.1 Input-output (I-O) table

In 1963, Wassily Leontief developed the I-O table. The I-O table is defined as the relationship among industries through their production and product consumption. Therefore, the matrix represents the economy by listing the supplying industries as rows and the consuming industries as columns (Stats SA, 2012:2).

The I-O tables comprise of two different tables, namely a product-by-product and an industry-by-industry table. In South Africa, the industry-by-industry I-O table is used to classify the industry supply-use (SU) tables. The SU tables allow for a thorough investigation of industries and products. Furthermore, the industry-by-industry I-O table illustrates the dependency of the various industries in the economy on one another (Stats SA, 2012:2).

The South African I-O table of 2011 consists of 50 industries categorised according to the SIC, which are numbered from 1 to 50. Table 1 (see appendix) presents the classification information of the 50 industries in the 2011 I-O table and Table 4.2 captures the 2011 I-O table of South Africa (Stats SA, 2012:3).

In the Microsoft Excel spreadsheets, compiled by Stats SA, the direct and indirect coefficients form the basis for the analysis of the I-O tables. The direct impact determines the distribution of a unit of output and the distribution of intermediate consumption per industry input. Therefore, the direct coefficients determine the distribution of intermediate consumption per industry input and output and gross value added (GVA). This enables an analysis into relative consumption patterns in both intermediate consumption and GVA (Stats SA, 2012:3-4).

Alternatively, an analysis of the value added returns to any potential investment in the various industries is enabled through the analysis of the indirect coefficient. The total value added return from a particular industry is illustrated by the diagonal matrix (Stats SA, 2011:4).

The off-diagonal, defined as the denotation of an element of a square matrix, which is not on the diagonal running from the upper left to the lower right, indicates the apparent benefits to other industries as a result of the consumption effect of the increased output of that particular industry. In contrast, the value added coefficient illustrates the supply of input industries that contribute to value added per industry (Stats SA, 2012:5).

4.2 Connecting the input-output approach with the network partition approach

With input-output analysis, randomness in the industry cluster analysis may occur; therefore, merging the input-output analysis with a network partitioning analysis method can help to mitigate the unpredictability within the input-output data. (Kagawa, Kondo, Nansai & Suh, 2013:1-3).

This approach aims to determine whether there is a strong link between clusters. Consequently, determining the total number of interactions between different clusters is minimised and the total within-cluster interactions are simultaneously maximised. In the case of network partitioning analysis, the optimal indicator matrix indicates the most efficient outcome for clustering. From the indicator matrix, the nonnegative matrix factorisation is derived and after that the second most efficient cluster is determined by means of K-means clustering. The K-means method is used to identify the energy-intensive cluster from the nonnegative matrix factorisation (Kagawa *et al.*, 2013:1-3). The K-means clustering is a method of vector quantisation, which is used, for cluster analysis in data moving. K-means clustering aims to partition n observation in k -clusters with the nearest mean, serving as a prototype of the cluster

The following section describes how the input-output approach is connected with the network partition approach to determine the energy-intensive clusters within the gold mining supply chain.

4.2.1 The simplified input-output approach

The first step in the simplified input-output approach is identifying the matrix $Z = (Z_{ij})$, $i, j = 1, \dots, n$ representing input of the commodity, j, i and n is the number of industries, and therefore, $i, j = 1, \dots, n$ (Kagawa *et al.*, 2012:7). The input coefficient matrix is defined as $A = (A_{ij}) = \left(\frac{Z_{ij}}{x_j}\right)$ ($i, j = 1, \dots, n$) if the output of industry j is defined as $x = (x_j)$ (Kagawa *et al.*, 2012:5).

a_{ij} is defined as the input from industry i required for producing a unit of output of industry j . Therefore, if a final consumer such as a jewellery refinery buys gold produced by the gold sector j_o th, the final demand is defined as fj_o of the j_o th sector and the $(n \times 1)$ final demand as fj_o . The final demand, fj_o , is produced by the j_o th sector. The productivity of the sector is expressed as $diag(fj_o)$, $diag(fj_o)$ is defined as the diagonalisation vector of fj_o . Therefore,

only the (j_o, j_o) can be expressed as a non-zero factor of the matrix. The j_o th sector would require input to produce the final demand; these inputs are expressed as $Adiag(fj_o)$. The inputs required to produce the final demand also require input and therefore the final demand can be estimated as $Adiag(Afj_o)$. For the purpose of this study, the final input-output model is defined as equation 4.1.

$$B = diag(fj_o) + Adiag(fj_o) + Adiag(Afj_o) \quad (4.1)$$

In equation 4.1, the matrix B (b_{ij}) is defined as the input from sector i , to produce the goods for industry j , for the final demand of the sector j_o th. The energy intensive element presented as the unit of output of sector i , is defined as the vector $\alpha = (\alpha_i)$. The energy output asserted directly to inter-industry from sector i to sector j , which are connected to the final demand j_o th, which is defined as the following (Kagawa *et al*, 2012:6):

$$G = diag(\alpha)B = diag(\alpha)diag(fj_o) + diag(\alpha)Adiag(fj_o) + diag(\alpha)Adiag(Afj_o) \quad (4.2)$$

The next section will identify the energy intensity taking into consideration the final demand equation (G).

4.2.2 Strength of relations matrix

The energy intensity among the inter-industry flow between industries i and j is considered as the strength relations matrix. The adjacency matrix $G^* = (g^*_{ij})$ ($i, j = 1, \dots, n$) is used as the strength relations matrix and is formulated as follows:

$$\begin{cases} g^*_{ij} = g_{ij} + g_{ij} & (i \neq j) \\ g^*_{ij} = 0 & (i = j) \end{cases} \quad (4.3)$$

The strength of the energy intensity of the input between different sectors is expressed by the strength of the G^* matrix (Kagawa *et al*, 2012:7).

4.2.3 Network partition approach

The clustering problem's purposes are to detect the K subset, $E_1, E_2, \dots, E_K$, to minimise the total sum of energy intensity between sectors in different clusters as well as to maximise the within cluster energy intensity. Therefore, a combined optimisation occurs and is estimated as follows:

$$Ncut = \sum_{K=1}^K \frac{Cut(E_K)}{\sum_{w \in E_k=0} d_u} \quad (4.4)$$

The cut value can be given as:

$$Cut(C_k) = \sum_{w \in E_k} \sum_{w \notin E_k} g_{uv}^* \quad (4.5)$$

This estimates the energy intensity of the linked sectors between the sectoral cluster C_k . The weighted element of each industrial sector is expressed as

$$d_u = \sum_{v \in V} g_{uv}^*. \quad (4.6)$$

Equation 4.4 can further be formulated in matrix notation:

$$\text{Minimise } Ncut = \text{Tr}\{H'((D - G^*)H'(HDH)^{-1})\} \quad (4.7)$$

Depending on $H1_k = 1_n, H \in \{0,1\}^{n \times K}$.

H is defined as $[h_1, h_2, \dots, h_n]$, signifying the indicator matrix in conjunction with the indicator vector $h_i \in \{0,1\}^{K-1}$ for sector i . The minimised cut matrix (equation 4.7) is defined as:

D = diagonal matrix

Tr = matrix trace operator

$D_u, 1_k$ the $(k \times 1)$ = weighted element of D

$D - G^*$ = Laplacian matrix

Finally, the combined optimisation problem is an NP-complete problem.

From equation 4.7, the combined optimisation problem is transformed into a generalised eigenvector. The generalised eigenvector can be defined as a rank of k related to matrix A . In matrix A , it can occur that there is not a complete set of eigenvectors. Therefore, the algebraic multiplicity of one eigenvalue (λ) is superior to its geometric multiplicity, formulated as $(A - \lambda I)$. Matrix A is a non-zero vector v that is linked to λ , the algebraic multiplicity $k \geq 1$ if $(A - \lambda I)^k v = 0$.

The spectral relaxation of the original problem can also be defined as the generalised eigenvalue. The spectral relaxation can be used to solve equation 4.7 by relaxing matrix H ; however, by implementing the spectral relaxation, assumptions arise that the indicator matrix H 's nonnegative constraints have been ignored. According to Kagawa *et al.* (2012:8), the

solution to the generalised eigenvalue problem cannot be regarded as the most significant partitions of the network (Kagawa *et al.*, 2012:8).

The second method conducted in this study is the multi-way cut approach. The multi-way cut approach is an outcome of the connection between the non-negative matrix factorisation and equation 4.8.

$$\text{Minimize } J_1 = \|D^{-1/2}G^*D^{-1/2} - HH'\|^2 \quad (4.8)$$

Therefore, the optimal solution to the $H = (h_{ij})$ matrix is expressed as follows:

$$\left(1 - \beta + \beta \frac{(D^{-1/2}G^*D^{-1/2} - H)_{ij}}{(HH'H)_{ij}}\right) \quad (4.9)$$

Where $0 < \beta \leq 1$, thus $\beta = 0.5$.

Kagawa (2012:8) stated that the matrix H_0 is attained through the expression of the following equation: $H_0 = E + 0.2J$. Spectral clustering through the k -means method approximates the indicator matrix ($n \times K$) expressed through $E \in \{0,1\}^{n \times K}$ where J is the ($n \times K$) matrix of one's. The indicator matrix combined with nonnegative values approximates the yields, $\hat{H} = (\hat{h}_{ij})$. The projected indicator matrix, $\hat{H}$, defined as ($K \times 1$) vector $\hat{h}_i (1, \dots, n)$ is viewed as the vector of sector i . Therefore, to find the clusters (K sets), the K means method is applied to matrix $\hat{H} = (\hat{h}_{ij})$ in order to find the centre clusters. The K means will allow for the objective function (J_2) and the cluster centre (m_k) to be minimised. The cluster centre (m_k) is expressed as $m_k = \frac{1}{|C_k|} \sum_{i \in C_k} \hat{h}_i$.

As stated, the K -means method is used to identify the centre clusters. Therefore, the k cluster is the total number of sectors $|C_k|$. In the initial cluster centre, different initialisations yield different cluster assignments. The cluster assignments $C_1^*, C_2^*, \dots, C_K^*$ are used to determine the partition of the network. From the centre cluster, an optimal cluster assignment, $C_1^{opt}, C_2^{opt}, \dots, C_K^{opt}$ is selected in order to minimise the computed normalised cut value (Kagawa *et al.*, 2012:9-10). The multi-way cut approach will identify the number of clusters.

4.2.4 Determining the number of clusters

To determine the number of clusters that will be used in this paper, the multi-way cut approach will be implemented. Using this approach, the optimal cluster assignment for any sum of clusters, K , will be identified (Kagawa *et al.*, 2012:11).

However, the multi-way cut approach does present a methodological problem. According to research (Kagawa, 2012:11), the modularity index was formulated to counter the methodological problem. The modularity index determines the number of clusters identified in the network partition analysis and, therefore, the K cluster can be expressed as follows (Kagawa *et al.*, 2012:11):

$$Q(K) = \sum_{k=1}^K \left\{ \frac{\sum_{i \in C_k^{opt}} \sum_{j \in C_k^{opt}} g_{ij}^*}{\sum_{i=1}^n \sum_{j=1}^n g_{ij}^*} - \left(\frac{\sum_{i \in C_k^{opt}} \sum_{j \in V} g_{ij}^*}{\sum_{i=1}^n \sum_{j=1}^n g_{ij}^*} \right) \right\} = \sum_{k=1}^K (P_{kk} - q_k^2) \quad (4.10)$$

The within cluster ration for the k_{th} cluster is expressed as P_{kk} and the equilateral cluster ration for the k_{th} cluster is expressed as q_k^2 . With the modularity index, the best cluster assignment is defined if the equilateral cluster ratio is low and the within cluster ratio is high. For the purpose of this dissertation, the optimal number of clusters (K^{opt}) is determined by the modularity index.

4.2.5 Preparation of basic data

For this section, the energy-intensive sectors are defined to identify energy intensity within the gold mining supply chain. As mentioned, the I-O table of South Africa 2011, provided by Stats SA is formulated to group the clusters.

For the analysis, the energy intensity of the combusted energy of both primary and secondary resources is considered in Table 4.1, Matrix A and measured as energy-intensity (GWh/Rm).

Table 4-1: I-O Table: A-Matrix of Electricity-intensity (GWh/Rm)

	A-matrix	Energy intensity (GWh/Rm)
1	Agriculture	0,320
2	Forestry	0,318
3	Fishing	0,317
4	Coal and lignite	0,643
5	Metal ores	0,650
6	Other mining	0,653
7	Food	0,021
8	Beverages and tobacco	0,021
9	Spinning and textiles	0,069
10	Knitted fabrics, fur	0,068
11	Leather and luggage	0,068
12	Footwear	0,068
13	Wood	0,070
14	Paper	0,211
15	Publishing	0,208
16	Coke oven manufacture	0,204
17	Nuclear fuel	0,218
18	Other chemicals	0,208
19	Rubber	0,534
20	Plastic	0,531
21	Glass	0,556
22	Non-metallic minerals	0,536
23	Furniture	0,070
24	Recycling and NEC	0,070
25	Basic iron and steel	1,137
26	Precious metals	1,149
27	Structural metal	1,107
28	General machinery	0,005
29	Electrical machinery	0,005
30	Electronic valves	0,005
31	Medical appliances	0,005
32	Motor vehicles	0,003
33	Electricity, gas and water	0,078
34	Distribution of water	0,009
35	Construction	0,002
36	Trade	0,008
37	Hotels and restaurants	0,018
38	Transport	0,008
39	Telecommunications	0,003
40	Financial intermediation	0,003
41	Insurance and pensions	0,001
42	Auxiliary financial	0,000
43	Real estate activities	0,025
44	Renting of machinery	0,009
45	Research	0,007
46	Computer activities	0,019
47	Other community activities	0,003
48	Education	0,019
49	Health and social work	0,014
50	Other services n.e.c.	0,006

As illustrated in Table 4.1, and as calculated in the database, the entire energy intensity of each sector was calculated by calculation energy-intensity linked with the energy inputs. The energy-intensity coefficient of industry i , denoted α_i , was then obtained by dividing the energy consumption by sectors in GWh by the quantity of industrial production. The diagonal matrix with energy intensity as well as the adjacency matrix G (50x50) is obtained by substituting the following:

- Diagonal energy-intensity coefficient matrix $diag(\alpha)$
- The input coefficient matrix A from the benchmark input-output table
- The diagonalised matrix for the energy intensity final demand (eq. 2)

Additionally, the symmetric adjacency matrix G was achieved using eq. (3) and then the degree matrix D was obtained from the (50x50) symmetric adjacency matrix (Kagawa *et al.*, 2012:17):

From the symmetric adjacency matrix G , the next section aims to find the energy-intensive clusters by using the K-means method.

4.3 Finding energy intensive clusters: K-means method

The symmetric adjacency matrix (50x50) is used in the network partitioning algorithm for different numbers of clusters, K , and identified optimal cluster sets for each number of clusters. The modularity index is calculated by using cluster sets. By defining the modularity index Q , the identification of energy-intensive clusters is illustrated.

