A Feasibility Study for Cemented Tungsten Carbides Recycling in South Africa to Support Investment Decisions

by
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Thesis presented in fulfilment of the requirements for the degree of Master of Engineering (Engineering Management) in the Faculty of Engineering at Stellenbosch University

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December 2018

Declaration

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Abstract

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This study evaluates the financial feasibility of recycling tungsten carbide in a South African context. This study is inspired by the inevitable value creation opportunities that accompanies the large amounts of tungsten carbide waste generated by the mining and tooling industry in South Africa. This is a unique waste-to-resource opportunity to deliver tungsten carbide to South Africa, as tungsten is not a widely available resource in this country, and therefore tungsten carbide must be imported for local use.

The first objective of this study was to gain a thorough understanding of the different tungsten carbide recycling methods and to map these value creation opportunities. The second objective was to understand the key elements which must be considered when conducting a financial feasibility study. The third objective was to financially model a selected number of recycling methods. The final objective was to create a business case with a feasibility framework.

An industrial partner, Pilot Tools (Pty) Ltd was consulted to gain general knowledge of tungsten carbide recycling plant inputs. Three recycling methods were selected and modelled financially, namely: the zinc recycling method (PRZ), the coldstream process, and acid leach method. Each of the three selected methods were modelled three times, each time at different capacities, resulting in nine models. Two direct recycling methods and one indirect recycling method were chosen to model. The financial model uses a factorial method which requires the input costs of equipment, raw material, labour, utilities, and waste treatment to estimate the total manufacturing costs and capital investment needed. input from specialists, data from literature and quotations were used for the equipment costs and adjusted using the Lang factor method. From this model a ten-year net present value (NPV) analysis is done on all nine processes.

A scenario analysis is conducted to determine the biggest risks of each input value to the ultimate ten-year NPV value. The NPV analysis and the scenario analysis forms the basis from which the business case is created. The final output of the study was a business case detailing when each of the recycling alternative becomes viable. This study found that all three of the recycling processes are financially feasible. The coldstream and zinc recycling processes are a much safer investment option as shown with the scenario analysis. The scaling opportunities of these two methods are also more financially viable than that of the acid leach method.

Due to the nature of the problem no one "best" option can be chosen, but the business case attempts to provide a best scenario given the decision criteria of investors. The best configuration for the zinc recycling method is the process optimised for 45.5 kg/h throughput. The process breaks even at 48.5% of maximum capacity with an IRR of 51.34% and a NPV of R127.88 million. The best configuration for the acid leach process is at 68.75 kg/h. The process breaks even at 82.50% of the maximum capacity with an IRR of 16.96% and a NPV of R72.94 million. The best configuration for the coldstream process is at 44.5 kg/h. The process breaks even at 49.50% of the maximum capacity with an IRR of 51.31% and a NPV of R131.39 million. Using the knowledge in gained in this study, a business case for tungsten carbide recycling in South Africa is created.

Opsomming

’n Haalbaarheidstudie vir Versterkte Wolfram Karbied Herwinning ter bevordering van Beleggings Besluite in ’n Suid Afrikaanse Konteks

(A Feasibility Study fot Tungsten Carbide Recycling in South Africa)

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Hierdie studie evalueer die finansieële haalbaarheid om wolfram karbied binne ’n Suid Afrikaanse konteks te herwin. Die studie word geïnpsireer deur die waarde toevoegings geleenthede wat gepaard gaan met die massa skroot wolfram karbied wat gegenereer word deur die myn en vervaardigings sektore in Suid-Afrika. Hierdie bied ’n unieke afval-tot-hulpbron geleentheid om wolfram karbied aan die Suid-Afrikaanse vervaardigins mark te lewer, aangesien dit ’n skaar hulpbron is wat meestal ingevoer word.

Die eerste doel van die studie was om ’n deeglike verstaan van die verskillende herwinnings prosesse, asook die gepaardgaande waarde toevoegingsgeleenthede, te bekom. Die tweede doel was om die sleutel elemente wat hierdie prosesse beïnvloed op ’n operasionele vlak sowel as ’n finansiele vlak te verstaan. Die derde doel se mikpunt was om finansiële modelle van ’n aantal verkose proseese te bou. Die vierde en laaste doel was om om ’n haalbaarheids raamwerk te ontwwikkel, wat beleggers assisteer om ’n beleggings besluite in terme van die herwinning van wolfram karbied te neem.

