THE CIRCULAR ECONOMY: A REVIEW IN MILIEU OF THE SOUTH AFRICAN MINING INDUSTRY

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DECLARATION

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

Signature: ______________________

This 12th day of February 2019

“Let’s go invent tomorrow instead of worrying about what happened yesterday”

Steve Jobs

ABSTRACT

Mining, as a global economy, provides revenues and development to countries. It generally follows the Linear Economy (LE), which takes, makes and disposes of resources. However, mining wastes pose significant risk to both human health and the environment (Mehta, et al., 2018). One such waste, acid mine drainage (AMD), is considered one of the biggest environmental challenges facing the global mining industry (Hudson-Edwards, et al., 2011). With the increasing global water issues, the current economic model used in mining needs altering. A better option would be implementing Circular Economy (CE). The CE is "a *regenerative system in which resource input and waste, emission, and energy leakage are minimised by slowing, closing, and narrowing material and energy loops"* (Geissdoerfer, et al., 2017, p. 3 & 10). The main benefit of CE being reusing water, recycling water, enhancing renewable resources and eradicating toxic chemicals in waste water management.

The aim of this research report is to assess the uptake of CE in gold mining in South Africa and to see if this methodology is supported by South African Legislation. This is answered using a mixed methodology approach using qualitative and quantitative data and a case study looking at five gold mining companies in South Africa, namely AngloGold Ashanti, DRDGOLD, Harmony, Gold Fields and Sibanye Stillwater.

Five main CE principles relevant to gold mining have been identified, namely: (1) Facilitating system effectiveness; (2) Preserving and enhancing renewable resources; (3) Optimising resource yields; (4) Collaboration and (5) Enhanced business models which entail transparent regulatory reporting. CE principles are mostly facilitated by South African legislation, with the exception of water regeneration, restorative systems and incentivised benefits to implement the CE.

Similarly, the case study, focusing on water management, indicate that the level of CE implementation in the gold mining sectors in South Africa has increased over the past 10-year period by all five mining houses. However, cross industry collaboration is lacking with miners not collaborating with other industries on the water issues faced by all industries. Positively an increase in environment data in later years can be seen by the companies studied. Thus, this research looking at CE in gold mining waste water management could equally be relevant in other mining industries both in South Africa and globally.

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ABBREVIATIONS AND ACRONYMS

AMD	Acid Mine Drainage
CE	Circular Economy
COMSA	Chamber of Mines of South Africa
CP	Cleaner Production
DEA	Department of Environmental Affairs
DMR	Department of Mineral Resources
DWS	Department of Water and Sanitation
EIA	Environmental Impact Assessment
EMP	Environmental Management Programme
EU	European Union
ICMM	International Council of Mining and Metals
IWMP	Industry Waste Management Plans
JSE	Johannesburg Stock Exchange
LE	Linear Economy
MPRDA	Mineral and Petroleum Resources Development Act
MWA	Mine Water Atlas
MWS	Mine Waste Solutions (AngloGold Ashanti Subsidiary)
NEMA	National Environmental Management Act
NEM:WA	National Environmental Management: Waste Act
NWA	National Water Act
RSA	Republic of South Africa
SD	Sustainable Development
UFCC	United Nations Climate Change
UNEP	United Nations Environment Programme
WRC	Water Research Council
WSA	Water Services Act

1. INTRODUCTION

The Linear Economy (LE) model displays a "*take-make-dispose"* resources model in order to make a profit for the corporations (Ellen MacArthur Foundation, 2012). This model relies on ever growing consumption patterns to grow its profit base and generally excludes the negative environmental externalities in its business model. This is not sustainable and so, recognising environmental limits, needs to change.

1.1. Towards a Circular Economy

One definition of the CE is "a *regenerative system in which resource input and waste, emission, and energy leakage are minimised by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling"* (Geissdoerfer, et al., 2017, p. 3 & 10). A benefit of CE is that products are re-designed to last and ultimately responsibility of the products rests with the manufacturers. CE looks to design out waste so that all by-products involved in getting goods to market are accounted for.

Waste management also costs money, and therefore directly impacts a company's profits. But this function is vital to ensuring that companies' environmental liabilities are fully taken care of. Appropriate waste management is therefore critical, as are the waste models that a company's operations implement. Multiple economic frameworks have been identified to aid the changing environment. Concepts like Cleaner Production (CP) which look at pollution prevention strategies and resource efficiency methods (Loiseau, et al., 2016) and the waste management hierarchy which proposes that waste should be reduced, reused, recycled or disposed of (Lottermoser, 2011) are examples of these frameworks.

In line with CP and the waste management hierarchy, further concepts such as biomimicry, cradle-to-cradle and industrial ecology review the micro material cycles of products and companies (Korhonen, et al., 2018). They are important as they derive the concept of Circular Economy (CE) which takes a wider holistic view.

The CE is gaining traction as the consumption patterns and global growth patterns are bypassing what is planetary reasonable or what resources can provide for. It looks at waste management, and the equilibrium between society, environment and the economy. The model tries to close the loop on the LE model by redesigning products so that waste by-products of production are minimized. Furthermore, the model looks at resource input and output efficiencies, decreasing resource leakages and using tools such as maintain, reuse and redistribute; refurbish and remanufacture; and then ultimately recycling (Ellen MacArthur Foundation, 2012). The aim is to design long-life products using leaner production cycles, increased consumer and producer awareness and extend the products life span (Bocken, et al., 2016).

Similarly, many governments are looking to it to be a tool for growth within their economies, by using legislation to promote the CE principles. The CE came about as a solution for myriad disruptive societal, economic and environmental conditions faced by specific countries which drove the need to change their economic model. This does not mean that the concepts outlined in this model are congruous to all economies in the world and can be implemented across different industries. Although there are good concepts identified in the CE model, the appropriateness of using this model for South African waste management within the gold mining industry needs to be determined.

1.2. South African regulations

South Africa does not have specific CE legislation. Yet environment protection and waste prevention are constitutional rights (RSA, 1996). Although the National Environmental Management Act (NEMA) and the National Environmental Management: Waste Act (NEM:WA) are governed by the Department of Environmental Affairs (DEA), the Department of Mineral Resources (DMR) is the competent and/ or environmental authority responsible for regulating environment and waste management for mining houses (RSA, 2008b). The DMR also regulates the mining industry and licensing there of through the Mineral and Petroleum Resources Development Act (MPRDA) (RSA, 2008a).

Water stewardship is governed by the Department of Water and Sanitation (DWS) through the Water Services Act (WSA) monitoring water quality (RSA, 1997) and the National Water Act (NWA) (RSA, 1998) regulating the protection of water as a resource (RSA, 1998). The DWS is responsible for water-use licenses and waste water discharge licenses used by mining houses.

1.3. Mining, pollution and waste management

Mining is a large global industry which provides many nations’ economies with revenues and job creation in addition to often facilitating social growth and infrastructure improvement.

However, according to Mehta et al. (2018), mine wastes pose significant risk to both human health and underground and ground water resources. These risks are increased when dealing with abandoned and ownerless mines where the environmental responsibilities are left unclaimed. Waste rock and tailing facilities are often marked by the presence of heavy metals and toxins which find their way into the ecosystem and water ways (Mehta, et al., 2018). Other wastes such as air pollution, soil contamination and geotechnical safety of the ground are large negative effects of gold mining (Gauteng Department of Agriculture and Rural Development , 2012).

Furthermore, gold mining is associated with acid mine drainage (AMD) which is globally considered to be at the forefront of environmental issues facing the mining industry (Hudson-Edwards, et al., 2011). AMD can pose serious health threats to communities if the AMD includes radioactive contaminants (Gauteng Department of Agriculture and Rural Development , 2012). The South African government is monitoring AMD locations for waste hazards, due to the severe human health threats associated with AMD. From a future development point of view, these locations will become unavailable for new development which could benefit the South African economy. This toxic hazard thus makes mine waste water one of South Africa's biggest challenges (Gauteng Department of Agriculture and Rural Development , 2012). According to Lottermoser (2011), AMD has the potential to be innovatively used in other production lifecycles, however the onus in on mining houses to unlock this potential by utilizing their economic frameworks used to develop their waste management plans and build the cost of environmental externalities into the business model.

Correspondingly, South Africa has experienced negative economic impacts associated with gold mining. An example being the sudden closure case of the Blyvooruitzicht mine which was placed under sequestration in 2013 (Lawyers for Human Rights, 2017). Unrehabilitated mineshafts affected health and access to basic human rights in terms of safe living environments, water and electricity (Lawyers for Human Rights, 2017). Putting the spotlight onto mining provisioning and how mines are planning for closure and rehabilitation.

This is where CE could benefit the gold mining industry. Positive CE projects have been implemented in the mining community in South Africa. Anglo American's eMalahleni Water Reclamation Project was hailed a success for drinking water in South Africa regarding to their waste water treatment plant (Sergienko, 2015). The water treatment plant has the capacity to process water from other mines in the area, as well as historic AMD legacy issues from ownerless and derelict mines, thus considering legacy water issues in the process. This project portrayed CE principles which facilitated system effectiveness, enhanced the use of natural resources, optimised resource efficiency, portrayed great stakeholder collaboration and enhanced business models which depicted transparent regulatory reporting (Anglo American, 2012). This project, in the coal mining industry, could be used in the gold mining industry.

1.4. Research aim and questions

The aim of this research report is to assess the uptake of CE in gold mining in South Africa and to see if this methodology is supported by South African Legislation. Key research questions raised during the dissertation planning were as follows:

Question 1:
What are the key CE principles relevant to mining and how have these been applied to and/or adopted by the mining industry?

Question 2:
Is the CE facilitated through mining legislation in South Africa?

Question 3:
Focusing on waste water management, has the level of CE implementation in the gold mining sectors in South Africa changed?

This research paper looks at answering the above questions while focusing on the LE and the CE with specific regards to water management in the gold mining industry in South Africa. In order to adequately answer the research questions above, a mixed methodology approach using qualitative and quantitative approaches, as well as analysing a case study. The following documents have been looked at to get to the answers as provided in Chapter 4:

- Reviewing academic literature;
- Reviewing South African legislation;
- Analysing AngloGold Ashanti, Harmony, Gold Fields, Sibanye Stillwater and DRDGOLD by reviewing annual and sustainability reports.

1.5. Structure of Report

Following the introduction, Chapter 2 looks at the literature which covers the LE and CE concepts, focusing on mining. Chapter 3 looks at the methodology followed to answer the research questions. In order to meet the aim of this research CE principles have been compared to the South African legislation and the CE implementation for five of the biggest mining houses in South Africa. These results are presented in Chapter 4. A discussion based on the findings is performed in Chapter 5. Finally, the research paper is concluded in Chapter 6.

2. LITERATURE REVIEW

2.1. The traditional linear economy

The LE displays a “*take-make-dispose*”’ resource model in order to profit from products sold (Ellen MacArthur Foundation, 2012). The model is mostly profit driven, with very little consideration of the potential waste generated in the process (Segura-Salazar & Tavares, 2018). This model relies on infinite and readily available raw materials, cheap energy and ever-growing global consumerism (Ellen MacArthur Foundation, 2015a). Within this model, companies are principally accountable to shareholders as their primary stakeholder.

Consumerism and capitalism are pillars of the LE model. Porritt (2007, p. 138) defines capitalism as the ‘*private ownership of the means of production and reliance upon markets to allocate goods and services*’. This system ultimately requires an ever-increasing purchasing cycle, as companies require a growing profit base year-on-year for the use of their resources. In this system, the consequence is that in order for a company to sustain their growth, more resources are required (land, water, electricity and products).

The Global Footprint Network (2015) found that current consumption rates required “*1.7 earths to provide the resources we use and absorb our waste”*. This is clearly unsustainable and adds more pressure on not only businesses but on societies to perform in the global economy. Furthermore, placing reliance on the market to allocate goods and services fails to consider scarce resources and the actual cost of externalities when it comes to environmental degradation and waste generation.

2.2. Towards a Circular Economy

Multiple studies have been performed to identify the limitations or “*planetary boundaries*” in which human existence should operate (Rockström, et al., 2009). Rockström et al. (2009) found that “*planetary boundaries*” (or the earth’s environmental limits) were being breached. Once breached, the result would be unendurable changes to the planet and environment as we know it (Rockström, et al., 2009). This could have irreversible consequences for humanity and the way in which business is performed. Climate change, loss of biodiversity and the acceptable levels of nitrogen in soil are three out of the ten identified critical limits which have already been breached. Other identified limits include atmospheric aerosol loading; chemical pollution; ocean acidification; stratospheric ozone depletion; interference with the phosphorous cycle; global freshwater use and changes in land use (Rockström, et al., 2009).

As environmental boundaries are breached, environmental liabilities are becoming more prevalent as communities start turning to the law for protection. Environmental liabilities such as the 2012 civil society's legal case against the municipality of Carolina, South Africa, after a mining operation contaminated municipal water making it unfit for human consumption. No action had been taken by the state to force the mine to rectify the situation (Centre for Environmental Rights, 2016). Similarly, Australian farmers took a coal miner's proposed expansion project to court, citing water security as being their main concern (McCarthy, 2016).

These environmental liabilities have increasingly affected businesses and governments globally. Businesses have become more aware that their governance structures need to take sustainability and environmental liabilities into account if they are to be given social licence to operate. Coupled with the increased production costs and the limitations to resource availability, companies have steadily started applying business strategies which move away from LE models and towards implementing cleaner production methods.

2.2.1. Cleaner Production and Waste Management Hierarchy

The United Nations Environment Programme (UNEP) defines Cleaner Production (CP) as an "*integrated preventive environmental strategy to processes, products, and services to increase overall efficiency, and reduce risks to humans and the environment*" (UNEP, 2006a, p. 7). The original ideology was pollution prevention rather than pollution treatment (Loiseau, et al., 2016). The newer definition requires energy and material resource efficiencies and can be broadly applied to products and production processes followed in any industry (UNEP, 2006b).

The following are the key CP principles (Sousa-Zomer, et al., 2017, UNEP, 2006b):

1. Reduce hazardous materials and wastes.
2. Close production loops through identifying leakages which reduce material losses.
3. Improve energy and material resource efficiencies to enable sustainable resource use.
4. Use technology to optimize processes and product design.
5. Refine product design to ensure durable products.

The CP and waste management hierarchy strategies are micro-level in scope, as they look at a product and the manufacturing processes used (Bocken, et al., 2016). These micro-level principles connect CP to CE in the areas of waste management and production design, aiding resource efficiencies in a company's business strategy . They are building blocks which allow individual companies to apply CP principle and ultimately enable CE implementation on a macro level across industries. (Sousa-Zomer, et al., 2017). This macro level thinking takes a broad approach and includes city and country development as part of CE implementation, meaning that a country should set their full waste management strategy, rather than companies setting and delivering their own.

Similar to CP, waste management hierarchy follows a set methodology to handle waste (Lèbre & Corder, 2015). The original guidelines were modelled for municipal waste management where waste generation should be prevented where possible (Reduce); waste should be reused (Reuse), recycled (Recycle) and then ultimately disposed of (Dispose). The final stage is based on disposal to landfill. Contrary to CP, the hierarchy looks at waste management from a priority perspective and requires prevention of waste to be prioritized over and above lower levels, namely reuse, recycling and disposal (Nilsen, 2017). The upper levels also include looking at reducing the use of raw materials in the production phase. Waste prevention starts in the designing and processing of products stage and although this change might not impact the total economic consumption pattern, the reduction in material usage can have a wide-reaching reduction in resources demanded for that product. This diverges from the LE is that the waste hierarchy calls for an investigation into both the input and output of the economic model, where waste potential is reviewed throughout the value chain (Nilsen, 2017).

Further, biomimicry and cradle-to-cradle have been identified as fundamental design approaches mimicking nature's waste management techniques with the hope of becoming a fully regenerative closed ecological-economic system including the planet and industrial systems (Lieder & Rashid, 2016). This means that the product's end of life use can be split into two main categories, being "biological nutrients", which are able to decompose naturally and "technical nutrients", which are less likely to decompose naturally. Lieder and Rashid (2016) found that these regenerative and remanufacturing processes look at critical materials and attempt to close the loop in supply chains by examining the full flow of goods and services. These approaches have evolved over time and have been added to an array of similar concepts which look for ways in which companies can become more sustainable.

Cradle-to-cradle essentially calls for a change in product design and looks at the full value chain to ensure that products can be returned to nature easily (Korhonen, et al., 2018). Although the concept is innovative and looks toward future generation of products, the bottle neck of this system is that the design is not well justified technically as virgin resources will still be needed to continue profitability growth. Similarly, the effects on nature of using more "biological nutrients" which decompose naturally is currently unknown and thus could result in ecological impacts currently not experienced (Ceschin & Gaziulusoy, 2016). This concept is currently being tested within manufacturing and the fashion industries.

The benefit of biomimicry is that it mimics nature's way of dealing with waste. The disadvantage of this system is that it assumes that the results from this system are sustainable when only the problem at hand or product design have been considered rather than looking at the entire system (Ceschin & Gaziulusoy, 2016). These categories will be discussed in more detail in 2.2.2. below.

On a more macro scale, industrial ecology is another concept identified which refers to material and energy flows within the industrial system and takes a wider view of the industries and their place in the economy. This includes technological advances and how new technology is required to make disruptive change in the current economy, leading to a more CE. (Lieder & Rashid, 2016)

Each of the concepts discussed above, namely cleaner production, waste management hierarchies, biomimicry, cradle-to-cradle, industrial ecology call for the review of material cycles and a more efficient use of energy and material resources (Korhonen, et al., 2018). These concepts are important and individually help derive the concept of CE. CE takes a wider holistic view, whereas the concepts discussed above are more product and process driven.

2.2.2. The Circular Economy

CE as a model, attempts to close the loop on the LE model by designing out waste so that all by-products of production are accounted for. This means that the environmental impacts of excessive waste generation can be mitigated as these waste products are either decreased, turned into other innovations or become part of different production cycles in a way to implement a more sustainable product (Golev, et al., 2016). Like CP, one of the aims of CE is to optimize resource use, both in terms of materials and components. Following on from the waste hierarchy discussed above, products should be kept at their highest value so that they can easily be reused, refurbished or eventually, recycled (Ellen MacArthur Foundation, 2015c).

Bocken et al. (2016) found that one key CE strategy is to slow resource loops by designing long-life products and extending the products life. The second is to close resource loops by implementing recycling within business models and optimize resource efficiencies in the production process. These can be achieved by mimicking the biological cycles in nature as discussed in the biomimicry approach in 2.2.1. above. The biological cycle is illustrated on the left in figure 1. Here materials can be broken down or biodegraded in a natural and organic way. Waste management follows natural cascades where organic matter is decomposed back into biochemical feedstocks. Where products do not naturally decompose, they move to the technical cycle as illustrated on the right of figure 1 below. Here the CE technical cycle looks to maintain, reuse and redistribute; refurbish and remanufacture; and then finally recycle as recycling is often the more expensive of the processes (Ellen MacArthur Foundation, 2012).

The aim is to extend the products life span. Reuse and refurbishment of products require an increase in the care and maintenance of the product. Only once components have been through the cycle multiple times and no longer carry any reusable value are the components "disposed of" by recycling them. These waste resources should be recycled into "*material having properties equivalent to those of the original material*" (Bocken, et al., 2016, p. 5).

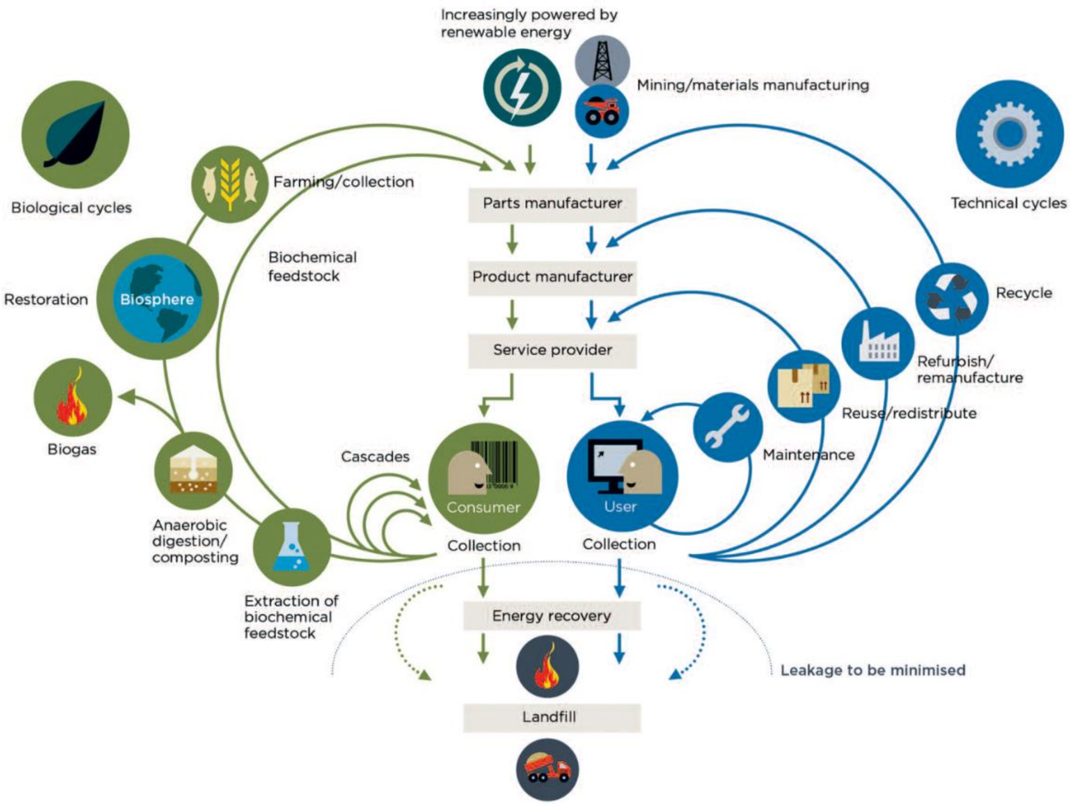

Figure 1: *The circular economy — an industrial system that is restorative by design (Ellen MacArthur Foundation, 2012)*

The smaller loops closest to the user and/or consumer normally have lower impact and are preferred practices. The further out one moves in the cycles, the higher the cost and impact on the environment (Ellen MacArthur Foundation, 2012). Although CE is a recent research topic in its current form, the methodology is being implemented worldwide with predominant focus on recycling rather than reusing and refurbishing. The waste recycling industry has become a growing global industry. Moreover, this concept can be seen in the mining industry where mines such as AngloGold Ashanti's Operations now include a Mine Waste Solutions (MWS) company which processes and extracts gold from mine dumps and tailings facilities on the surface.

However, the concept of the CE is more than waste recycling, and calls for leaner production cycles, increased consumer and producer awareness with regards to their planetary responsibilities and new ways of seeing how systems are interconnected and linked. Lieder and Rashid (2016) illustrate how CE is an integrated approach based on waste management, product design, resource efficiencies and supply chain conformations. It requires out of the box thinking, new ways of innovation and open paths of communication.

The Ellen MacArthur Foundation (2015b) found that by reducing the reliance on resources through reusing, refurbishing and recycling older products, a cost saving of up to $630 billion in Europe could be realised. The report also found that the CE model could reduce primary material and resource consumption in Europe by 32% by 2030 and 53% by 2050 (Ellen MacArthur Foundation, 2015b). However, these saving are reliant on multilevel stakeholder collaboration efforts and shows the complexity when looking at the CE model to ascertain which of the CE principles are relevant to an industry.

Brown et al. (2018, p. 1) found that collaboration is a key element of CE and noted that the '*required system change is beyond individual companies and requires transition towards inter-organisational collaborative networks*'. Similarly, Lieder and Rashid (2016) found that the CE could contribute to the global economy and can be broken into specific areas, namely:

- Revolution of economic structures and business motivations. These include key management decisions for a company and how companies lead, monitor and organize themselves.
- Governmental and inter-governmental initiatives which play a large role in ensuring that optimal buy-in is obtained. Government is ultimately responsible for policies and laws being implemented, regulated and monitored.

One of the challenges is the complexity of finding partners to collaborate with, developing trust to facilitate activities which include sharing data and sensitive information, as well as costs and liabilities to be shared between partners (Brown, et al., 2018).

According to the Ellen MacArthur Foundation (2012, p. 2), the CE offers "*a coherent framework for systems-level redesign and as such offers us an opportunity to harness innovation and creativity to enable a positive, restorative economy*". This can be achieved by decoupling economic growth from the usage of finite natural resources whilst minimising environmental impacts (Brown, et al., 2018, Ghisellini, et al., 2016, Geissdoerfer, et al., 2017). This framework includes systems thinking in terms of looking at the global economy as a whole and how the different aspects of the economy (environment, resources and the public) work together to create economic and other benefits. This indicates that CE follows a macro-level approach, rather than a micro-product-based approach.

The envisioned benefits not only include optimizing resource yields by eliminating leakages from the whole system in terms of waste, pollution and toxic chemicals, but also by reducing renewable resource inputs and changing consumption patterns (Brown, et al., 2018, Ghisellini et al. 2016, Lieder & Rashid 2016).

In the CE, the entire life-cycle of a product should be considered, as well as the product's association with the environment and economy (Ghisellini, et al., 2016). A benefit of this model is that products are re-designed to last. The idea is that users will move from ownership to leasing so that the responsibility rests with manufacturers to place the product back into a regenerative cycle, as seen in figure 1, once the consumer no longer has use for it. Users will be persuaded to move to a service model, leaving ownership and ultimately responsibility of the products with the manufacturers.

A negative aspect about the CE model, as outlined above is that it explicitly excludes the mining industry in the circularity and sees the mining industry as a feeder into the CE model. The above model is based on manufacturers who go directly to end-users (Ellen MacArthur Foundation, 2012). Manufacturers, who, if they leased the mine's products, would not outright own it and therefore could not resell or even re-lease the products to the end consumer. But by not including the mining industry a vital opportunity of researching ways to recover currently mineralized waste (both from a technical and economical perspective) is lost (Lèbre, et al., 2017a). More importantly, historic mining legacies, such as acid mine drainage in mining, will be unaddressed or remediated (Lèbre, et al., 2017a).

2.2.3. Contrasting from the Linear Economy

The LE and CE are concepts of an economic modelling spectrum with LE on one extreme and CE on the other. Components like the cleaner production and waste hierarchy move the LE model towards the CE.

One of the disadvantages of the LE model is the postulation that products can be returned to nature without cost or repercussions. The LE model assumes that products are no longer seen as economically valued and viable once used, thus missing an opportunity to improve not only product sustainability, but bottom-line profits. The CE model looks at increasing the use of secondary production of minerals and metals in the production cycle and expects to decrease the demand for virgin raw resources to be used by manufacturers. The concept of Material Banks, whereby products and buildings are redesigned in such a way as to store valuable material inputs which can later be easily reused, further illustrates how the CE intends to increase secondary productions of materials (European Circular Economy Stakeholder Platform, 2015). This concept is similar to stockpiling in mining, whereby stockpiling stores ore for later use. The issue with stockpiling is that it lacks the adequate reuse planning required to get it to be easily reused and can negatively impact the environment while being stored (Mehta, et al., 2018).

CE should also not be confused with sustainability. Mining houses following LE, use the concept of sustainability to offset the damage done by mining. Although CE is similar to sustainability regarding environmental protection, the CE model calls for an entire redesign of the current economic assumptions. CE calls for regenerative production strategies that design out waste, while leaving a product (and its waste) which can easily be reused or refurbished into a new or different commercially viable product (Ellen MacArthur Foundation, 2015c, Ghisellini, et al., 2016, Geissdoerfer, et al., 2017). Ultimately the product can be fully recycled at the products end of life. Sustainability, like CE, has a strong people aspect (society, health and safety, and community involvement) however it allows companies to determine their own sustainability policies and frameworks independently (i.e. without seeing how these policies or frameworks will affect the whole economy rather than just their own company) (Geissdoerfer, et al., 2017).