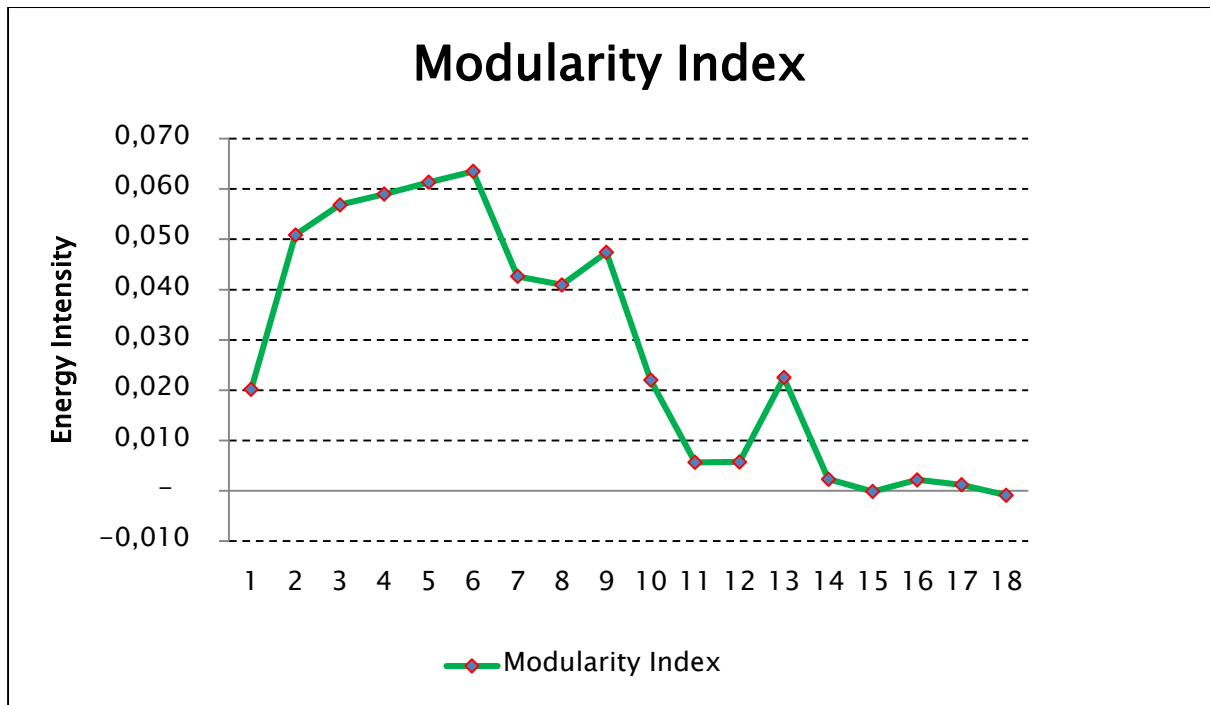


Figure 4-1: Relationship between the number of clusters and the modularity index

The most significant clusters were identified in the Newman-Girvan modularity index as identified in figure 4.1. Figure 4.1 is an illustration of the number of clusters and the modularity index. As illustrated, when $K = 6$, the modularity index reaches the maximum value of 0.064. Between $K = 2$ -5, the modularity index is slightly lower than the maximum value. Therefore, the optimal number of industrial clusters used for the study is six, as it represents the highest value.

Table 4-2: Energy clustering information

Sector	Cluster ID	Sector no.
Electronic valves	1	30
Telecommunications	1	39
Real estate activities	1	43
Research	1	45
Computer activities	1	46
Other community activities	1	47
Health and social work	1	49
Agriculture	2	1
Forestry	2	2
Food	2	7
Other chemicals	2	18
Trade	2	36

Sector	Cluster ID	Sector no.
Transport	2	38
Other mining	3	6
Coke oven manufacture	3	16
Fishing	4	3
Beverages and tobacco	4	8
Spinning and textiles	4	9
Knitted fabrics, fur	4	10
Leather and luggage	4	11
Footwear	4	12
Wood	4	13
Paper	4	14
Publishing	4	15
Nuclear fuel	4	17
Rubber	4	19
Plastic	4	20
Glass	4	21
Non-metallic minerals	4	22
Furniture	4	23
Recycling and NEC	4	24
Electrical machinery	4	29
Medical appliances	4	31
Motor vehicles	4	32
Distribution of water	4	34
Construction	4	35
Hotels and restaurants	4	37
Renting of machinery	4	44
Education	4	48
Other services nec	4	50
Financial intermediation	5	40
Insurance and pensions	5	41
Auxiliary financial	5	42
Metal ores	6	5
Basic iron and steel	6	25
Precious metals	6	26
Structural metal	6	27
General machinery	6	28
Coal and lignite	7	4
Electricity, gas and water	7	33

Table 4.2 is the clustering solutions file for any number of clusters, K . Having the same numbers means belonging to a cluster. Therefore, the complete solution of clusters is presented in Table 4.2.

The section above discusses the methods to identify the energy-intensive clusters in the gold mining supply chain. Therefore, an analytical method is performed to identify energy-intensive clusters from the mining supply chains by integrating input-output analysis with network partition analysis, consequently forming the underlying database for the empirical analysis.

The network partitioning analysis was used to eliminate the randomness within the input-output data and to identify the energy-intensive clusters. Seven clusters were defined. The seven clusters were identified by means of the multi-way cut approach. This approach formed the optimal cluster assignment.

The next section will illustrate the results obtained from the method applied in the discussion above. The aim is to find the energy-intensive industrial clusters in the gold mining supply chain in South Africa.

4.4 Empirical results

Although the gold mining industry itself contributes only 1.7% to South Africa's overall GDP, the contribution of all upstream sectors that feed into the gold mining sector as final products, such as the production of basic iron and steel, precious metals, structural metal and general machinery amounts to approximately 8.3% of the GDP (2014).

Therefore, major inter-industrial distributions are stimulated by the final demand of the gold mining supply chain. The gold mining supply chain consequently plays a vital role in the sustainable growth and expansion of the South African economy.

Because of the analysis, seven clusters were detected. The following section will describe the seven clusters that were identified in the data. These seven clusters illustrated will follow from the highest within-cluster effect to the lowest. Gold represent 80% of metal ores. Therefore, metal ores will represent the gold industry. In the figures presented below, the line width in the figure represents the amount of embodied energy rations among industries producing different products. Figure 4.2 is an illustration of the highest within cluster in the gold mining supply chain.

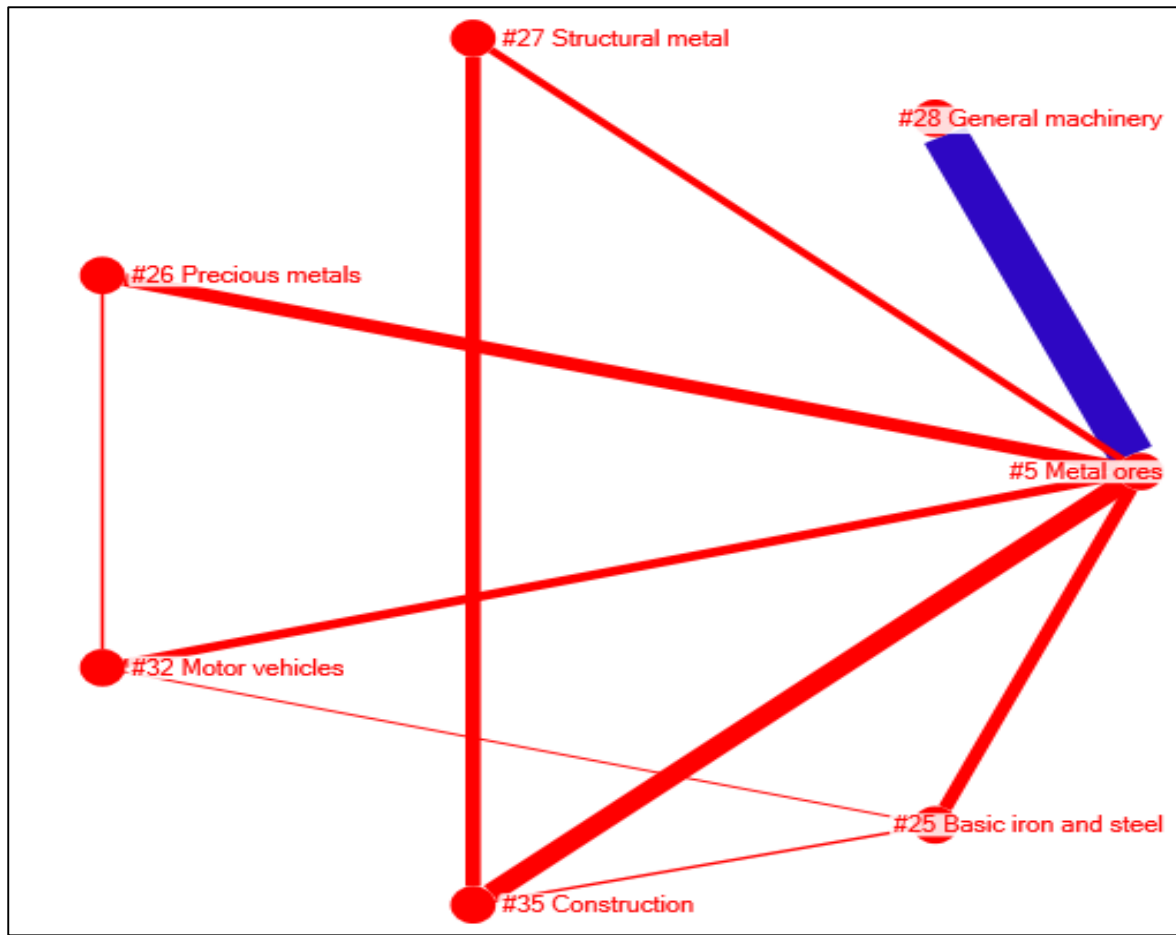


Figure 4-2: The highest within cluster in the gold mining supply chain

Figure 4.2 illustrates the within-group sum and between-group sum as estimated using the comprehensive resolution presented in Table 4.1. From the results, the within-group sum for the sixth cluster (#5 metal ores, #25 basic iron and steel, #26 precious metals, #27 structural metal, 28# general machinery) has the highest within-cluster effect and is the most energy-intensive in the gold mining supply chain. Analyses of the degrees of the sectors in this cluster revealed that the level of metal ores (#5) and general machinery (#28) was the highest. The data indicated that a decrease in the energy consumption, in general, of machinery and metal ores in the cluster is the most significant concern. These estimation results suggest that general machinery is essential to improve efficiency and also to reduce energy consumption at the stage of manufacturing. These findings recommend the on-going significance of energy saving measures in metal ores (#5) and general machinery (#28). Further improvements, in general, in machinery are expected to improve energy preservation.

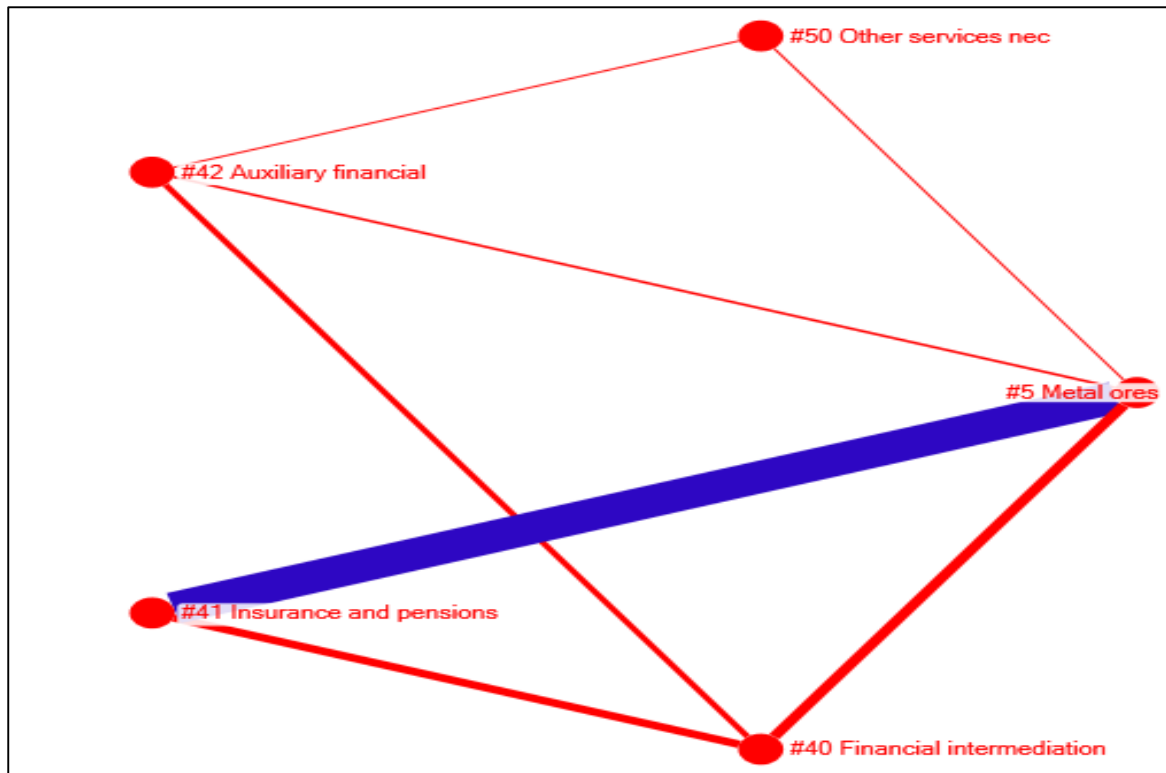


Figure 4-3: The second highest within cluster in the gold mining supply chain

Figure 4.3 illustrates the within-group sum and between-group sum as estimated using the complete solution presented in Table 4.1. Cluster 5, shown in Figure 4.3, has the second highest within cluster effect. From the results, Figure 4.3 shows the inter-sectoral transactions, such as exchanges between #5 metal ores, #42 auxiliary financial, #50 other services nec, #40 financial intermediation, #41 insurance and pensions. The sixth cluster is the second highest of the seven clusters and this cluster, including five industries, is playing a crucial role in energy-intensive sectors in the gold mining supply chain. Analyses of the degrees of the sectors in this cluster revealed that the level of metal ores (#5) and Insurance and Pension (#35) was the highest within cluster effect. These results suggest the continuing importance of energy saving measures in metal ores (#5) and Insurance and Pension (#35).

The data indicated that a decrease in the energy consumption in insurance (#35) and pension and financial intermediation in the cluster is the most significant contributor to decreasing energy consumption. Therefore, further improvements in the financial sector are anticipated to improve energy preservation.