'n Suid-Afrikaanse maatskappy en bedryfsvennoot, Pilot Tools (Pty) Ltd, was geraadpleeg om algemene wolfram karbied proses insette te bekom en die prosesse beter te verstaan. Na aanlyding van die besoek aan Pilot Tools, sowel as die literatuur studies, is drie prosesse gekies om finsieël gemodeleer te word. Die drie verkose prosesse is: die sink herwinnings proses, suur loog proses, asook die coldstream proses. Elkeen van die drie prosesse was drie keer gemodeleer teen verskillende maksimum kapasiteite. Die uiteinde is dus nege modelle. Die finansieële model maak gebruik van 'n faktoriaal metode wat insetkostes van toerusting, rou materiale, arbeid, water en elektrisiteit, en afval verydering gebruik om die totale vervaardigingskoste en nodige kapitale beleggings te bepaal. Insette van spesialiste, data uit literatuur en kwotasies is verkry om die toerusting kostes te bepaal. Die kwotasies was aangepas deur die Lang faktor metode te gebruik. Die finansieële model word gebruik om 'n tien jaar netto huidige waarde analise uit te voer op die nege modelle.

'n Senario analise word uitgevoer om die risiko van elke insetwaarde op die uitsette te bepaal. Die netto huidige waarde analise, gelykbreeksanalise, sowel as die senario analise vorm die kern van waar die haalbaarheids raamwerk ontwikkel word. Die haalbaarheids raamwerk detaileer ook teen watter deurset elkeen van die prosesse lewensvatbaar raak. Die studie het bevind dat elkeen van die drie prosesse haalbaar is. Die coldstream proses en sink herwinnings prosesse is egter as meer finansieel lewensvatbare opsies deur die senario analise bewys. Hierdie twee prosesse kan ook makliker en veiliger geskaleer word as die suur loog prosess.

Die probleem verleen hom nie aan een "beste" oplossing nie, maar die haalbaarheids raamwerk probeer om 'n beste oplossing vir gegewe scenarios te beskryf. Die beste opset vir die sink herwwinnings proses is waar die proses geoptimeer word vir 45.5 kg/h deurset. Die proses breek gelyk by 48.5% van die maksimum kapasiteit van die proses met 'n interne opbrengskoers van 51.34% en 'n netto huidige waarde van R127.88 miljoen. Die beste opset vir die suur loog proses is waard die proses geoptimeer is vir 68.75 kg/h. Die proses breek breek gelyk teen 82.50% van die maksimum kapasiteit met 'n interne opbrengskoers van 16.96% en 'n netto huidige waarde van R72.94 miljoen. Die beste opset vir die coldstream proses is waar die proses geoptimeer word vir

44.5 kg/h deurset. Die proses breek gelyk by 489.5% van die maksimum kapasiteit van die proses met 'n interne opbrengskoers van 51.31% en 'n netto huidige waarde van R131.39 miljoen. Die kennis verkry deur adie verskeie analises word gebruik om die haalbaarheids raamwerk te bou.

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Chapter 1

Introduction

This chapter explores the research problem and background of Tungsten Carbide-Cobalt recycling. Important aspects of tungsten carbide (WC) in a South African as well as a global context are discussed, with emphasis on the creation, recycling, and beneficiation of WC-Co scrap. The above provides a background to the research problem. This section further discusses the aims and objectives of the thesis. The reasons for conducting the research is also clarified. A theory and literature analysis provides an overview of the intended research as well as some critical analysis of relevant literature to better understand the challenges faced by this industry. To conclude, the scope and limitations, as well as the importance of the research are explored and discussed.

1.1 Background and Motivation

Tungsten carbide is a compound containing the same amounts of tungsten and carbon atoms. Cemented tungsten carbide is traditionally widely used in tools for metal cutting and rock drilling. Tungsten carbide cobalt composite materials are so-called hardmetals and is the most widely used material in hard-facing applications according to **?**. The wear resistance and fracture toughness properties are significant features of tungsten carbides and even more so for cemented tungsten carbides. This group of materials can withstand deformation, impacts, heavy loads, high pressures, corrosion, and high temperatures.