2.2.4. Summary of the CE principles identified

As derived from the literature review above, the main CE principles have been outlined in table 1 below. These principles have been grouped into six broad principles. In terms of each broad principle identified, these have further been divided into sub-principles and who the author of the sub-principle was. The sub-principles were based on the way the principles were broken down within the different literature found. A CE reasoning for each principle and/or sub-principle is given in the third column.

Table 1: Assessing CE principles identified from the literature review above

CE Principle	Sub-principle	CE reasoning	Author
1. Facilitate system effectiveness	Decoupling economic growth from the usage of finite natural resources	This economic framework looks at how the global economy can grow without having their growth linked to the use of natural resources.	(Ellen MacArthur Foundation, 2012).
	A regenerative system	The CE attempts to create a regenerative global economy which attempts to find equilibrium between society, environment and the economy.	(Ellen MacArthur Foundation, 2012, Brown, et al., 2018, Ghisellini, et al., 2016, Geissdoerfer, et al., 2017, Lieder & Rashid, 2016).
	A coherent framework for systems level redesigned to harness innovation and create a restorative economy.	A restorative system ensures that operations use fewer natural resources, whilst being able to restore the environment to its natural state post use. Thus, waste management should be restorative.	(Ellen MacArthur Foundation, 2012, Brown, et al., 2018, Ghisellini, et al., 2016, Geissdoerfer, et al., 2017).
	Excessive waste generation mitigated.	Following the waste management hierarchy, waste generation should be prevented where possible, waste should be reused, recycled and then ultimately disposed of.	(Lèbre & Corder, 2015, Nilsen, 2017, Lieder & Rashid, 2016, Ellen MacArthur Foundation, 2015c, Golev, et al., 2016, Bocken et al., 2016).
1. Facilitate system effectiveness (continued)	Longer-lasting product, redesigned to minimise waste and other environmental externalities.	Using CP principle of refining product design to ensure durable products are created. The entire life cycle of a product should be considered. Value chains that aims to eliminate the production of waste are linked through the superior design of the system and business model (i.e. redesigning the waste system).	(Geissdoerfer, et al., 2017,Sousa-Zomer, et al., 2017,UNEP, 2006b,Ghisellini, et al., 2016, Ellen MacArthur Foundation, 2012, Brown, et al., 2018, Ghisellini, et al., 2016).
	The business model includes the full range of environmental liabilities and externalities.	With CE, business models are required to be adequately updated to include the cost of environmental externalities so to facilitate system effectiveness and account for the true project feasibility.	(Brown, et al., 2018, Ghisellini et al. 2016, Lieder & Rashid 2016).
2. Preserve and enhance renewable resources	Reuse of resources in production.	Resource lifespan is increased by redesigning waste management processes to reuse resources already in use, by keeping resources at their highest value in terms of "technical" and "biological" nutrient cycles.	(Lèbre & Corder, 2015, Nilsen, 2017, Lieder & Rashid, 2016, Ellen MacArthur Foundation, 2015c, Golev, et al., 2016, Bocken et al., 2016).

	Eliminate toxic waste through better waste design processes. This is part of system refurbishment.	The CE principles requires waste management procedures which eliminate the use of toxic chemicals, which impair reuse and return to the biosphere.	(Sousa-Zomer, et al., 2017, UNEP, 2006b).
	Clear waste management strategies with long-term plans communicated.	The further out one moves in the cycles (re-use, recycling etc), the higher the cost and impact on the environment. The smaller loops closest to the user/consumer normally have lower impact and are preferred practices. The plans specify which element of the cycle will be used which makes implementation easier. Clear waste management planning should be clearly communicated to ensure optimal deployment.	(Nilsen, 2017, Bocken et al., 2016).
3. Optimise resource yields	Review of material cycles so that loops can be closed and leakages in the Waste Management Process can be diminished.	Closing production loops through identifying leakages which reduce material losses. Resource inputs, emission, and energy leakage are minimised to ensure efficient usage of resources.	(Brown, et al., 2018, Ghisellini et al. 2016, Lieder & Rashid 2016, Geissdoerfer, et al., 2017,Sousa-Zomer, et al., 2017,UNEP, 2006b, Lèbre & Corder, 2015, Nilsen, 2017, Ellen MacArthur Foundation, 2015c).
	More efficient use of energy and material resources	CE requires improved energy and material resource efficiencies to enable efficient usage of resources and minimized waste generation.	(Geissdoerfer, et al., 2017, Sousa-Zomer, et al., 2017, UNEP, 2006b, Korhonen, et al., 2018).
	Waste by-products of production are minimized.	Waste by-products are either decreased, turned into other innovations or become part of different production cycles in a way to implement a more sustainable product that can easily be reused, refurbished or recycled. This includes the need for new technology to initiate the innovation.	(Golev, et al., 2016, Ellen MacArthur Foundation, 2015c).
4. Collaborate	Stakeholder Collaboration	Collaboration is a core CE principle. Governmental, inter-governmental, inter-industry and affected communities are some of the stakeholders whom play a large role in ensuring that optimal buy-in is obtained. In order to achieve this, communication is critical for developing trust and ensuring that projects are implemented successfully. Furthermore, collaboration is required outside of the mining industry which could help bring innovative ideas and solutions.	(Brown et al., 2018, Lieder & Rashid, 2016, Geissdoerfer, et al., 2017).
5. Monitoring legislation	Tax benefits and/ or incentives for including CE principles into business models.	Legislation promoting CE provide a clear indication of the benefits from both an incentive and tax perspective for implementing the CE. This principle can be further broken down into the legislation system being inherently adaptable and resilient.	(Lieder & Rashid, 2016, Geng, et al., 2010, Li & Yu, 2011).

		This provides companies the incentive to manage and reduce their waste.	
	Clear model for charges and tariffs	CE calls for externalities to be costed effectively so that resources are adequately priced. China's current legislation looks at 'resource pricing reform'. This helps companies better cost their externalities and product pricing strategies to be more efficient.	(Lieder & Rashid, 2016, Geng, et al., 2010, Li & Yu, 2011).
	Enforcing legislation through monitoring	Government is ultimately responsible for policies and laws being implemented, regulated and monitored.	(Brown, et al., 2018, Ghisellini et al. 2016, Lieder & Rashid 2016).
6. Technology	Using technology to optimise processes and product design.	Industrial ecology refers to material and energy flows using technology to make disruptive changes in the industry as a whole and while optimising process and product design.	(Sousa-Zomer, et al., 2017, UNEP, 2006b, Lieder & Rashid, 2016, Lottermoser, 2011, Kefeni, et al., 2017).

2.3. The mining industry, a large consumer of resources and generator of waste.

2.3.1. The mining life cycle and activities

The mining industry is a large contributor to the global economy. It is an industry of significance to lower and middle income as well as resource-based economies, not only as job creators, but also for major sources of government revenues (ICMM, 2014). Mining houses have multifaceted relationships with the economies of their host and other countries and, very often, the social development of countries. Global mining houses bring investment to local economies and can have remarkable value chains in terms of forward and backward linkages. Figure 2 show the potential time frames, labour levels and revenues to be received during the mine lifecycle. Mining is generally long term, with an average operation period between 2 and 100 years. Similarly, revenues are generally experienced evenly over the operational period while tapering off during closure and decommissioning. Costs and labour activity are usually highest during the initial construction phase.

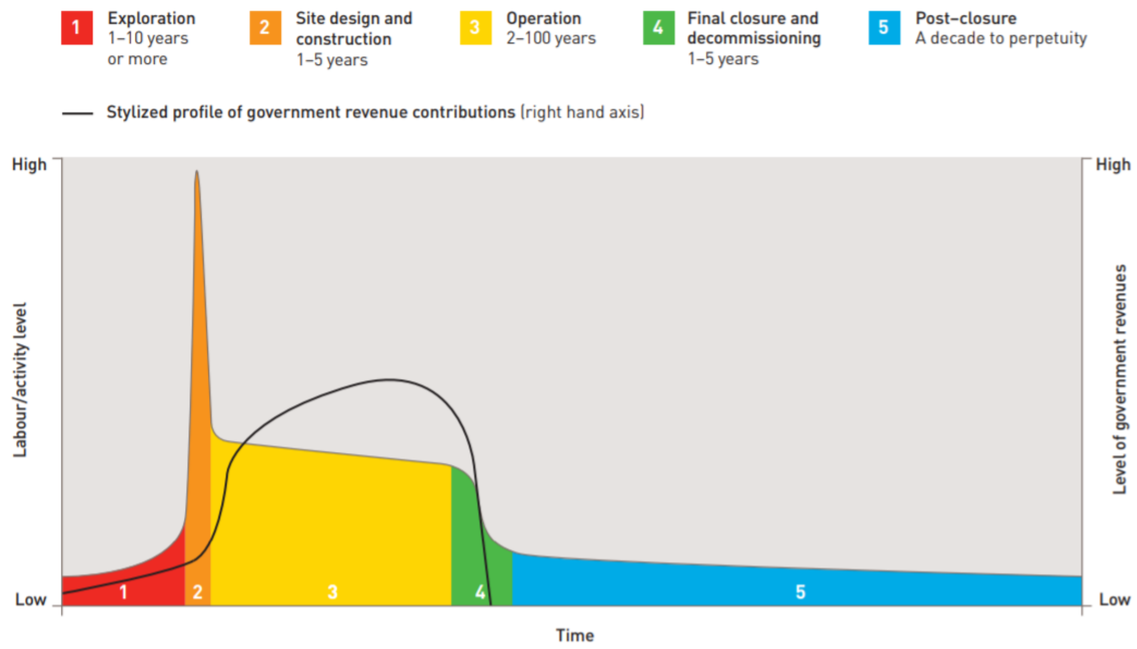

Figure 2: *The mine project life cycle (ICMM, 2014)*

Developing country governments' often fail to provide infrastructure and services, leaving the burden of providing infrastructure in terms of roads, schools and hospitals on mining houses (Massoud & El-Fadel, 2002). Although mining houses have brought development to developing countries, they have been seen to have disruptive societal, economic and environmental impacts which need to be addressed (ICMM, 2014). While mining is not the only culprit with regards to negative environmental impacts, and arguably not the most significant contributor to the global environmental changes, it has a recurrent negative reputation when it comes to environmental degradation and has seen catastrophic waste failures.

Different mining methods are used depending on the resource mined. These include open-pit and surface stripping or hydraulic leaching methods or underground mining methods (Aubertin & Bussière, 2001). The method chosen sequentially influences the amount and types of waste generated (Aubertin & Bussière, 2001). This in turn will affect a mining companies decision on which method to use as waste can be minimised by the choice of mining method.

The mining value chain, irrespective of the mining method, typical follows activity flows as seen in figure 3 below, which are the mining of ore; processing the ore to get mineral concentrate and finally metallurgical processes that refine the mineral concentrate. Each of these activities produce a different type of waste.

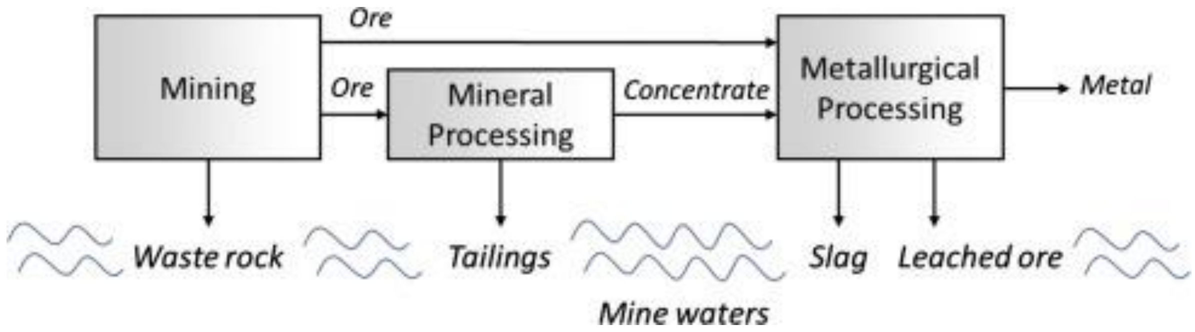

Figure 3: *Mining activities and their waste streams generated at the different stages of the LE model (Lèbre, et al., 2017b)*

Waste rock is produced when mining ore. In open-pit mining the waste rock includes soil excavated to reach the intended ore resource (Aubertin & Bussière, 2001). In a study performed by Mudd (2010), he found that the excavated quantity of waste rock far outweighs the amount of ore processed from the same rock and that the waste rock quantity processed is increasing as the ore grades of many resources are declining. Profitability for mining houses is decreasing, as it becomes harder and more expensive to mine resources of a lower grade, thus making project feasibility more pressured. This raises several global challenges, including the risk of supply and price volatility. These risks were cited as one of major concern for developed countries which catapulted the CE principles in those developed countries (Ellen MacArthur Foundation, 2012).

Further waste, such as tailings, are produced as the minerals are processed (as seen in figure 3 above) (Lèbre, et al., 2017a). These facilities are often marked by the presence of heavy metals and toxins with high leaching potential which make their way into the ecosystem and water ways (Mehta, et al., 2018). A concentrate is sent from the mineral processing to the metallurgical processing. Because of the metallurgical processors, slag and leaching are the waste by-product that is left. Mineral and metallurgical processes are responsible for the production of approximately 15 gigatons of waste per annum (Lèbre, et al., 2017a).

Water, as a vital part of all mining activities, encounters each of these waste streams and if not properly treated, becomes contaminated with acidification and heavy metal solubilisation which are detrimental to the environment around them (Lèbre & Corder, 2015). Mine water waste includes water that is pumped to the surface during underground mining, residues produced during the clarification process in the mining or mineral processing phase or wastes and slug produces when treating the polluted water (Aubertin & Bussière, 2001). According to Mehta et al. (2018), mine wastes poses a substantial risk to human health, as well as natural water resources. The water quantity as well as water quality should be considered as a change in either could imbalance ecological systems.

Along with mine water waste, AMD is globally considered to be at the forefront of environmental issues facing the mining industry, with an estimated future cost of approximately $100 billion needed to remedy the issue (Hudson-Edwards, et al., 2011). AMD is caused when pyrite is exposed to oxygen and water, generating sulphuric acid which mobilizes heavy metals (Kefeni, et al., 2017). Although AMD occurs naturally, mining accelerates it by the exposing more sulphide mineral, which, if left untreated, could contaminate ground water resources. Further, AMD affects the underground water quality, mainly experienced after mine dewatering ceases after closure. Tailing facilities, containing similar AMD generating possibilities, pollute ground and surface water during and post mining (McCarthy, 2011).

Mining wastes are not limited to those mentioned in figure 3. Other wastes such as air pollution, soil contamination and geotechnical safety of the ground should also be considered. Air pollution includes fine particulate matter and dust pollution which could include radioactive contaminants which have far reaching effects on human health (Gauteng Department of Agriculture and Rural Development , 2012). The health risks dust can pose includes lung chemical toxicity due to high levels of uranium which is often present in mining waste (Bobbins & Trangos, 2018). Geotechnical safety fears include ground instability which could lead to sink holes or inner mine ground failures, as well as unsealed mines shafts which can present hazards to nearby communities (Gauteng Department of Agriculture and Rural Development , 2012).

2.3.2. Approaches to managing waste

There is to wide variety of waste generated by mining; namely waste rock, tailing facilities, water waste and AMD. Some companies retreat their waste to extract ore and mineral resources that they missed during the initial mining process. Other companies recycle some of their waste in their operations. An example of this is waste rock and tailings recycled into backfills in underground mines or waste water recycled in the mining operation.

Waste rock is generally disposed of in stockpiles on the surface. However, this waste area can become part of a mining operations recycling initiative and be used as construction material in infrastructure development for laying of foundations, road and dam development (Aubertin & Bussière, 2001).

Historically, mining waste management techniques advised the storage of contaminated waste in tailing facilities near the mining sites and tailing were discharges to wetlands or rivers water ways (Hudson-Edwards, et al., 2011). Current initiatives for tailings waste management include using tailing as backfill in underground mines or storing them in lined tailing facilities near the mining sites that are tightly managed to ensure that the tailings facilities do not leak into the environment around them. Often tailings are mixed with a flocculant to thicken the substance to prevent dust pollution and contain the mixture during storage (Hudson-Edwards, et al., 2011). Tailings facilities are often vegetated to ensure better soil stability and dust suppression, however tailing facilities have become renowned for their negative AMD generation which have long lasting impacts on the environment around them (Hobbs, et al., 2010). Although unsulfured and/ or alkaline tailings have successfully been used for making hydrogeological barriers for the mining operations, many tailing facility dam failures have had significant impacts on the environment and communities around the facilities (Aubertin & Bussière, 2001).

According to Lottermoser (2011), AMD has the potential of being recycled in such a way that it is possible to recover heavy metals. In addition, waste water can not only become potable water, but depending on the treatment method applied, could even generate electricity. In gold mining, myriad waste water treatments are available, such as metal-accumulating algae, reverse osmosis, filtration or Ion exchange (Lottermoser, 2011). Similarly, animal and plant-based wastes have been found to have AMD remediation properties (Kefeni, et al., 2017). Thus, opportunity exists if correctly valued and implemented in the company's business plan. However, the mining industry's ability to control and mitigate of AMD in terms of mining wastes is seen as one of the largest global environmental challenges (Hudson-Edwards, et al., 2011). Similarly, the negative reputation the mining industry has with regards to adequately managing historic waste affects how communities view and support their long-term post-closure waste management plans.

Other challenges currently faced by the mining industry in terms of waste management are the large number of technical waste management processes available to choose from; socio-economic changes calling for better waste management and more strict governance and regulations in countries which are impacting the need for better waste management plans (Oelofse, et al., 2007). This means that generally waste management processes are trial and error until an adequate fit is found, while trying to set up the process within the legal regulatory time frames. Equally, opportunities exist if the mining industry collaborate with other industries to find solutions to waste disposal.

The mining industry generally follows the LE model, with some of the waste is reused in operations. But better waste management strategies have been proposed and are currently being utilized to ensure that sustainable practices are followed. These include following the waste management hierarchy towards cleaner production.

2.3.3. Mining waste management hierarchies

As discussed in 2.2.1. above, mining also follows a set methodology to handle mine waste, called the waste management hierarchy (Lèbre & Corder, 2015). The original waste hierarchy as illustrated in figure 4 follows the priorities of reduction, reuse, recycling and ultimately disposal. The issue with this model is that mining waste cannot be disposed to landfill the way regular municipal waste can be. For this reason, Lèbre and Corder (2015) adapted this guideline to be used for mining waste management, as seen in figure 5 below.

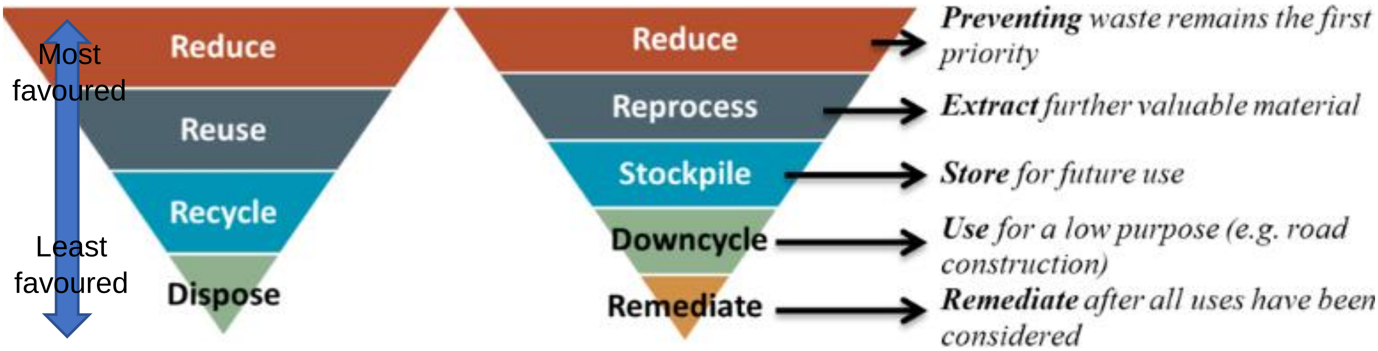

Figure 4: *An adapted figure showing the generic waste management hierarchy on the left and Lèbre et al. hierarchy taking mine waste management into account on the right (Lèbre & Corder, 2015)*

The adjusted guideline, as seen in figure 4 above, show that the prevention of waste generation is still prioritized (**R**educe). This is followed by reprocessing where waste streams are re-mined for any traces of residual mineral elements (**R**eprocess). Recycling in the municipal waste hierarchy is replaced with stockpiling for later use (**S**tockpile).

Stockpiling is a natural occurrence in gold mining, and often not treated as waste, as valuable minerals can still be remined at a later stage. Mehta et al. (2018, p. 12) found that due to the history of mine abandonment, '*future potential uses of the contamination source*' should be taken into account when mines are being planned. These should include reuse plans and including risk assessments regarding reducing or removing impacts on groundwater.

Finally, figure 4 calls for downcycling to replace the principle of disposal, where waste is converted to a lesser purpose material (for example waste rock can be used in construction or backfill). The negative of this is that the waste will need to be non-hazardous or inert in order to be downcycled (Lèbre & Corder, 2015). Ultimately remediation is required for all mines to ensure that any environmental liabilities have been mitigated by the end of life of mine and that the mine sites have been rehabilitated (**R**emediate).

The waste management approach can be misleading as the processes are not mutually exclusive and can be implemented in parallel. This model sees all waste streams as separate silos and does not look at legacy waste issues nor promote economic resilience regarding waste management (Lèbre & Corder, 2015). Lèbre and Corder (2015) found that multiple factors were responsible for degrading effective waste management strategies used by mining houses. These include economic conditions, technological boundaries which caused ineffective processing, management culture and regulations which disincentivised resource recovery (Lèbre & Corder, 2015). Although effective management of waste is a legal requirement for mining houses in South Africa, Lottermoser (2011) suggested that mines should change their view to be one that views waste as a resource, and that zero waste should be the ultimate solution.

Thus, waste management strategies need long-term plans which can be implemented during all mining life stages so that valuable mineral resources are not sterilized by the waste management strategies (Lèbre & Corder, 2015). The treatment of mining waste water can be done at each phase of the mines value chain and should not be deferred until the end of mine. This process significantly brings down the cost of treating the environmental externalities (Lèbre, et al., 2017b).

Environmental externalities, including climate change and completing rehabilitation projects and cost forecasting of these, are some of the issues currently facing the mining industry (Mudd, 2009). Typically, these extra costs will influence the mining industry budgets for new projects. In addition to decreasing mineral accessibility, as minerals reach exhaustion, major disturbances can be expected in the global mining economy if new ore deposits are not found as demand far outweighs supply and trade is compromised (Douce, 2016). This has the possibility of having a knock-on effect on all other global industries needing the resources in order to manufacture goods for their markets. Therefore, it is clear that a new economic model is needed that looks at all the above concerns. A better option would be to consider the principles as set up for the CE in section 2.2 as these could guide mining houses to move from a '*take, make and dispose of'* resources model to a regenerative one which includes the full cost of externalities and changing the way that waste is viewed.

2.4. CE implementation by governments and companies

Geissdoerfer et al. (2017) found that different companies and governments have defined goals differently, which in turn determines which of the CE principles these companies and governments focus on. Each set of stakeholders are different and thus a thorough analysis is required in order to ascertain which goals and risks a company or government want to deal with.

Two methods (top-down and bottom-up) have been identified in how governments are implementing CE with the ultimate goal of decoupling environmental pressures from economic growth (Ghisellini, et al., 2016). This can be seen graphically in figure 5 below.

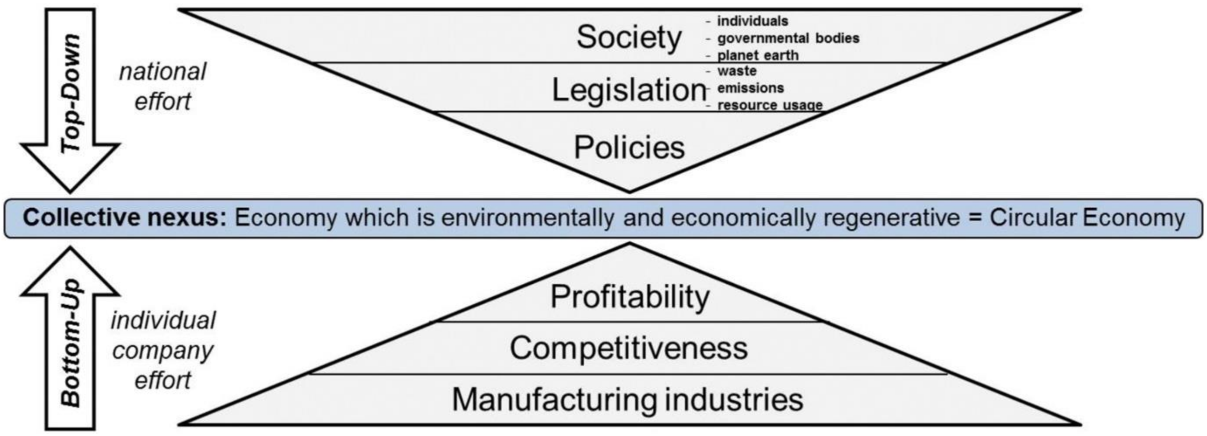

Figure 5: *Proposed CE implementation strategy as proposed by Lieder showing a top-down and bottom-up approach (Lieder & Rashid, 2016)*

China looks at the CE as a top-down approach whereby political legislation has been the driving force (Li & Yu, 2011). This is seen at the top part of figure 5 above. The Chinese government hopes to encourage better waste management by implementing tax benefits for companies as well as encouraging companies and the state to research better technologies to further the CE model (Li & Yu, 2011). China's current legislation looks at '*tax redesign, financial subsidies, and resource pricing reform*' (Geng, et al., 2010, p. 6). Similarly, CE initiatives are further funded by governmental tax on companies' waste generation (Geng, et al., 2010). The consequence is twofold – firstly companies product pricing strategies are better placed to cost their externalities and secondly it provides companies the incentive to manage and reduce their waste.

Current projects within the European Union (EU) show a combination of top-down and bottom-up efforts. Studies have found that there are several factors influencing CE and waste management in the EU, namely political will, funding available for CE projects and the current multi-level governance structures. The findings show national governments should prioritize waste management plans and set national waste management strategies whereas the reality is that local governments run decentralised waste management programmes in a multi-level governance structure. Recommendations proposed include: (1) there be better cooperation between waste management authorities, (2) collaboration efforts are improved between all affected governmental departments and (3) inter-governmental targets are set and communicated more clearly (Malinauskaite, et al., 2017).

The United States of America applies the bottom-up approach, whereby companies drive CE by using it as an environmental and waste management tool. This is seen as the bottom part of figure 5 above where CE is driven by individual company effort rather than from national pressure. No clear CE regulations have been set or are being proposed (Ghisellini, et al., 2016).

The top-down approach is where national effort in forms of policy and legislation drive a countries CE implementation. Bottom-up approach is where companies and individuals drive CE implementations. Nether approach is more beneficial that the other, however it is important to note that business and regulators should work together as companies generally understand their environmental impacts better, whereas regulators look at environmental issues and policy in terms of societal benefits rather than specific companies (Lieder & Rashid, 2016).

As the CE concept is relatively new in South Africa, the legal framework needs to be analysed to ascertain if the legislation currently aids and assists companies to implement CE principles.

2.5. South African regulations in terms of CE principles

South Africa does not have specific CE legislation. However, the South African Constitution has identified environment protection and waste prevention as human rights which businesses need to comply with, and this Constitution is the leading document which overarches all law (RSA, 1996).

National legislation is enacted in terms of an Act of Parliament, with each Act meant to govern complex systems and/or functional areas and managed by dedicated government departments. The national legislation, amongst other reasons, is required for the preservation of economic accord whilst also protecting the environment (RSA, 1996).