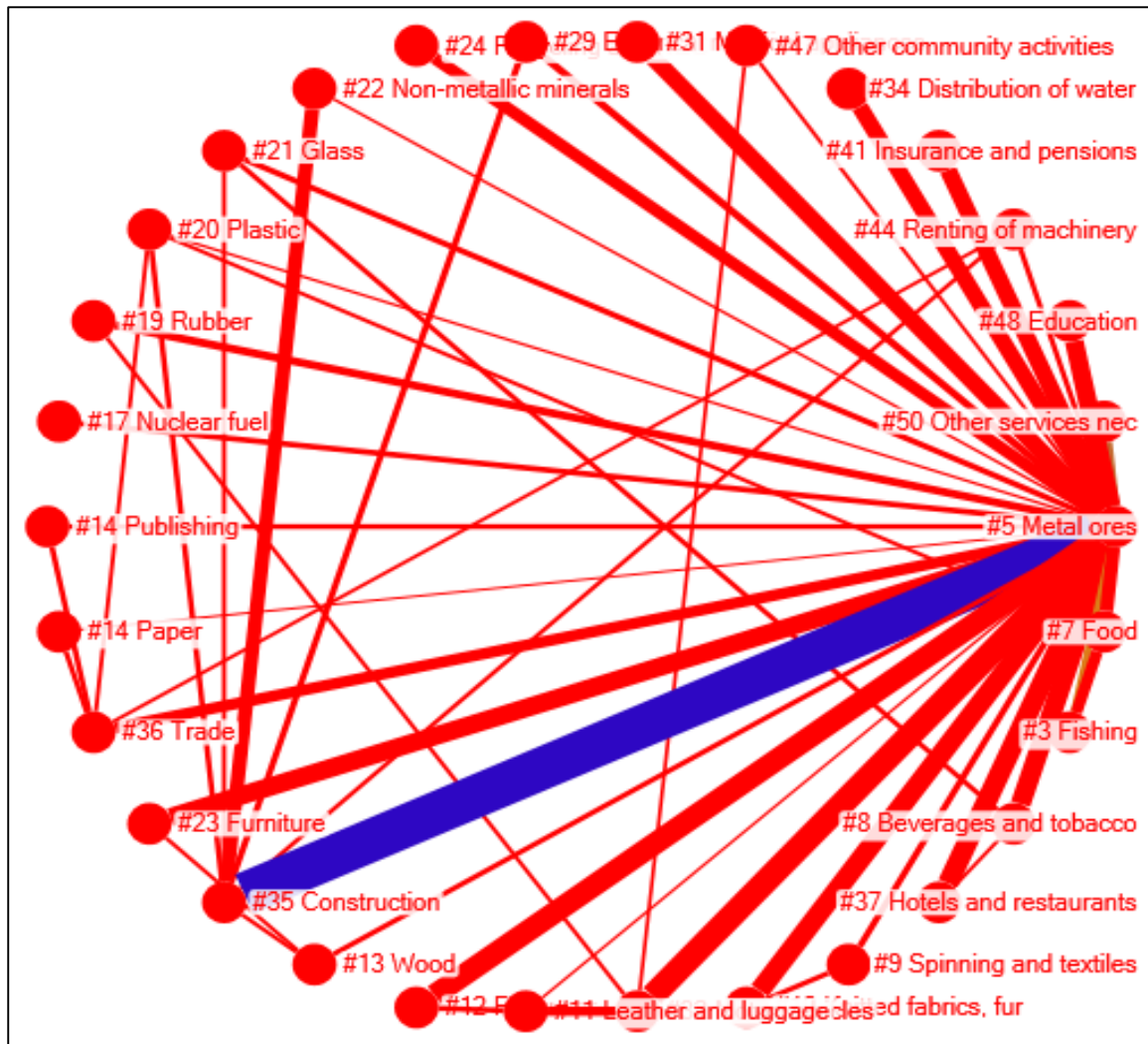


Figure 4-4: The third highest within cluster in the gold mining supply chain

Cluster 4, illustrated in Figure 4.4, has the third highest within cluster effect. Cluster 4 consists of 34 industries, namely: #35 construction, #32 motor vehicles, #26 precious metals, #27 structural metal, #28 general machinery, #40 financial intermediation, #41 insurance and pensions, #42 auxiliary financial, #50 other services nec, #7 food, #3 fishing, #8 beverages and tobacco, #37 hotels and restaurants, #9 spinning and textiles, #10 knitted fabrics, fur, #11 leather and luggage, #12 footwear, #13 wood, #23 furniture, #36 trade, #14 paper, #14 publishing, #17 nuclear fuel, #19 rubber, #20 plastic, #21 glass, #22 non-metallic minerals, #24 recycling and nec, #29 electrical machinery, #31 medical appliances, #47 other community activities, #34 distribution of water, #44 renting of machinery, #48 education #5 metal ores. Analyses of the degrees of the sectors in this cluster revealed that the degree of metal ores (#5) and construction (#35) was the highest within cluster effect.

The data indicated that a decrease in the energy consumption in construction, footwear, wood and knitted fabrics in the cluster is the most significant contributor to decreasing energy consumption. These results suggest that construction is important to improve energy efficiency, but also to reduce energy consumption at the stage of construction. These results recommend the on-going significance of energy saving measures in construction (#35), footwear (#12), wood (#13) and knitted fabrics (#10). Therefore, further improvements in the construction sector are projected to enhance energy efficiency.

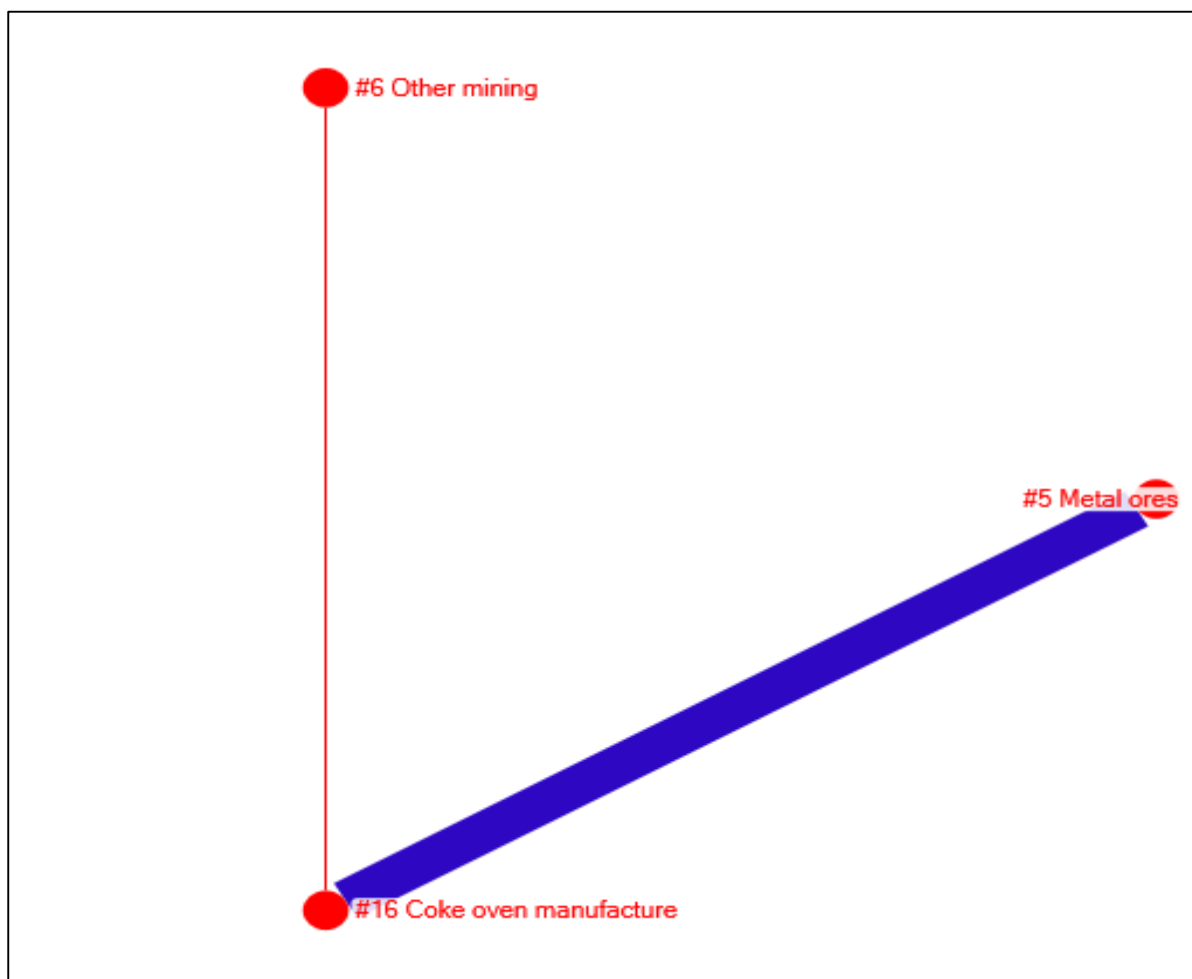


Figure 4-5 :The fourth highest within cluster in the gold mining supply chain.

Cluster 3, illustrated in Figure 4.5, has the fourth highest within cluster effect. Cluster 3 consists of three industries, namely: #5 metal ores, #6 other mining and #16 coke oven manufacture. Analyses of the degrees of the sectors in this cluster revealed that the level of metal ores (#5) and coke oven manufacture (#16) was the highest within cluster effect.

The data indicated that a decrease in the energy consumption in coke oven manufacturing in the cluster is the most significant concern to decrease energy consumption. These estimation results suggest that coke oven manufacture is important to improve efficiency and also to reduce energy consumption at the stage of manufacturing. These findings recommend the ongoing significance of energy-saving measures in coke oven manufacturing (#16). Further improvements in coke oven manufacturing are expected to improve energy preservation. It is important that coke oven manufacture adopts production processes with high environmental performance and also that they collaborate closely with the metal ores sector.

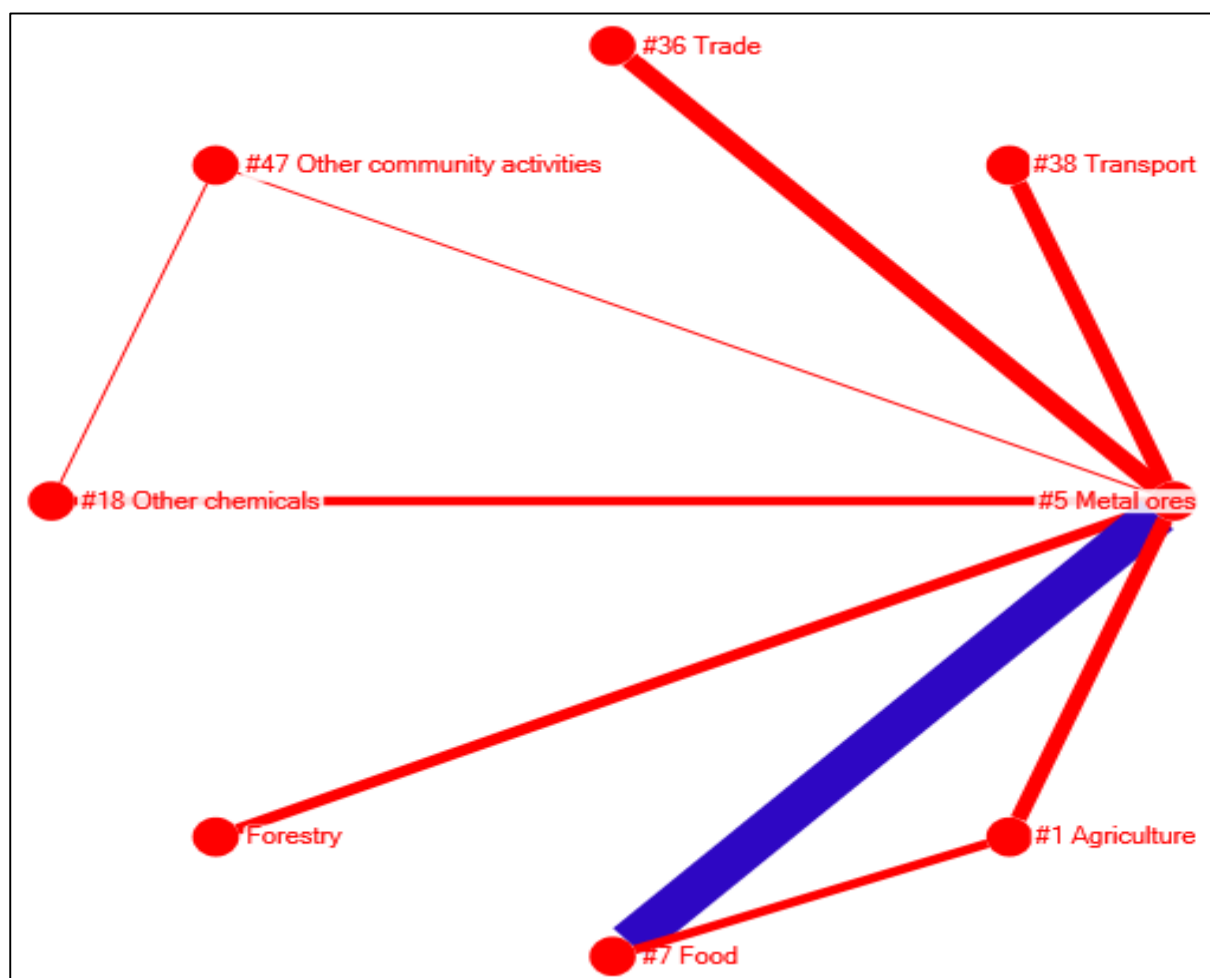


Figure 4-6: The fifth highest within cluster in the gold mining supply chain

Cluster 2, illustrated in Figure 4.6, has the fifth highest within cluster effect. Cluster 2 consists of three industries, namely: #1 agriculture, #2 forestry, #7 food, #18 other chemicals, #36 trade, #38 transport. Analyses of the degrees of the sectors in this cluster revealed that the degree of metal ores (#5) and Food (#7) was the highest within cluster effect.

The data indicated that a decrease in the energy consumption of metal ores (#5), food (#7) and trade (#36) in the cluster is the most significant concern to reduce energy consumption. These estimation results suggest that food (#7) is necessary to improve efficiency and to reduce energy consumption at the stage of manufacturing. These findings recommend the on-going significance of energy-saving measures in food (#7) and trade (#36). Further improvements in food (#7) are expected to improve energy preservation.