(**?**)

Recently this material has entered the medical and agricultural industries due to its high wear resistance properties. Cemented WC is now used in the tooling, mining, agricultural, and medical industries. The first WC containing 6 wt% Co cemented hardmetal appeared in 1926 under the name ”widia” meaning ”diamond-like” due to the materials superior hardness and wear resistance, with a patent issued to Osram Studiengeselchaft, a German company in the same year. (**?**)

South Africa falls outside the top eight countries producing tungsten. The total amount of tungsten originating outside of these eight countries amounts to only 12% of total tungsten production. This means that South Africa has to import most of the tungsten needed for WC production purposes or import the already processed WC powder directly. For emerging manufacturing countries such as South Africa, tightening restriction on exports of tungsten materials by the largest producer of tungsten, China, is increasing the total cost of importing tungsten and tungsten-containing materials such as WC as demand increases and global supply decreases.
(**?**)

If present production volumes of tungsten carbide continue, then the worlds resources may be depleted in roughly 40 years. This leads to recycling of tungsten carbide becoming increasingly important in a global context as well as a South African context as the main component of tungsten carbide products, tungsten, is subject to supply risk (**?**). WC is ranked second on the British Geological Surveys (BGS) supply chain criticality list. Tungsten is a finite and scarce raw material, therefore saving and recycling of tungsten products becomes important and even necessary. Recycled materials emit roughly 40% less carbon dioxide and require 70% less energy to produce the same amount of WC, as mined earth contains between 0.3% to 0.5% tungsten. Therefore 15 tons of mined earth yields roughly the same amount of tungsten as recycling 70kg of tungsten carbide (**?**). WC-Co forms the basic structure from which other cemented carbides are formed. Thus the availability of this specific composition is vital to the whole industry of cemented carbides.

Tests for WC-Co recycling were done in South Africa at Pilot Tools (Pty) Ltd. These tests were based on the zinc recycling process (PRZ) and the acid leaching methods (AC), both of these processes are widely used throughout the world. The tests focussed specifically on whether the recycled powder was suitable for mining applications. The tests were successful in the sense that the PRZ process was able to produce powders suitable for manufacturing alloys within the benchmark ranges for mining tools. The powder obtained from the AC process is unsuitable for manufacturing mining-grade tools, but can be used for other commercial applications (**?**). According to **?**, tungsten carbide recycling is not limited by the currently available technologies, but by the lack of the appropriate post-consumer collection efforts.

Local South African companies such as Element6, Speciality Metals, and Pilot Tools manufacture tungsten carbide products for the tooling, mining, and agricultural leaders globally as well as in South Africa. Production by Element6 is mainly focussed on producing tooling products and manufacturing machine parts such as inserts, wear part tools, mill rolls, drill bits, and recycling tools. Speciality Metals focus on the production of tungsten carbide powders for different applications such as cast tungsten carbide products as well as sintered products. Pilot Tools focus on producing milling, drilling, and turning inserts. These companies produce a large amount of WC scrap. However, the most scrap produced in South Africa will be from end-of-life mining and tooling products.

The tungsten carbide scrap is sold to local scrap dealers such as Speciality Metals. This presents a problem as local scrap dealers do not have the needed knowledge or process capabilities to recycle WC locally, and subsequently they export the scrap to international markets or sell to companies such as Sandvik, Kennametal, and Globemetal who recycle the WC scrap to WC powder or an intermediary product, ammonium paratungstate (APT). The recycled WC is then imported as either WC powder or other WC products, at a premium. This opens the opportunity for South Africa to start recycling WC scrap locally, and cut out the transportation, export, and import costs, and create employment opportunities locally.

The tungsten carbide scrap beneficiation processes must be sustainable and be applied inside of South Africa. If these beneficiation processes is successful, then all downstream operations within the tungsten carbide industry will be positively influenced by less expensive input materials and costs. The proposed research will explore the different recycling possibilities for WC scrap. Current infeasible possibilities will also be explored so as to remain relevant in the future by helping with the making of informed decisions regarding recycling options as well as strategies.