Equally, affordable basic water and sanitation services are a constitutional right, where the South African government acts as water quality and sanitation stewards for the South African people (RSA, 1996). As seen in figure 6 below, this stewardship is governed by the DWS through the Water Services Act (WSA) (RSA, 1997) and NWA (RSA, 1998).

The WSA not only regulates drinking water and sanitation services in terms of water quality but also prescribes municipality responsibilities as water service authorities and regulates the relationships between municipalities and mines where mines become Water Services Intermediaries, supplying water services to those municipalities (RSA, 1997). These regulations are important in terms of collaboration efforts on water projects between mining houses and municipalities. This is important as mines are prohibited from supplying water to communities directly. The NWA regulates the protection of water as a resource and all water usage, including the water usage of mines. This includes regulating mining water tariffs, prevention and remedying effects of pollution and environmental degradation as well as water waste discharges and disposals (RSA, 1998). The DWS is responsible for water-use licenses and waste water discharge licenses used by mining houses.

Environment and waste management are governed by the DEA which is regulated by the NEMA and the NEM:WA. However, for mining, the Minister of Mineral Resources implements environmental and waste-management requirements in terms of the NEMA and NEM:WA, with the DMR being the competent environmental authority responsible for regulating and monitoring the NEMA and NEM:WA requirements (RSA, 2008b). As a result of this, the mining industry follows a “One Environmental System” whereby the DMR is responsible for licencing, monitoring and regulating NEMA, NEM:WA and aspects of NWA and WSA. Figure 6 shows how the South African legal framework is enacted for mining. Each of the Acts and the departments responsible for these are further discussed below.

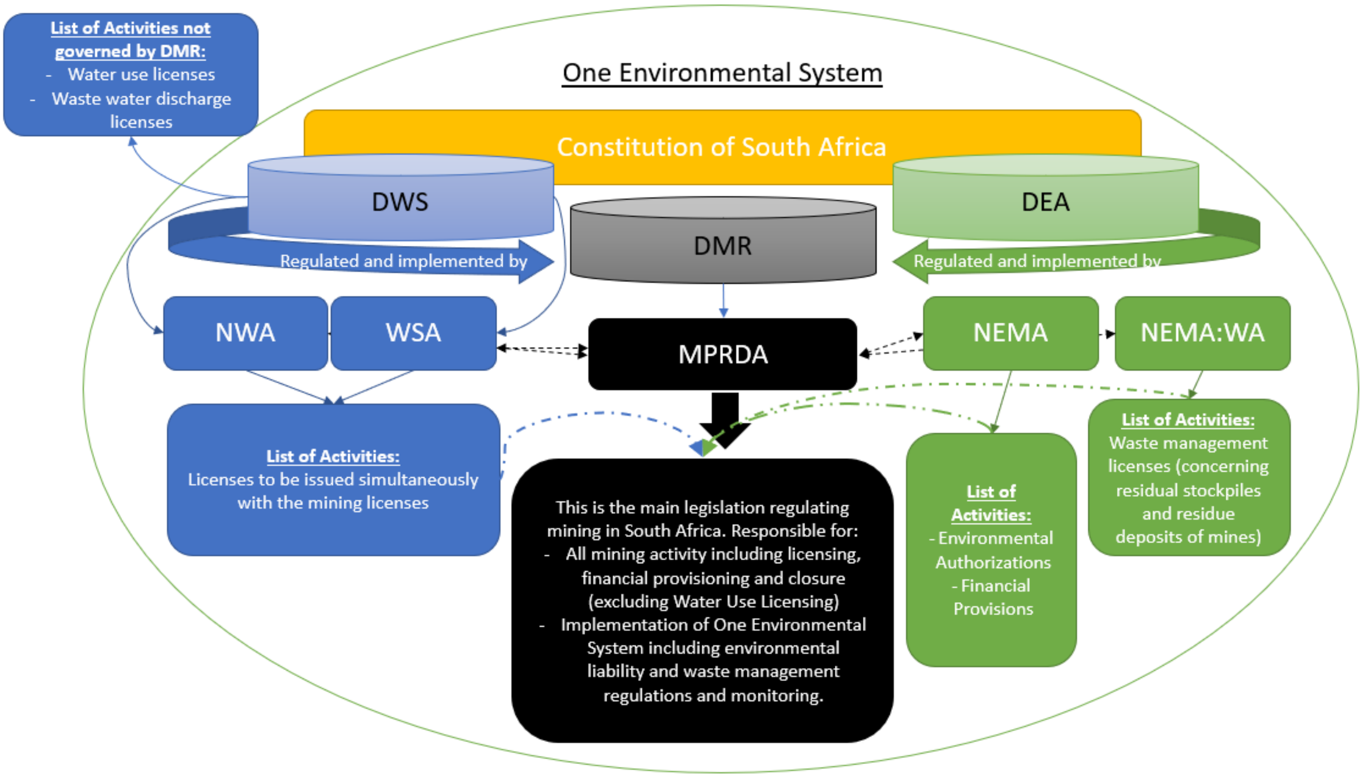

Figure 6: *The South African legal framework depicting how the legislation is enacted for mining in a One Environmental System (Source: Authors own)*

2.5.1. Department of Water and Sanitation

The DWS uses National Water Management Strategies to manage and control water. The key strategies are summarised in an annual performance plan in which goals and objectives are reviewed and monitored (Department of Water and Sanitation, 2018). Water quality programmes, such as the Green Drop and Blue Drop water quality certifications are used to ensure that municipalities are achieving water quality standards (Department of Water Affairs, 2013). Water management areas are designated and established as part of the National Water Management Strategy so that these tracts can be more easily managed. Responsible authorities or water service authorities (e.g. local governments and municipalities) are assigned the power and duty of management of the water in the catchment areas and water management areas. The responsible authorities are endorsed to perform their functions independently from national government (Department of Water and Sanitation, 2018). These authorities, within the ambit of the DWS, are responsible for water-use licenses and waste-water-discharge licenses used by mining houses. This is seen as the section outside of the "One Environmental System" shown in figure 6 above. The adverse effect is that a national, integrated approach is lost with each municipality dealing with similar issues in their own manner and not learning from the whole system. Having said that, and in line with the One Environmental Systems, the Minister of DWS may, after consultation with the DEA, identify areas which require waste investigation on properties that may have excessive contaminations which require urgent remediation (S65 of NEM:WA) (RSA, 2008c). Clear communication is critical between all governmental departments, being the DWS, DEA and DMR.

Additionally, the WSA obliges the DWS Minister to set up and maintain a National Water Services Information System, capturing data which will help monitor and regulate water use, water quality and the institutions providing water services to the public. As discussed in 2.4.2 above, the WRC has been given the mandate to fulfil the above requirements, allowing the DWS to achieve their own mandates regarding water quality (Department of Water and Sanitation, 2018). The information system's adoption has been slow as adequate training and skills development is required to ensure its success (Department of Water and Sanitation, 2017). Likewise, the South Africa political terrain has seen many developments regarding governmental department alternations, strategic plan revisions and proposed changes in legislation which have hampered systems progress and implementation across the board.

2.5.2. Department of Environmental Affairs

To manage waste regulations, NEM:WA was specifically enacted regarding waste management and waste treatment. This legislation also regulates waste management licenses (concerning residual stockpiles and residue deposits of mines) in mining and is the most relevant Act in terms of how CE principles are used for the treatment and management of waste water in mining. According to Section 1 of NEM:WA, two waste definitions affect companies namely:

- '*"**general waste**" means waste that does not pose an immediate hazard or threat to health or to the environment, and includes—*
    - *(a) domestic waste;*
    - *(b) building and demolition waste;*
    - *(c) business waste: and*
    - *(d) inert waste;*
- *"**hazardous waste**" means any waste that contains organic or inorganic elements or compounds that may, owing to the inherent physical, chemical or toxicological characteristics of that waste, have a detrimental impact on health and the environment'* (RSA, 2008c, p. 14).

NEM:WA does not recognise waste water as a separately identifiable important waste stream in mining. There is a disconnect between the waste types definition in NEM:WA and waste types listed in the schedules to the Act which creates uncertainty when classifying waste types in mineral wastes (Department of Environmental Affairs, 2018). Additionally, only one waste management licence is required where more than one waste-generating activity is found on the same location (RSA, 2008c). The disadvantage of this is that the environmental damage is different per waste type. As licensing requirements need a detailed description of how the wastes are going to be managed, if only one permit is required, mining houses will be less likely to describe in detail how each of the expected pollutants are going to be mitigated and managed (Thomashausen, et al., 2018).

According to Section 16 of NEM:WA, the '*General duty in respect of waste management:*
(1) A holder of waste must, within the holder's power, take all reasonable measures to-

- *(a)* ***avoid*** *the generation of waste of waste and where such generation cannot be avoided, to minimise the toxicity and amounts of waste that are generated;*
- *(b)* ***reduce****,* ***re-use****,* ***recycle*** *and* ***recover*** *waste;*
- *(c) where waste must be disposed of, ensure that the waste is treated and* ***disposed*** *of in an environmentally sound manner;*
- *(d) manage the waste in such a manner that it does not endanger health or the environment or cause a nuisance through noise, odour or visual impacts;…*

… (f) ***prevent*** *the waste from being used for any unauthorised purpose.*' (RSA, 2008c, p. 17). NEM:WA further defines "***treatment***" as any method used in order to '***minimise*** *the impact of the waste on the environment prior to further use or disposal*' (RSA, 2008c, p. 32).

The above legislation shows how the Waste Act follows the waste management hierarchy as discussed in 2.2.1. and 2.3.3 above. However, it fails to include legislation promoting innovative ways in which waste can be redesigned into different production cycles as is required by the CE.

Conversely, NEM:WA discusses the concept of the Extended Producer Responsibility. As per S18(2)(g) this necessitates '*the requirements that must be complied with in respect of the design, composition or production of a product or packaging, including a requirement that-*

(i) ***clean production measures be implemented****;*
(ii) the composition, volume or weight of packaging be restricted; and
(iii) packaging be designed so that it can be reduced, re-used, recycled or recovered'
(RSA, 2008c, p. 18).

Although these requirements are geared towards production and manufacturing companies, they can be used to optimise the waste management processes to ensure that leakages are minimised and that clean production measures are implemented in mining which would minimise waste water generated and positively impact the environment by designing out harmful wastes.

Although waste management processes and plans are regulated by NEM:WA, NEMA legislation looks at environmental laws on the whole. The DEA follows an integrated environmental system management approach which '*acknowledges that all elements of the environment are linked and interrelated, and… must take into account the effects of decisions on all aspects of the environment and all people in the environment by pursuing the selection of the best practicable environmental option' (NEMA S2(4)(b))* (RSA, 2008b, p. 17).

NEMA requires mines to show Environmental Impact Assessments (EIAs), EMPs, upfront mine plans, financial provisioning for rehabilitation and post closure plans. The EIAs are the environmental impacts associated with an activity which have been systematically identified, assessed and reported on (RSA, 2008b). The EMPs contain further detail regarding the '*management and control of stock piles and deposits, mine closure requirements and procedures (including the liabilities required for such), financial provisioning and monitoring of the environmental management programme performance*' (RSA, 2008b, p. 37). These are submitted as part of the mine licensing applications to the DMR for review.

NEMA explicitly discusses mine closure and the environmental authorisation on that. Section 24R of the Act states that miners remain responsible for the management of '*any environmental liability, pollution or ecological degradation, the pumping and treatment of polluted or extraneous water*' until a closure certificate is issued (RSA, 2008b, p. 56). The DEA recognises that sustainable closures of mines can only be made if the '*interconnected or integrated impact resulting in a cumulative impact*' is reviewed as the department understands the connectedness of all systems (RSA, 2008b, p. 37).

Furthermore, the Act refers to corrective action where companies are found to be in breach. These requirements are passed on to the DMR as the environmental authorities for monitoring and regulation. This process can be seen in figure 6 above which shows how NEMA and NEM:WA fall within the One Environmental System for mining.

2.5.3. Department of Mineral Resources

The predominant legislation governing the mining industry is the MPRDA (RSA, 2008a), regulated through the DMR. The DMR is not only responsible for the administration, applications and granting of prospecting rights, mining rights and mining permits, but also monitoring environmental laws including approving EIAs, EMPs, monitoring the performance of the EMPs and undertaking corrective actions where compliance with the environmental laws are not enforced.

According to the MPRDA, mining houses are granted mining licenses on the condition that they get water-use licenses from the DWS. Water-use licenses are issued by the DWS when miners indicate how they plan to use the water and provide water rehabilitation plans. Consequently, the onus is on the miner to obtain the water-use license. There is a history of minimal communication between the government divisions (DMR and DWS) regarding water-use licenses. The government departments have a lack of resources (in terms of funding and staff available), regulatory enforcements and of sharing data and information between departments. This has ensured that inadequate monitoring has occurred (Gauteng Department of Agriculture and Rural Development , 2012). The implementation of the 'One Environmental System' (figure 6) proposed that the licensing processes of DMR and DWS run concurrently and that timeframes have been agreed upon between the departments to ensure that water-use licenses are obtained in time for mines to start mining (Department of Environmental Affairs, 2015).

The MPRDA also regulates mine closure and issuing closure certificates after the fact. S43(5) of MPRDA states that '*no closure certificate may be issued unless the Chief Inspector and each government department charged with the administration of any law which relates to any matter affecting the environment have confirmed in writing that the provisions pertaining to… management pollution to water resources, the pumping and treatment of extraneous water and compliance to the conditions of the environmental authorisation have been addressed*' (RSA, 2008a, p. 41). Thus, the onus is on the mine to ensure that mining operations are designed with the end-of-life in mind regarding their waste management, in order to obtain both mine licenses and closure certificates.

Legislation is not always followed nor regulated. For instance, mining is still being found within protected areas, meant to protect endangered species and conserve threatened biomes because the ability to generate jobs outweighs the need to protect environments (Chevallier, 2015). Although South Africa has an extensive legal framework, the DMR faces criticism for not monitoring and enforcing the laws adequately enough to ensure that environmental laws and waste management strategies are effectively implemented by mining houses (Centre for Environmental Rights, 2016). Further criticism is that the DMR is both the issuer and enforcer of the environmental authorisations.

2.6. The South African mining industry

According to the International Council of Mining and Metals (ICMM) and as depicted in figure 7 below, South Africa was ranked 7th in the top 20 countries in 2012 in terms of the global mining production value (ICMM, 2014). As stated by the ICMM (2014), in line with the growth in consumerism, the role of mining in the global economy has grown extensively and continues to be an industry of global importance.

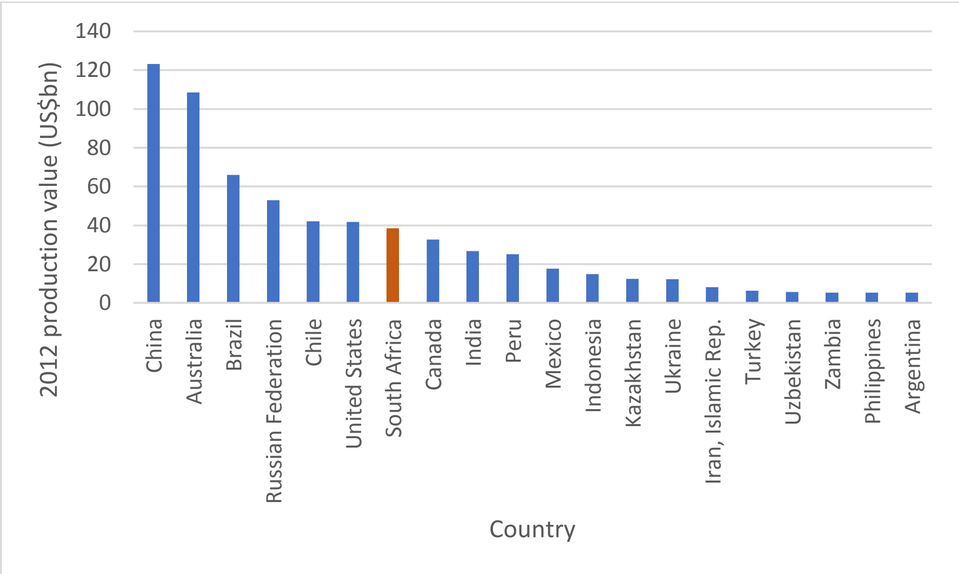

Figure 7: *Top 20 countries in terms of global mineral production as adopted from COMSA (2016)*

The Chamber of Mines of South Africa (COMSA) (2016) noted that mining contributed R304.4 billion to the South African economy in 2016, approximately 7.3% of the total GDP in real terms. Although contributing positively to the South African economy in terms of job creation and foreign investment, negative disruptive impacts in terms of societal, economic and environmental impacts have affected mining communities in South Africa in recent years (ICMM, 2014). An example of this negative impact can be seen in the case of the Blyvooruitzicht mine. Blyvooruitzicht is a gold mine in South Africa that was placed under sequestration in 2013 and affected over 6000 people living on the mine site (Mathews, 2014). Residents living on the Blyvooruitzicht mine are experiencing health issues related to unrehabilitated shafts and tailing facilities. Access to clean water and electricity has become problematic (Lawyers for Human Rights, 2017). It illustrates how sudden closure has negative repercussions for both the environment and communities affected by mining. Further, it shows how mining houses can place the environmental and societal financial burden on the South African government to rectify.

Although normal mines plan for closure, liquidations can see mines close before the end of their mining right. This sudden closure with regards to the Blyvooruitzicht case discussed above was exasperated by lack of adequate financial provisioning for closure and rehabilitation (Liefferink & Liefferink, 2014). While government and the mining industry acknowledge the calamity, lack of collaboration among stakeholders led to further community and society breakdown. A sudden closure like this has left society uncertain of mining companies and their willingness to undertake active and innovative measures regarding their environmental liabilities (Lawyers for Human Rights, 2017). "*The catastrophe at Blyvooruitzicht is the result of a toxic cocktail involving private sector abdication of responsibility, inadequate legislative framework and state enforcement efforts, and an underestimation on the part of all role players in anticipating the scope and severity of the impacts of a sudden liquidation of a major mining operation*" (Lawyers for Human Rights, 2017, p. 4).

Furthermore, health and safety for major mining houses in the area was affected due to mine shaft flooding owing to the interconnectedness of the mining compartments. Gold mines, have historically has been seen as interlinked where one gold mine's closure can have costly knock-on effects for other mining houses. This industry is the focus area for this research, in part, due to the wide-reaching consequences mine water management can have on multiple mines, the environment and society simultaneously.

2.6.1 Gold mining

Gold mining in South Africa made up approximately 4.4% of the 2016 global gold production and employed about 115,000 people (COMSA, 2016). Despite a growing global gold industry, South Africa is producing less tonnage and hiring fewer people year-on-year, as can be seen in figures 8 and figure 9 below. Figure 8 illustrates how the South African gold production contributed 13.5% of the global gold production in 2004. This figure has dropped significantly to producing only 4.4% of the global gold production by 2016. Where the global gold production increased from 2504 tonnes reported in 2004 to 3222.3 tonnes in 2016, the South African gold production has decreased by approximately 58% to 142.1 tonnes in 2016 from 337.3 tonnes reported in 2004 (COMSA, 2016). Figure 9 illustrates how South Africa is hiring fewer people year-on-year in the gold industry. A decrease of approximately 35% can be seen between 2004 and 2016.

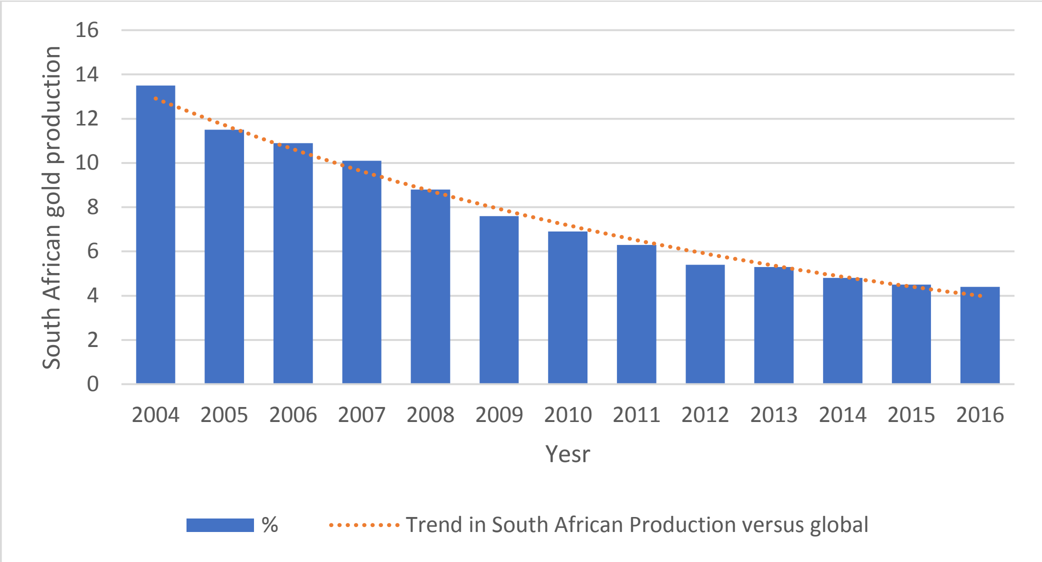

***Figure 8**: South African gold industry as a percentage of total global gold production from 2004 until 2016 as adopted from COMSA (2016)*

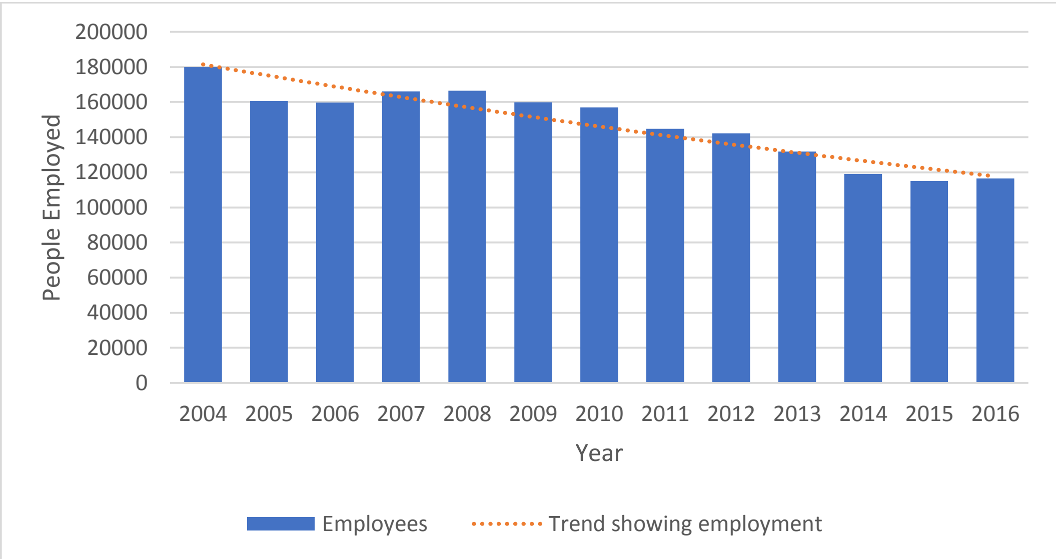

***Figure 9:** Employment figures in the South African gold industry from 2004 until 2016 as adopted from COMSA (2016)*

South African gold mining is predominantly found in underground mines and is graphically located in the north eastern regions in South Africa, as depicted in yellow in figure 10 below. Recent years have seen the increase in surface operations which reclaim gold from old tailing facilities.

By 1997 the gold mining industry was the single biggest source of mineral wastes produced in South Africa, producing approximately 221 tonnes of waste annually (Oelofse, et al., 2007). Furthermore 270 tailing dams covering roughly 400 km2 where found to be mostly unlined and causing soil and water pollution .

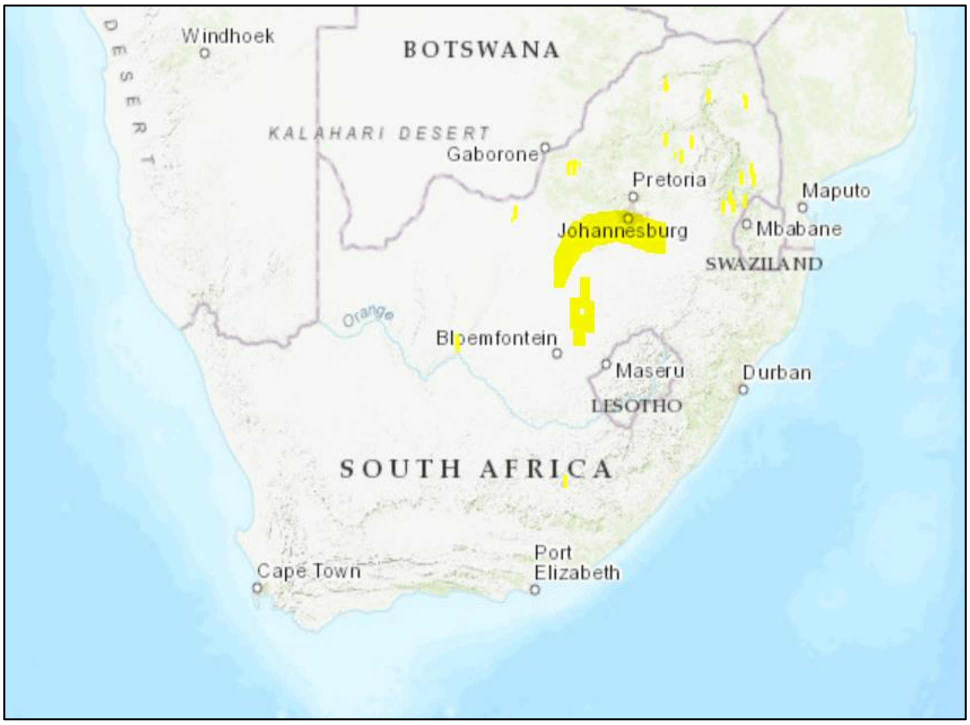

***Figure 10**: The South African Mine Water Atlas depicting the location of gold mining in South Africa as adopted by the South African Water Research Council (2016)*

In the South African context, AMD is widely accepted as being the costliest socio-economic and environmental (Oelofse, et al., 2007). However, AMD and mine water wastes are finally receiving adequate attention with government and investors looking for longer term solutions (Gauteng Department of Agriculture and Rural Development , 2012). This includes looking at mine dumps and tailing facilities and how these can negatively affect the environment when seepage occurs (Gauteng Department of Agriculture and Rural Development , 2012). Yet Oelofse, et al. (2007) state that mining houses generally incorrectly assume that the AMD impact will decrease to appropriate concentrations when their operations cease. This mind set exasperates the AMD issue in South Africa as mines are not adequately providing for the AMD mine closure requirements.

Several health issues can arise from AMD, especially where AMD contains elevated levels of radioactivity which has been known to cause cancer (Oelofse, et al., 2007). Due to the human health risks associated with AMD, the South African government is monitoring the physical locations of waste hazards. These locations will become unavailable for future development until the toxic hazards have been removed making mine waste water one of South Africa's biggest challenges (Gauteng Department of Agriculture and Rural Development , 2012).

2.6.2 Water consumption and pollution

The Water Research Commission (WRC), in collaboration with the DWS, miners, Council for Geoscience and others have compiled a South African Mine Water Atlas (MWA), which illustrates the vulnerability of water resources in South Africa. The model is based on a geo-environmental model method which takes into account the receiving water resource's vulnerability (from both a surface and underground perspective, the mineral-deposit geology and the mining method/ activities in an area (South African Mine Water Atlas, 2018). The measurement used for vulnerability and water threats is a rating based on the geo-environmental model whereby the risk is captured on a list of subset components. These will be discussed below. By compiling and tracking national water data and the mine water threats, the DWS is better able to monitor and regulate water quality. The mine water threats have been split into ground water vulnerability, as seen in figure 11 below, and surface water threats, as depicted in figure 12 below.