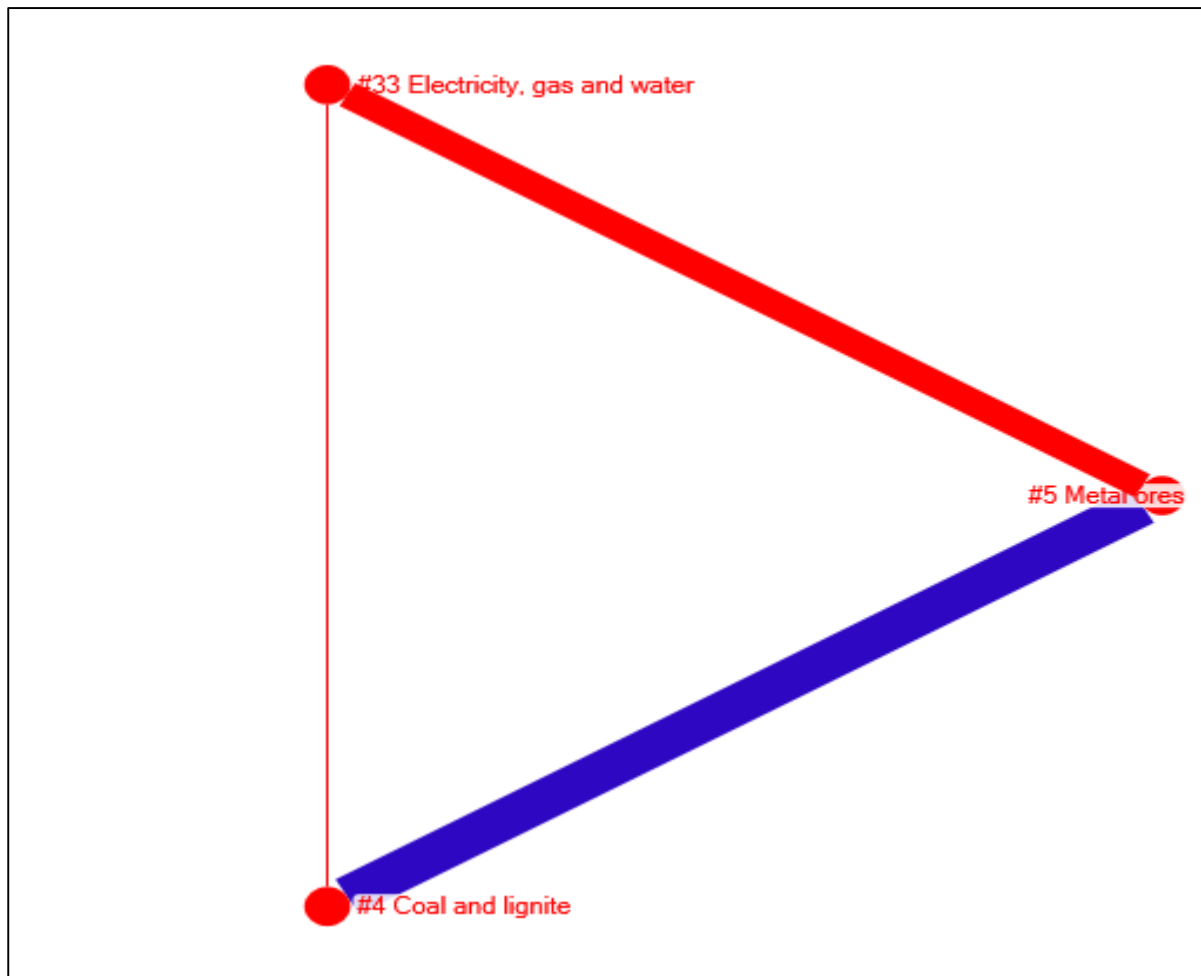


Figure 4-7: The six highest within cluster in the gold mining supply chain

Cluster 7, illustrated in Figure 4.7, has the sixth highest within cluster effect. Cluster 7 consists of three industries, namely: #5 metal ores, # coal and lignite and #33 electricity, gas and water. Analyses of the degrees of the sectors in this cluster revealed that the level of metal ores (#5) and coal and lignite (#4) was the highest within cluster effect.

The data indicated that a decrease in the energy consumption of coal and lignite (#4) and metal ores (#5) in the cluster is the most significant concern. These estimation results suggest that coal and lignite (#4) are necessary to improve efficiency and to reduce energy consumption at the stage of manufacturing. These findings recommend the on-going significance of energy-saving measures in metal ores (#5) and coal and lignite (#4). Further improvements in coal and lignite (#4) are expected to improve energy preservation.

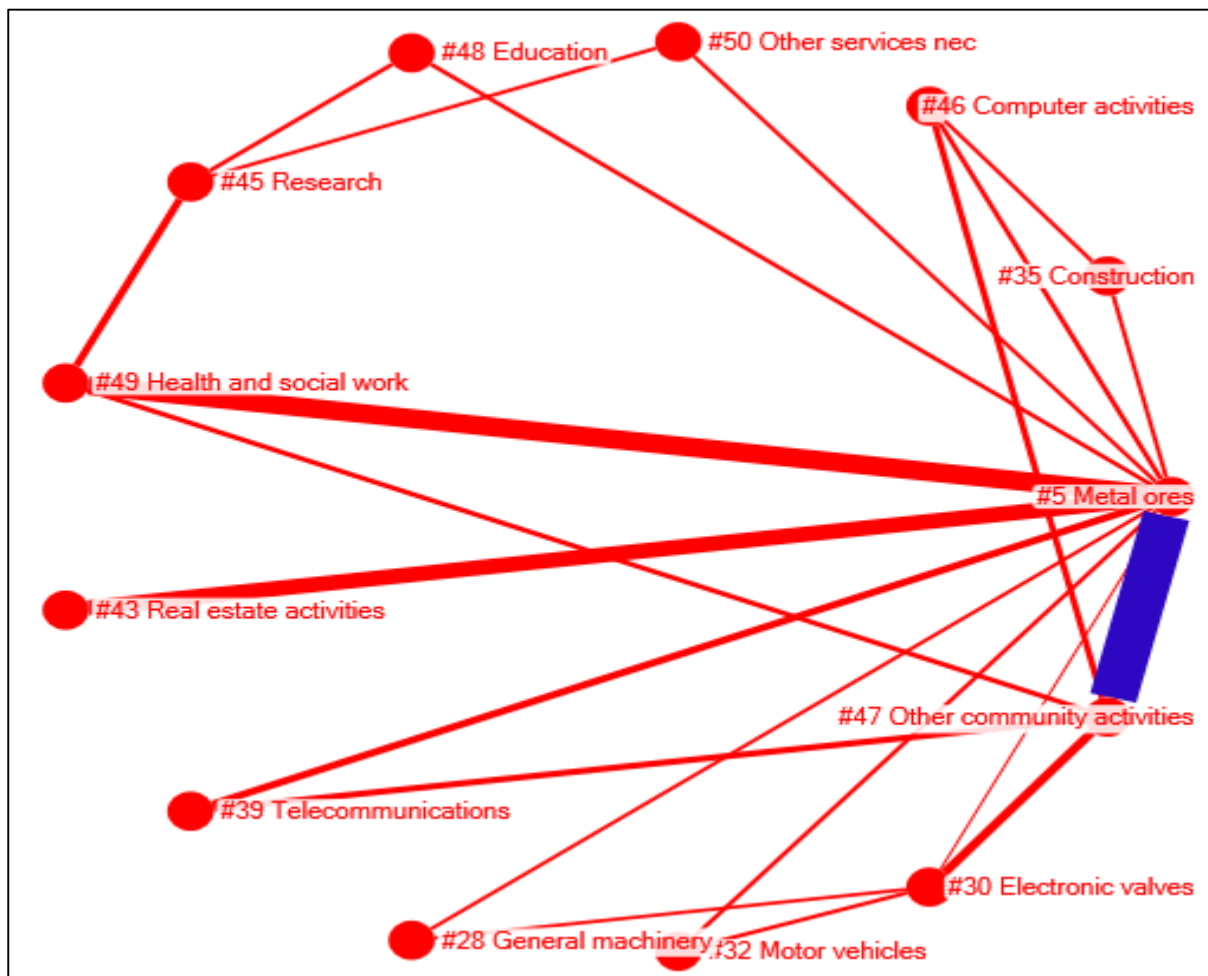


Figure 4-8: The seventh highest within cluster in the gold mining supply chain

Cluster 1, illustrated in Figure 4.8, has the second highest within cluster effect. Cluster 1 consist of 19 industries, namely: #5 metal ores, #25 basic iron and steel, #35 construction, #32 motor vehicles, #26 precious metals, #27 structural metal, #28 general machinery, #40 financial intermediation, #41 insurance and pensions, #42 auxiliary financial, #50 other services nec, #47 other community activities, #30 electronic valves, #39 telecommunications, #43 real estate activities, #49 health and social work, #45 research #48 education, #46 computer activities.

Analyses of the degrees of the sectors in this cluster revealed that the degree of metal ores (#5) and other community activities (#47) was the highest within cluster effect.

The data indicated that a decrease in the energy consumption of coal and lignite (#4) and metal ores (#5) in the cluster is the most significant concern. These estimation results suggest that coal and lignite (#4) are necessary to improve efficiency and to reduce energy consumption at the stage of manufacturing. These findings recommend the on-going significance of energy-saving measures in metal ores (#5) and coal and lignite (#4). Further improvements in coal and lignite (#4) are expected to improve energy preservation.

4.4.1 Manufacturing sector: Largest energy consumer in the gold mining supply chain in South Africa

South Africa's manufacturing sector has developed into a sector that can compete on the international front. The manufacturing sector stimulates the growth of other sectors such as the gold sector. In 2013, the sector contributed the third largest (15.2%) to the South African GDP. Energy is considered as an irreplaceable input in the manufacturing sector.

From the analysis, the manufacturing sector is the most important sector in the gold mining supply chain's energy intensity. In Table 4.3, the industry structure of the gold mining supply chain of 2014 is formulated. It is evident that the secondary industries' intermediate input to the gold mining supply chain is by far the most significant, from which the manufacturing sector is contributing 50.41% of the total intermediate input in the gold mining supply chain.

The majority of manufactured gold is allocated to jewellery manufacturing, followed by coin manufacturing, dental products and lastly industrial products. Therefore, jewellery manufacturing contributes the most to manufacturing in the gold mining supply chain and is the largest category of gold fabrication in South Africa. A decline in recent years in the use of gold in industrial products has occurred due to its substitution with copper etc. The gold mining industry consumes high volumes of energy to produce an ounce of gold, and therefore, the sustainability of the gold industry and particularly jewellery manufacturing depends on energy.

Table 4-3: Industry structure: Gold mining [SIC: 23], rand millions at basic prices 2014

		Intermediate input / costs		Intermediate output / sales	
SIC	Industry / product	R millions	%	R millions	%
1-2	Primary industries	349.1	2.65	-	-
1	..Agriculture, forestry & fishing	14.1	0.11	-	-
2	..Mining & quarrying	335.0	2.54	-	-
21	Coal mining	55.7	0.42	-	-
23	Gold & uranium ore mining	-	-	-	-
22/24/25/29	Other mining	279.3	2.12	-	-
3-5	Secondary industries	9 527.7	72.23	1 803.5	62.25
3	..Manufacturing	6 649.5	50.41	1 803.5	62.25
301-306	Food, beverages & tobacco	8.2	0.06	-	-
301-304	Food	1.6	0.01	-	-
305	Beverages	2.5	0.02	-	-
306	Tobacco	4.1	0.03	-	-
311-317	Textiles, clothing & leather	141.0	1.07	-	-
311-312	Textiles	41.8	0.32	-	-
313-315	Wearing apparel	75.3	0.57	-	-
316	Leather & leather products	4.7	0.04	-	-
317	Footwear	19.2	0.15	-	-
321-326	Wood & paper; publishing & printing	1 415.4	10.73	-	-
321-322	Wood & wood products	1 378.5	10.45	-	-
323	Paper & paper products	31.0	0.23	-	-
324-326	Printing, publishing & recorded media	5.9	0.04	-	-
331-338	Petroleum, chemicals, rubber & plastic	2 070.7	15.70	55.8	1.93
331-333	Coke & refined petroleum	184.2	1.40	-	-
334	Basic chemicals	739.5	5.61	55.8	1.93
335-336	Other chemicals & man-made fibers	852.1	6.46	-	-
337	Rubber products	185.4	1.41	-	-
338	Plastic products	109.5	0.83	-	-
341-342	Other non-metallic mineral products	342.4	2.60	9.4	0.32
341	Glass & glass products	13.6	0.10	9.4	0.32
342	Non-metallic minerals	328.9	2.49	-	-
351-359	Metals, machinery & equipment	2 058.4	15.60	88.2	3.05
351	Basic iron & steel	170.3	1.29	-	-
352	Basic non-ferrous metals	83.6	0.63	88.1	3.04
353-355	Metal products excluding machinery	647.8	4.91	0.1	0.00
356-359	Machinery & equipment	1 156.8	8.77	-	-
361-366	Electrical machinery & apparatus	216.3	1.64	-	-
371-376	Radio, TV, instruments, watches & clocks	53.4	0.40	-	-
371-373	Television, radio & communication equipment	7.7	0.06	-	-
374-376	Professional & scientific equipment	45.6	0.35	-	-
381-387	Transport equipment	327.0	2.48	-	-
381-383	Motor vehicles, parts & accessories	46.8	0.36	-	-
384-387	Other transport equipment	280.2	2.12	-	-
391-392	Furniture & other manufacturing	16.6	0.13	1 650.0	56.95

Table 4-3: Industry structure: Gold mining [SIC: 23], rand millions at basic prices 2014 (continued)

391	Furniture	3.2	0.02	-	-
392-393	Other manufacturing	13.5	0.10	1 650.0	56.95
4	..Electricity, gas & water	2 759.1	20.92	-	-
41	Electricity, gas & steam	2 579.3	19.55	-	-
42	Water supply	179.8	1.36	-	-
5	..Construction (contractors)	119.1	0.90	-	-
51	Building construction	8.0	0.06	-	-
52-53	Civil engineering & other construction	111.1	0.84	-	-
6-9	Tertiary industries	3 314.1	25.12	1 093.6	37.75
6	..Trade, catering & accommodation services	948.2	7.19	-	-
61-63	Wholesale & retail trade	948.2	7.19	-	-
64	Catering & accommodation services	-	-	-	-
7	..Transport, storage & communication	280.4	2.13	-	-
71-74	Transport & storage	248.7	1.89	-	-
75	Communication	31.7	0.24	-	-
8	..Finance, insurance, real estate & business services	1 555.9	11.80	1 093.6	37.75
81-82	Finance & insurance	92.6	0.70	-	-
83-88	Business services	1 463.3	11.09	1 093.6	37.75
9	..Community, social & personal services	529.6	4.01	-	-
93-96	Community, social & personal: Other services	-	-	-	-
93	Other services: Medical, dental & veterinary	-	-	-	-
94-96	Other services: Excluding medical, dental & veterinary	-	-	-	-
98	Community, social & personal: Other producers	529.6	4.01	-	-
99	General government services	-	-	-	-
Total		13 190.9	100.00	2 897.1	100.00

It is vital for energy policy to focus on the manufacturing sector within the gold mining supply chain. The formulation of policies targeting the manufacturing sector to decrease energy consumption is essential for a decline in energy intensity. The Precious Metals Act No. 35 released in 2005 is an amendment of the Mining Rights Act No. 20 of 1967. The purpose of this act was to promote the beneficiation of precious metals in South Africa. Numerous policies have been published to promote energy efficiency and renewable energy strategies. The aim is for energy policy to focus on sectors such as the manufacturing sector to enable more energy efficiency in the gold mining supply chain.