? said ”In recent years, stringent environmental controls and resource conservation policies have led to renewed interest in developing W recycling techniques that are not only economically viable but also ecologically acceptable. Thus, direct recycling techniques, i.e. transformation of the as-supplied scrap to a product of commercial value by physical or chemical means, are becoming increasingly important, compared to indirect recycling via the APT route.”

All of the above drives the need to evaluate the different recycling processes in terms of economic feasibility and long-term viability in South Africa

1.2 Research problem statement and objectives

The research problem and objectives are set forth in this section. The importance of this study is also briefly discussed.

1.2.1 Problem Statement

The author of this paper could find little evidence of cemented tungsten carbide recycling efforts in South Africa, with the only know recycling plant being the one situated at Pilot Tools in Johannesburg.

This research study should answer the question as to which recycling methods will be financially feasible within South Africa, given the current standing as well as the future projected standing of the WC market in South Africa.

A general lack of knowledge in the area of recycling exists in South Africa and therefore this research should provide decision support as to which WC recycling method is the best suited to create value from WC scrap. This should be true for current as well as future business scenarios. The research should take into account the financial feasibility of each method used.

1.2.2 Research Aim and Objectives

The intended research set forth in this document aims to investigate tungsten carbide cobalt recycling by identifying the different methods available to recycle tungsten carbide cobalt scrap originating from different sources. The scrap originates from different sources as it is used in different compositions in different industries.

This study seeks to identify the feasibility of different recycling methods. The feasibility is analysed in terms of the financial feasibility of each method.

By analysing the financial feasibility, assistance is provided for decision making as to the best current recycling method. The goal of the study is to create value from locally produced cemented tungsten carbide scrap by assisting with selecting the best recycling method to add the desired value. Waste to resource theory applies here.

To reach the aims three objectives are developed. The objectives are:

1. Identify, research, and map the different methods available for the recycling of tungsten carbide scrap.

2. Identify key elements influencing the selected projects.

3. Create cost models to evaluate the financial feasibility of selected tungsten carbide recycling methods in South Africa.

4. Create a business case for tungsten carbide recycling.

1.2.3 Scope, Assumptions and Limitations of the study

The main focus of this study is on straight cemented WC grades with a particular focus on WC-Co, as this is the most common alloy used in the South African mining industry. Non-straight cemented WC grades containing more than one cementing ingredients such as nickel as well as cobalt will not be discussed in this study.

Scraps obtained from manufacturing processes (new scrap) are not included in this study as these materials are usually recycled within a process and is thus not available for large scale collection and subsequent recycling efforts. Scrap obtained from end-of-life products (old scrap) are included in this study as this form of scrap is prevalent in South Africa. As mentioned in the previous section, scrap originates from different industries, which results in scrap consisting of different compositions. Due to this this study will mainly focus on scrap from the mining sector in South Africa.

The study assumes that the process input scrap is kept separate from other materials and that the scrap is already sorted and prepared for the recycling processes. The output material of each recycling method will be used as the basis of the economic analysis performed in this study, thus no further production steps will be performed.

The scope of the decision support model is limited to support for an investment decision and therefore does not take into account decision support for a finance decision.

1.2.4 Importance of the research problem

The proposed research has several economic advantages to South Africa. The advantages include:

- By implementing the research proposed in this document. More jobs will be created with a WC recycling value chain in South Africa.
- The sustainable recycling of WC scrap sourced from South Africa will result in downstream operations to be positively influenced by the reduction in cost of sourcing raw tungsten carbide.
- By recycling locally South Africa can reduce its dependence on imported raw tungsten carbide, thus decreasing the already substantial trade deficit and empowering local people and companies to add value to the economy of South Africa.

1.3 Research Approach and Strategy

The research approach will consist of comprehensive literature studies on the following areas:

- The properties, applications and production of WC
- Recycling Methods for WC products from different sources
- Financial Modelling

The literature studies will identify relevant literature which will form the basis for the research study. The next step for the research study is to develop a feasibility study and perform a Monte-Carlo simulation to recreate variation in the model. To validate the model, a real-life case study will be performed at a company residing in South Africa.