The methodology used to identify ground water vulnerability takes the national groundwater archive and borehole assessments into account which indicate quality and water levels in underground water reserves (South African Mine Water Atlas, 2018). Figure 11A looks at the potential underground water risk, specifically when associated with mining. Figure 11B looks at the impact that underground water will have on surface water resources. The ground water vulnerability is moderate to high in the locations where gold mining is present and mostly due to AMD in the gold mining locations. The AMD issue in South Africa due to gold mining is far reaching, with rapid solutions needed to resolve the threats it imposes. As discussed above, Oelofse et al. (2007) found that closure plans in mining houses Environmental Management Programmes (EMPs) currently are not adequate to protect water resources affected by their mining. Also, the longer-term impacts from mining and mine waste dumps and their AMD-generating-potential are not fully provided for by mining houses and to assume that these risks will decrease when mining ceases is erroneous if environmental liabilities are to be fully covered by the polluter (Oelofse, et al., 2007).

In non-gold mining areas, high ground water vulnerability can be seen. The main cause for these is other mining types, like coal, platinum and uranium mining, in the northern regions of South Africa which place pressure on underground water systems. Similarly, fracking and the karoo coalfields have been identified as a high threat to ground water vulnerability in the karoo basin.

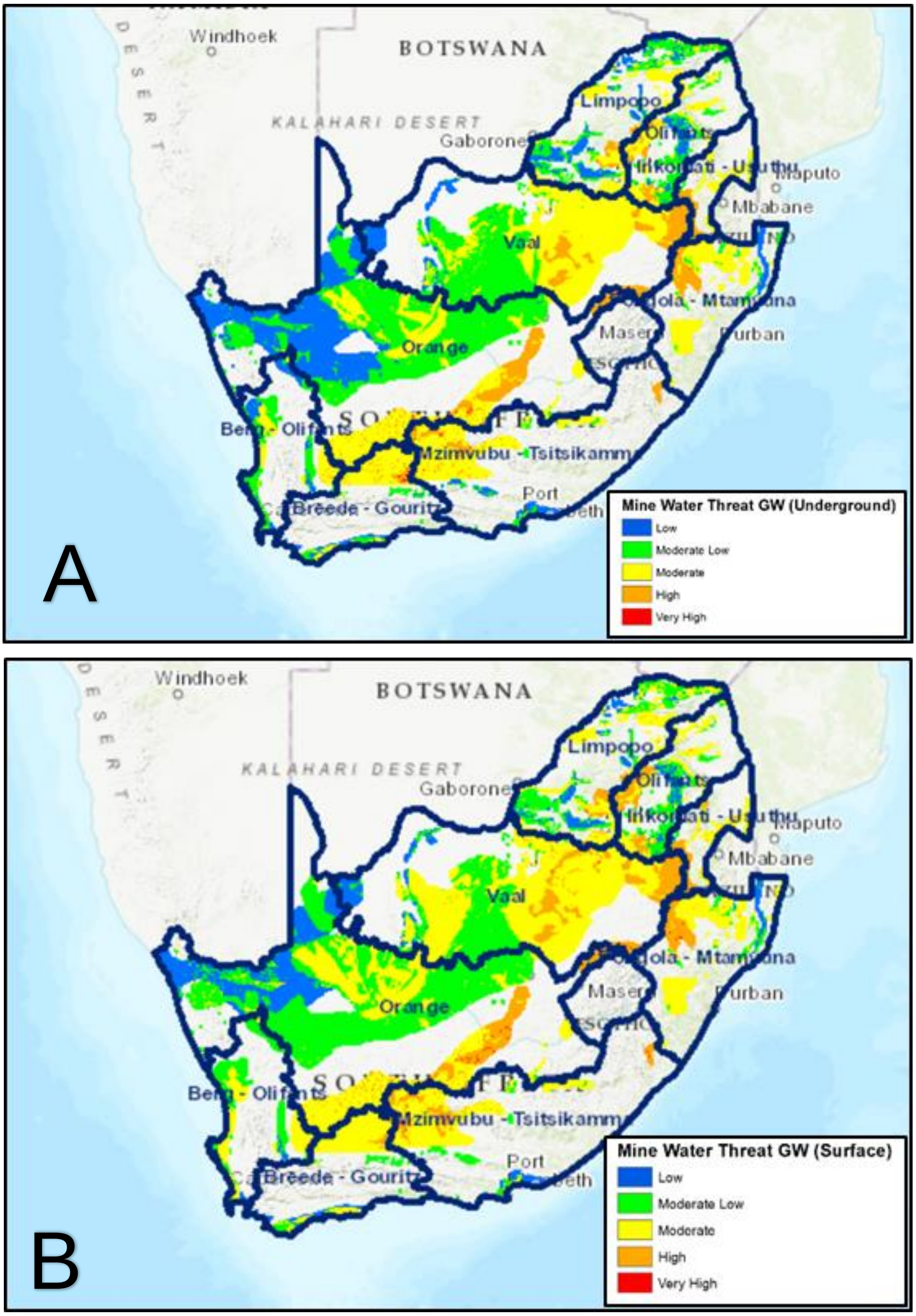

Figure 11: *Mine Water Atlas depicting Mine Water threats to ground water as adopted by the South African Water Research Council for underground water (A) and surface water (B) (2016)*

The surface water methodology takes surface water quality and quantity into account, along with biodiversity and aquatic life (South African Mine Water Atlas, 2018). The surface water threat as seen in figure 12 spans from *moderate* to *very high* where gold is mined. This means that there is a high need to protect ecological integrity in gold mining areas and that more rigorous waste water management is required to ensure that surface water threats from gold mining in the area are mitigated (South African Mine Water Atlas, 2018).

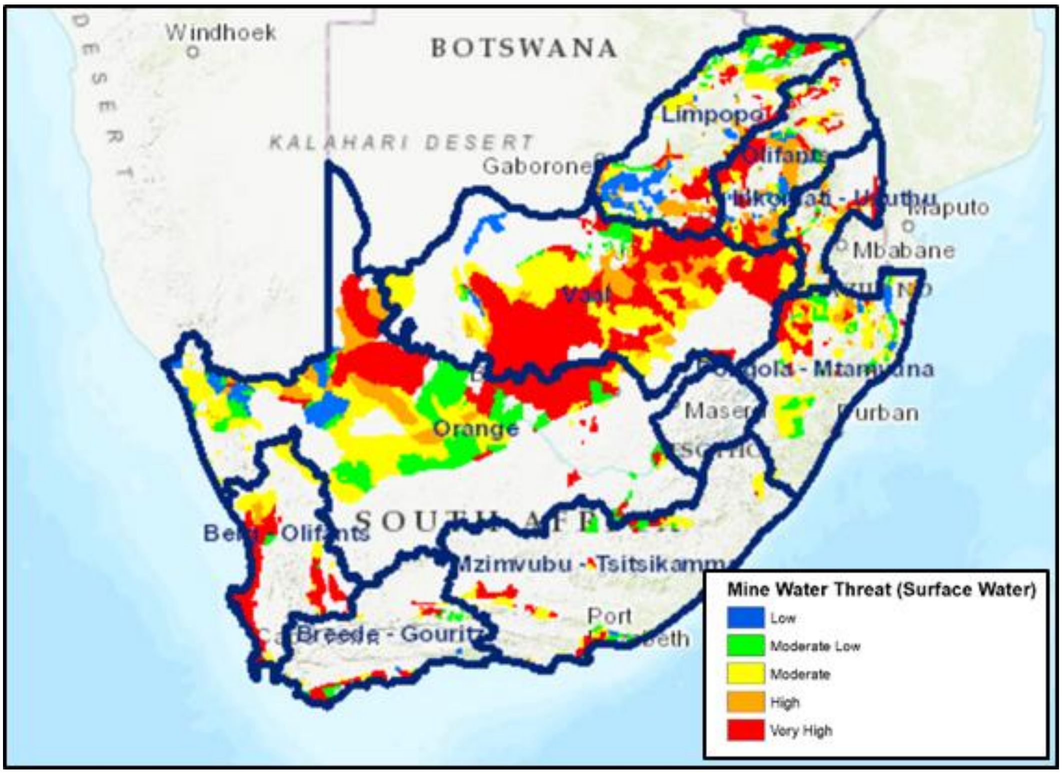

Figure 12: *The South African Mine Water Atlas depicting Mine Water threats of surface water in South Africa as adopted by the South African Water Research Council (2016)*

In non-gold mining areas, high surface water threats can be seen. The main cause for these is other mining types, like coal, platinum and uranium mining, in the northern regions of South Africa which threaten surface water. Similarly diamond mining on the west coast of South Africa accounts for the high surface water threat seen in figure 12 above (South African Mine Water Atlas, 2018).

Equally, a severe drought in the South African region had escalated water crises by the end of 2015. Scientists described an approaching environmental water crisis predominately due to water quality rather than quantity (Creamer, 29 July 2015). In the past, South African gold mines have experienced an oversupply of underground water and as such, have needed to pump out excess water to avoid flooding. Hence a paradox seems to exist between the current water crisis and drought in South Africa, and mine flooding and pumping. As can be seen in figure 11 and 12 above, the mining directly threatens ground water vulnerability and surface water threat. The gold mining industry should assume more responsibility here to drive solutions to the water threats which are exasperated by the water crises affecting communities and industries.

Similarly, due to the interconnectivity of underground mines, companies like AngloGold Ashanti have assumed water pumping of mines where their owners are no longer able to do so (namely Blyvooruitzicht mine) (AngloGold Ashanti, 2011b). Majority of this water is discharged into water ways and not utilized to assist the affected industries and communities above due to legislation issues cited. Although mining houses are currently talking to the responsible water service authorities, this process has been slow and ineffective (AngloGold Ashanti, 2011a).

Pumping required to reduce mine shaft flooding is a significant cost for the mining house.
Due to the interconnectivity of the mines, a joint responsibility is required for water pumping by all miners in a region (DRDGOLD Limited, 2006). This interconnectivity is illustrated in figure 13 below, showing the close proximity of the mines to each other.

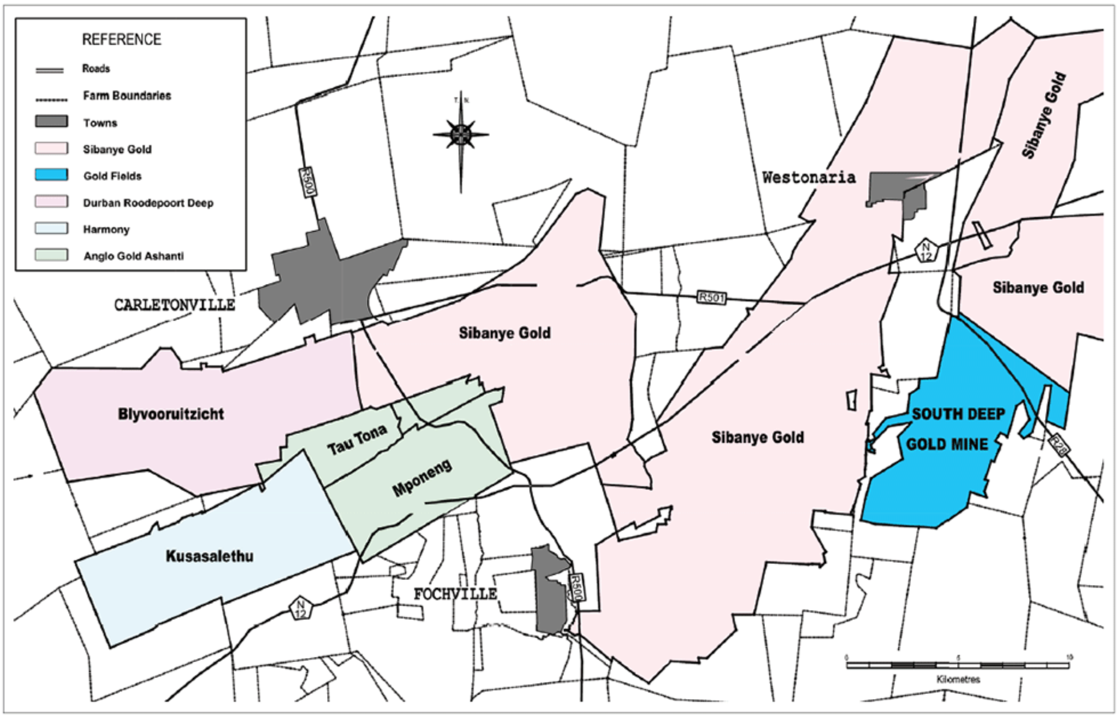

Figure 13: *Gold mines interconnectedness as seen by proximity of the Anglo Ashanti, Sibanye, Gold Fields, DRDGold and Harmony mines in South Africa (Gold Fields, 2017)*

In 2011, an industry working group consisting of the South Africa government, gold mines and affected communities, started to review the mine flooding issue due to the high costs associated with water pumping being borne by a few of the major miners (Harmony Gold Mining Company Limited, 2006b). This working group was also commissioned to review mine water management and mine water waste to create solutions to issues felt by the industry. The gold industry has a history of petitioning government to take responsibility for AMD left by ownerless and abandoned mines (DRDGOLD Limited, 2018). However, they fail to understand and account for their own environmental responsibilities regarding AMD. The correlation between mine closure and CE is the opportunity which can be found in both, to diversify an industry that is past its peak in South Africa.

2.7. CE and the South African mining industry

From the discussion above it is evident that, whilst implementing some positive initiatives to manage its waste and address water pollution, the mining industry has not implemented CE in totality. In the South African context legislation is a driver towards this. Part 7 of NEM:WA calls for industries to prepare and submit an Industry Waste Management Plan (IWMP) per sector to the DEA (RSA, 2008c). The IWMPs are meant to be an industry wide look at waste generation; how the sector as a whole can mitigate and prevent these wastes; and how the industry can decrease waste generation through the product design, packaging and the overall production process. This links into the CE principles as it calls for collaboration efforts by all industry participants to look for innovative waste controls. These are then presented to government to see where industry and government can collaborate to ensure that solutions gain the funding they require. Currently the DEA has called upon Paper and Packaging; Electrical and Electronic Equipment; and Lighting Industries to prepare new IWMPs.

The Plan should look at the particular waste streams generated by the industries and ensure a holistic approach is taken to manage the waste throughout its lifecycle (Department of Environmental Affairs, 2017b). The DEA has also called for the new plans to follow the CE concepts as this aim to retain resources within the South African economy due to their perceived value in the future. To this end focusing on reusing, repairing and recycling are aligned with the Extended Producer Responsibility, as discussed in 2.5.2 above and as defined by NEM:WA (Department of Environmental Affairs, 2017b). Additionally, the DEA has identified CE as a potential way in which the waste sector in South Africa can create jobs, reduce poverty and minimize the waste generated, through effective means such as educated consumption, resource optimization and waste recovery (Department of Environmental Affairs, 2017a).

Currently the mining industry submits individual EMPs for each mine and do not look at the holistic management approach to waste generated by the industry. Although not legally requested to submit an IWMP yet, the mining industry should take a proactive stance when considering their role in waste management at an economic level. The mining industry could ultimately be front runners regarding water waste management and be called upon to advise on governmental national waste management policies as subject area experts.

Golev et al. (2016) noted that the mining industry can adopt more circular traits by better planning for closure and rehabilitation at the planning phase of the mine design. Optimal waste management plans, designed at the inception of the mining plan, better equips mines to control waste. The onus is on the mining industry if they plan to be included in the changes proposed by the CE concept.

For mines that are already established, the CE concepts can be implemented by collaborating with government, other mining houses and business to find innovative, localised solutions to current waste management challenges, while ensuring that financial provisions for rehabilitation are adequate and closure plans are well established for each mine. This should also be done on a regional and national basis.

Large South Africa's mining houses have started looking at ways to implement the CE specifically with regards to their waste water treatment. Projects like Anglo American's eMalahleni Water Reclamation Project have implemented the CE concept in the coal mining industry and have been hailed a success story for drinking water in South Africa (Sergienko, 2015). Not only did this project portray great stakeholder collaboration but showed how mines were able to build water waste costs into their future projections. This project followed the principles of CE and can be seen as a bottom-up approach to implementing the CE in South Africa. Some major mining houses have taken the polluter-pays principle to heart and are turning potentially large externalities into collaboration efforts with governments and communities.

Anglo American's eMalahleni approach to water followed a circular model as follows:

1. Facilitates system effectiveness by ensuring that waste water is recycled efficiently enough to become potable drinking water of a high-quality. This restorative waste

system ensures that their operations are using less water, while water is regenerated over the life of mine and beyond (Anglo American, 2012).

2. Preserves and enhances renewable resources by removing toxic chemicals from their mine waste water. Their water and waste management processes are well established and communicated to the community at large. This enables Anglo America to reuse water in their productions as well as supply the neighbouring city with drinking water (Anglo American, 2012).

3. Optimises resource efficiency by using innovation redesign principles to ensure that water use is maximised. All the while, the waste generated by the water treatment plant is turned into gypsum bricks which have been used to build over 66 houses, with 300 more commissioned. This project has generated approximately 800 jobs and elaborates how waste can be converted into a profitable alternative life cycle (UFCC, 2012).

4. Increases effective collaboration efforts across industries. Representatives from DMR, DWS, DEA and the local eMalahleni municipality were invited to sit on an Authorities Steering Committee which oversaw the project development. Public participation was encouraged by answering any questions raised by non-profit organizations (NGO's) or the community individually. Campaigning the local eMalahleni community by promoting treated mine water and discussing water quality issues by distributing "taste testing" samples (ICMM, 2012).

5. Complies with legislation in a transparent manner and actively communicates with all stakeholders regarding regulations followed. Their closure planning has shifted from provisioning for physical closure to long term sustainability planning, ensuring a strong socio-economic and environmental foundation is set for the neighbouring communities. This change in mentality is seen by the proactive projects which take waste management costs into account in their business models before projects are accepted (Anglo American, 2012).

These CE principles, as espoused by Anglo American, can be seen graphically in figure 14 below, with innovation, redesign, resource efficiency, partnerships, engagement and community being the key concepts followed.

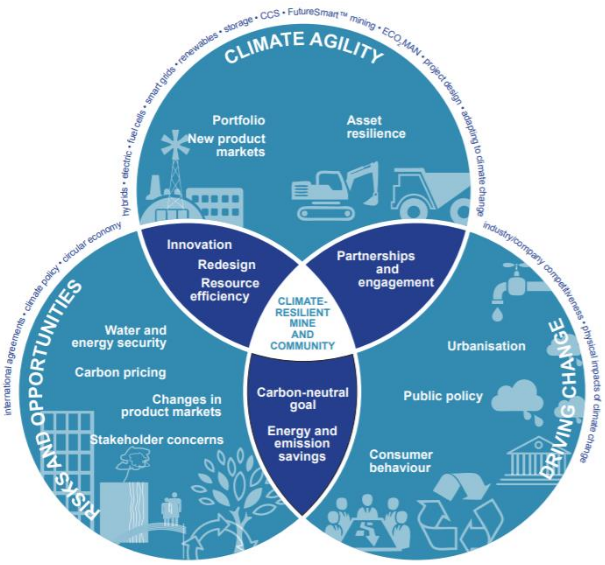

Figure 14: *Anglo American's CE concept driving their sustainability report (Anglo American, 2016)*

In the eMalahleni Water Reclamation Project, Anglo American became a Water Services Intermediary, supplying treated waste water to the city and municipality eMalahleni.
The key benefits as identified by the ICMM (2012) of this project were as follows:

- Inclusive collaboration with multiple stakeholders.
- Potable water in a water-restricted environment is supplied to the municipality.
- A state-of-the-art water plant which can be used by other mines in the area.
- Due to the success of the project and additional capacity commission for the water treatment plant, Anglo American will start processing water from other mines in the area, along with waste water from ownerless and derelict mines, thus starting to clean up legacy water issues.

One challenge of not implementing such disruptive changes to the gold mining industry more broadly in South Africa, is that production costs, especially costs relating to water management, could become unfeasible and leave the South African gold mines unprofitable and thus inoperable. This could have the further impact of leaving the costs of rehabilitation on the South African government to bare, should gold mines file for bankruptcy. Following the CE waste water management principles could give the South African mining industry an opportunity to pivot their business from solely resource-based to a more lucrative one utilizing the growth potential of turning their waste into a profitable alternative like Anglo American did for coal mining in eMalahleni.

3. METHODOLOGY

This chapter designates the research methodology used for assessing CE principles and the South African gold mining industry, specifically observing waste water management. Research methodology are the methods used to conduct the research regarding CE. They encompass the process used to conduct the research, data collections and data analysis performed.

3.1. Research Approach

This research is multifaceted with qualitative data, quantitative data as well as reviewing management plans and strategy documents. The benefits of qualitative research is that the analysis provides more depth and cross-case comparisons when recording behaviours and complex scenarios, whereas the disadvantage of this method is that the results can be influenced by the researchers personal preferences and biases (Johnson & Onwuegbuzie, 2004). The strength of quantitative research is that it is able to show trends and correlations and add more depth to the qualitative findings (Johnson & Onwuegbuzie, 2004). The weakness of this method is that it is that the researcher might miss an important component as their focus is on hypothesis testing rather than on hypothesis generation (Johnson & Onwuegbuzie, 2004). A mixed method uses both combines the qualitative and quantitative research techniques and methods in one single study (Johnson & Onwuegbuzie, 2004). Thus, mixed methods research is best placed to obtain answers to the research questions by taking the strengths of both quantitative and qualitative research techniques (Johnson & Onwuegbuzie, 2004).

Further, a case study was undertaken to establish if there has been an uptake of the CE principles in the gold mining industry over a 10-year period. The periods 2006, 2011 and 2016 were reviewed in depth. The years were selected based on all miners having their audited annual financial statements available for review at the start of this research. Table 2 below shows a summary of the research approach used to answer each question, what analysis was performed and what the output was.

Table 2: Summary of the research approach used

Question	Source of data	Analysis	Output
1. What are the key CE principles relevant	Academic literature	Review to identify CE principles, and which	List of principles applicable to water

to mining and how these have been applied to and/or adopted by the mining industry?		of these are applicable to the mining sector and deal with waste management	management in the mining sector
2. Is the CE facilitated through mining legislation in South Africa?	SA legislation: • The Constitution • MPRDA • NEMA • NEM:WA • NWA and WSA	Identify which sections of legislation relate to the principles identified in question 1 and if CE principles are accommodated by the current legislation.	Colour coded tables commenting on how legislation facilitates individual principles
3.Focusing on waste water management, has there been an uptake in the CE principles used by the gold mining industry in South Africa?	Annual financial and sustainability reports for the following gold mining companies: • AngloGold Ashanti, • Harmony Gold • Gold Fields • Sibanye Stillwater • DRDGOLD For the 2006, 2011 and 2016 years.	Analyse water consumption and production for each of the mining houses from 2006 until 2016. Identify water and waste management activities and initiatives for the 2006, 2011 and 2016 years.	Water consumption and gold production for each operation have been graphed. This help show potential correlation to better waste management techniques used. Tables discussing initiatives and activities, colour coded to indicate alignment with CE principles.

3.2. Qualitative Approach

An interpretative qualitative approach was used in order to better understand the CE research available specifically in mining. A systematic review of academic articles found on ScienceDirect (a renowned database) was undertaken in order to explore the research question and discover theory already hypothesized (Johnson & Onwuegbuzie, 2004). As this is a recent topic the presence of non-peer-reviewed articles could not be ignored as this help recognize how the CE framework is being implemented in industries currently. Furthermore, as this is a new topic in the mining sphere, CE literature found in other industries were interpreted and extrapolated to how these principles would and could be used in a mining setting. These have been concluded in the Literature review in Chapter 2 above.

The extensive literature search focused predominantly on the key words "circular economy" and "mining" was performed. At the time of this research, the findings show 796 research papers found on ScienceDirect.

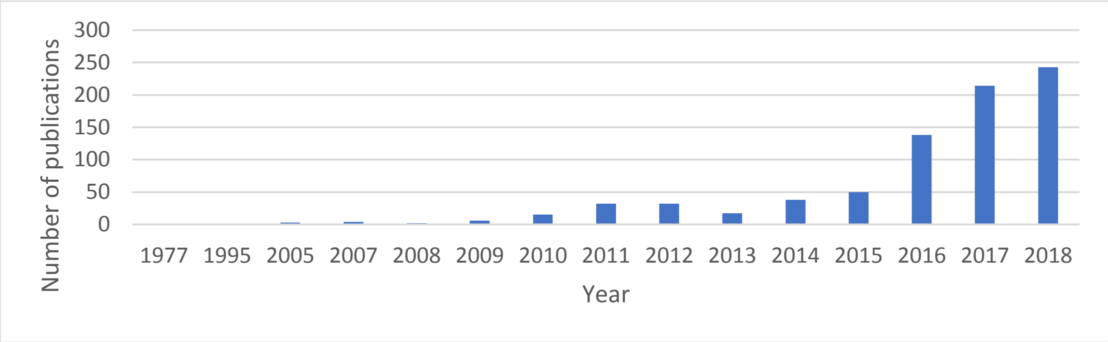

***Figure 15**: Distribution of the publications found with "Circular Economy" and "mining"*

As can be seen in figure 15 above, this topic has received a strong upsurge in the number of publications in recent years, with 57% of the publications found in 2017 and 2018. The literature helps categorized the different aspects of CE and builds a framework for implementation which is used when analysing legislation and in the case study performed in Chapter 4 below.

The most relevant research papers were used to identify core CE principles, relevant to the gold mining sector.

Additionally, a qualitative review of the South African legislative environment in mining was undertaken in Chapter 4.2. These were compared to the CE principles as determined in Chapter 4.1. This assessment was used to ascertain how the legislation aids, hinders or keeps neutral the application of CE in mining in SA. Key regulations reviewed were:

- Mineral and Petroleum Resources Development Act 28 of 2002
- National Environmental Management Act 107 of 2008
- National Environmental Management: Waste Act 59 of 2008
- National Water Act 36 of 1998
- Water Services Act 108 of 1997

As already illustrated and discussed, these are the main pieces of legislation that regulate water management in the mining sector and hence the review is limited to these. Additionally, only the primary legislation, not regulations and guidelines, were reviewed. The concept of the CE includes waste management in the overall company lifecycle, and thus the South African integrated legal framework needed to be looked at holistically.

In a 2011 report, the DEA stated that approximately 88% of South African waste was generated by the mining industry in 1997 (Department of Environmental Affairs, 2011). In 2012 a '*National Waste Information Baseline Report*' was compiled in which mining wastes were excluded as the definition of waste within the National Waste Act was changed to specifically exclude mining waste (Department of Environmental Affairs, 2012). This meant that the new Baseline report was not comparable to the 1997 report and that the waste generation figures in South Africa were distorted between 1997 and the 2012 baseline calculations. Limitations such as data accuracy and the reliance on secondary data collection for the DEA suggest that the total waste and hazardous waste generated in South Africa are underestimated. Similarly, since mining wastes are commonly managed onsite, the exactness of these numbers cannot always be confirmed (Department of Environmental Affairs, 2018).

NEMA and NEM:WA were amended in 2014, and included, amongst other changes, '*wastes resulting from exploration, mining, quarrying, and physical and chemical treatment of minerals*' as ***hazardous waste*** as they could '*have a detrimental impact on health and the environment*' (RSA, 2008c, p. 94). For this reason, NEMA and NEM:WA are examined separately during the analysis phase as both are very relevant and applicable to water and water waste management in mining.

3.3. Case Study Approach

Finally, a case study was undertaken of the extent that companies in the South African mining industry have implemented circular practices in their waste water processes. According to Yin (2015) case studies are a good way to determine the real-life issues that are being dealt with and help indicate what has changed over time.