4.5 Summary

The aim of Chapter 4 was to methodically identify energy-intensive clusters within the gold mining supply chain by combining the input-output analysis with network partition analysis.

The first step in the empirical analysis determined the sectors in the industries that were part of the gold mining supply chain. For the purpose of this dissertation, energy-intensive clusters in the gold mining supply chain were extracted by means of the input-output table of 2011 and found strong linkages with downstream industries. The strength of the relations matrix linked with the final demand for the gold mining sector is estimated. Subsequently, the multi-way cut approach was applied using nonnegative matrix factorisation on the matrix to find energy-intensive clusters in the South African gold mining supply chain. Furthermore, the most significant clusters were identified in the Newman-Girvan modularity index as identified in figure 4.1.

From the results, seven clusters were found to be the most energy intensive clusters in the gold mining supply chain. The results of the analysis indicate the cluster with the highest within cluster effect, which consists of five sectors, namely #5 metal ores, #25 basic iron and steel, #26 precious metals, #27 structural metal, 28# general machinery. The sectors that form the cluster are the most energy-intensive sectors in the gold mining supply chain. Therefore, these findings also establish the significance of observing the embodied energy consumption of the seven clusters. The ‘within-cluster effect’ is regarded as an indicator of the energy intensity in the industrial clusters identified from the gold mining supply chain and quantitatively analysed the significance of industrial clusters regarding the energy policy. These results illustrate the measurement of the within-cluster effect that permits the quantitative difference of energy-intensive clusters that should be prioritised in energy-saving methods in the gold mining supply chain of the sectors involved.

The most significant concern is to decrease the energy demand in these clusters. The manufacturing sector is the most significant contributor to the intermediate inputs in the gold mining supply chain. The majority of manufactured gold is allocated to jewellery manufacturing. The gold mining industry consumes high volumes of energy to produce an ounce of gold, and therefore, the sustainability of the gold industry and particularly jewellery manufacturing depends on energy. The method used in this study supports the identification of significant energy policy components in line with energy intensity.

From a policy perspective, forming industry groups around energy-intensive clusters and encouraging constant deliberation with appropriate stakeholders can be an effective approach to decrease energy consumption and misuse. The policy also reassures energy-saving objectives that are mutually conducted by both the gold mining sector and other industries. Identifying energy-intensive clusters can help to prioritise the relevant supply chain partners to engage and assist in effective energy policy-making. Energy policy should also focus on the manufacturing sectors to enable more energy efficiency in the gold mining supply chain.

The next chapter seeks to summarise the dissertation and to determine the implications for energy policy in South Africa.

Chapter 5: Conclusion and recommendations

5.1. Introduction

The aim of this study was to provide a comprehensive overview of the energy-intensive clusters in the gold mining supply chain, aiming to find the nature, level, and probable impact on energy policy in South Africa.

In recent years, South Africa has experienced major energy supply shortages. The country has struggled through a major energy crisis that had an enormous impact on the economy. Only after 1994, did the DOE implement strategies to add infrastructure aiming to increase energy supply. Various energy policies have since focused on energy-efficiency strategies and renewable energy. Eskom supplies 95% of South Africa's energy and in recent times has demand exceeded its energy supply capabilities. Medupi is the first coal-fired power plant to be built in South Africa in more than 20 years, which is projected to be fully finished in 2022.

The gold mining supply chain consumes high volumes of energy and is regarded as the highest energy user in South Africa. In the gold mining supply chain, there are numerous sectors that form energy-intensive clusters. One of these sectors, which contribute the most, is the manufacturing sector. This sector accounts for more than 50% of energy consumption in the gold mining supply chain and it is, therefore, vital that energy policy should focus on this area to implement energy saving measurements. The question that policy-makers are pondering seems to be how to cut power consumption effectively. Co-operation between the private sector and the DOE is vital to assist policy-makers in formulating energy policies that promote the following strategies:

- Renewable energy
- Innovative energy efficiency methods
- Private sector involvement in energy supply
- Adequate infrastructure

If the above-mentioned strategies are implemented, a vast improvement is expected in these energy-intensive clusters.

The five objective of this study, as outlined in Chapter 1, was to provide a review of the DOE's current energy policies through an analysis of the current policy and strategy documentation. These policies were examined to identify to determine the current energy situation in the literature. After that, a method was used to combine a simplified input-output approach with the network partition approach to determine the strength of the relation matrix. This approach was utilised in a case study to identify energy-intensive industry clusters in the South African gold mining supply chain.

The next section summarises the key findings made in the preceding chapters.

5.2. Summary of the results and conclusions of the study

The aim of this dissertation was to identify energy-intensive clusters within the gold mining supply chain with the intention of identifying the broader economic implications of energy usage. To provide a sound theoretical base for the literature in this study, **Chapter 2** provided an overview of the energy policies relevant to this study to identify the gaps in the current energy policies. These policies focus on the energy-intensive users in South Africa. South Africa is currently in the midst of an energy supply crisis.

The White Paper on the energy policy (1998) is the blueprint for energy policy in South Africa. Numerous policies have evolved from this Paper. The White Paper on energy was formulated to emphasise the importance of integrated resource planning methodologies to promote energy infrastructure to add additional electricity supply. However, the institutions failed to deliver the DOE's objectives. A lack of comprehensive planning for further energy supply along with inexpensive energy has resulted in high-energy consumption in the economy and especially in the gold mining sector. It is evident that energy policy should promote the forming of industry consortia around energy-intensive clusters. The relationship between government and industry is significant in encouraging an effective strategy to reduce energy use and misuse. The energy sector remains dependent on coal as a source of energy. The IRP will result in coal forming 55% of the mix by 2030, as opposed to more than 80% currently. Thus, the policy is closing down coal. However, current and historical structure of the energy supply industry cannot be changed in the short-term without major financial and economic costs and therefore this requires time.

A lack of implementation of renewable energy resources and derelict power stations has fuelled the issue of energy supply shortages, which is an indication of poor implementation of energy policy since the release of the White Paper on Energy (1998). With the current supply constraints, emphasis on renewable energy, infrastructure, and new technology cannot be stressed enough.

No additional energy supply capacity was added before 2008. Only after that, the promotion of renewables was implemented. The DOE formulated an Integrated Resource Planning Policy to promote renewable energy, which also failed its objectives. South Africa is facing a second energy crisis, with the new power station construction, Medupi, predicted to be finished in 2020/2021. High-energy users such as the gold mining industry will be largely affected, attributable to its energy intensity. These negative occurrences will spill over to other linked sectors. To gain and maintain a sustainable future for the supply of energy, it is crucial for the DOE and Eskom to take responsibility and actions to improve the outlook of the energy sector.

To summarise, Chapter 2 contains an illustration of the timeline of energy policies in South Africa, which is an indication of the lack of implementation of these policies. It is evident that the high-energy users such as the gold mining sector and linked industry clusters are affected by this predicament. In Chapter 3, a review of the main role players forming the gold mining supply chain was identified.

Chapter 3 presented an overview of the gold mining industry in South Africa. The aim of this chapter was to analyse the gold mining sector by identifying energy clusters and energy intensity within the sector's supply chain. At present (2015), the mining sector is facing a stern challenge, mostly because of the dramatic decrease in commodity prices. High production costs and labour conflict mainly contributed to this predicament. It is notable that the industry previously contributed positively to the economy; however, more recently (2015), mining companies were operating at a loss. By analysing the present and past economic performance of the industry, in addition to the linkages in the gold mining sector, it is evident that any form of disruption in the gold mining sector can hamper the country's economic growth.

Nevertheless, the gold mining supply chain presents the opportunity for upstream industries to convert raw material into intermediary products, thereby creating upstream linkages, which are converted into finished products by the downstream industries. These linkages are significant

to promote beneficiation. To improve and sustain beneficiation, government has to intervene with appropriate policies, which will enable the promotion of beneficiation in the gold sector. This is where the gold mining supply chain can implement a sustainable beneficiation process. Within the gold mining supply chain, numerous energy clusters are formed, resulting in high-energy intensity, which is partly due to a concentrated form of mining. In Chapter 4, these clusters were identified.

Notable energy-efficiency strategies can assist with a decline in energy consumption. Each process in the gold mining supply chain contributes to an increase in energy usage. Therefore, it is fundamental to identify energy-intensive clusters to enable the promotion of energy efficiency. Energy efficiency can only be implemented if the industry role players and government collaborate. It is vital for the role players to execute policies and processes set out by the government to support the gold sector. A major lack of communication between the National Union of Mineworkers (NUM), government, and enterprises such as AngloGold Ashanti, Gold Fields, Harmony Gold, and Sibanye Gold is bearing down on the economy. These entities have to work together to eliminate labour conflict and political constraints. The Mining Act of South Africa can provide a framework for efficient collaboration.

Chapter 3 emphasises the significance of the gold mining industry as one of the most influential sectors of the South African economy. The current energy supply constraints combined with the energy intensity will inevitably require further restructuring of the sector.

The next chapter, **Chapter 4**, identifies the energy-intensive clusters in the gold mining supply chain. This chapter used an analytical method by combining input-output analysis with network partition analysis to identify energy-intensive clusters in the gold mining supply chain. The within-cluster effect was used as an indicator of the energy intensity in the energy clusters identified from the gold mining supply chain.

The input-output (IO) table formed the basis of the empirical analysis. The input-output (IO) table creates randomness in the cluster industry data; therefore, the network partitioning analysis method was used to merge with the input-output (IO) table. Network partition analysis determined whether there is a strong linkage between clusters. This approach further determined that the number of the interactions between different clusters is minimised and that the total of within-cluster interactions is simultaneously maximised, thereby creating the most

efficient result for clustering. The second most effective cluster was identified through K-means clustering. The K-means method identified the energy intensity. These clusters were illustrated by the modularity index. In this study, the seven most energy-intensive clusters were identified from the data and ranked from the highest within-cluster effect to the lowest.

From the data, metal ores represented the gold industry as gold consists of more than 80% of metal ores.

From the results, the sixth cluster, Figure 4.2, expressed the highest within cluster effect in the gold mining supply chain. Cluster 6 consists of #5 metal ores, #25 basic iron and steel, #26 precious metals, #27 structural metal, and 28# general machinery. These five industry linkages are the result of high-energy usage in the gold mining supply chain and can be regarded as the most energy-intensive cluster. The demand by nature of energy of the within-cluster effect of this cluster exposes exceedingly high levels of energy demanded between metal ores (#5) and general machinery (#28), signifying that the most significant concern is to decrease the demand for energy by general machinery in the clusters.

To conclude in **Chapter 4** energy-intensive clusters in the gold mining supply chain were extracted from the input-output table of 2011 and found strong linkages with downstream industries, especially Cluster 6. The manufacturing sector is the greatest contributor to energy intensity in the gold mining supply chain. It is evident that the secondary industries' intermediate input to the gold mining supply chain is by far the most significant, with the manufacturing sector contributing 50.41% of the total intermediate input gold mining supply chain. Methods to improve energy efficiency proposed in this study allow the identification of significant and detailed energy policy given decreasing energy intensity. The analysis of energy clusters formed in the gold mining supply chains should also be addressed in future studies. Table 5.1 is a summary of the research objectives of this study as outlined in Chapter 1.

The research question in this study was as follows: *“Which sectors form energy-intensive clusters in South Africa’s gold mining supply chain and what are the implications for energy policy?”* To answer the research question, seven clusters were identified that form energy-intensive clusters in South Africa’s gold mining supply chain. The implications for energy policy are significant, as policy-makers must focus on the sectors within these energy-intensive clusters to find ways to promote energy-efficiency strategies.

Table 5-1: Summary of research objectives

Research objective	How this was achieved
1. To provide a review of the DOE's current energy policies through an analysis of the current policy and strategy documentation.	A complete overview of the DOE energy policies was conducted. Numerous energy policies were discussed and it is evident that there is a lack of implementation of energy policy. The energy policy implemented by the DOE has numerous shortcomings. The current energy policies and strategy documents were reviewed (White paper on the energy (1998), National Energy Act, White paper on renewable energy, White paper on renewable energy and Nuclear Energy Act). The DOE, in cooperation with Eskom, has framed a comprehensive programme to stabilise the electricity supply and distribution structure. Energy policy should promote the forming of industry consortia around energy-intensive clusters and encourage continuous debate with relevant stakeholders (i.e. between government and industry) as an effective strategy to reduce energy use and misuse. To enforce a sustainable future in the supply of energy, it is essential for the DOE and Eskom to be held accountable for all activities within the energy sector.
2. Review the related approaches and methods to identify supply chain clusters in the literature.	The first step in the empirical analysis was to determine which sectors in the IDE is part of the gold mining supply chain. A 2011 I-O table of South Africa forms the underlying database for the empirical analysis. By using the I-O tables, the sectors that form part of the value chain were determined. Once the sector was identified, the SA SAM (2011) was used to determine the networks of the sectors in the clusters linked together.

Table 5-2: Summary of research objectives (continue)

Research objective	How this was achieved
2. Review the related approaches and methods to identify supply chain clusters in the literature (continue).	Once these industry clusters were identified, the K-means method was used to identify energy-intensive clusters. This information was required to sign the cluster diagram NodeXL. To identify the gold mining industry itself as metal ores, the SPA (structural path analysis) was used to determine the networks of metal ores to all other sectors in this particular cluster. These approaches and methods were used to determine the energy clusters in the gold mining supply chain.
3. Apply a new method to combine the simplified input-output approach with the network partition approach to determine the strength of the relation matrix.	A simplified input-output table combined with the network partition approach determined the strength of the relation matrix. Consequently, the highest within cluster was identified and subsequently the energy-intensive clusters within the gold mining supply chain were identified. When merging the input-output analysis with a network partitioning analysis method, randomness in the industry cluster analysis occurred. This helped to mitigate the unpredictability within the input-output data. Network partition analysis defines the limitations between groups in the form of a cut value or a normalised cut value. This approach aimed to determine whether there is a strong linkage between clusters or not.

Table 5-1: Summary of research objectives (continued)

Research objective	How this was achieved
4. Determine the effectiveness of the method by using a case study to identify energy-intensive industry clusters in the South African gold mining supply chain.	The seven most energy intensive clusters were identified in the gold mining supply chain. The seven clusters identified, which were illustrated figures, represented the highest within-cluster effect to the lowest. The gold sector consists of 80% of metal ores. Therefore, metal ores will represent the gold industry. From the results, the within-group sum for the 6th cluster (#5 metal ores, #25 basic iron and steel, #26 precious metals, #27 structural metal, 28# general machinery) has the highest within-cluster effect and is the most energy-intensive in the gold mining supply chain.
5. Inform on the broader economic implications of the DoE and Eskom's current energy policies.	The current energy supply constraints are a result of poorly implemented policies by the DOE and Eskom. From a policy perspective, forming industry groups around energy-intensive clusters and encouraging constant deliberation with appropriate stakeholders can be an effective approach to decrease energy consumption and misuse. The IRP (2010) focused on renewable energies aimed at reducing carbon emissions and decreasing the effect of energy intensity on the South African economy. The policy also reassures energy-saving objectives that are mutually conducted by both the gold mining sector and other industries. Identifying energy intensive clusters can help to prioritise the relevant supply chain partners to engage and assist in effective energy policy-making. Energy policy should also focus on the manufacturing sectors to enable more energy efficiency in the gold mining supply chain.