1.4 Document Overview

Chapter **??** provides the background, objectives, scope, and limitations of the research problem. Chapter **??** contains a literature Study on the background of WC-Co and the different applications, properties, and production method, as well as an overview of the South African market conditions for WC-Co. Chapter **??** takes an in-depth look at the available WC-Co recycling methods and takes a further look at the challenges in cemented WC recycling in South Africa. Chapter **??** is a comprehensive background study on the requirements for a financial feasibility study for implementing a cemented WC recycling plant in South Africa. Chapter **??** discuss the research methodology used for the case study conducted in chapter **??** and identify the inputs needed to conduct this study. Finally chapter **??** provides a conclusion and summary of the results obtained in this research study.

See figure **??** for a complete document overview per chapter.

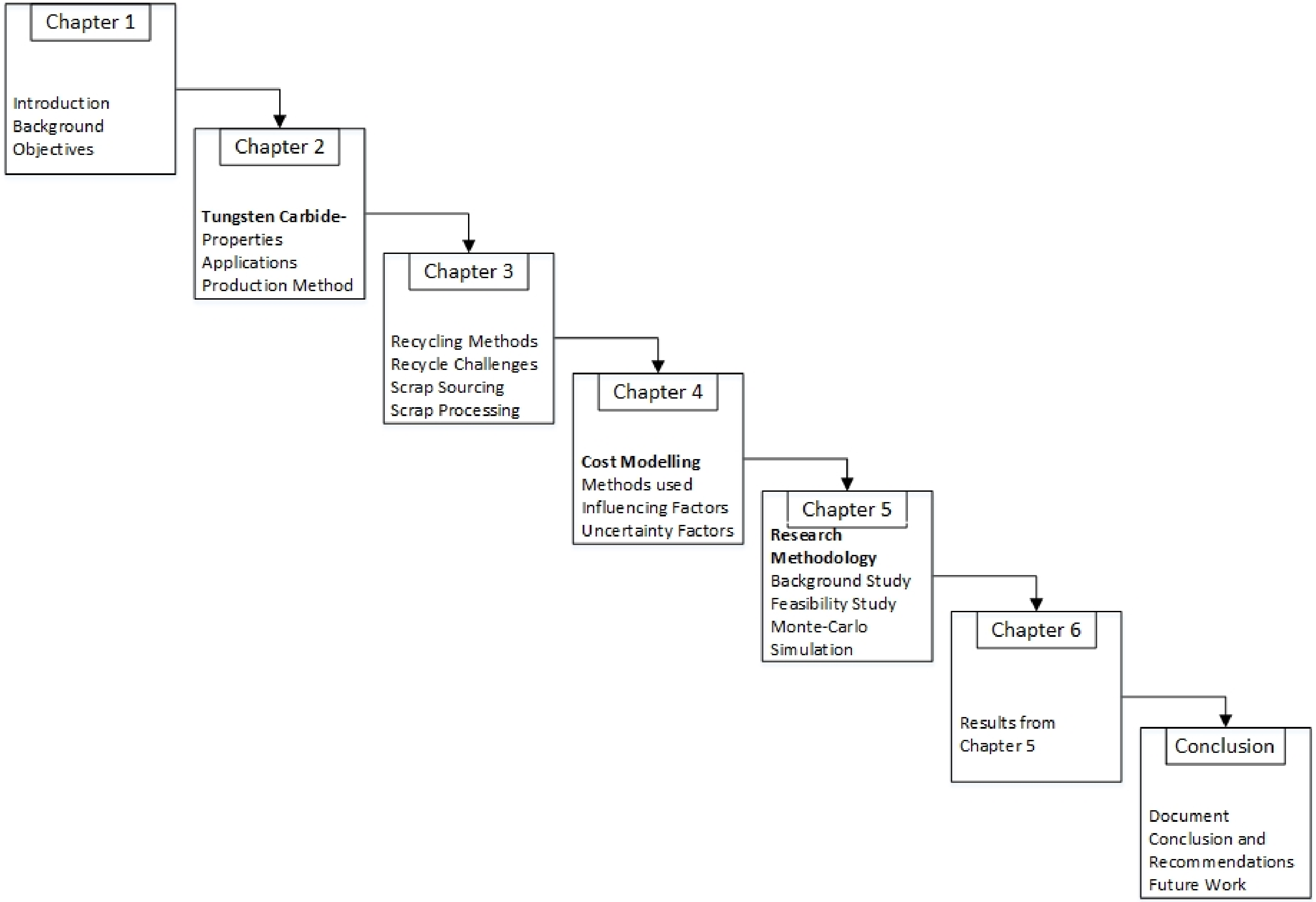

Figure 1.1: Per Chapter Document Overview and Structure

Chapter 2