The limitations of this interpretivist method are the level of judgement made by discourse analysis of publicly available information and making generalizations on a company's CE performance when multiple other variables could have an effect (Yin, 2015). In order to curb this and gain transparency, the data collection procedure followed was to review company financial statements, mineral resource and ore reserve reports and sustainability reports of the South African operations for the top five gold mining companies listed on the Johannesburg Stock Exchange (JSE) as part of the JSE Gold Index (Kitco Metals Inc., 2018). A gold index looks at a segment of the stock market in order to gain a view of the overall industry and generally include the biggest and most constant industry players. Investors can then invest in the index to gain a good exposure in the industry whilst mitigating their risks of investing in an individual company (Kitco Metals Inc., 2016). The companies on the JSE Gold

Index, namely AngloGold Ashanti, DRDGOLD, Harmony, Gold Fields and Sibanye Stillwater were reviewed for the periods of 2006, 2011, 2016. These time periods enabled an assessment of how the CE concept within mining water waste management has been taken up over time. Selecting multiple organisations helps to reduce bias by providing substantive proposition as analytic generalizations can be formed when more than one case is studied (Yin, 2015). Bias was also mitigated by performing a search on the company's media profile to establish any reputational information on the mining house.

AngloGold Ashanti is a multinational entity that has mines in South America, Africa and Australia. The focus is on three gold operations in South Africa, namely Vaal River, West Wits and a surface operation, MWS, which was acquired in 2012 as a tailings reprocessing operation (AngloGold Ashanti, 2013).

Harmony Gold mine has mines in South Africa and Papua New Guinea and is the third largest producer of gold in South Africa (Harmony Gold Mining Company Limited, 2016). The South African operations are the focus for this case study. These comprise of one open-pit mine (Kalgold), nine underground mines (namely Tshepong, Phakisa, Bambanani, Joel, Doornkop, Target, Kusasalethu, Masimong and Unisel) and several surface operations (Harmony Gold Mining Company Limited, 2016).

Gold Fields is an international mining house with operations in South Africa, Peru, Venezuela, Ghana and Australia. In line with the cases studied above, the South African operations will be the primary concern. In 2006 the South African operations consisted of Driefontein, Kloof and Beatrix mines producing approximately 2.6 million ounces (Gold Fields Limited, 2006). In 2007 production commenced at the newly developed South Deep mine, and 2010 saw Driefontein and Kloof mines merge into Kloof/Driefontein complex (KDC) (Gold Fields Limited, 2011). In 2012 the Gold Fields group restructured operations, after a steady decline in gold production. In February 2013, according to the restructuring efforts, the majority of Gold Fields' assets in South Africa were unbundled into Sibanye Gold (Gold Fields Limited, 2013a). For the above reasons more than 3 financial years needed to be reviewed to ensure that the above changes are accounted for in the annual reports. Additional years reviewed were 2009, 2012, 2013 and 2017.

Sibanye Stillwater (registered as Sibanye Gold Limited) is a gold and platinum mining company with mines in South Africa. Sibanye's gold division arose due to the unbundling of Gold Fields in 2013, as discussed above. Data for Sibanye Gold is only available from 2013 as the company was only incorporated in November 2012 (Sibanye Stillwater, 2017a). This is why Sibanye forms part of the 2016 dataset, to ensure that the data was consistent for the periods selected across all companies. Furthermore, production and water consumption figures will be looked at from 2013 until 2016 (Sibanye Stillwater, 2017a). The gold mining operations consist of three mines from Gold Fields; namely Driefontein, Kloof and Beatrix and Cooke mine, which was acquired in 2013 from One Gold (Sibanye Stillwater, 2013).

DRDGOLD is a South African gold producer, renowned for their surface gold tailings retreatment operations. The liquidation of their North West Operation in 2005 had reputationally damaged the miner (DRDGOLD Limited, 2006, Czernowalow, 2005). Further controversy was faced by the group when they voluntarily liquidated all their foreign subsidiaries on 30 June 2010 and then, in 2011 DRDGOLD put their Blyvooruitzicht mine into business rescue (DRDGOLD Limited, 2011). Blyvooruitzicht, which DRDGOLD sold to Village Main Reef Limited in 2012, has been marked as one of the most devastating sudden mine closures faced in South Africa's recent history (Lawyers for Human Rights, 2017).

3.4. Quantitative Approach

The quantitative methodology approach was used in conjunction with the qualitative and case study approaches. Publicly available documents, such as audited financial statements, sustainability reports (including water use data), were quantitatively analysed for the above outlined list of South African gold mining companies, to determine their gold-production values and water-use values year-on-year for 10 years. In some instances, more data was required than that provided by 2006, 2011 and 2016 publicly available documents.

This analysis was used, in conjunction with the cases studied discussed above, to determine if waste management techniques provided a decrease in the water-use values of the companies and if water-use values could point to CE being implemented in a mines waste management methodology.

The above steps formed the structure and basis of the research to address the main research question regarding the similarities and differences between the Circular Economy and the South African economy with specific regards to waste water management in the gold mining industry.

4. RESULTS

Key research questions raised are as follows:

1. How has CE been applied to/adopted by the mining industry and what are the key principles relevant to mining?
2. Is the CE facilitated through mining legislation in South Africa?
3. Focusing on waste water management, has the level of CE implementation in the gold mining sectors in South Africa changed?

These are answered in 4.1, 4.2 and finally by a case study presented in 4.3.

Tables 4 to 8 have been used to compare the CE Principles as identified in Questions 1 with the Legislation (Question 2) and table 9 to 12 have been used for the Case Study (Question 3). Each table has been colour-coded to show how the CE principles have been met. The coding criteria for Question 2 looks at the CE principles and compares these to South African legislation. The following criteria was used to identify whether the principle had been met or not.

- ***Not met*** – not mentioned, thought of or implied by legislation. This principle cell is highlighted in red.
- ***Partially met*** – principle has been mentioned but is not implemented in legislation. The cell is highlighted in orange.
- ***Compliant*** – Principle here has been mentioned in the legislation and has regulations which need to be adhered to in order for companies to be compliant with the law. This principle cell is highlighted in green.

Similar to the coding criteria for Question 2, Question 3 looks at the CE principles and compares these to South African gold mines. The following criteria was used to identify whether the principle had been met or not.

- ***Not met*** – not mentioned, thought of or implied by the company. This principle cell is highlighted in red.
- ***Partially met*** – principle has been mentioned but is not implemented by the company. The cell is highlighted in orange.
- ***Compliant*** – Full principle here has been mentioned by the company and has been implemented in the case study reviewed. This principle cell is highlighted in green.

4.1. How has CE been applied to/adopted by the mining industry globally and what are the key principles relevant to mining?

As derived from the literature review performed in section 2 above, the main CE principles can be seen in table 1 above (2.2.4). These principles have been grouped into six broad principles. Based on the CE reasoning given in table 1, the principle is reviewed for its relevance in mining. Each broad principle is broken down into smaller subsets in the table below to explain how the principle is devised.

__Table 3:__ Assessing CE principles identified from the literature review for relevance in mining

CE Principle	Sub-principle	Application to the mining industry	Mining CE sub-principle
1. Facilitate system effectiveness	Decoupling economic growth from the usage of finite natural resources	This research looks at one aspect of an industry within the South African economy, namely mining, and one waste stream of that industry, namely water waste. The larger economic system is not being reviewed and thus, this sub-principle cannot be fully assessed. Sub-principles below will look at waste water management in further depth.	n/a
	A regenerative system	The global economy is not being reviewed in this research. Applying this sub-principle to mining and water waste management, water as a natural resource is used in every single mining operation and thus assessed here. While it is not possible necessarily to "regenerate" water, it is possible to treat it. Additionally, the CE principle speaks of equilibrium between society, environment and the economy. For the purposes of mining, that equilibrium is needed to be maintained for the duration that water is being used by the mine, and when mining is discontinued. In order to facilitate a more granular review in the questions that follow, this CE principle needs to be ring-fenced to meet with the considerations discussed, as follows "Water regenerated over and beyond the life of mine".	Water regenerated over and beyond the life of mine
	A coherent framework for systems level redesigned to harness innovation and create a restorative economy.	As stated above, the global economy is not being reviewed. Applying this sub-principle to mining, water waste management systems affect environmental liabilities experienced by mines. Additionally, miners are responsible to restore the mine site and affected natural resources to their pre-mining condition. In order to facilitate answering the questions that follow, this CE sub-principle will look at the waste management system in isolation.	Restorative Waste Management Systems
	Excessive waste generation mitigated.	In mining, the prevention of waste generation is still prioritized, followed by reprocessing for any traces of residual mineral elements. Recycling and stockpiling are used as valuable minerals can still be remined at a later stage. Ultimately remediation is legally required at the end-of-mine and the mine site is rehabilitated. For CE to be implemented in mining, waste water needs to be eradicated by the mines end-of-life and the site should be able to be reused and returned to commercially viable land to be utilized by the communities affected. The waste hierarchy can be used to obtain this.	Excessive waste generation mitigated.
	Longer-lasting product, redesigned to minimise waste and other environmental externalities.	Although mining does not produce products in the manufacturing sense, the mine's entire lifecycle should be optimised and planned for. The waste management plant should be redesigned, maintained and repaired during the life of mine. Additionally, the CE principle speaks of value chains that aims to eliminate the production of waste. End-of-life planning is thus essential and should be designed at the inception of the mine plan to better equip mines to control waste.	End-of Mine/ End-of-life (designing out negative externalities)

CE Principle	Sub-principle	Application to the mining industry	Mining CE sub-principle
1. Facilitate system effectiveness (cont.)	The business model includes the full range of environmental liabilities and externalities.	For the purpose of this research and the application of this sub-principle to mining, waste management is the business model being focused on. Waste can represent large environmental liabilities and thus costs, which the business model should account for. Similarly, project feasibility is important in the mining industry where new mines are being proposed. The applicability of the mining lifecycle is taken into account, as well as all expected and potentially unexpected costs into their business models, which makes the project feasibility phase easier to handle.	Waste water costs, as an externality, are included into mines business models.
2. Preserve and enhance renewable resources	Reuse of resources in production.	Water lifespan (i.e. potability) is increased by redesigning waste management processes (meaning that water as a resource is kept at its highest value always in terms of “technical” and “biological” nutrient cycles). This sub-principle in mining looks at the possibility of achieving commercially viable/ potable value from mining waste water.	Water waste reused.
	Eliminate toxic waste through better waste design processes. This is part of system refurbishment.	Mining often uses toxic chemicals during their mineral and metallurgical processing. CE calls for the reduction of hazardous materials and wastes during production.	Waste management processes eliminate the use of toxic chemicals.
	Clear waste management strategies with long-term plans communicated.	As profitability for mining houses is the driving force behind project feasibility and where lower grade makes it more expensive to mine resources, clear long terms strategies are required. Having a clear waste management plan will help mining companies reduce their environmental externalities and decrease their end-of-life liabilities. Clear waste management plans, implemented well, leads to lower environmental and waste failures.	Clear Waste Management Plans (specifically for waste water management)
3. Optimise resource yields	Review of material cycles so that loops can be closed and leakages in the Waste Management Process can be diminished.	Mines use myriad of natural resources. As this research is focused on waste water management, leakages in this process should be minimized throughout the mine lifecycle to ensure efficient usage of natural resources such as energy and water.	Leakages in the Waste Management Process should be diminished or redesigned.
	More efficient use of energy and material resources	As this research is focused on waste water management, resource efficiencies within this process need to be explored. CE requires a shift towards efficient usage and as such resource inputs should be minimized (an example of this is water usage minimised during mining and in operations).	More efficient use of resources.
	Waste by-products of production are minimized.	Looking specifically at mine waste water, CE requires that the waste generated is used in a different production cycle to increase its lifespan.	Innovation in water waste maximised.

CE Principle	Sub-principle	Application to the mining industry	Mining CE sub-principle
4. Collaborate	Stakeholder Collaboration	Mining houses are no stranger to effective stakeholder management as this gives miners the social license to operate. Without full stakeholder acceptance, project feasibility is limited. Collaboration, on the other hand, is working together by finding partners affected by the same issue, developing trust so that sharing data and sensitive information is facilitated, and sharing costs and liabilities in a fair manner.	Collaboration
5. Monitoring legislation	Tax benefits and/ or incentives for including CE principles into business models.	As CE is a broad concept, tax benefits and incentives according to the legislation will be looked at in terms of the aim of this research which is: waste water management in the gold mining industry. Thus, this sub-principle is applicable to the mining industry in terms of waste water externalities being built into business model.	Tax benefits and/ or incentives for including waste water externalities into business model.
	Clear model for charges and tariffs	Mining companies also require that externalities to be costed effectively so that resources are adequately managed. Furthermore, more of the externalities are experienced post closure and thus financial provisioning to be able to provide for these costs is required. Better costing environmental liabilities will enable closure to happen more easily.	Clear model for provisioning, charges and tariffs
	Enforcing legislation through monitoring	With clear legislation in place, the mining industry will be better placed to implement CE models. Knowing which penalties and fines the mining industry is subject to, should they breaching legislation can promote following the regulations.	Enforcing legislation through monitoring
6. Technology	Using technology to optimise processes and product design.	Multiple technology identified in this research for mining waste water including metal-accumulating algae, reverse osmosis, filtration or Ion exchange, and animal and plant-based wastes used to remediate AMD. Mining is entering the 4th industrial revolution, with new technology becoming available and changing the face of the industry. Much of the new technology is used to improve efficiency and productivity within the mining lifecycle in terms of mineral exploration, autonomous drillers and vehicles and health and safety (Marr, 2018). Technology is a large part of the mining industry, with majority of the fourth industrial revolution linking technology and innovation to help improve profitability. This principle is very broad, and multiple technologies can be used in mining waste water management to try move the industry towards zero waste. However, this research looks to see the uptake of the CE principles rather than research different elements of technology and whether these can be seen as disruptive within the water waste management space. For this reason, technology will not be focused on as a separately identified CE principle but will be inferred to when looking at clear waste management plans as identified in CE Principle 2. ***Preserve and enhance renewable resources.***	n/a

Although six broad principles have been identified, based on the outcome of this analysis only five principles are relevant to the mining industry. These include: 1) Facilitate system effectiveness; 2) Preserve and enhance renewable resources; 3) Optimise resource yields; 4) Collaborate and 5) Legislate. CE as an economic model is larger than mining and affects many aspects of systems thinking and how each of the smaller elements make up the whole. For this reason, the 5 principles relate specifically to waste water management in gold mining and could be different depending on the aspect of an industry that is being analysed. The 5 principles will be used as the framework against which the legislation will be assessed, to answer question 2.

4.2. Are the CE principles facilitated by mining legislation in South Africa?

The first aspect of answering Question 2 was thoroughly reviewing South African legislation, keeping in mind key words, such as “Circular Economy”, “Waste Hierarchy”, “Cleaner Production”, “Reduce”, “Reuse”, ”Recycle” and “Dispose” for CE relevance. A breakdown of the South African legislations affecting mining and waste water management can be found in the literature review under section 2.5 above.

None of the South African legislation (MPDRA, NEMA, NEM:WA, NWA, WSA) explicitly mentions, defines or refers to CE which is expected as this is a relatively new concept in South Africa. NEMA and NEM:WA, however, refer and/ or infer to CE-related items which make up the CE principles as follows:

- ***Cleaner Production*** – referred to by NEM:WA in the preamble to the act calling for minimizing pollution by using cleaner production techniques. Similarly, “clean production” is a definition in NEM:WA to explain the integrated preventative environmental strategies needed to reduce pollution.
- The ***waste management hierarchy*** – inferred in NEMA and NEM:WA as the priority set when managing waste. NEMA discusses the attributes which make up the waste hierarchy (reduce, reuse, recycle and dispose) as part of its definition for Sustainable development.
- **“Reduce”, “Reuse”, ”Recycle” and “Dispose”** – NEM:WA contains the definition for “Recycle” and “Re-use”. Similarly, these aspects are enacted as part of the waste priority requirements. NEMA discusses these words as part of the definition for Sustainable development and the implementation requirements as enacted.

This shows that in terms of legislation, South Africa is making advances, albeit slowly, in the inclusion of CE principles within its legislative framework. Legislation is normally lagging. Thus, the next review of NEMA and NEM:WA, CE principles or CE in totality might be implemented.

The second component of answering question 2 was comparing the CE principles, as amended to relate specifically to mining in **4.1.** above, to the South African legislation. This comparison can be found in the tables 4 to 8 below. Colour coding here indicates if the CE Principle has not been met by legislation (highlighted in red), only partially met (orange) or has been met by legislation (green). A table has been used per separate CE principle.

The coding criteria looks at the CE principles and compares these to South African legislation. The following criteria was used to identify whether the principle had been met or not.

- ***Not met*** – not mentioned, thought of or implied by legislation. This principle cell is highlighted in red.
- ***Partially met*** – principle has been mentioned but is not implemented in legislation. The cell is highlighted in orange.
- ***Compliant*** – Principle here has been mentioned in the legislation and has regulations which need to be adhered to in order for companies to be compliant with the law. This principle cell is highlighted in green.

Table 4: *Legislation relevant to the CE principle 1 - facilitate system effectiveness regarding mine waste water management in South Africa*

Mining CE sub-principle	MPRDA	NEMA	NEM:WA	NWA/ WSA
Water regenerated over life of mine	None of the Acts' look at Water regeneration or the possibility of waste systems being restorative in nature. Although closure regulations recommend that environmental damage is adequately treated during and by the end of life of the mine, the treatments do not need to ensure that the system is left better off than before mining occurred.			
Restorative Waste Mgnt Systems				
Excessive waste generation mitigated	The MPRDA was amended in 2014 to align the Act with the environmental laws as designated by NEMA and NWA. For this reason, the MPRDA does not regulate waste water recycling but indicates that mining permit holders will need to comply with the NWA for Water-use and NEMA for environmental degradation.	NEMA requests that waste (in any form) *'is avoided, or where it cannot be altogether avoided, minimised and re-used or **recycled** where possible and otherwise disposed of in a responsible manner'* (RSA, 2008b).	The Act states that '*the generation of waste is avoided, or where it cannot be avoided, that it is reduced, re-used, recycled or recovered and only as a last resort treated and safely disposed of'*. The description follows the waste hierarchy as discussed in Chapter 2 but does not include regenerating. Thus, this principle has only partially been met.	The NWA does not explicitly discuss system effectiveness and how government can be facilitators of this CE principle.
End-of Mine/ End-of-life (designing out negative externalities)	According to S43(1) of the MPRDA, the holder of the mining license will remain responsible for any environmental and pollution liabilities until the Minister as issued a closure certificate. Closure must comply with NEMA terms and certificates will only be issued if full closure plans have been signed off by each governmental department with any law relating to mining.	NEMA regulates mine closure and the environmental authorisation on those. A financial provision is required to be held for the rehabilitation required on any potential environmental liability which might arise. This is further discussed in the 'Charges and tariffs' section below.	Act does not specifically discuss end-of-life of a mine. However, it discusses multiple waste definitions which need to be treated as they occur (i.e. during the life of mine), including waste generated by mining. These waste streams are included in the Act's definition of hazardous waste as they could '*have a detrimental impact on health and the environment*' (RSA, 2008c).	
Waste water costs, as an externality, are included into mines business models.	The MPRDA does not regulate environmental externalities that are caused by mining, as these are regulated by NEMA. They are, however, responsible for enforcing the externality legislation which are included in NEMA and NEM:WA.	S2(4)(p) outlining the Principles of the Act and describes the Polluter Pays principle as '*the costs of remedying pollution, environmental degradation and consequent adverse health effects and of preventing, controlling or minimising further pollution, environmental damage or adverse health effects must be paid for by those responsible for harming the environment*'.	The Act defines "**best practicable environmental option**" as the '*option that provides the most benefit or causes the least damage to the environment as a whole, at a cost acceptable to society, in the long term as well as in the short term'* (RSA, 2008c). The disadvantage is that externalities are not explicitly called to be included in the production lifecycle and end-of-life by this act.	NWA refers to tariffs for the use of water and penalty provisions which could be made to reduce companies waste water discharges. Furthermore, the pricing strategy uses waste characteristics to decide the waste discharge costs. The onus is on the mine to ensure that these costs are built into their business models when applying for licenses.

***Table 5:** Legislation relevant to the CE principle 2 - preserving and enhancing renewable resources regarding mine waste water management in South Africa*

Mining CE sub-principle	**MPRDA**	**NEMA**	**NEM:WA**	**NWA/ WSA**
Water waste reused.	The MPRDA does not regulate waste water re-use but indicates that mining permit holders will need to comply with the NWA. Similarly, environmental laws are designated by NEMA and NWA.	Waste management has a specific environmental management act and is further regulated by the NEM:WA.	The Act discusses the concept of the extended producer responsibility. As per S18(2)(a) this entails additional regulations which can be imposed to look at how the extended producer responsibility programme includes '*the requirements for the reduction, re-use, recycling, recovery, treatment and disposal of waste*'. No mention is made of the quality of the water.	NWA regulates the compulsory water-use licences which are required where water resource quality is under threat. This is generally the case in mining. Mining houses require water-use licenses in order to mine. These licenses include the requirement to ensure that adequate treatment is undertaken or that an authorised person will undertake the purification of said water waste.
Waste management processes eliminate the use of toxic chemicals.	According to S37(1)(a), the *'Environmental Management Principles are set out in S2 of NEMA and apply to all prospecting and mining operations'* (RSA, 2008a). Thus NEMA and NEM:WA regulates all elements which affect the environment and the MPRDA enforces the regulation. Ultimately the Minister of Mineral Resources is responsible to ensure that environmental implementation is done.	Waste management has a specific environmental management act and is further regulated by the NEM:WA.	Mining Waste water treatment is a requirement as part of the licensing needs of the Act. Mines are not allowed to dispose of untreated waste water. See Waste Management Plans discussed below.	Section 29 of the NWA discusses the conditions relating to the protection of water resources and water management (including monitoring, costs, return flow or discharge including specifying treatment which is required due to chemical or physical components). The Act calls for specifying the waste treatment, pollution control and monitoring equipment used.

Mining CE sub-principle	MPRDA	NEMA	NEM:WA	NWA/ WSA
Clear Waste Management Plans (specifically for waste water management)	See above. Although the Waste Management processes and plans are regulated by NEM:WA, MPRDA requires that all mining or prospective mining houses provide Environmental Management Plans and Programmes. The waste management process will be included in these.	NEMA requires that both an Environmental Management Plan (as regulated by S11) and an EMP (as regulated by S24) are submitted to the competent authority for approval (2008b). The plan and programme must contain any environmental impact which might be caused by the mine, the norms and standards of the environment (and in this case water quality norms and standards) and how the mining house will manage and monitor the impact.	A Waste Management Plan is required as part of the licensing requirements. These requirements call for the amount and type of wastes which are going to be generated, and how these waste streams are going to be monitored and managed. These plans should specify any re-use, recycling or recovery of waste that will be undertaken or the use of a waste disposal facility.	Section 26 deals with waste water management standards and practices for the use of water. These include waste quantity and quality discharged, waste water treatment management practices and potential financial provisioning for waste generated. The DWS Minister may make regulations which limit or restrict the extent of water-use or require that water resources be monitored, measured and recorded.

Table 6: *Legislation relevant to the CE principle 3 - optimising resource yields regarding mine waste water management in South Africa*

Mining CE sub-principle	**MPRDA**	**NEMA**	**NEM:WA**	**NWA/ WSA**
Leakages in the Waste Management Process should be diminished or redesigned.	The process of identifying potential leakages in the waste management process is not monitored by MPRDA.	NEMA follows an integrated environmental system management approach which means that the whole environmental system (including waste management and potential leakages) will need to be reviewed so that adequate management strategies can be incorporated.	The concept of the extended producer responsibility who should design clean production methods as discussed in 'Department of Environmental Affairs' above shows that this principle is met.	Water Management strategies are used to optimise resource yields. Please see the sections above for further detail.
More efficient use of resources.	The MPRDA was amended in 2014 to align the Act with the environmental laws as designated by NEMA and NWA. For the above reason the MPRDA does not regulate water re-use but indicates that mining permit holders will need to comply with the NWA.	S2(4)(a)(ii) outlining the Principles of the Act states that '*pollution and degradation of the environment are avoided, or, where they cannot be altogether avoided, are minimised and remedied*'.	According to S16 as discussed in the *Department of Environmental Affairs* section above, waste generation should be minimised. However, water use minimisation is not explicitly mentioned and is subject to the legislation in NWA. Thus, the laws proposed in NEM:WA do not adequately meet this CE principle.	The water use tariffs are made to incentivise effective and efficient water use. However, the Act does not explicitly call for water use to be minimised
Innovation in water waste maximised.	The MPRDA does not regulate the potential different production cycles which waste water can fall into. It does indicate that mining permit holders will need to comply with the NWA.	S24E of the Act discusses the minimum conditions attached to environmental authorisations to '*ensure that adequate provision is made for the ongoing management and monitoring of the impacts of the activity on the environment throughout the life cycle of the activity*' (RSA, 2008b).	The Act requests that a producer must carry out a life cycle assessment to identify all procedures which occur so that better waste management plans can be obtained and standardized.	Water use is regulated and monitored by the National Water Act. The DWS monitors tariffs for both water-used as well as waste water management. NEMA designates these services to DWS as DWS exercises functions which could affect the environment.

Table 7: *Legislation relevant to the CE principle 4 - collaboration regarding mine waste water management in South Africa*

Mining CE sub-principle	**MPRDA**	**NEMA**	**NEM:WA**	**NWA/ WSA**
Stakeholder Collaboration	Following the implementation of the One Environmental System, DEA outsources the Environmental Authorisation and the DWS have agreed to abide by the same timeframes for licensing to ensure that systems are run in parallel and that decision are reached simultaneously (Department of Environmental Affairs, 2015). According to the MPRDA, the Minister may also request collaboration from Mining houses in terms of any data which might be required to ensure that all laws are followed. No data may be destroyed or deleted (RSA, 2008a).	The Act calls for collaboration efforts between all organs of State. Furthermore, following the One Environmental System, DEA outsources the Environmental Authorisation to the Minister of the DMR.	Waste licences are required for mining – however these will be issued by the Minister of Mineral Resources in accordance with NEMA:WA (i.e. the Minister of mineral resources is the Waste Management licensing authority). The Act calls for co-operative governance between all organs of State. This means that the waste management licensing authority should coordinate and communicate the licensing decisions to the DEA.	Section 22(4) states '*In the interests of co-operative governance, a responsible authority may promote arrangements with other organs of state to combine their respective licence requirements into a single licence requirement'* (RSA, 1998) Although the MPRDA was amended in 2014 to make the DMR the Competent Authority for monitoring and issuing all licences related to mining, the DWS is still responsible for issuing Water-use licenses due the water related issues in South Africa (Department of Environmental Affairs, 2015).

Table 8: *Legislation relevant to the CE principle 5 - beneficial, tariffs and monitoring regarding mine waste water management in South Africa.*

Mining CE sub-principle	**MPRDA**	**NEMA**	**NEM:WA**	**NWA/ WSA**
Tax benefits and/ or incentives for including waste water externalities into business model.	None of the Acts' look at the financial tax benefits for including externalities into their business models. Tax benefits are regulated by the Income Tax Act (South African Institute of Chartered Accountants, 2012). Currently no subsidies are made exclusively for waste water management projects in mining. However, S37A of the Income Tax Act regulates mining rehabilitation funds for environmental damages. Tax deductions can be made on all payments which are made on behalf of mining rehabilitation costs. Similarly, charges/ tariffs for water-use and waste disposal are tax-deductible (South African Institute of Chartered Accountants, 2012). Currently South Africa does not have mining specific environmental taxes.			
Clear model for provisioning, charges and tariffs	Charges and tariffs for waste management are regulated by NEM:WA and NEMA. Water-use is regulated by NWA.	The financial provisions, which are made at the start of the mine, are made for the potential environmental liabilities which might occur over the life of mine. A portion may be retained 'for any latent, residual or any other environmental impact, including the pumping of polluted or extraneous water' after the closure certificate has been granted. The Insolvency Act does not apply to any form of the financial provisioning as contemplated in NEMA and thus the provision can be used for the environmental liabilities should a mine become insolvent.	Tariffs are charged by municipalities in terms of collection, waste storage and disposal. However, this applies to solid waste and does not explicitly include water waste management in this. Furthermore the act mentions that the methodology of the pricing strategies used includes monitoring the incentives for minimising, re-using, recycling and recovering waste.	The Minister of Water and Sanitation determines charges to be given for the use of water. The Act refers to tariffs for the use of water and penalty provisions which could be made to reduce companies waste water discharges. The pricing strategy for waste discharge take the waste characteristics into account to ensure the polluter pays for the pollution made.
Enforcing legislation through monitoring	The DMR becomes the Competent Authority for monitoring all laws set up in MPRDA, NEMA and NWA which affect mining houses as part of the One Environmental System. Environmental Liabilities follow the NEMA and NEM:WA enforcements.	S32 of the Act deals with Legal Standing to enforce environmental laws. Any person or group may apply to the court to ensure that laws are enforced. Also the South African Police service has the power to issue and enforce compliance notices to any offenders of the Act.	The Act clarifies '*institutional arrangements and planning matters*', which are required for companies to ensure that they have functional Waste Management Plans. Moreover, offenders (where a person is found to be in contravention with the Act) can be fined up to R10,000,000 or imprisoned for up to 10 years. Offenders will also be responsible for any other penalties imposed by NEMA.	Mines require a water-use license to operate. In certain scenarios, the license applicant is requested to supply financial provisioning/ security for the protection of water. The onus for monitoring of water resources in mining is on the Minister of Water and Sanitation. However, the Minister can request data, within reasonable timeframes, from mining houses as and when needed.