This chapter reviews the main conclusions of this study and, although falling outside the scope of the study, attempts to make relevant policy recommendations from the conclusions drawn.

Based on the results, there are some areas that this study did not address, which are areas for future research. As more data becomes available, future research can address these questions in a much more in-depth manner than has been possible here. The policy recommendations are geared toward providing a pathway to identify energy clusters in the gold mining supply chain with the aim to reduce energy consumption therefore creating opportunities further studies.

5.3. Policy recommendations

The conclusion highlights significant areas of intervention that will ensure a continuous and efficient implementation of energy policy.

Increased energy intensity in the gold mining supply chain provides both opportunities and challenges for the economy. Energy-intensive sectors provide opportunities for policy-makers to invest in energy-efficient methods to reduce energy intensity. The challenge that this imposes is that the energy intensity in the gold sector creates spillover effects to other sectors.

Though policy recommendations are not the main aim of this study, it is, however, significant to emphasise some general policy recommendations.

5.3.1 Energy efficiency strategies

It is vital for energy policy to promote energy efficiency strategies and policies. The significance of the measurements for energy efficiency can be determined by measuring the within cluster effect in the energy clusters.

This allows the proposal and implementation of effective energy policy for each cluster. Reliable and detailed data on energy usage promotes efficiency opportunities in all sectors and contributes to the development of effective energy-efficiency strategies. Based on the analysis of energy clusters in the gold mining supply chains, the DOE in collaboration with Eskom should formulate and regularly update strategies and action plans to improve energy efficiency in the gold sector. Government intervention is also required, especially to enhance and extend tax incentives for energy efficiency investments. The DOE must implement policies to ensure

that energy efficiency strategies are met to promote technically feasible energy-saving measurements. Furthermore, government should review energy regulations in the energy sector on an annual basis to ensure that the high-energy user's energy consumption is maintain to decrease their demand for energy.

As identified in the empirical analysis, manufacturing is the highest contributor to energy consumption. The government should focus on this sector when formulating energy policy. Once manufacturing can improve its energy efficiency, the gold mining supply chain will become less energy intensive. Furthermore, the following strategies and action plans should be implemented:

- Identify concerns that are preventing energy efficiency investments and attempt to overcome these concerns.
- Promote renewable energy infrastructure expansions.
- Promote energy-saving strategies initiatives in the gold mining supply chain.
- Promote energy policies that are most likely to yield the largest, most cost-effective improvements in the energy sector.
- Implement objectives and timelines for energy policy, and establish evaluation methods for these policies.
- Maintain consistency with energy, and economic strategies and plans among the high-energy users.
- Continue to provide investment certainty and a stable supply network.

Another concerning issue is the growing energy demand. The DOE must ensure reliable and secure energy supply through the following actions:

- Use energy and economic resources more efficiently.
- Expand energy sources in supply chain networks.
- Change energy structures and economy to improve management of environment effects.
- Promote a skilled labour force with the required knowledge and expertise to design, construct, operate, and sustain current energy supply structures.
- Additional renewable energy resources.

The DOE must monitor, implement, and evaluate energy policies in high-energy use sectors. The following principles should direct policies:

- Energy-efficiency policy should be assessed throughout and after implementation to promote efficient decision-making.
- Monitoring and evaluation of energy policy should be established when new policies are implemented.

5.3.2 Energy infrastructure investments

A lack of infrastructure and derelict power stations has forced the issue to draft a comprehensive, integrated energy policy system across all sources of electricity generation. Most energy policies previously released in South Africa focused on promoting additional electricity supply infrastructure and investments, which allowed for the upgrade of older power stations. It is evident that the majority of energy policy in South Africa was never implemented as the Medupi power station is the first power station to be built in more than 20 years. South Africa will suffer substantial financial losses and costs to reconstruct and expand the electricity infrastructure to secure current and future supply

Government should facilitate private investment in the energy sector by supporting energy efficiency capacity through measurements such as energy-efficiency technology research and private lending. It is vital for the private sector to engage with the DOE in finding ways to assist in electricity generation. For example, Sasol, which is an internationally integrated electricity and chemicals company, and is regarded as the biggest company in South Africa, generates its own energy. The DOE can focus on the following areas to increase electricity infrastructure:

- Energy-efficient supply opportunities in sectors with high-energy use.
- New energy infrastructure, technology, and renewable energy are becoming increasingly important.
- Education and training programmes to ensure sectors with high-energy use to have a skilled labour force.
- Cooperation with the private sector to develop public-private partnerships that enable energy supply infrastructure.

- Promote a balance between energy infrastructure investments and opportunities to improve the production process and energy efficiency.
- Sufficient energy supply is required to sustain economic growth.
- Promote renewable energy infrastructure expansions.

Furthermore, investment in research and development initiatives is vital to solving the fundamental value of South Africa's gold mining sector by discovering new strategies in support of energy-intensive clusters to be more energy efficient.

The question to consider is whether energy policy promotes energy infrastructure investments in sectors with high-energy use or any additional energy infrastructure in any other sector it might fuel and transform the economy into an energy intensive industry in the long term.

5.4 Concluding remarks

This study has provided evidence for questions and possible solutions about energy-intensive clusters in the gold mining supply chain.

Energy-intensive clusters in the gold mining supply chain were identified, stressing the significant number of high energy users in the economy. This paper has provided evidence on some concerns and possible solutions regarding the decrease of energy intensity in the gold mining supply chain of South Africa.

A thorough literature review and an empirical analysis made it possible to steer the debate in the direction of some clearer ground. At the beginning of this paper, the following research question was identified:

- Which sectors form energy-intensive clusters in South Africa's gold mining supply chain and what are the implications for energy policy?

This question was answered by the approaches summarised in the preceding section.

The solutions to the research question are as follows:

- Seven energy intensive clusters were identified in the gold mining supply chain, with the strongest connection forming between metal ores and general machinery in the cluster with the highest within cluster effect. However, manufacturing within the gold mining supply chain was found to be the greatest contributor to energy intensity. Energy policies should promote energy efficiency and renewable energy strategies that support the high-energy users, especially manufacturing, in the cluster.

However, as clarified in preceding chapters, identifying the energy-intensive clusters for targeted policies would present significant challenges, since there is considerable difference in the vulnerability in the energy intensity among linked sectors within the gold mining supply chain. Policy-makers may want to deliberate supporting only those vulnerable industries that also make a significant contribution to the economy. The gold ores are being depleted and in 20 to 30 years, production will close down completely.

Suggestions for further research on this topic include the expansion of the models presented in this study as more data becomes available. Research could also be undertaken on energy efficiency in all industries in South Africa to determine the exact impact of energy intensity on South Africa's economic growth. Country analyses of energy intensity in various other sectors and other countries with resource-based economies will provide a different insight into energy-intensive clusters than the more general approach followed in this study.

This study shows that energy policy in South Africa has major shortcomings. The various institutions are not implementing these energy policies accordingly. Energy intensity will remain a major concern in the coming years if the issue is not addressed. Suggestions for further research on this topic include the expansion of the models presented in this study, as more data becomes available.

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Appendices

Appendix 1-1: Classification information input-output table (2011)

Industry number	SIC Code	Description
I1	SIC 11	Agriculture, hunting and related services
I2	SIC 12	Forestry, logging and related services
I3	SIC 13	Fishing, operation of fish hatcheries and fish farms
I4	SIC 21	Mining of coal and lignite
I5	SIC 23 & 24	Mining of gold, uranium and metal ores
I6	SIC 25	Other mining and quarrying
I7	SIC 301-4	Manufacture of food products
I8	SIC 305-6	Manufacture of beverage and tobacco products
I9	SIC 311-2	Spinning, weaving, finishing of textiles and manufacture of other textiles
I10	SIC 313-5	Manufacture of knitted, crocheted fabrics, wearing apparel, fur articles and dyeing of fur
I11	SIC 316	Tanning and dressing of leather, manufacture of luggage, handbags, saddler and harness
I12	SIC 317	Manufacture of footwear
I13	SIC 321-2	Manufacture of products of wood, cork, straw and plaiting materials; and sawmilling and planing of wood
I14	SIC 323	Manufacture of paper and paper products
I15	SIC 324-6	Publishing, printing and service activities related to printing; and reproduction of recorded media
I16	SIC 331-2	Manufacture of coke oven products; and petroleum refineries/ synthesizers
I17	SIC 333-4	Processing of nuclear fuel; and basic chemicals
I18	SIC 335-6	Manufacture of other chemical products, and man-made fibres
I19	SIC 337	Manufacture of rubber products
I20	SIC 338	Manufacture of plastic products
I21	SIC 341	Manufacture of glass and glass products
I22	SIC 342	Manufacture of non-metallic mineral products (nec)
I23	SIC 391	Manufacture of furniture
I24	SIC 392 & 395	Manufacture nec and recycling nec
I25	SIC 351 & 353	Manufacture of basic iron and steel and casting of metals
I26	SIC 352	Manufacture of precious metals and non-ferrous metals
I27	SIC 354-5	Manufacture of structural metal products, tanks, reservoirs and steam generators, and other fabricated metal products, metalwork service activities
I28	SIC 356-9	Manufacture of general purpose machinery, special purpose machinery, household appliances, and office, accounting and computing machinery
I29	SIC 36	Manufacture of electrical machinery and apparatus nec
I30	SIC 371-3	Manufacture of electronic valves, tubes, other electric components; television and radio transmitters, apparatus for line telephony and line telegraphy; and television and radio receivers, sound or video recording or reproducing apparatus and associated goods
I31	SIC 374-6	Manufacture of medical appliances and instruments and appliances for measuring, checking, testing, navigating and other purposes; manufacture

Industry number	SIC Code	Description
		of optical instruments and photographic equipment; and watches and clocks
I32	SIC 381-387	Manufacture of motor vehicles, bodies (coachwork) for motor vehicles, locomotives, aircraft, spacecraft, trailers and semi-trailers; motor vehicle and engine parts and accessories; building and repairing ships and boats, and manufacture of transport equipment not elsewhere classified.
I33	SIC 41	Electricity, gas steam and hot water supply
I34	SIC 42	Collection, purification and distribution of water
I35	SIC 5	Construction
I36	SIC 61 & 62 & 63	Wholesale and commission trade, retail trade; and sale, maintenance and repair of motor vehicles and motor cycles, retail trade in automotive fuel
I37	SIC 64	Hotels and restaurants
I38	SIC 71 & 72 & 73 & 74	Transport (land, water, air); and supporting and auxiliary transport activities, activities of travel agencies
I39	SIC 75	Post and telecommunications
I40	SIC 81	Financial intermediation, except insurance and pension funding
I41	SIC 82	Insurance and pension funding, except compulsory social security
I42	SIC 83	Activities auxiliary to financial intermediation
I43	SIC 84	Real estate activities
I44	SIC 85	Renting of machinery and equipment, without operator, and of personal and household goods
I45	SIC 87	Research and development
I46	SIC 86 & 88	Computer and related activities; and other business activities
I47	SIC 94	Other community, social and personal service activities (including government)
I48	SIC 92	Education
I49	SIC 93	Health and social work
I50	SIC 9	Other service activities nec

Source: Stats SA (2011)

Appendix 1-2: Industry-by-industry I-O table for South Africa, 2012 (R million)

Input-output table		2011 R million				
Order	Description	Agriculture	Forestry	Fishing	Coal and lignite	Metal ores
		I1	I2	I3	I4	I5
I1	Agriculture	2 828	311	30	8	17
I2	Forestry	0	0	0	0	0
I3	Fishing	0	0	0	0	0
I4	Coal and lignite	21	0	0	10	4 121
I5	Metal ores	0	0	0	0	3
I6	Other mining	1 003	111	10	90	393
I7	Food	14 517	1 596	155	6	8
I8	Beverages and tobacco	0	0	0	143	270
I9	Spinning and textiles	1 278	141	14	59	455
I10	Knitted fabrics, fur	0	0	0	62	306
I11	Leather and luggage	0	0	0	43	93
I12	Footwear	0	0	0	18	281
I13	Wood	425	33	2	64	2 568
I14	Paper	31	15	3	22	157
I15	Publishing	6	3	1	3	21
I16	Coke oven manufacture	4 960	546	55	584	3 355
I17	Nuclear fuel	0	0	0	83	1 596
I18	Other chemicals	13 586	1 496	145	1 538	10 510
I19	Rubber	225	25	3	522	1 724
I20	Plastic	174	19	2	109	526
I21	Glass	14	2	0	15	66
I22	Non-metallic minerals	237	28	3	73	779
I23	Furniture	0	0	0	2	20
I24	Recycling and NEC	0	0	0	23	707
I25	Basic iron and steel	90	10	0	82	1 105
I26	Precious metals	14	1	0	14	258
I27	Structural metal	2 743	297	25	1 112	8 312
I28	General machinery	1 188	131	12	1 043	8 127
I29	Electrical machinery	125	13	2	491	1 615
I30	Electronic valves	0	0	0	77	172
I31	Medical appliances	0	0	0	4	23
I32	Motor vehicles	1 065	117	11	563	2 373
I33	Electricity, gas and water	1 508	166	16	1 321	7 071
I34	Distribution of water	385	43	5	276	1 859
I35	Construction	187	21	2	390	2 016
I36	Trade	8 979	988	96	1 396	8 770
I37	Hotels and restaurants	2	0	0	16	55
I38	Transport	16 183	1 781	173	17 271	17 990
I39	Telecommunications	145	14	0	222	669
I40	Financial intermediation	2 939	92	235	1 135	1 938
I41	Insurance and pensions	1 717	189	18	252	670
I42	Auxiliary financial	0	0	0	1 374	4 221
I43	Real estate activities	42	4	0	36	471
I44	Renting of machinery	0	0	0	0	0
I45	Research	0	0	0	0	0
I46	Computer activities	211	22	2	760	2 316
I47	Other community activities	0	0	0	0	0
I48	Education	0	0	0	0	1
I49	Health and social work	3 834	421	41	0	0
I50	Other services nec	2 376	262	24	2 217	6 095
Total		83 039	8 899	1 085	33 529	104 102
Net taxes on products		2 266	252	23	460	2 410
Gross value added		49 680	12 114	2 665	55 115	171 355
Employees' compensation		16 917	1 923	947	15 852	63 259
Other taxes less subsidies		-283	138	17	583	1 403
Gross operating surplus		33 046	10 053	1 701	38 680	106 693
Output		134 985	21 265	3 773	89 104	277 867