Tungsten Carbide Cobalt Properties, Applications and Production

This chapter provides an overview of the literature relevant to the study. Data was collected from the sources described in Figure **??**. The literature discussed in this chapter includes properties, applications, and production processes of tungsten carbide cobalt. The cermet's properties are discussed providing greater understanding as to why this material group is used in specific applications.

During the brief discussion on the production process of the material, each step is examined. A market overview provides trade statistics on tungsten carbide cobalt. Finally, previous and current beneficiation strategies are discussed followed by the historical prices for WC-Co powder.

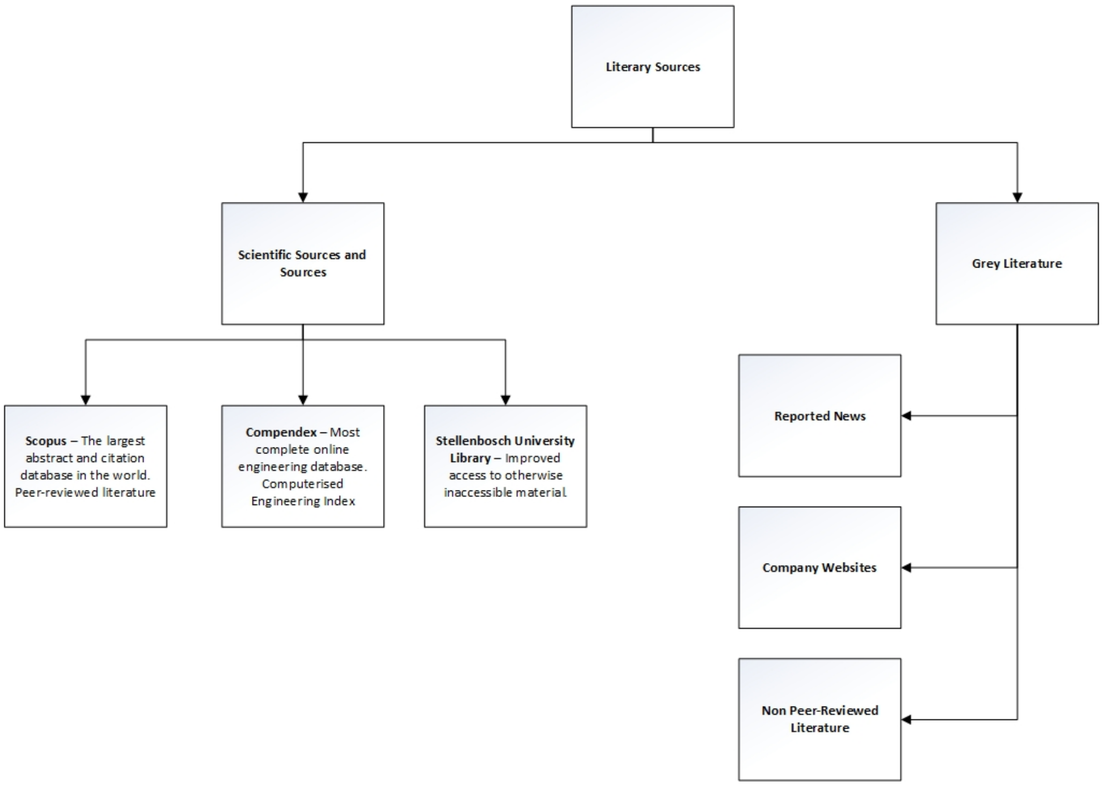

Figure 2.1: Literature Sources Used

2.1 Properties

Tungsten carbide cobalt is classified as a cermet. A cermet is a heat-resistant material made of ceramic and sintered metal. WC-Co is an alloy that consists of a hard ceramic phase (WC) as well as a ductile metallic phase, the cobalt (Co) binder (**?**).