The tables above illustrate how a majority of the CE Principles are covered by South African legislation, with the exception of water regeneration, restorative systems and incentivised benefits to implement the CE. These are seen as red in the tables above. CE is increasingly being addressed in new legislation (particularly by NEMA legislation as majority of the CE principles are illustrated as green), however, still some gaps are found.

There are some problematic features regarding the current legislation and the CE principles:

1. The Acts requires that adequate information systems are available for monitoring and gathering the required quality data to ensure that programs implemented are working.
2. The waste prevention responsibility is entrusted to mines, where they are permitted to outline waste management strategies best suited to an individual mine rather than for the gold mining industry and/or mining industry as a whole.
3. The waste manage strategy in mining relies on conventional waste management processes which follow the waste hierarchy but do not recommend or incentivise innovative ways to turn the waste generation into different product cycles.
4. Waste disposal should be removed from the waste hierarchy as this disincentivises the waste management definition as disposal is not an effective solution for mining.
5. The IWMPs propose incentives and subsidies on waste streams for a given subset of industries – rather than looking at the whole waste industry, including industrial waste generated from mining. Currently the IWMP has not been called for from the mining industry.
6. Environmental tax laws, sustainability levies and subsidies in the mining industry are minimal and thus there are no clear subsidies/ incentives are given to adequately treat waste in an innovative manner that turns the waste into a progressive profitable value stream.
7. Weak legislation enforcement where no clear consequences have been illustrated by South African courts in terms of environmental offenders who breach the regulations.
8. The legislation is flexible to interpretation.

As a majority of the CE principles are covered, CE can be implemented in the gold mining industry in South Africa in an uninhibited way.

4.3 Case study looking at AngloGold Ashanti, DRDGOLD, Harmony, Gold Fields and Sibanye Stillwater

Focusing on waste management, including water management and water consumption, this case study looks at whether the level of CE implementation in the gold mining sector in South Africa has changed. The case study looks at the South African operations of the top five gold mining companies listed as part of the JSE's Gold Index, namely AngloGold Ashanti, Harmony, Gold Fields, Sibanye Stillwater and DRDGOLD, for the periods of 2006, 2011, 2016. These time periods enabled an assessment of how the CE concept within mining water waste management has been taken up over time. The assumption is that circular practices would be incrementally implemented in recent years.

The legislation infers to the mitigation hierarchy and cleaner production (as discussed above). The research below shows that there is a correlation to the legislation as mining companies make use of words such as reduce, reuse and recycle, thus there is a connection to legislation and the CE principles.

Question 3 looks at the CE principles and compares these to South African gold mines. The following criteria was used to identify whether the principle had been met or not.

- ***Not met*** – not mentioned, thought of or implied by the company. This principle cell is highlighted in red.
- ***Partially met*** – principle has been mentioned but is not implemented by the company. The cell is highlighted in orange.
- ***Compliant*** – Full principle here has been mentioned by the company and has been implemented in the case study reviewed. This principle cell is highlighted in green.

4.3.1. AngloGold Ashanti

The year 2006 saw the development of AngloGold Ashanti's first environmental guidelines including water and waste management. Two water incidents occurred during 2006, where tailing facilities overflowed into nearby natural waterways. This prompted a review on water use and a policy change regarding targets for the reduction of water use. Furthermore, the company stated that extensive mine-closure planning was found to be required. These were to be implemented in 2007 (AngloGold Ashanti, 2006).

In 2009, AngloGold Ashanti implemented group-wide standards for multiple environmental management aspects, including waste and water (AngloGold Ashanti, 2011a). By 2011 an integrated water management programme was piloted in the AngloGold Ashanti South African mines due to AMD and ground water contamination occurring. Water pumping was found to prevent the contamination of water; however, this generated significant costs for the company. Similarly, a global strategy was proposed to address legacy discharge water quality issues, reduce raw water consumption, and improve monitoring and reporting and the mines transparency thereof (AngloGold Ashanti, 2011a). Although water pumping curbs the AMD issue during the mining operations, the AMD issues will become exasperated when the mines close (Oelofse, et al., 2007).

There is a clear indication that AngloGold Ashanti have implemented better environmental management programmes over the 10-year period spanning from 2006 until 2016 as can be seen from the change in reporting from a Report to Society in 2006 to a full reporting module including an Integrated Report as well as a Sustainable Development Report in their 2016 publication. Also noted in 2016, AngloGold Ashanti incurred no reportable environmental incidents in the South African and Continental Africa regions (AngloGold Ashanti, 2016b).

By 2016, the company was following a Sustainability Development Strategy which first and foremost focuses on safety and the human element. This gives the company the social licence to operate. They also have strong responsible environmental stewardship policies which contain management frameworks and guidelines to govern tailing facilities, cyanide usage, energy and greenhouse gases emissions, water and waste management (AngloGold Ashanti, 2016b). However, the management of each of these are siloed and not managed as one interconnected environmental system. The strategy for 2017 looks to enhance and strengthen collaboration efforts by looking at innovative partnerships that change the way the company does business (AngloGold Ashanti, 2017a).

Production at AngloGold Ashanti has decreased over the last 10 years. The data for AngloGold Ashanti's gold production in South Africa comes from the annual integrated reports (2009, 2014, 2016a). The figures for the years 2006 to 2008 were derived from water usage and water efficiency figures in the Report to Society (2006, 2008). These calculations were checked against the totals as provided in the Annual reports. Figure 16 below shows the decline in gold production.

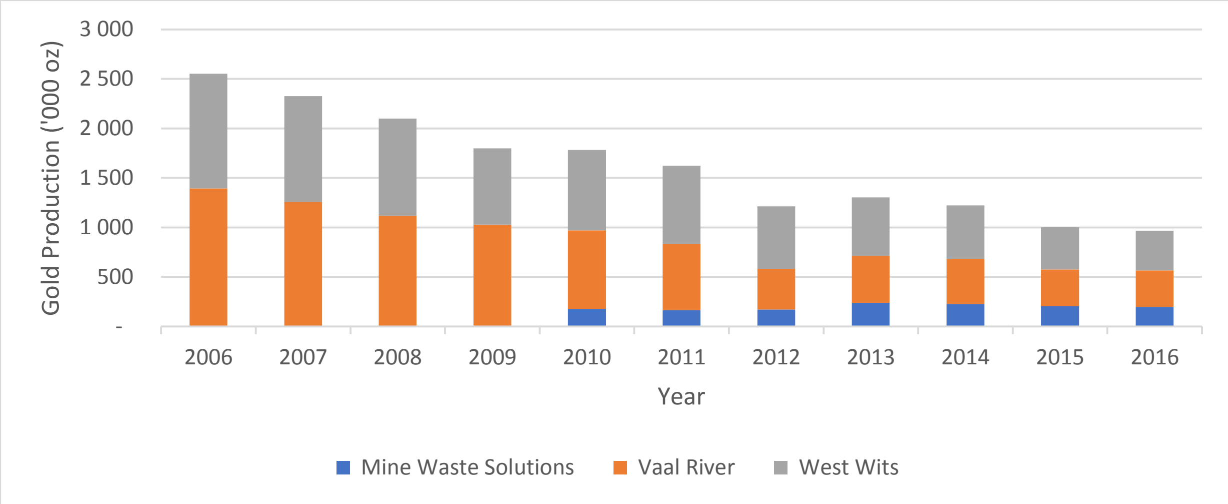

***Figure 16:** Derived gold production for AngloGold Ashanti's South African operations from 2006 until 2016 (AngloGold Ashanti, 2006; AngloGold Ashanti, 2008; AngloGold Ashanti, 2009; AngloGold Ashanti, 2014; AngloGold Ashanti, 2016a)*

Water consumption values were obtained from the annual reports (2006, 2008, 2011b, 2016a). The water consumption increased for MWS between acquisition in 2013 and 2014 due to a tailings facility failure which caused a spike in the water consumption for the new operation (AngloGold Ashanti, 2013). As can be seen in figure 17 the water consumption for MWS has started to decline from 2014. Furthermore, figure 17 indicates a gradual decline in water consumption for the underground mining activities.

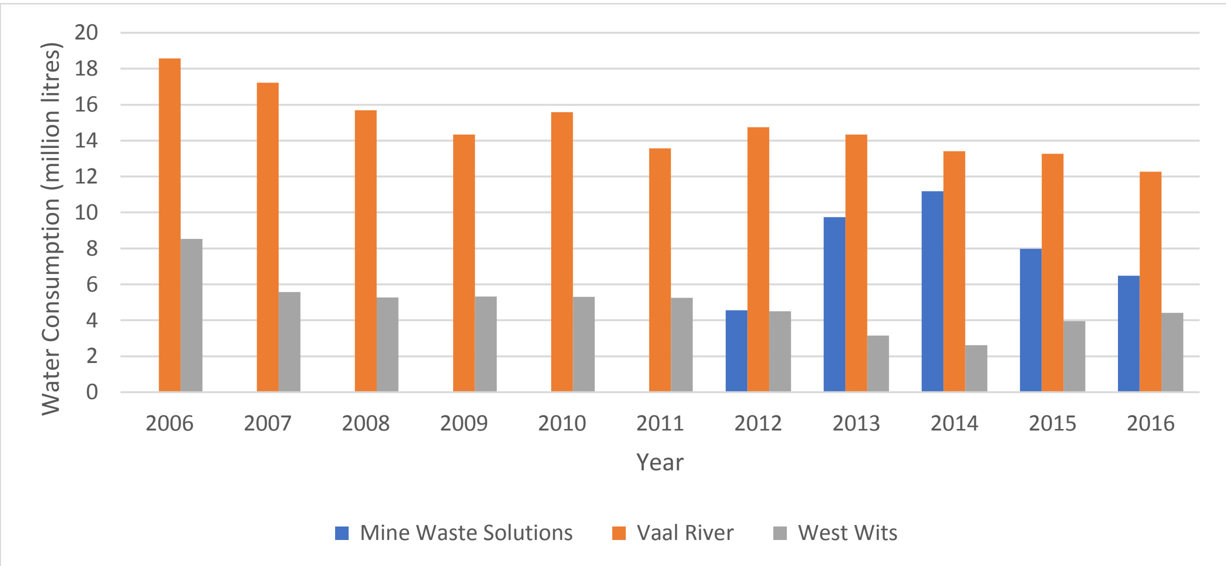

***Figure 17:** Adapted water consumption for AngloGold Ashanti's South African operations from 2006 until 2016 (AngloGold Ashanti, 2006; AngloGold Ashanti, 2008; AngloGold Ashanti, 2011b; AngloGold Ashanti, 2016a)*

Although it seems that the water consumed by AngloGold Ashanti has decreased over the last 10 years as shown in figure 17, the production decrease as shown in figure 16 is much more drastic questioning the correlation between the decrease in gold produced and decrease in water consumed. In figure 16, it shows that production has more than halved from 2006 and 2016, but in figure 17, although water use has also decreased, it has not decreased nearly as drastically as production. It appears that AngloGold Ashanti is using more water per ounce, and not less, as time goes on.

Further research shows the implementation of the first of AngloGold Ashanti's Water-use Cycle programmes. This was established at their Mponeng Mine based on the West Wits facility, one of the deepest gold mines globally, and is depicted in figure 18 below. According to AngloGold Ashanti, all mines have been fitted with water trenches to capture excess water, 80% of all water used in the mine is reused and water is used in a semi-closed loop system which aims to preserve water while improving gold recovery rates (AngloGold Ashanti, 2017b).

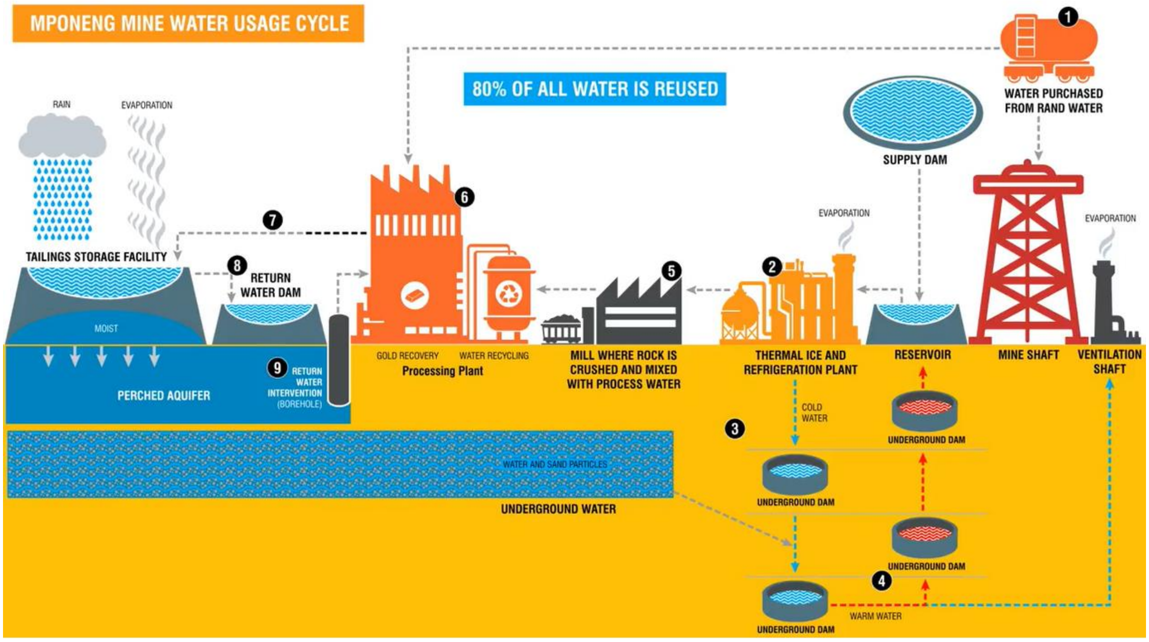

Figure 18: *An adapted figure showing the water usage cycle at the AngloGold Ashanti's Mponeng Mine (AngloGold Ashanti, 2017b)*

Table 9 below looks at further CE principles to ascertain if AngloGold Ashanti follows a circular trajectory.

Table 9: *AngloGold Ashanti's CE commitments regarding mine waste water management in South Africa.*

Mining CE sub-principle	2006	2011	2016
1. Facilitate system effectiveness: - Water regenerated - Restorative Waste Management Systems - Excessive waste generation mitigated. - End-of-life/ rehabilitation planned - Waste water costs, included business model	Rehabilitation policies and environmental programmes are found to be lacking and requiring extensive review. No recycling of waste water or restoration of the waste system mentioned in annual report (AngloGold Ashanti, 2006).	Rehabilitation policies have been updated and continuously reviewed. AngloGold Ashanti plans mines with closure in mind (AngloGold Ashanti, 2011a). Regarding their waste and water systems – they aim to operate a 'closed loop' system, where all water used in the mine will be recycled instead of being discharged to the environment. This will reduce their water consumption and the water contamination potential (AngloGold Ashanti, 2011a).	AngloGold Ashanti implemented Integrated Closure Management Plans which enables early forecast of realistic costs needed to close. Provision is also made for restoration. Water is sourced from underground, surface waterways and purchased from water utilities. Waste water is recycled where possible (AngloGold Ashanti, 2016b).
2. Preserve and enhance renewable resources - Waste water reused - Waste management processes eliminate the use of toxic chemicals - Clear Waste Management Plans	Waste management plans and other environmental policies are expected to be adopted in 2007 (AngloGold Ashanti, 2006).	Specific waste management policies including chemical waste, have been set up. They include waste *avoidance, reduction, reuse, recycling, treatment and disposal* (AngloGold Ashanti, 2011a).	Mine Waste Solution was acquired in 2012 to remine waste and reclaim gold. Tailing storage facilities and cyanide are managed on a local and regional basis, with external review to ensure that optimal global waste management standards are met (AngloGold Ashanti, 2016b).
3. Optimise resource yields - Leakages identified - More efficient use of resources - Innovation in water waste maximized	Targets as per the annual report (2006) are starting to be set – however this principle is not met in 2006.	A group-wide complex water security strategy was proposed. Project initiation would commence in 2012 to improve the integrated water management policy, reduce water consumption, address discharge water quality matters and improve reporting transparency. This process requires extra review. Strict top-down water reduction targets set in 2011 show a 10% year-on-year reduction in the use of potable water (AngloGold Ashanti, 2011a). However, the company has also experienced year-on-year production decreases, thus it is questionable if these targets have been reached at a milled per ton basis.	They have strong responsible environmental stewardship policies which contain management frameworks and guidelines to govern tailing facilities, cyanide usage, energy and greenhouse gases emissions, water and waste management (AngloGold Ashanti, 2016b). Innovative solutions to water usage have not been implemented

4. Collaboration	No collaboration efforts were found. AngloGold Ashanti instituted legal action against various government Ministers/ departments and other mines due to underground water pumping responsibilities not undertaken upstream from their Vaal River mines (AngloGold Ashanti, 2006).	AMD and other underground water contamination cause substantial issues in South Africa. Extensive water pumping is required to prevent further contamination issues, but at a significant cost. Additionally, due to the interconnectivity of underground mines, AngloGold Ashanti has assumed the pumping of the Blyvooruitzicht mine as their owners are no longer doing so (AngloGold Ashanti, 2011b). Feasibility studies had been started in 2011 when an industry working group started to look at the issue of mine flooding. This group consists of the South Africa government, mines within the gold mining industry and affected communities. A proposal to supply treated pumped water had been made, however municipalities were hesitant to accept mine water and discussions were still underway to ascertain if potential business opportunities can be created with excess mine water (AngloGold Ashanti, 2011a).	AngloGold Ashanti have joined to the ICMM Water position statement which requires them to collaborate with stakeholders (including government) and become stewards of water.
5. Beneficial Legislation - Tax benefits/incentives - Clear model for provisioning, charges and tariffs - Enforcing legislation through monitoring	AngloGold Ashanti reports compliance of current '*environmental laws, regulations and requirements*'. A financial provision is required and will be provided for restoration costs due to environmental damages of mining (AngloGold Ashanti, 2006). However, the model for provisioning is not clear in the public domain, and thus this principle has not been met.	AngloGold Ashanti have identified that environmental management is one of the legal requirements for operating. Furthermore, without proper closure planning the mine indicates that they will likely to be exposed to *'higher costs, missed opportunities, compensation claims and reputational damage*' (AngloGold Ashanti, 2011a). Thus their 2011 waste and water policies help obtain cost efficiencies and assist in mitigating unnecessary closure costs.	The DWS has implemented firm water restrictions given the current drought conditions being faced in South Africa. This requires better models and valuation techniques to be used by the mine to ensure that the regulation is followed. This also requires that better water monitoring is completed by the mine.

From the qualitative research conducted above, AngloGold Ashanti is implementing more CE principles in their practices year-on-year. Although AngloGold Ashanti is following clearer environmental and sustainable strategies, the company lacks innovative ways in which waste water can be creatively included in a different production cycle, which is required of CE implementation. Furthermore, although environmental reporting has increased recently, their water use per ounce appears to be incrementally increasing, in contradiction to water-use comments in their Sustainable Development Report.

4.3.2. Harmony

Harmony implements an extensive waste policy as they believe that these plans enable them to factor realistic costs into their mining and mine closure plans. Similarly, this enables them to design their operations in an optimal manner whereby mineral residue is reclaimed during the life of the respective mine, waste generation is minimised, and water reuse and recycling are maximised so that their environmental footprint is decreased (Harmony Gold Mining Company Limited, 2016).

As discussed in the Methodology chapter, the South African operations are the focus of this case study. Harmony's gold production can be seen in figure 19 below.

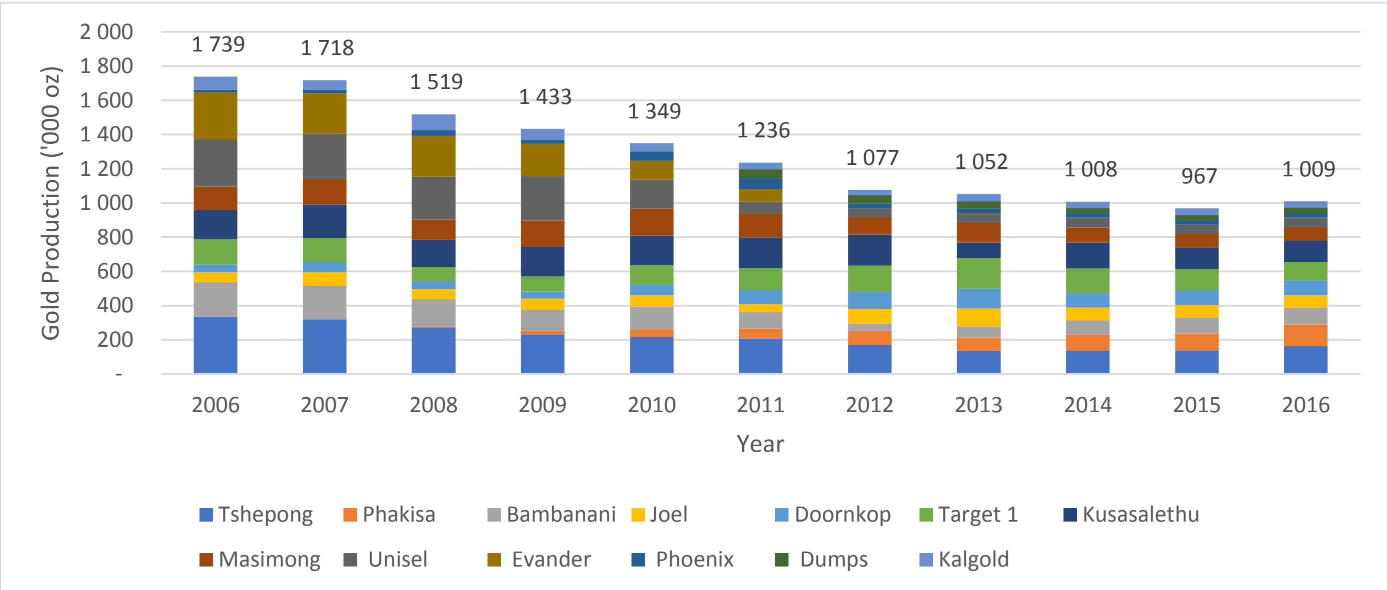

Figure 19: *Adapted gold production for Harmony's South African operations from 2006 until 2016 (Harmony Gold Mining Company Limited, 2008; Harmony Gold Mining Company Limited, 2011a; Harmony Gold Mining Company Limited, 2013; Harmony Gold Mining Company Limited, 2016)*

The data for Harmony's South African gold production comes from their integrated annual reports. The 2012 and 2013 integrated reports reported production in kilograms. These figures were converted to show consistent data for the mining house in the above graph.

Kalgold, as the miners open-pit mine, obtains water from a surface-based aquifer. Kalgold's water usage has decreased by approximately 80% in the 2016 financial year mainly due to the increase in use of recycled water (Harmony Gold Mining Company Limited, 2016). The gold production for the same period at Kalgold only decreased by approximately 8%. All other operations are supplied by municipalities and water service authorities, pumped water from underground mines, recycled and surface water run-off.

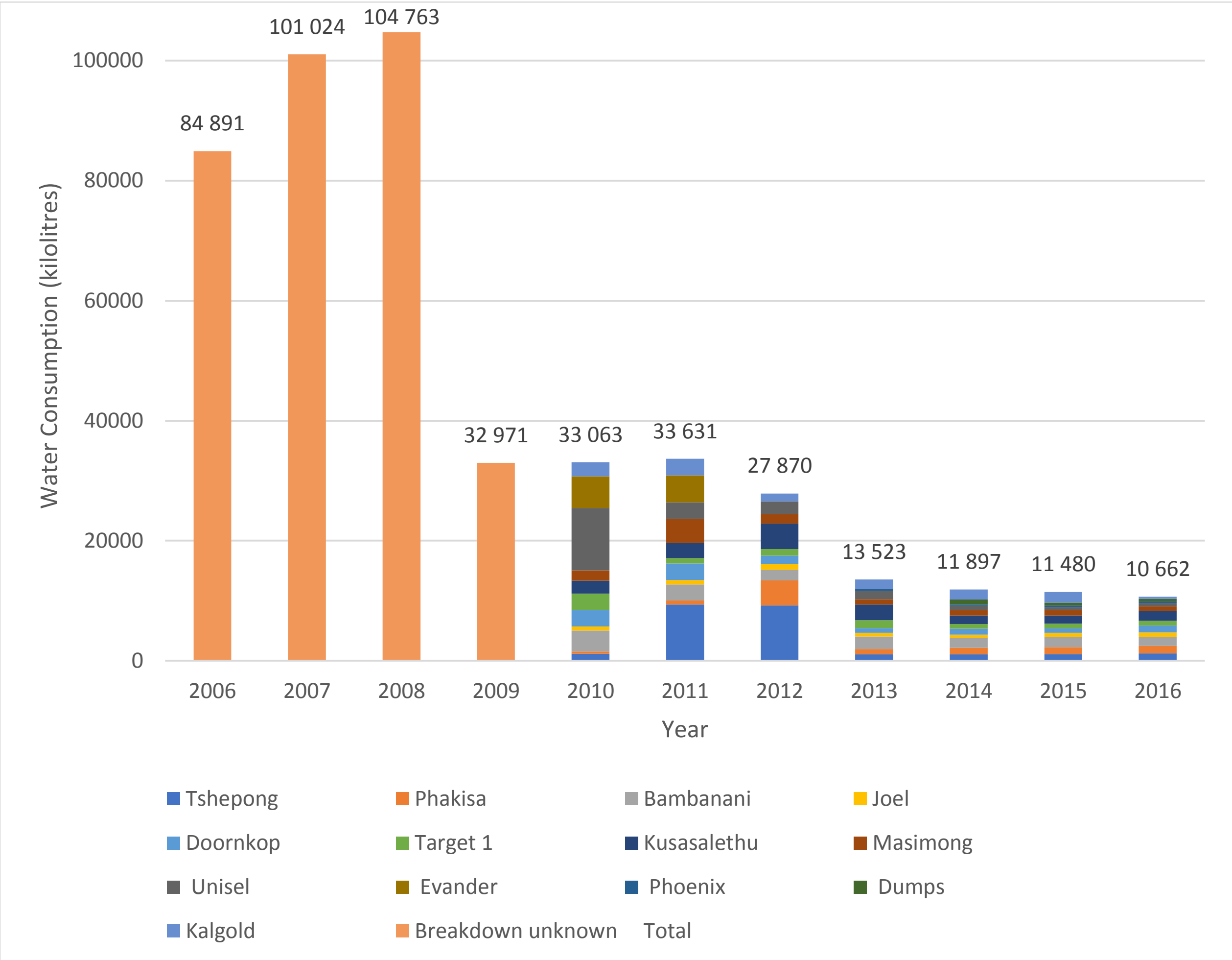

Figure 20: *Adapted Harmony's water consumption for their South African operations from 2006 until 2016 (Harmony Gold Mining Company Limited, 2006b; Harmony Gold Mining Company Limited, 2009; Harmony Gold Mining Company Limited, 2011a; Harmony Gold Mining Company Limited, 2013; Harmony Gold Mining Company Limited, 2016)*

Figure 20 shows the water consumption figures for Harmony for the periods 2006 until 2016. This data was sourced from multiple sources. The 2006 to 2009 water consumption volumes were only publicly available in totality and were not split into the difference operations. The figure indicates the changes made in publicly available information by the company to year-on-year.