Industry-by-industry I-O table for South Africa, 2012 (R million) (continued)

Input-output table							
Order	Description	Other mining	Food	Beverages and tobacco	Spinning and textiles	Knitted fabrics, fur	
		I6	I7	I8	I9	I10	
I1	Agriculture	1	52 027	5 908	3 363		31
I2	Forestry	0	0	0	0		0
I3	Fishing	0	2 262	0	0		0
I4	Coal and lignite	839	823	110	343		87
I5	Metal ores	0	0	0	0		0
I6	Other mining	45	350	0	10		0
I7	Food	0	37 548	1 987	29		0
I8	Beverages and tobacco	15	198	10 277	0		0
I9	Spinning and textiles	57	0	121	3 644		4 238
I10	Knitted fabrics, fur	38	0	0	57		1 770
I11	Leather and luggage	11	0	0	34		0
I12	Footwear	45	0	0	0		1
I13	Wood	107	2 281	1 277	120		45
I14	Paper	40	2 624	1 343	182		91
I15	Publishing	3	55	4	18		5
I16	Coke oven manufacture	627	17	0	0		0
I17	Nuclear fuel	180	1 651	1 095	1 613		278
I18	Other chemicals	1 637	670	215	534		226
I19	Rubber	295	0	0	12		32
I20	Plastic	102	3 982	1 454	268		157
I21	Glass	9	197	1 388	1		0
I22	Non-metallic minerals	53	0	0	0		0
I23	Furniture	3	0	0	0		0
I24	Recycling and NEC	109	43	6	5		7
I25	Basic iron and steel	143	0	0	107		2
I26	Precious metals	26	1	0	38		0
I27	Structural metal	982	0	27	31		43
I28	General machinery	1 188	0	0	0		0
I29	Electrical machinery	225	0	0	5		0
I30	Electronic valves	24	0	0	0		0
I31	Medical appliances	3	0	0	0		0
I32	Motor vehicles	419	267	59	17		18
I33	Electricity, gas and water	1 682	3 067	281	597		235
I34	Distribution of water	229	262	883	20		9
I35	Construction	244	528	236	22		108
I36	Trade	1 283	15 256	5 411	2 150		1 763
I37	Hotels and restaurants	8	40	14	5		4
I38	Transport	7 539	12 191	1 983	978		658
I39	Telecommunications	268	1 113	271	314		436
I40	Financial intermediation	2 488	1 320	346	335		504
I41	Insurance and pensions	138	479	88	96		79
I42	Auxiliary financial	2 678	0	0	0		0
I43	Real estate activities	300	2 002	415	350		301
I44	Renting of machinery	0	359	40	22		15
I45	Research	0	18	4	8		3
I46	Computer activities	891	8 021	1 644	494		308
I47	Other community activities	0	0	0	0		0
I48	Education	2	62	23	7		6
I49	Health and social work	0	0	0	0		0
I50	Other services nec	2 132	15 630	8 075	2 970		1 812
	Total	27 111	165 348	44 988	18 800		13 271
	Net taxes on products	418	1 932	5 013	912		1 285
	Gross value added	29 890	55 060	25 853	3 545		4 087
	Employees' compensation	10 865	30 394	11 518	2 957		4 615
	Other taxes less subsidies	230	17	362	32		58
	Gross operating surplus	18 796	24 648	13 973	556		-586
	Output	57 419	222 339	75 854	23 257		18 644

Industry-by-industry I-O table for South Africa, 2012 (R million) (continued)

Input-output table							
Order	Description	Leather and luggage	Footwear	Wood	Paper	Publishing	
		I11	I12	I13	I14	I15	
I1	Agriculture	2 779	438	19	77		46
I2	Forestry	0	0	5 431	7 007		65
I3	Fishing	0	0	0	0		0
I4	Coal and lignite	8	2	182	3 028		25
I5	Metal ores	0	0	27	0		1
I6	Other mining	0	0	262	1		141
I7	Food	1	0	2	258		0
I8	Beverages and tobacco	0	0	0	0		0
I9	Spinning and textiles	14	201	32	364		210
I10	Knitted fabrics, fur	0	0	0	0		0
I11	Leather and luggage	246	1 189	0	29		1
I12	Footwear	2	369	0	0		0
I13	Wood	5	34	5 557	715		50
I14	Paper	14	71	229	12 331		5 657
I15	Publishing	1	3	7	103		1 355
I16	Coke oven manufacture	0	0	10	157		24
I17	Nuclear fuel	234	419	201	2 334		137
I18	Other chemicals	44	41	529	1 701		1 534
I19	Rubber	1	309	87	1		23
I20	Plastic	24	49	289	125		179
I21	Glass	0	0	76	0		13
I22	Non-metallic minerals	0	0	34	21		1
I23	Furniture	0	0	0	1		0
I24	Recycling and NEC	1	2	71	11		199
I25	Basic iron and steel	2	19	307	0		1
I26	Precious metals	0	0	61	39		54
I27	Structural metal	103	85	436	62		275
I28	General machinery	0	0	10	0		0
I29	Electrical machinery	0	0	0	0		0
I30	Electronic valves	0	0	0	0		148
I31	Medical appliances	0	0	0	0		0
I32	Motor vehicles	3	6	66	36		44
I33	Electricity, gas and water	42	60	414	998		213
I34	Distribution of water	2	3	14	31		8
I35	Construction	6	75	169	40		1 096
I36	Trade	394	597	1 717	4 784		2 700
I37	Hotels and restaurants	2	2	10	13		23
I38	Transport	147	321	1 965	2 262		1 459
I39	Telecommunications	44	145	349	318		940
I40	Financial intermediation	93	130	442	162		512
I41	Insurance and pensions	14	25	131	126		115
I42	Auxiliary financial	0	0	0	0		0
I43	Real estate activities	46	114	373	497		649
I44	Renting of machinery	3	5	22	239		56
I45	Research	4	3	2	30		40
I46	Computer activities	71	128	685	971		1 488
I47	Other community activities	0	0	0	0		0
I48	Education	2	1	7	23		17
I49	Health and social work	0	0	0	0		0
I50	Other services nec	599	677	2 220	9 253		4 724
	Total	4 949	5 520	22 443	48 147		24 225
	Net taxes on products	44	757	154	618		276
	Gross value added	359	1 491	8 247	10 208		11 811
	Employees' compensation	474	1 140	6 716	6 994		11 018
	Other taxes less subsidies	-11	43	88	-24		173
	Gross operating surplus	-104	308	1 443	3 238		619
	Output	5 352	7 768	30 844	58 974		36 311

Industry-by-industry I-O table for South Africa, 2012 (R million) (continued)

Input-output table						
Order	Description	Coke oven manufacture	Nuclear fuel	Other chemicals	Rubber	Plastic
		I16	I17	I18	I19	I20
I1	Agriculture	76	88	397	794	8
I2	Forestry	0	0	41	31	0
I3	Fishing	0	0	0	0	0
I4	Coal and lignite	8 644	452	126	87	15
I5	Metal ores	38	0	0	0	0
I6	Other mining	62 245	3 583	1 883	0	268
I7	Food	0	615	2 435	0	0
I8	Beverages and tobacco	0	0	0	0	0
I9	Spinning and textiles	13	0	430	477	2
I10	Knitted fabrics, fur	0	0	0	0	0
I11	Leather and luggage	0	0	0	0	0
I12	Footwear	0	0	0	0	0
I13	Wood	951	275	1 378	10	53
I14	Paper	189	205	2 239	14	187
I15	Publishing	11	8	78	4	21
I16	Coke oven manufacture	533	3 092	838	165	33
I17	Nuclear fuel	1 719	35 117	14 990	3 780	8 070
I18	Other chemicals	87	2 326	12 071	1 087	667
I19	Rubber	0	38	0	465	110
I20	Plastic	220	304	2 622	144	1 006
I21	Glass	4	6	674	0	3
I22	Non-metallic minerals	63	0	102	0	13
I23	Furniture	0	0	0	0	0
I24	Recycling and NEC	5	53	38	3	11
I25	Basic iron and steel	84	146	156	342	96
I26	Precious metals	201	8	90	0	16
I27	Structural metal	0	854	43	158	567
I28	General machinery	0	1	0	0	1
I29	Electrical machinery	0	2	0	0	0
I30	Electronic valves	0	10	0	0	0
I31	Medical appliances	0	0	1	0	0
I32	Motor vehicles	52	42	116	11	32
I33	Electricity, gas and water	797	6 746	2 517	286	395
I34	Distribution of water	34	81	44	11	16
I35	Construction	4 553	425	97	8	83
I36	Trade	4 581	7 277	8 061	1 281	2 051
I37	Hotels and restaurants	14	26	31	5	45
I38	Transport	2 308	3 423	6 842	662	1 090
I39	Telecommunications	74	748	830	126	308
I40	Financial intermediation	115	178	1 555	142	313
I41	Insurance and pensions	114	226	242	45	101
I42	Auxiliary financial	0	0	0	0	0
I43	Real estate activities	290	536	864	174	464
I44	Renting of machinery	26	78	90	22	16
I45	Research	100	20	46	2	4
I46	Computer activities	986	2 044	7 227	583	434
I47	Other community activities	0	0	0	0	0
I48	Education	1	34	51	9	10
I49	Health and social work	0	0	0	0	0
I50	Other services nec	3 222	6 887	8 817	781	2 761
Total		92 351	75 954	78 062	11 712	19 274
Net taxes on products		451	1 649	1 041	273	261
Gross value added		20 395	15 530	22 781	3 711	9 978
Employees' compensation		3 744	8 977	17 469	2 934	9 884
Other taxes less subsidies		398	-1 550	303	-4	-72
Gross operating surplus		16 253	8 104	5 008	782	166
Output		113 197	93 133	101 884	15 696	29 513

Industry-by-industry I-O table for South Africa, 2012 (R million) (continued)

Input-output table								
Order	Description	Glass	Non-metallic minerals		Furniture	Recycling and NEC		Basic iron and steel
		I21	I22		I23	I24		I25
I1	Agriculture	15	62		20	1 232		10
I2	Forestry	0	0		398	31		0
I3	Fishing	0	0		0	69		0
I4	Coal and lignite	31	1 818		35	20		2 662
I5	Metal ores	0	0		0	487		49 789
I6	Other mining	1 025	8 257		2	5 134		175
I7	Food	0	0		0	676		0
I8	Beverages and tobacco	0	0		0	1		0
I9	Spinning and textiles	0	1		307	275		0
I10	Knitted fabrics, fur	0	0		0	107		0
I11	Leather and luggage	0	0		344	23		0
I12	Footwear	0	0		0	0		0
I13	Wood	58	378		2 964	144		194
I14	Paper	39	326		115	431		58
I15	Publishing	2	7		5	4		6
I16	Coke oven manufacture	0	33		0	34		4 103
I17	Nuclear fuel	90	293		439	735		722
I18	Other chemicals	43	762		316	114		644
I19	Rubber	0	1		53	554		0
I20	Plastic	81	147		302	452		76
I21	Glass	1 891	19		118	10		1
I22	Non-metallic minerals	0	3 433		19	198		89
I23	Furniture	0	0		154	0		4
I24	Recycling and NEC	2	16		28	6 516		4 637
I25	Basic iron and steel	0	111		413	157		9 055
I26	Precious metals	0	50		162	404		5 964
I27	Structural metal	0	138		1 511	51		83
I28	General machinery	0	0		1	3		63
I29	Electrical machinery	0	0		2	35		13
I30	Electronic valves	0	0		0	14		8
I31	Medical appliances	0	0		0	1		0
I32	Motor vehicles	25	59		20	41		40
I33	Electricity, gas and water	557	886		177	317		4 425
I34	Distribution of water	13	25		7	17		142
I35	Construction	9	44		11	51		377
I36	Trade	661	2 290		1 543	2 307		6 203
I37	Hotels and restaurants	3	18		4	12		6
I38	Transport	370	3 075		1 253	847		4 700
I39	Telecommunications	98	262		242	223		229
I40	Financial intermediation	90	425		361	440		197
I41	Insurance and pensions	27	90		77	66		251
I42	Auxiliary financial	0	0		0	0		0
I43	Real estate activities	89	209		416	331		226
I44	Renting of machinery	18	41		16	24		45
I45	Research	4	3		2	9		22
I46	Computer activities	298	801		472	440		1 851
I47	Other community activities	0	0		0	0		0
I48	Education	4	6		3	4		25
I49	Health and social work	0	0		0	0		0
I50	Other services nec	624	2 905		1 991	1 304		7 864
Total		6 169	26 988		14 303	24 348		104 958
Net taxes on products		78	207		191	300		1 867
Gross value added		2 841	11 172		3 416	13 734		8 326
Employees' compensation		1 731	4 156		3 601	3 922		13 710
Other taxes less subsidies		23	26		19	51		170
Gross operating surplus		1 087	6 990		-204	9 760		-5 554
Output		9 088	38 368		17 910	38 381		115 151

Industry-by-industry I-O table for South Africa, 2012 (R million) (continued)

Input-output table						
Order	Description	Precious metals	Structural metal	General machinery	Electrical machinery	Electronic valves
		I26	I27	I28	I29	I30
I1	Agriculture	36	42	108	87	0
I2	Forestry	0	0	0	0	0
I3	Fishing	0	0	0	0	0
I4	Coal and lignite	15	72	39	24	5
I5	Metal ores	13 191	4 914	4 148	5 564	1 403
I6	Other mining	51	21	248	0	4
I7	Food	0	0	14	0	0
I8	Beverages and tobacco	0	0	0	0	0
I9	Spinning and textiles	0	9	84	29	34
I10	Knitted fabrics, fur	0	0	0	0	0
I11	Leather and luggage	0	0	0	0	0
I12	Footwear	0	0	0	0	0
I13	Wood	19	332	143	50	78
I14	Paper	16	84	177	101	36
I15	Publishing	2	14	24	12	3
I16	Coke oven manufacture	260	2	22	789	0
I17	Nuclear fuel	2 781	175	740	833	117
I18	Other chemicals	42	783	303	346	5
I19	Rubber	0	20	327	5	46
I20	Plastic	17	76	347	872	86
I21	Glass	0	1	85	50	1
I22	Non-metallic minerals	5	66	51	37	0
I23	Furniture	0	0	0	0	0
I24	Recycling and NEC	439	1 101	253	116	2
I25	Basic iron and steel	766	20 603	12 516	3 926	229
I26	Precious metals	2 157	4 768	659	3 788	22
I27	Structural metal	0	3 892	2 725	1 789	86
I28	General machinery	0	420	4 265	379	0
I29	Electrical machinery	0	240	2 415	1 926	795
I30	Electronic valves	0	42	3 210	2 581	2 124
I31	Medical appliances	0	0	0	0	0
I32	Motor vehicles	8	213	208	200	5
I33	Electricity, gas and water	1 758	848	534	394	51
I34	Distribution of water	70	24	16	16	2
I35	Construction	125	342	208	68	84
I36	Trade	1 273	7 268	5 626	3 859	608
I37	Hotels and restaurants	2	21	42	30	6
I38	Transport	352	1 839	2 047	1 129	360
I39	Telecommunications	73	973	1 183	477	154
I40	Financial intermediation	155	1 007	1 253	420	90
I41	Insurance and pensions	42	209	241	142	27
I42	Auxiliary financial	0	0	0	0	0
I43	Real estate activities	69	1 004	941	423	176
I44	Renting of machinery	8	79	79	26	13
I45	Research	2	10	62	4	66
I46	Computer activities	223	1 103	1 151	1 216	173
I47	Other community activities	0	0	0	0	0
I48	Education	3	14	44	516	5
I49	Health and social work	0	0	0	0	0
I50	Other services nec	1 650	4 693	5 235	3 692	611
	Total	25 609	57 323	51 773	35 916	7 507
	Net taxes on products	243	407	473	554	62
	Gross value added	9 987	21 946	20 795	7 975	2 805
	Employees' compensation	2 882	17 944	15 514	7 708	2 145
	Other taxes less subsidies	-4	-53	-467	102	3
	Gross operating surplus	7 109	4 055	5 748	165	657
	Output	35 838	79 676	73 042	44 445	10 373