The largest decrease in water consumption as depicted in figure 20 was between 2008 and 2009. According to Harmony's Sustainability Report (2009), water consumption decreased in part due to Rand Uranium being excluded from the water usage figures in 2009. However, the main reason was due to water usage reporting inaccuracies pre-2009 where certain sources were double counted for (Harmony Gold Mining Company Limited, 2009).

Further data discrepancies were found between the 2011 and 2013 financial statements regarding the 2011 water use figures for Tshepong, Masimong and Unisel. The 2013 financials state that they revised their definition of the water used for primary activities and thus decreased these locations in line with the new definition. The financial statements also give a limited assurance on the '***Water used for primary activity (kilolitres)***' figures. Harmony's auditors' further states that *'We have not carried out any work on data [selected sustainable development information] reported for prior reporting periods, nor have we performed work in respect of future projections and targets.'* (Harmony Gold Mining Company Limited, 2013, p. 86), making their accuracy, reliability and validity difficult to ascertain. Generally, water data appears to be inconsistent and poorly reported on for Harmony.

Table 10 below qualitatively looks if Harmony follows a circular trajectory by reviewing their uptake of CE principles.

Table 10: *Harmony's CE commitments regarding mine waste water management in South Africa.*

Mining CE sub-principle	2006	2011	2016
1. Facilitate system effectiveness: - Water regenerated - Restorative Waste Management Systems - Excessive waste generation mitigated. - End-of-life/ rehabilitation planned - Waste water costs, included business model	Environmental liabilities include '*current technological, environmental and regulatory requirements*' (Harmony Gold Mining Company Limited, 2006a). Harmony makes annual provisions for mine closure to an environmental trust fund. Each operation follows EMPs which details the individual impacts, mitigation procedures and individual rehabilitation requirements for each stage of the mines life cycle (Harmony Gold Mining Company Limited, 2006b). Although rehabilitation and mine closures are provided for, the concepts of recycling waste water and restorative waste streams is not mentioned, and thus this sub-principle has not been met.	Harmony makes extensive use of water in their operations. They reported a decrease in their fresh water intake by recycling and reusing water. The environmental liabilities (from mine closure, rehabilitation and pollution control) follow an EMP which is compliant with South African legislation. The company notes that acid mine drainage is not an issue or risk for them (Harmony Gold Mining Company Limited, 2011b). This is unlikely, given the legacy issues faced by other gold mining houses in South Africa.	Harmony has a strong rehabilitation programme which aims to create jobs as well as find sustainable alternative uses for the rehabilitated land, including renewable energy projects (such as solar and biogas projects) and viable agricultural projects. Their system effectiveness has further been increased with their steady increase in the use of recycled water in their mining processes. However, the company does not use innovative thinking in attempting to regenerate water and use restorative waste systems in their current operations.
2. Preserve and enhance renewable resources - Waste water reused - Waste management processes eliminate the use of toxic chemicals - Clear Waste Management Plans	Harmony's biggest waste generated is their tailings and thus clear waste management plans have been alluded to in the Annual Report (2006a). Limited information is given as to how this is achieved. Harmony remarks that they face significant risks, due to the hazards associated with their type of mining, including toxic chemicals. '*Managing waste responsibly remains a challenge at our operations*' (Harmony Gold Mining Company Limited, 2006b).	A baseline has been set up in 2008. The group is attempting to reduce their water consumption based on the baseline figures and have designed waste management targets to deal with hazardous and other waste. Harmony has started an initiative to reuse water in their operations as well as the retreatment of water. Two operations, Kalgold and Doornkop have achieved 34% and 35% water reuse rates in 2011 respectively (Harmony Gold Mining Company Limited, 2011b).	Harmony has introduced a water re-use program to reduce their dependency on groundwater. Similarly, Kalgold, their open-cast mine, has modified their plant and tailings storage facilities to facilitate the recovery of water for reuse. Furthermore, water processing dams have been strengthened to increase holding capacity and decrease overflows, due to the new NEM:WA requires whereby all tailings dams need to be lined. Waste management processes have been effective in reducing toxic chemical usage, as well as decrease the amount of chemical toxins stored (2016). Harmony continues to review their full waste management process.

3. Optimise resource yields - Leakages identified - More efficient use of resources - Innovation in water waste maximized	Although policy is in the process of being set with fatalities and a safe mining environment being the main concern, minimising water usage and innovative waste water processes are lacking.	Harmony has found that remining tailing facilities to reclaim gold has become profitable (depending on the gold price). Thus, business models are changing to take tailings waste into account and allowing companies to take a closer look at their waste streams.	Water restrictions are an operational risk for Harmony – thus a firm strategy was started in 2013 to reduce the reliance on potable water and maximise the use of recycled water. Furthermore, water treatment plants have been constructed at some of the mining operations with the intention to reuse and recycle mine water as well as prevent further pollution as part of their waste management strategy.
4. Collaboration	Regular meetings are held with most stakeholders (including regional and provision government officials and local affected communities). An issue identified in the Annual Report pertains to the increased environmental costs of treating and pumping water of adjacent mines, where these mines neglect their obligation (2006a).	The DMR has been approached to find a solution for region mine closure instead of individual mine closure. This is due to the interconnected nature of mining operations, and the joint responsibility required for water pumping due to latent flooding of deep groundwater in the gold mines. Harmony has identified that collaborative support is required from both gold mining companies and the government (on behalf of legacy issues). This is currently lacking.	Harmony prides themselves with regards to their history of effective multi-stakeholder engagement to find solutions to issues as they arise. New environmental laws call for stronger financial provisioning. In the companies Integrated Annual Report they refer to financial provisioning being stringent and often impractical. According to Harmony, they are collaborating with government to rationalise the legal frameworks. This reads as lobbying the government to ensure the company is protected over and above their environmental responsibilities.
5. Beneficial Legislation - Tax benefits/incentives - Clear model for provisioning, charges and tariffs - Enforcing legislation through monitoring	Full legislation has been followed in 2006, with integrated water-use licence applications being submitted for each operation. However, the model for provisioning is not clear in the public domain, and thus this principle has only been partially met.	Majority of Harmony's mines have water-use licences; however, some operations are outstanding. Harmony have noted the risk taken as it could be subject to penalties and fines, operational disruptions or their water licences being revoked. Due to the above risk, Harmony anticipates that their water management measures to have an enlarged cost going forward.	Harmony operates in terms of the MPRDA regulations. In recent years they have engaged with the Chamber of Mines and the South African government on policy and legislation. EMP's are in place for each operation and have been approved by the DMR. Where possible, the company attempts to build the cost of externalities into their business models.

The CE principles implemented at Harmony are expanding. This can be seen by the movement from red, through orange and sometimes to green in table 9 above. New rehabilitation strategies look to circulate and recirculate waste water in their plants, which will maximise their reuse of waste water (Harmony Gold Mining Company Limited, 2016). There is a clear increase in the water and waste management policies of the company. Their strategies have become more environmentally sounds and better reported on in their annual financial statements.

Limited data is available in earlier periods, with better data becoming available in subsequent years. There is a clear increase in publicly available data accessible in later years, however the reliability of the data is questionable.

4.3.3. Gold Fields

As discussed in the Methodology section, multiple changes have occurred in Gold Fields over the last 10-year period. These changes can be seen by the large decrease in the gold production from South African operations in figure 21 below. Figure 21 depicts the production profile of Gold Fields from the period 2006 until 2016.

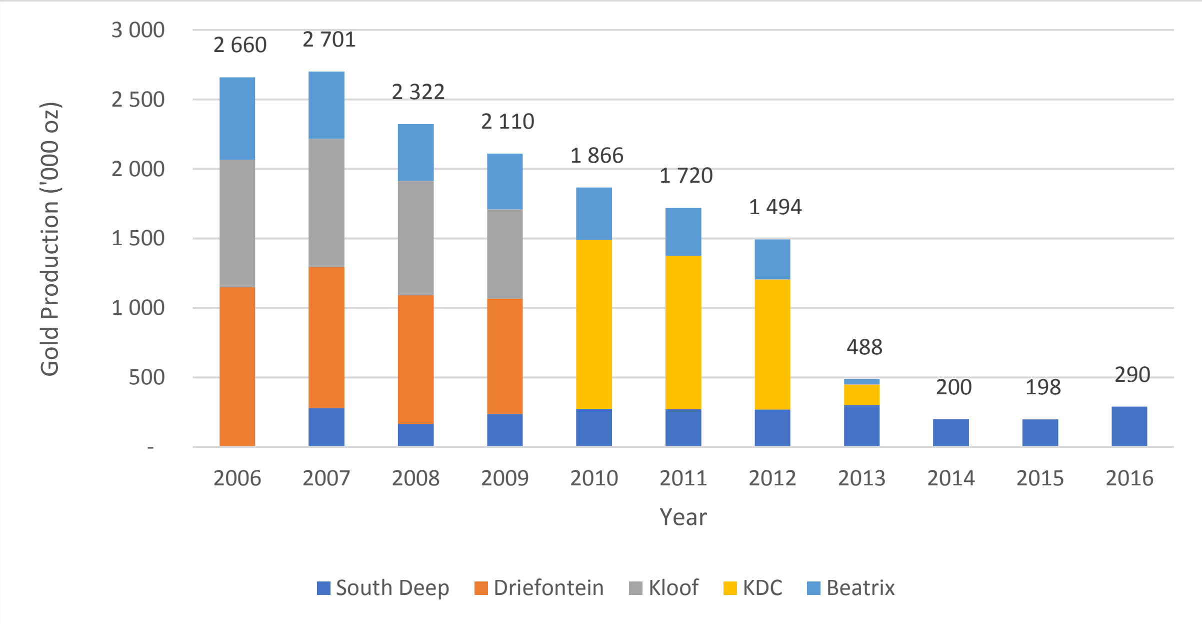

***Figure 21**: Graphical gold production for the Gold Fields South African operations, as publicised in the annual reports (Gold Fields Limited, 2006; Gold Fields Limited, 2009; Gold Fields Limited, 2011; Gold Fields Limited, 2013a; Gold Fields Limited, 2016a)*

The water consumption reporting methodology changed in 2012 when individual operational water consumption figures were discontinued in the public domain and only group-wide water consumption values were reported. This change is shown in figure 22 below. Changes in reporting methodology have seen unexplained discrepancies in their annual financial statement environmental figures. Further limited environmental data was made publicly available after 2011.

The problem with group-wide water-use figures is that they include international operations and make analysis less congruent year-on-year, where using only publicly available data. A decreased water consumption rates in South Africa cannot be ascertained, due to the lack of environmental data transparency.

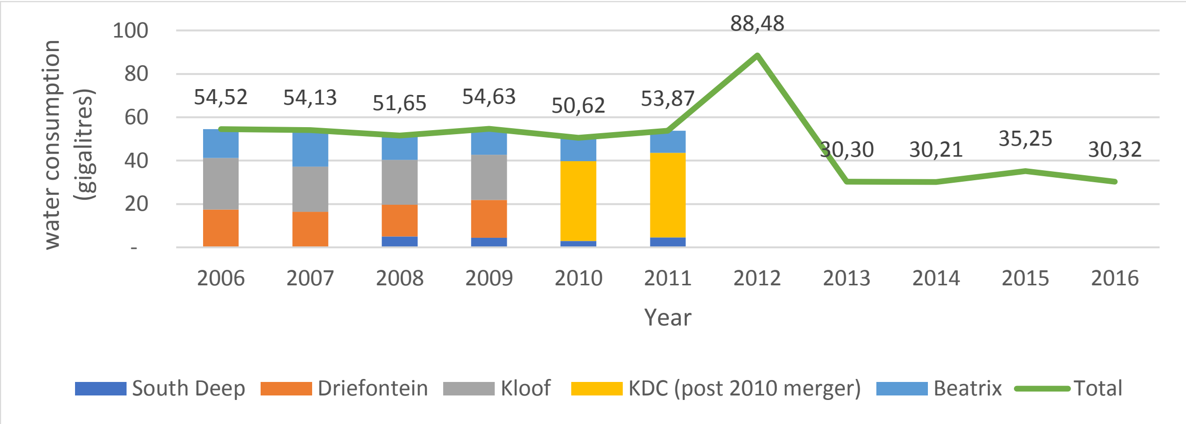

Figure 22: *Adapted Gold Fields' water consumption in South Africa from 2006 until 2016 (Gold Fields Limited, 2009; Gold Fields Limited, 2011; Gold Fields Limited, 2013b; Gold Fields Limited, 2016b).*

Gold Fields' water consumption data, as illustrated in figure 22 above, was assembled from the annual reports (2009, 2011, 2013b, 2016b). Discrepancies were found between data disclosure after the KDC merger, incorporating Kloof and Driefontein, thus individual mine water consumption figures for 2008 and 2009 were obtained from the 2009 annual report.

The 2012's water consumption was made up of 23.7 gigalitres from continued operations and thus 64.8 gigalitres recalculated as water consumption by the unbundled assets (KDC (made up of Driefontein and Kloof) and Beatrix). The large increase of approximately 20% in water consumption in 2012 is unclear and not reported on in either the 2012 nor 2013 reports (Gold Fields Limited, 2012, Gold Fields Limited, 2013b). Furthermore, Gold Fields gold productions rates decreased by approximately 90% between 2012 and 2014 due to the unbundling of majority of their South African operations. However, their group water consumption increased approximately 30% for continued operations from 23.7 gigalitres 2012 to 30.21 gigalitres during this period.

Looking beyond the above tables, Gold Fiends demonstrated a commitment to CE principles by founding their water project in 2011, called Liquid Gold. This project looks to increase the amount of potable water for the local mining communities. Water treatment is done by the implementation of two reverse osmosis plants which were constructed to treat water from KDC and South Deep operations in 2011. This project was started to manage risk, mitigate AMD and de-watering requirements of the mine (Gold Fields Limited, 2011). This enabled Gold Fields to reuse water in their own operations in addition to reducing their overall water requirements, and thus water costs, from Rand Water Board, a water service provider (Gold Fields Limited, 2013b). Furthermore, pumped underground water and mine waste water were treated to drinking quality at a central treatment facility housed on the Kloof Mine location (Sibanye Stillwater, 2014a).

Liquid Gold also incorporated storm water management procedures which facilitated separating clean surface runoff and mine waste water. This project showed good stakeholder collaboration with the DWA being informed of all elements of the water management strategy (Gold Fields Limited, 2013b). This is a collaboration project between Sibanye and Gold Fields. The general community, including agriculture and business water demand needs were assessed (Sibanye Stillwater, 2014a). Liquid Gold was transferred to Sibanye Gold as part of the restructuring exercise in 2013, with Sibanye Gold calling the project SibanyeAMANZI. By 2014, the new plants were able to supply Rand Water with potable treated water fit for human consumption (Sibanye Stillwater, 2014a).

Gold Fields continued water treatment CE commitments by installing three reverse osmosis in South Deep to treat waste water after the unbundling. However, the current drought conditions in South Africa has led to a two of the reverse osmosis plants being inoperable (Gold Fields Limited, 2016b).

Table 11 below looks at further CE principles to ascertain if Gold Fields follows a circular trajectory.

Table 11: *Gold Fields' CE commitments regarding mine waste water management in South Africa.*

Mining CE sub-principle	**2006**	**2011**	**2016**
1. Facilitate system effectiveness: - Water regenerated - Restorative Waste Management Systems - Excessive waste generation mitigated. - End-of-life/ rehabilitation planned - Waste water costs, included business model	The main waste types produced are waste rock and tailings, which are disposed of in waste rock dumps and tailing storage facilities. Rehabilitation provisions have been increased due to the change in South African regulations. The proposal is that the rehabilitation plans be revised in 2007 (Gold Fields Limited, 2006).	Waste rock is recycled and used in construction projects. Similarly, water is starting to be recycled and reused. Concurrent rehabilitation plans have been implemented across majority of the operations by implementing integrative environmental management policies which are reviewed at each stage of the mining lifecycle (Gold Fields Limited, 2011). However, the excessive waste has not been mitigated and clear waste water costs have not been included in the business model, thus this principle has only been partially met.	Gold Field has identified opportunities and projects to improve their water and waste management plan. They aim to reuse and recycle resources to reduce waste streams and recycled and reused more water than they withdrew in 2016 (44.3Gℓ versus 30.3Gℓ). Further investigation is required to determine the validity of their recycled and reused calculations. Restorative waste systems are currently being reviewed to ensure that rehabilitation efforts optimise operating costs. This should be completed in 2017.
2. Preserve and enhance renewable resources - Waste water reused - Waste management processes eliminate the use of toxic chemicals - Clear Waste Management Plans	Gold Fields acknowledges that waste management is currently followed but does not divulge information regarding details of the plan. Waste water is not reused. Gold Fields disposes of hazardous waste through third parties at permitted disposal sites.	Gold Fields have implemented Liquid Gold, a project which looks at the potential water liability in South Africa and is key to the mines integrated water management strategy. The project looks to reclaim chemicals and minerals that are found as a by-product of water treatment which can add to the profit base. Risk management plans look at containing pollution from runoff, reusing water during processing (starting a closed water system) and recycling water (Gold Fields Limited, 2011).	Due to the divesting in South Africa, Gold Fields' focus is on integrated post-closure water and waste management plans. This will be done by revegetating mines, adequate and technologically advanced water monitoring and treatment to ensure that AMD is prevented or contained and maintaining adequate waste inventory data so that waste can be effectively managed. The programme is due to be finalised in 2017 (2016b).

Mining CE sub-principle	**2006**	**2011**	**2016**
3. Optimise resource yields - Leakages identified - More efficient use of resources - Innovation in water waste maximized	Inter group operations initiatives are underway to identify water leakages and improve pipeline monitoring. Gold Fields believes that water management (especially of legacy issues) should be managed by the South African government in consultation with mining houses. Thus, industrial collaboration efforts for regional waste water management are not effective (2006).	On-site water treatment is being completed at the tailing storage facilities to decrease the risk of AMD and contamination spillages (Gold Fields Limited, 2011). Furthermore, the company is optimising resource yields by using technology during water pumping which monitors the systems to identify efficiencies.	The reuse and recycling values for the group appear to indicate that the system used more recycled and reused water than fresh water. However, water supply issues were experienced in 2015 and 2016 (Gold Fields Limited, 2016b). Due to the lack of individual operation water consumption values, it is undeterminable if Gold Fields has minimized their water-use or are looking at innovative ways to re-design the waste water process.
4. Collaboration	Mining houses set up the Far West Rand Dolomitic Water Association (FWRDA) in 1964 to manage sink hole risks, however the annual report notes that this association cannot be used for '*the regional gold miners' rehabilitation and closure activities*' and should not be considered for waste water management (Gold Fields Limited, 2006).	Various stakeholders are collaborated with to plan the mines rehabilitation and closure plans. The Social and Labour Plan is discussed with government to identify key development areas. Regular engagement is had with the FWDRA. Additionally, Gold Fields founded the Mining Interest Group, which is an industry-wide committee set up to deal with legacy mining issues in the area (2011).	Gold Fields collaborates with Sibanye Gold regarding water treatment and water supply. The two mining houses have a joint working group to review potential legacy contamination issues that affect them. Due to the closure of Ezulwini (a Sibanye Gold Mine), further engagement has been undertaken to ascertain the risk this closure will have on the Gold Fields South Deep operation as well as their supply of water from Ezulwini. Moreover, industry-wide consultations are taking place with government to clarify the proposed Mining Chanter.

Mining CE sub-principle	2006	2011	2016
5. Beneficial Legislation - Tax benefits/incentives - Clear model for provisioning, charges and tariffs - Enforcing legislation through monitoring	Closure plans have been reviewed in terms of the MPRDA requirements, however further closure planning will be undertaken in the forthcoming years. Provisions are made to an environmental trust (Gold Fields Limited, 2006). Gold Fields has noted that environmental data disclosure requires improvement.	Changes in government environmental regulations has been identified as a risk for Gold Fields as the requirements are increasing the potential environmental liabilities that the mine now faces (2011). Environmental liabilities are considered and built into the companies operating model so as to mitigate any future costs. The company reports separate environmental data (including water usage) per operation.	Gold Fields submitted amendments to their 2011 water-use license in 2015 but are currently still waiting for its approval. Many changes have been seen in the regulatory environment in South Africa since the 2014 amendment to the MPRDA, with parts of the bill still awaiting ratification. Government has also indicated that the Mining Charter is being overhauled. Gold Fields, represented by the Chamber of Mines, has applied to the South African High Court for clarity on the proposed Mining Charter. Consultations are taking place between government and the mining industry, with governmental strategies and policies still pending (Gold Fields Limited, 2016b).

Gold Fields CE implementation have increased marginally year-on-year as can be illustrated from their move from red to orange as illustrated in table 10 above. This was predominantly due to their integrated waste and water management plans which look at concurrent rehabilitation strategies to mitigate waste liabilities in the future. A clear increase in water management could be seen with the implementation of the Liquid Gold Project, however this was discontinued after the asset unbundling. Further, updated waste management plans were pending at the end of 2016, with new programmes due in 2017.

The mine is dependent on other mining houses and are affected by decisions made by them. Water supply issues experienced in South Africa have exasperated this dependence on water supply and treatment. Collaboration efforts are often done through the South African court systems to fight government rather than creating an environment where all players can collaborate on projects together, defeating the CE principle of collaboration.

4.3.4. Sibanye Stillwater

The gold mining operations consist of the four South African operations, namely Driefontein, Kloof, Beatrix and Cooke (from 2013 onwards). The gold production figures are represented in figure 23 below. Figure 23 illustrates a marginal increase in production in 2013 due to Cooke becoming operational.

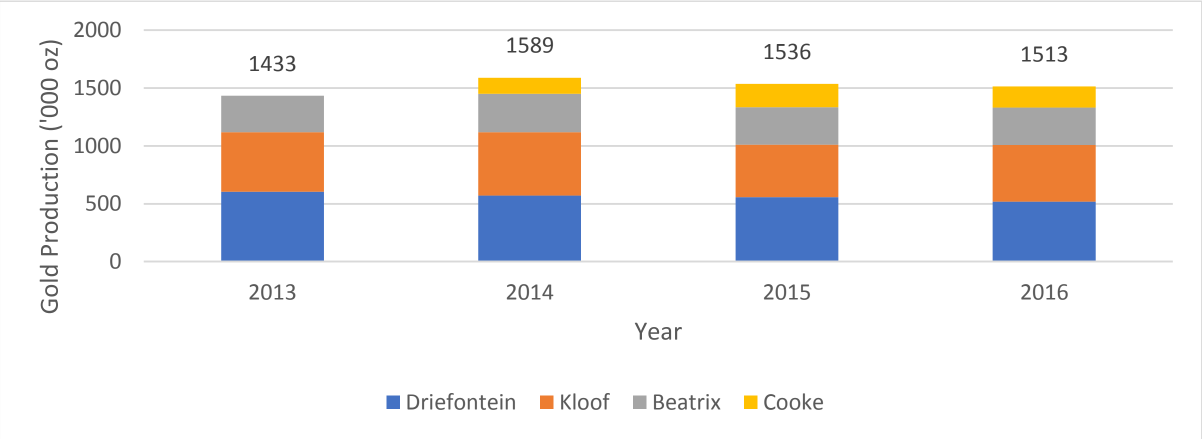

Figure 23: *Graphical gold production for the Sibanye Stillwater's South African operations, as publicised on their website (Sibanye Stillwater, 2018a; Sibanye Stillwater, 2018b; Sibanye Stillwater, 2018c; Sibanye Stillwater, 2018d)*

Sibanye's CE commitments can be found in the water management policies implemented and their keen interest in funding and partaking in innovative projects, such as Mining Phakisa, a government funded project (Sibanye Stillwater, 2016). As a company, their break down in the water data available is considerably more extensive than other gold mining companies, however Sibanye's water data is only available in totality. The company breaks their water data into water withdrawal, which is the total amount of water withdrawn from municipal sources and ground fissure sources; water used, which is the amount of water used in all mining operations and water discharged, which is the uncontaminated fissure water withdrawn at source due to safety requirements but discharged back into the environment without treatment. Figure 24 below depicts a marginal decrease in water used and water discharged over the last four-year period. The 2013 increase in water use and discharge is due to purchase of Cooke.

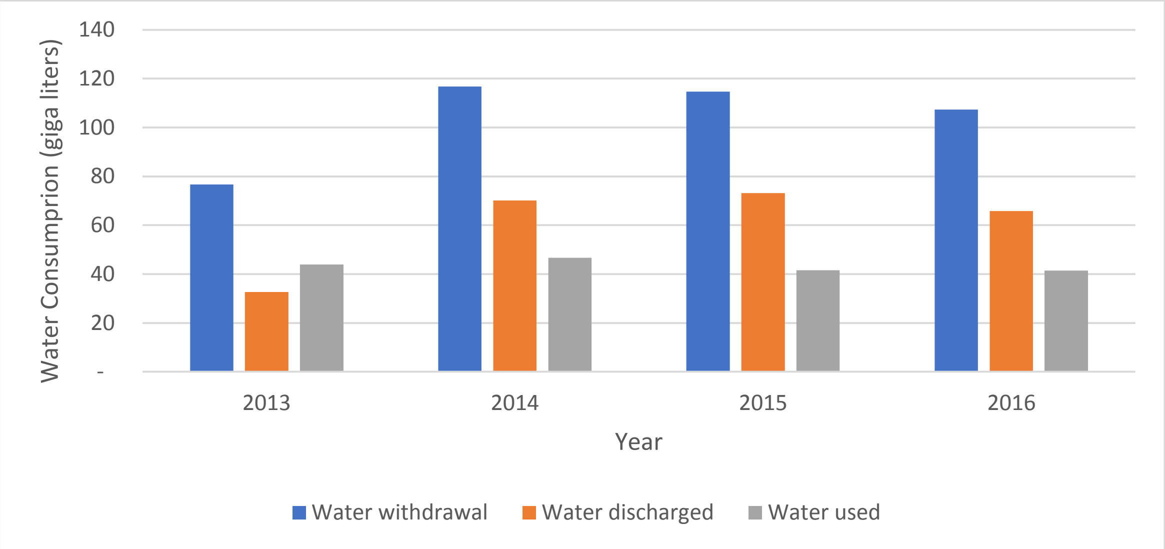

Figure 24: *Sibanye's water consumption, discharge and use from 2013 until 2016 (Sibanye Stillwater, 2014b; Sibanye Stillwater, 2016)*

Following the 2016 DWS regulations for all users to reduce their water purchases by 15%, Sibanye implemented automated water monitoring tools which have helped flag excessive consumption in their operations, as well as potential leakages (Sibanye Stillwater, 2017b). Figure 25 shows the decrease in the average daily water consumption for Sibanye following the implementation of the monitoring systems.

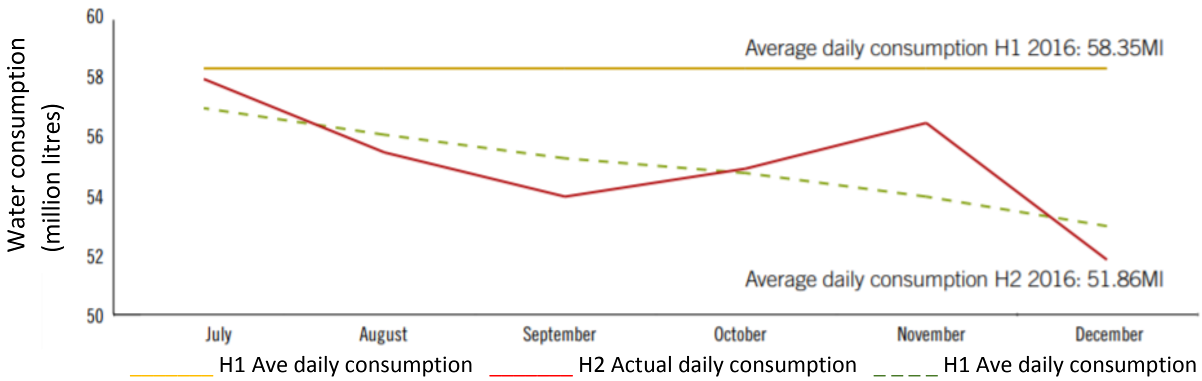

***Figure 25**: Sibanye's average daily portable water consumption after the implementation of water monitoring systems (Ml) (Sibanye Stillwater, 2017b)*

Additionally, Sibanye's AMD and water management project, SibanyeAMANZI, is gaining strides in becoming a proactive integrative water management project (Sibanye Stillwater, 2014a). With the establishment of the water-technology innovation hub, numerous water treatment approaches have been tested to best facilitate by-product recovery and obtain quality drinking water (Sibanye Stillwater, 2014a).

As SibanyeAMANZI matures, multiple issues such as water availability in terms of quality and quantity and regulatory requirements have been identified as project disturbances. New water-use licenses and environmental activity authorisations need to be obtained, as a result of changes in Sibanye's Water Management Policies, before projects may commence. These are often delayed by DWS and the DMR. Legally, mining houses in South Africa, are not allowed to supply water directly to their neighbouring communities and thus are forced to supply water to water service authorities. This perceived handicap of compliance requirements limits the mines from making good water management decisions which could affect the region and not only the individual mine. Mismanagement of municipalities, obligated to be water service authorities, slow down innovative mining water management projects. Finally, Sibanye note that legacy environmental issues interrupt innovative water projects authorisations with the government wanting the mining industry to take ownership of the legacy issues (Sibanye Stillwater, 2017c).

Sibanye follows a sustainability trajectory where they aim to collaborate with all stakeholders by investing in organic projects. CE is not currently a business model which they actively utilize. Further CE commitments can be seen in table 12 below.

Table 12: *Sibanye Stillwater's CE commitments regarding mine waste water management in South Africa.*

Mining CE sub-principle	2016
1. Facilitate system effectiveness: - Water regenerated - Restorative Waste Management Systems - Excessive waste generation mitigated. - End-of-life/ rehabilitation planned - Waste water costs, included business model	Sibanye has thorough water management and rehabilitation plans. Given their water-use licenses, certain percentages of water withdrawn is to be discharged back into the environment to ensure environmental water reserves are maintained. Similarly, waste rock is recycled and retreated in order to reclaim gold. Rehabilitation and closure plans are extensive and include concurrent monitoring of biodiversity, soil and water in affected areas. Given the closure of one of the Cooke shafts (Ezulwini), the closure plans will be tested in the forthcoming years. At a cost of approximately R156 million per year for pumping Ezulwini and treating water, the knock-on effect is set to be felt by other mines in the area (Sibanye Stillwater, 2016).
2. Preserve and enhance renewable resources - Waste water reused - Waste management processes eliminate the use of toxic chemicals - Clear Waste Management Plans	In 2014, water recycle and reuse figures were given per mining operation as Sibanye recirculated mine waste water in their operations (Sibanye Stillwater, 2014b). In 2016 reporting methodology changed with water-use values being shown rather than the recycled and reused volumes (Sibanye Stillwater, 2016). Although Sibanye is in the early stages of a mining company, they have clear waste management plans which look to remove toxic chemicals from their processes.
3. Optimise resource yields - Leakages identified - More efficient use of resources - Innovation in water waste maximized	Sibanye's water and waste management plan minimises water use and optimizes water wastage through metering, water quality and water balance management. Similarly, they use available underground water to replace water supplied by municipalities. Several innovation projects were started, including the four water management projects which will biologically treat mine water and tailings to reclaim minerals and toxins used in mining. Additionally, the modifications to the Western Basin AMD treatment plant and Kloof water treatments plants demineralises mine water and improves water quality (Sibanye Stillwater, 2016). Leakages in the water cycle are identified by using technology and automated metering systems which notify the mine of any issues. An example of this is the water leak found on the Randfontein Estate, which lead to water savings and conservation by being able to quickly identify issues (Sibanye Stillwater, 2017b).
4. Collaboration	The miner collaborates with Gold Fields on multiple levels, one being the Sibanye-Gold Fields Alliance Project. This project looks to upskill the communities affected by mining through creating Agri-parks and small enterprises. Sibanye also supplies Gold Fields with water. Sibanye partakes in the government-funded project, Mining Phakisa. This project was initiated in 2015 to enable innovative initiatives to benefit the whole mining industry. This includes an innovation hub to help with the development of technology and other quick-win

Mining CE sub-principle	2016
	projects. However, lack of collaboration from various stakeholders has delayed development of the project (Sibanye Stillwater, 2016).
5. Beneficial Legislation - Tax benefits/incentives - Clear model for provisioning, charges and tariffs - Enforcing legislation through monitoring	Uncertainty around South African regulations is deterring the company from investing in further projects as the company worries that legislation will impede business operations (Sibanye Stillwater, 2016). Nevertheless, Sibanye's future focus is to develop both individual and regional-based mine closure plans, considering socio-economic impacts and gaining an understanding of the accurate water management costs needed for closure (Sibanye Stillwater, 2016). This will help them better model factual closure costs into their business plans.

Sibanye is a relatively young gold mine operation and has the highest level of CE implementation out of all the gold miners analysed. Collaboration would be green; however, efforts have been noted as a concern due to sluggish stakeholders. They currently have good reporting standards and access to data. Similarly, several ambitious innovation projects are referred to, which if implemented could follow majority of the CE principles.

4.3.5. DRDGOLD

Gold production figures for DRDGOLD, as seen in figure 26 below, show the changes in operations due to closing operations in South Africa. There is a gradual decrease in gold production by the company between 2006 and 2016. A decrease in gold production in 2012 of approximately 40% is due to the sale of Blyvooruitzicht.

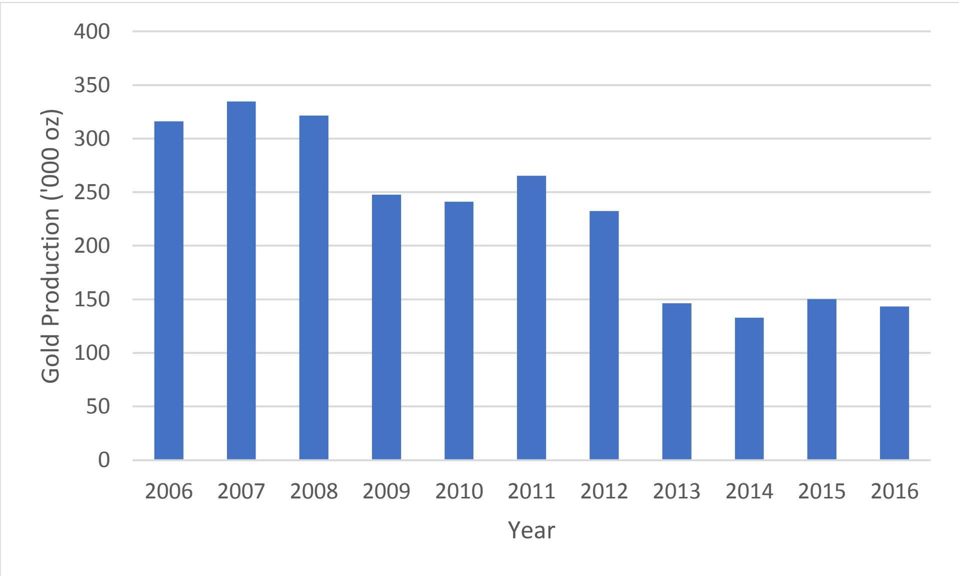

Figure 26: *Adapted gold production for DRDGOLD's South African operations from 2006 until 2016 (DRDGOLD Limited, 2006; DRDGOLD Limited, 2011; DRDGOLD Limited, 2013; DRDGOLD Limited, 2016a)*

As depicted in figure 27, water consumption values are not publicly available between 2006 and 2008 and thus these periods are unable to be analysed. Although a decrease can be seen in the company's water use, there was a 30% increase in water in 2016. This was primarily due to low rain fall volumes and thus potable water irrigation was required for the Crown vegetation project. Additionally, issues were experiences when dirty water reused caused production failures, which meant that extra fresh water was used in place of recycled water (DRDGOLD Limited, 2016b).

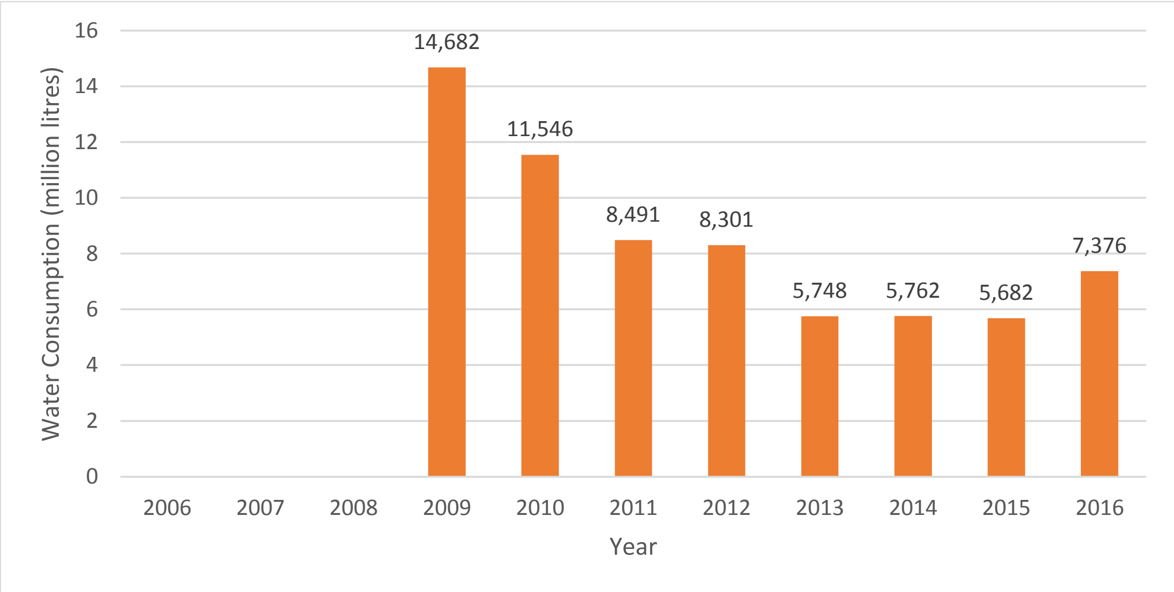

Figure 27: *Adapted water consumption for DRDGOLD's South African operations from 2006 until 2016 (DRDGOLD Limited, 2006; DRDGOLD Limited, 2011; DRDGOLD Limited, 2013; DRDGOLD Limited, 2016a)*

Their CE commitments were analysed in table 13 below.

Table 13: *DRDGOLD's CE commitments regarding mine waste water management in South Africa.*

Mining CE sub-principle	**2006**	**2011**	**2016**
1. Facilitate system effectiveness: - Water regenerated - Restorative Waste Management Systems - Excessive waste generation mitigated. - End-of-life/ rehabilitation planned - Waste water costs, included business model	Water discharge volumes and quality are observed and reported to DWS. No mention of water recycled or reused in operations. The mine follows a concurrent rehabilitation plan which is set to decrease the final end of mine liabilities. No finite plans are mentioned regarding how this will be done.	Integrative environmental management plans look at raising potential internal risks and completing EIA's. DRDGOLD is currently growing their recycling business (reclaiming gold in waste). DRDGOLD is unable to financially provide their rehabilitation provisions and thus DRDGOLD has proposed alternatives to the DMR for review. Furthermore, DRDGOLD has approached the DMR to transfer the environmental rehabilitation responsibilities of two mines to a different company.	The company recycles water and has started adapting infrastructure so that the recycled water can be reused in operations. DRDGOLD's EMP contains rehabilitation plans for all operations run by them. This includes the closure plans and the financial provisions made to make closure possible. The company intends to obtain closure for their rehabilitation sites concluded in the next five years (DRDGOLD Limited, 2016b).
2. Preserve and enhance renewable resources - Waste water reused - Waste management processes eliminate the use of toxic chemicals - Clear Waste Management Plans	DRDGOLD is completing the analysis of environmental risks the company faces. Waste data collection has started to ascertain the toxic waste content. However clear waste management plans are still pending.	The water management plan solely measures water usage. However, the company is considering using pumped underground water for their surface gold retreatments plants. DRDGOLD is at risk of failing to comply with new regulations to monitor air and water quality and hazardous waste as environmental requirements increase. A clear lack of innovation is seen regarding environmental liabilities and the management of such.	No toxins or chemicals are referred to in the Annual Report. AMD continues to be a concern for the company, given that their main business line is to reclaim gold from legacy tailing facilities. Water and waste management programs use water treatment plants to treat water for reuse in operations. A second waste water treatment plant has been proposed which will increase the amount of waste water reused in processes.
3. Optimise resource yields - Leakages identified - More efficient use of resources - Innovation in water waste maximized	See above.	DRDGOLD tries to minimise water use by recycling waste water. They supply two Blyvooruitzicht employee villages with water. The Blyvooruitzicht mine also discharges water in the Wonderfontein Spruit which has been reported to the DWS as being of good quality. A treatment plant has been started here to treat water to be reused in their Blyvooruitzicht operations.	Fresh water use has been minimised due to the reuse of recycled water in the operations. Innovative technologies and processes '*designed for extraction efficiency*', are used for gold reclamation operations with the expectation that these limit environmental impacts. Although the company believes in innovation as a core to business, understandably the exact innovation projects are not described in the Annual Report (DRDGOLD Limited, 2016b).

Mining CE sub-principle	2006	2011	2016
4. Collaboration	Due to underground water pumping required to stop flooding, a committee has been started with other mines in the region. This committee will also review water pollution issues faced by the mines near Wonderfontein Spruit (affects the Blyvoor mine). Legal action was taken after DRDGOLD's North west mining operations were closed as the water pumping fell to other miners in the areas. The regulators ruled that water pumping is the responsibility of all miners in a region, even if it originates from closed mines in the region.	DRDGOLD is part of the Mining Interest Group (founded by Gold Fields) which has been set up to engage with government (DMR, DWS and DEA), municipalities, local authorities, public stakeholders and communities. Along with other mining houses, DRDGOLD submitted a potential solution for treating AMD on their mines by treating all waste water from multiple mines in a centralized location at one of DRDGOLDS mining operation and discharge any new water into the Tweelopies Spruit. This proposal was rejected by government and the annual report states that the government has accepted the responsibility of treating AMD. There appears to be a breakdown in communication between DRDGOLD and the government regarding solution finding or collaboration efforts.	DMR with the support of the DWS have appointed TCTA to implement the start of their AMD treatment plan by upgrading water plants in each of the water basins affected. DRDGOLD has signed an agreement leasing land and allowing TCTA to dispose of their by-product on their Ergo tailing facility. They will use TCTA treated grey water in their operations. No further mention is made of the Blyvooruitzicht mine closure or the current issues being faced at this operation in their financial or annual report. The lack of solution finding or collaboration on the closure of one of their assets is of concern regarding the company's collaboration efforts. Thus, this sub-principle has not been met.
5. Beneficial Legislation - Tax benefits/incentives - Clear model for provisioning, charges and tariffs - Enforcing legislation through monitoring	DRDGOLD makes environmental provisions to a trust fund to cover the expected environmental liabilities faced at closure. According to the Annual report they are in compliance with MPRDA with their provision increasing by 19% in 2006 (DRDGOLD Limited, 2006).	DRDGOLD noted the increasing environmental laws which they are becoming subjected to and how these regulations have the risk of affecting profitability, raising the question regarding environmental costs being built into their business operating models. As the ensure current compliance of legislation, it is arguable that the company does not forward-think about potential environmental legislation (and thus costs) in the pipeline, but rather attempts to deter liability by using the Company's	Systems are used to manage mining and environmental legislation. These include reporting to stakeholders and ensuring data is management and stored. Currently water-use licences for two mining operations are pending, which raises a legislation compliance risk. Additionally, the auditors have provided limited assurance on the company's environmental reports for 2016 (DRDGOLD Limited, 2016b). According to the rehabilitation provision in their Integrated Report, DRDGOLD invests provisions

Mining CE sub-principle	2006	2011	2016
	The concurrent rehabilitation plans are said to lower the final rehabilitation liabilities.	Act to change the company structures and ring fence responsibilities until these can be liquidated.	in an environmental fund and plans to make up the environmental liability short fall by the sale of remaining assets at the operations (2016a).

DRDGOLD appears to be under constant pressure to ensure that environmental liabilities are provided for. Their reports state that the mine follows a concurrent rehabilitation plan which is set to decrease the final end-of-mine liabilities (DRDGOLD Limited, 2016a). However, as a mine they do not provide adequate financial provisioning to support end-of-mine and their business models do not have waste and water management correctly accounted for. Additionally, no finite plans are mentioned regarding how their waste and water management will be done. DRDGOLD's EMP contains their rehabilitation plans for all operations run by them. This includes the closure plans and the financial provisions made to make closure possible. The company intends to obtain closure for their rehabilitation sites concluded in the next five years (DRDGOLD Limited, 2016b).

According to the rehabilitation provision in their Integrated Report, DRDGOLD invests provisions in an environmental fund and plans to make up the environmental liability short-fall by the sale of remaining assets at the operations (2016a). The readers are not provided comprehensive information as to how the rehabilitation provisions will be utilized and the reporting lacks transparency and accountability. In the Blyvooruitzicht case discussed in 2.5 above, Liefferink (2014) found that Blyvooruitzicht had only provided R35 million of the approximate R891 million required for environmental liabilities. The environmental damage was primarily due to radioactive and toxic tailings which caused both water and soil contamination. This indicates that even if regulation is implemented, mining houses such as DRDGOLD can damage the industry as well as the environment due to government's lack of monitoring. This reckless mentally left Blyvooruitzicht residents stranded when DRDGOLD cut losses at the mine and abdicated their responsibility towards society and the environment after a defunct sale of the Blyvooruitzicht to Village Reef Mines.

In 2006 DRDGOLD noted on the issue of dewatering ownerless mines, that "t*his raised major issues for the entire mining industry, as clearly there was a serious disconnect between environmental and corporate law and no mining company wanted a precedent to be established that would add environmental costs at their disused mines*" (DRDGOLD Limited, 2006, p. 32).

Following the above trajectory, it is difficult to believe that DRDGOLD follows any definitive environment and waste management plans. However there has been a marginal increase in their CE implementation year-on-year. Collaboration is of concern for the miner as it has consistently stayed red. Their reports often criticize and chastise government for not contributing more actively in cleaning up the AMD legacy issue in the gold mining areas, nor accepting their solutions to the water management issues. This fault-finding behaviour erodes collaboration as blame deflecting is attempted rather than engaging in constructive innovative debates to find solutions.

5. DISCUSSION

In summary, this research set out to investigate whether CE principles are supported by South African legislation and if there is an uptake in the CE principles used by the gold mining industry regarding water management. Chapter 4 identified five main CE principles relevant to gold mining, being: (1) Facilitating system effectiveness; (2) Preserving and enhancing renewable resources; (3) Optimising resource yields; (4) Collaboration and (5) Enhanced business models which entail transparent regulatory reporting.

5.1. Legislation discussion

The key legislative frameworks governing waste management in the mining industry meets a majority of the CE principles. NEMA and NEM:WA support CE principles better than the other legislative elements examined, as evidenced by the green cells in tables 3 to 7. However, gaps have been identified within all legislation which can be seen by the red cells in these tables. These gaps relate to the sub-principles of water regeneration, restorative systems and incentivised benefits to implement the CE.

Water regeneration or the possibility of waste systems being restorative in nature is not a legislative requirement. Although legislation calls for adequately treatment of environmental damage, the system does not need to function better than before mining occurred. Equally, there are currently no incentives to design out waste or follow CE principles. These incentives need to look beyond the mining company and encompass all industries to look for better waste management solutions to leverage opportunities from waste. Government incentives help fund companies to become more innovative.

Part 7 of NEM:WA which calls for IWMP per sector should be updated to look at cross industry waste management plans. These strategies should look for innovative solutions to change the paradigm from waste-as-a-cost, to waste-as-a-profitable-alternative-revenue-stream. Further recommendations are discussed below in 6.1.

5.2. Case study discussion

The case study, focusing on water management, indicates that the level of CE implementation in the gold mining sector in South Africa has broadly increased over the past 10-year period by all five mining houses. Improvements can be seen by the mining houses sampled, in the changing of colour from red to green in the tables 8 to 12 above. However cross-industry collaboration is lacking with mines not collaborating with other industries on the water issues faced by all industries.

For CE to be really integrated, it needs to be integrated in the full economy with multiple players being engaged and different industries collaborating on issues. This worked very well in the Anglo American's eMalahleni Water Reclamation Project, as mentioned in the literature review. Emalahleni showed excellent cross-industry collaboration (ICMM, 2012, Anglo American, 2012). Traditionally, the mining industry is a competitive industry that uses cost reductions for competitive advantage. The CE calls for industry to have open discussions regarding how something can be done better as a collective so that all mines can benefit. This principle should be a focus area for the mining industry.

Environmental reporting standards have increased across the board, with the exception that a majority of the mining houses obtained limited assurance on these figures by their auditors, making their reliability and validity difficult to verify. A challenge is that each financial report refers to differing water consumption terminology making the company reports difficult to compare. To illustrate, Sibanye provides water-use figures which are broken down into different categories (withdrawn, discharged, used), whereas DRDGOLD only provides water used and water recycled. The non-standardisation of environmental information makes analysing the reports difficult. Further reporting issues were found where data which was publicly available in a prior reporting report is no longer publicly available when water use calculations change. This makes comparing data for a company and across companies difficult. Trying to find publicly available data was a challenge. Even though legislation regarding monitoring of environmental liabilities is clear, companies tend to lack transparency in their environmental data and how they intend to implement their strategies which have been reported on. On a positive note, a clear change can be seen in the information which is provided year-on-year, as well as companies' efforts to implement cleaner production and waste management hierarchies (aspects of the CE principles).

Mudd (2009) found that environmental externalities, including climate change and completing rehabilitation projects and cost forecasting of these, are some of the issues currently facing the mining industry. This research found that the five mining houses studied had the potential of not adequately providing for mine closure and assumed that their AMD-generating-potential risks will decrease when mining ceases. Oelofse, et al. (2007) found this mentality to be flawed and that environmental liabilities were not currently fully covered by the polluter. This has been seen to have a knock-on effect on all other industries and communities affected by sudden closure. This example was illustrated by the sudden Blvooruitzicht mine closure (Lawyers for

Human Rights, 2017). This demonstrated how the mining house had used language such as "concurrent rehabilitation plans" as a means to lower the final rehabilitation liabilities, but upon investigation, rehabilitation provisions were underprovided for. The "concurrent rehabilitation plans" language could be seen across the gold miners studied.

Based on the finding above, gold mining in South Africa would be a prime candidate for advancing the implementation of CE principles to facilitate effective regional and national water management. Furthermore, it could include CE uptake for other commodities, other resources (electricity, air and biodiversity) and then finally look at how CE can be implemented in water management in other industries. Other areas for research include looking at the CE principles in terms of different waste streams affected by mining.

6. CONCLUSION AND RECOMMENDATIONS

The research found that CE principles, such as reusing water, recycling water, enhancing renewable resources, eradicating toxic chemicals and collaboration have broadly been applied to and adopted by the mining industry. This is specifically evident in Anglo American's eMalahleni Water Reclamation Project which used CE principles in its development.

Five key principles relevant to gold mining waste water management were ascertained, namely: (1) Facilitating system effectiveness; (2) Preserving and enhancing renewable resources; (3) Optimising resource yields; (4) Collaboration and (5) Legislation. These CE principles are mostly facilitated through mining legislation in South Africa. The exception being that restorative systems are not prioritized by legislation and CE implementation is not incentivised in mining. No major legislation inhibited the way in which CE principles can be applied to the gold mining industry in South Africa.

6.1. Legislation recommendations

Although the legislation is adequate and good in places, the focus should be on implementing collaborative strategies which take the current legislation and promote innovative ways in which waste management can be modernised across industries.

Legislation could be strengthened with regards to government incentivising companies to implement better waste management plans to account for all environmental externalities, as well as improving the monitoring thereof. However, clarification is needed concerning the differences between the Insolvency Act versus the MPRDA regarding liquidation and how the financial provisioning can be both assessed and accessed to implement mine closure and prevent environmental externalities in the event of sudden closure, should mining houses file for bankruptcy. This confusion is currently a major gap identified during this research, with the Blvooruitzicht mine showing the dire negative consequences of delayed reaction-times by stakeholders (Lawyers for Human Rights, 2017).

As referred to in the literature review, within the South African context, government (like most other governments) has identified legislation to monitor the mining industry and their environmental liabilities. Legislation should be applied on a regional basis, calling for gold mines to collaborate more closely together regarding their regional waste management. Similarly, Part 7 of NEM:WA which calls for IWMP per sector should be updated to look at cross industry waste management plans. These strategies should look for innovative solutions to change the paradigm from waste-as-a-cost, to waste-as-a-profitable-alternative-revenue-stream.

Although this research focused on waste water management in gold mining, such enhancements to the legislative landscape of including incentivization, clarity regarding liquidation and financial provisioning and promoting collaborative strategies can be applied to the mining of other commodities, their waste streams and natural resources utilized by all mining houses in South Africa, as the same legislation governs mining across all commodities and waste streams.

6.2. South African recommendations

Focusing on waste water management, the level of CE implementation in the gold mining sectors in South Africa has increased over the past 10-year period. However as discussed above in 5.2. environmental reporting terminology is not standardised in South Africa, making their reliability and validity difficult to verify. One recommendation would be that legislation should mandate what environmental data is presented, for how long it should be held and what metric to use in showing the data. This would remove the ability of companies to distort or misrepresent their information or to hide behind confusing or over-simplified data or metrics.

6.3. Global recommendations

Although this research looked at mine water waste in gold mining in South Africa, water issues are global and there is a growing awareness of the challenges faced by miners and other industries such as manufacturing. Thus, this research looking at CE in gold mining waste water management is equally relevant in other mining industries both in South Africa and globally. Similarly, the case study looked at international mining houses based in South Africa. These are global companies that are facing similar issues at their international locations and thus this research could be relevant to their other locations.

6.4. Limitations and future research

Although the Ellen MacArthur Foundation (2012) views the mining industry as a feeder to the circular model, systems thinking shows that the environment is a sum of all its parts. A crucial area for future research would be looking at the validity of including mining more fully in the CE definition. Understanding that this could require a change in CE definition where product responsibility would no longer rest with manufactures but rather with the miners in contravention to the current CE definition where the manufactures bare responsibility for the product and thus the resources which make up that product (Bocken, et al., 2016, Ghisellini, et al., 2016, Lieder & Rashid, 2016).

One of the limitations to using a case study and quantitative research techniques in a mixed research approach is the lack of direct interaction and fieldwork with the companies (Johnson & Onwuegbuzie, 2004). Publicly available data may not always convey the complete environmental situation within a company.

Further research is suggested to perform fieldwork through direct interaction with the companies to validate and test the results. This would provide better deductions regarding the uptake of the CE principles in the mining industry in South Africa. Further research with access to data would be able to show a company’s uptake in technology in their waste water management programmes, something that was not able to be ascertained in this research.

Although not definitively studied in this research, the CE implementation in smaller and more localised mining houses is an area for future research. Reviewing small to medium miners would be fascinating, especially looking at the area of collaboration and their access to larger mining houses, inter-industry companies and government.

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