Industry-by-industry I-O table for South Africa, 2012 (R million) (continued)

Input-output table						
Order	Description	Medical appliances	Motor vehicles	Electricity, gas and water	Distribution of water	Construction
		I31	I32	I33	I34	I35
I1	Agriculture	16	195	11	0	5
I2	Forestry	0	0	0	0	0
I3	Fishing	0	0	2	0	0
I4	Coal and lignite	1	12	24 531	2 003	0
I5	Metal ores	0	9 042	0	0	0
I6	Other mining	0	66	28	18	6 401
I7	Food	0	0	81	0	0
I8	Beverages and tobacco	0	0	0	0	0
I9	Spinning and textiles	35	1 666	0	0	1 538
I10	Knitted fabrics, fur	0	0	16	0	0
I11	Leather and luggage	0	3 243	0	0	0
I12	Footwear	0	0	0	7	263
I13	Wood	7	924	122	35	3 151
I14	Paper	32	760	48	8	451
I15	Publishing	3	30	33	5	81
I16	Coke oven manufacture	0	16	1 147	114	7 521
I17	Nuclear fuel	136	1 218	64	197	0
I18	Other chemicals	20	1 899	237	693	4 485
I19	Rubber	8	2 321	5	42	0
I20	Plastic	173	2 325	4	7	6 476
I21	Glass	172	729	50	20	928
I22	Non-metallic minerals	0	1 036	58	40	27 893
I23	Furniture	0	0	0	8	186
I24	Recycling and NEC	4	81	8	3	33
I25	Basic iron and steel	101	16 903	481	133	14 714
I26	Precious metals	70	6 475	0	31	0
I27	Structural metal	137	4 891	556	481	26 430
I28	General machinery	26	2 750	335	616	1 141
I29	Electrical machinery	130	1 701	2 867	233	10 927
I30	Electronic valves	865	3 420	0	0	0
I31	Medical appliances	64	0	2	13	0
I32	Motor vehicles	15	33 175	103	32	0
I33	Electricity, gas and water	82	1 397	7 602	358	800
I34	Distribution of water	3	42	11	13 150	76
I35	Construction	23	414	26	260	14 226
I36	Trade	425	19 153	1 800	552	27 533
I37	Hotels and restaurants	10	55	32	7	270
I38	Transport	240	5 207	2 065	519	7 065
I39	Telecommunications	279	1 133	394	218	6 144
I40	Financial intermediation	632	691	3 397	1 442	2 934
I41	Insurance and pensions	40	335	293	106	1 324
I42	Auxiliary financial	0	0	0	0	0
I43	Real estate activities	259	1 288	81	53	3 081
I44	Renting of machinery	14	109	11	78	1 991
I45	Research	3	126	0	0	0
I46	Computer activities	167	4 851	1 694	574	23 797
I47	Other community activities	0	0	0	0	0
I48	Education	6	35	21	91	0
I49	Health and social work	0	0	43	0	0
I50	Other services nec	742	18 342	99	145	4 393
Total		4 941	148 059	48 355	22 290	206 255
Net taxes on products		50	4 012	398	75	3 335
Gross value added		1 779	28 822	56 413	16 399	83 000
Employees' compensation		1 049	21 022	20 246	3 629	36 931
Other taxes less subsidies		46	-268	-287	-441	955
Gross operating surplus		684	8 069	36 453	13 211	45 114
Output		6 770	180 894	105 166	38 764	292 591

Industry-by-industry I-O table for South Africa, 2012 (R million) (continued)

Input-output table						
Order	Description	Trade	Hotels and restaurants	Transport	Telecommunications	Financial intermediation
		I36	I37	I38	I39	I40
I1	Agriculture	24	267	2	2	0
I2	Forestry	0	0	0	0	0
I3	Fishing	0	86	3	3	0
I4	Coal and lignite	0	68	148	151	0
I5	Metal ores	0	0	0	0	0
I6	Other mining	0	13	505	513	0
I7	Food	1 240	3 038	75	77	0
I8	Beverages and tobacco	0	6 033	1 269	1 290	0
I9	Spinning and textiles	0	72	583	593	4
I10	Knitted fabrics, fur	971	11	88	89	1
I11	Leather and luggage	0	0	0	0	0
I12	Footwear	101	0	0	0	0
I13	Wood	1 822	53	786	724	0
I14	Paper	14 706	45	1 126	1 032	113
I15	Publishing	13 195	100	251	274	288
I16	Coke oven manufacture	8 451	117	17 767	18 068	221
I17	Nuclear fuel	0	0	94	96	1
I18	Other chemicals	2 813	585	1 812	1 843	117
I19	Rubber	67	0	2 509	2 551	20
I20	Plastic	6 666	0	224	184	0
I21	Glass	34	36	43	44	0
I22	Non-metallic minerals	660	107	744	756	3
I23	Furniture	930	15	68	69	36
I24	Recycling and NEC	1 122	33	383	361	1 095
I25	Basic iron and steel	0	0	811	824	0
I26	Precious metals	0	0	10	10	0
I27	Structural metal	4 334	179	678	689	58
I28	General machinery	4 310	3	806	820	1
I29	Electrical machinery	806	42	738	751	12
I30	Electronic valves	561	0	315	320	125
I31	Medical appliances	0	2	1	1	15
I32	Motor vehicles	9 054	0	6 202	4 262	51
I33	Electricity, gas and water	4 228	1 030	2 513	466	524
I34	Distribution of water	1 772	76	239	44	38
I35	Construction	534	458	6 588	4 240	72
I36	Trade	24 767	2 745	19 011	16 107	754
I37	Hotels and restaurants	452	133	1 616	981	18
I38	Transport	23 117	2 495	17 512	9 373	801
I39	Telecommunications	22 353	3 216	6 074	2 746	5 098
I40	Financial intermediation	18 954	948	5 238	1 818	7 106
I41	Insurance and pensions	4 393	190	3 493	239	573
I42	Auxiliary financial	0	0	0	0	33 617
I43	Real estate activities	34 307	2 869	4 198	3 204	2 832
I44	Renting of machinery	2 536	60	2 870	552	431
I45	Research	9	0	43	13	562
I46	Computer activities	29 298	2 971	13 714	10 264	2 855
I47	Other community activities	0	0	1 013	725	83
I48	Education	289	30	506	77	1 144
I49	Health and social work	0	0	1 034	740	1 913
I50	Other services nec	1 414	2 655	13 196	9 452	455
Total		240 295	30 782	136 899	97 439	61 035
Net taxes on products		3 172	2 392	5 683	5 739	45
Gross value added		297 775	24 225	157 679	69 466	127 236
Employees' compensation		141 871	9 449	52 631	23 837	57 729
Other taxes less subsidies		5 774	623	2 186	694	1 775
Gross operating surplus		150 130	14 153	102 862	44 935	67 732
Output		541 242	57 399	300 261	172 644	188 315

Industry-by-industry I-O table for South Africa, 2012 (R million) (continued)

Input-output table						
Order	Description	Insurance and pensions	Auxiliary financial	Real estate activities	Renting of machinery	Research
		I41	I42	I43	I44	I45
I1	Agriculture	0	0	40	4	1
I2	Forestry	0	0	0	0	0
I3	Fishing	0	0	5	0	0
I4	Coal and lignite	0	0	0	0	0
I5	Metal ores	0	0	0	0	0
I6	Other mining	0	0	0	0	0
I7	Food	0	0	812	81	29
I8	Beverages and tobacco	0	0	0	0	0
I9	Spinning and textiles	1	0	0	0	0
I10	Knitted fabrics, fur	0	0	30	3	1
I11	Leather and luggage	0	0	0	0	0
I12	Footwear	0	0	0	0	0
I13	Wood	0	0	398	1	0
I14	Paper	16	6	2 631	233	84
I15	Publishing	41	16	3 359	335	126
I16	Coke oven manufacture	31	12	3 306	330	118
I17	Nuclear fuel	0	0	7	1	0
I18	Other chemicals	16	6	1 541	154	55
I19	Rubber	3	1	71	7	3
I20	Plastic	0	0	357	1	0
I21	Glass	0	0	16	2	1
I22	Non-metallic minerals	0	0	123	12	4
I23	Furniture	5	2	326	32	12
I24	Recycling and NEC	154	60	734	78	31
I25	Basic iron and steel	0	0	0	0	0
I26	Precious metals	0	0	0	0	0
I27	Structural metal	8	3	1 063	106	38
I28	General machinery	0	0	1 671	167	59
I29	Electrical machinery	2	1	369	37	13
I30	Electronic valves	18	7	0	0	0
I31	Medical appliances	2	1	314	31	11
I32	Motor vehicles	7	3	416	119	23
I33	Electricity, gas and water	74	29	6 628	135	37
I34	Distribution of water	5	2	630	13	4
I35	Construction	10	4	3 612	134	66
I36	Trade	106	41	19 405	1 248	564
I37	Hotels and restaurants	3	1	152	61	8
I38	Transport	113	44	1 868	393	500
I39	Telecommunications	718	280	3 599	715	235
I40	Financial intermediation	45 180	14	21 182	1 968	59
I41	Insurance and pensions	2 689	31	1 284	138	19
I42	Auxiliary financial	4 736	64 535	0	0	0
I43	Real estate activities	399	156	5 215	308	72
I44	Renting of machinery	61	24	171	366	27
I45	Research	79	31	69	7	91
I46	Computer activities	402	157	7 429	698	194
I47	Other community activities	12	5	0	0	0
I48	Education	161	63	228	12	28
I49	Health and social work	269	105	8 294	458	229
I50	Other services nec	64	25	12 168	694	340
Total		55 386	65 665	109 520	9 080	3 081
Net taxes on products		6	2	1 297	105	45
Gross value added		64 256	62 029	158 173	6 346	2 034
Employees' compensation		28 400	41 298	9 580	1 937	1 868
Other taxes less subsidies		1 254	735	17 510	119	-8
Gross operating surplus		34 602	19 996	131 083	4 290	174
Output		119 647	127 697	268 990	15 531	5 160

Industry-by-industry I-O table for South Africa, 2012 (R million) (continued)

Input-output table									
Order	Description	Computer activities	Other community activities	Education	Health and social work	Other services NEC			
		I46	I47	I48	I49	I50			
I1	Agriculture	57	287	32	169	3 316			
I2	Forestry	0	0	0	0	80			
I3	Fishing	6	68	3	17	236			
I4	Coal and lignite	0	1 174	14	74	141			
I5	Metal ores	0	0	0	0	28			
I6	Other mining	0	1 448	151	804	2 850			
I7	Food	1 159	1 756	149	792	3 886			
I8	Beverages and tobacco	0	970	17	88	3 621			
I9	Spinning and textiles	0	645	41	220	1 554			
I10	Knitted fabrics, fur	42	465	122	650	595			
I11	Leather and luggage	0	86	21	113	99			
I12	Footwear	0	10	32	172	124			
I13	Wood	74	851	142	598	1 572			
I14	Paper	3 519	1 396	305	1 477	1 073			
I15	Publishing	4 980	1 928	443	2 122	1 079			
I16	Coke oven manufacture	4 722	4 479	176	934	3 319			
I17	Nuclear fuel	10	284	181	959	803			
I18	Other chemicals	2 201	12 783	638	3 388	4 203			
I19	Rubber	102	455	24	128	279			
I20	Plastic	66	55	26	47	2 395			
I21	Glass	22	325	33	175	376			
I22	Non-metallic minerals	175	1 332	40	210	3 196			
I23	Furniture	465	172	73	387	239			
I24	Recycling and NEC	1 191	472	114	451	766			
I25	Basic iron and steel	0	308	7	35	1 439			
I26	Precious metals	0	45	0	0	108			
I27	Structural metal	1 518	3 778	148	788	5 619			
I28	General machinery	2 387	1 016	128	679	569			
I29	Electrical machinery	528	2 978	50	264	4 413			
I30	Electronic valves	0	7 308	445	2 362	1 185			
I31	Medical appliances	449	317	13	71	41			
I32	Motor vehicles	1 017	12 985	779	4 286	2 431			
I33	Electricity, gas and water	4 767	2 432	794	1 809	2 078			
I34	Distribution of water	453	474	75	172	180			
I35	Construction	4 612	2 543	155	537	1 238			
I36	Trade	24 927	14 350	857	4 387	11 702			
I37	Hotels and restaurants	490	578	133	83	279			
I38	Transport	7 600	20 091	130	764	4 728			
I39	Telecommunications	14 990	36 429	1 642	6 754	7 123			
I40	Financial intermediation	8 823	8 945	105	487	3 467			
I41	Insurance and pensions	1 473	3 349	89	864	909			
I42	Auxiliary financial	0	0	0	0	13 763			
I43	Real estate activities	9 433	7 949	1 176	6 576	5 858			
I44	Renting of machinery	669	33	179	580	950			
I45	Research	66	11	608	2 017	968			
I46	Computer activities	8 558	42 787	9 097	16 421	16 744			
I47	Other community activities	0	103 536	0	10 586	99			
I48	Education	790	1	68	113	624			
I49	Health and social work	10 409	19 440	2 619	475	3 780			
I50	Other services nec	15 360	4 205	1 491	862	6 274			
Total		138 114	327 327	23 565	75 951	132 396			
Net taxes on products		1 794	16 548	194	929	3 178			
Gross value added		111 723	431 698	19 918	54 200	231 154			
Employees' compensation		70 529	381 453	10 007	26 648	87 345			
Other taxes less subsidies		814	4 603	677	1 217	455			
Gross operating surplus		40 380	45 642	9 234	26 335	143 354			
Output		251 631	775 574	43 677	131 081	366 728			

Source: Stats SA (2012)