Tungsten carbide can be cemented into a composite by a binder material such as nickel or cobalt. This yields favourable characteristics such as high hardness (800-200 HV) and a high transverse rupture strength (800-2900 N/mm^2). A comparison to other materials in terms of hardness and transverse rupture strength can be seen in figure **??**.

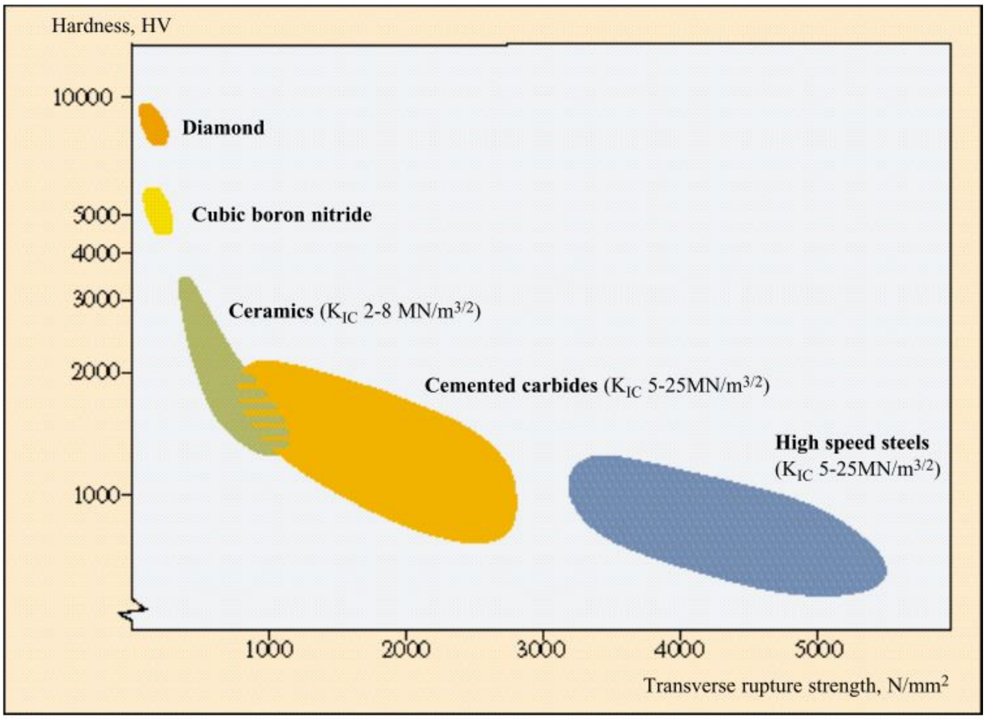

Figure 2.2: Hardness comparison of different materials (?).

Notable properties of WC-Co include hardness, strength, high thermal conductivity, high electrical conductivity, as well as high breaking ductility (?). The hardness of this cermet is influenced by the WC grain size as well as the percentage cobalt content (?). By varying the cobalt content in the alloy, the cermet can vary in hardness comparable to tempered steel to super-hard alloys. As the cobalt content increase, the hardness of the material will decrease, and therefore the wear resistance as well. With an increase in WC grain sizes the hardness and wear resistance will decrease. Denotations of the different WC grain sizes can be seen in table **??**. This classification system for WC-Co hard metals was proposed in 1999 by the "Hard Metals" working group of the German industrial union for powder metallurgy. This classification is widely accepted today. Prices of WC is influenced by the grain size of the powder.

Fracture toughness is also impacted by the WC grain sizes and the Cobalt content in the WC-Co structure. The fracture toughness will increase if either one of the cobalt content or grain sizes of WC is increased.

The most important characteristic of WC-Co is the high wear resistance of the material, which is directly proportionate to the hardness of the material (**?**). Other important properties include fracture toughness and material density. A comparison of different cemented carbide alloys and straight grades can be seen in table **??**. WC-Co is valued for its all-around capabilities with regards to other carbides, as can be seen in table **??**.

Residual porosity is a concern when producing WC-Co, as an increase in residual porosity will have an adverse effect on the toughness of the material. At high porosity levels, the wear resistance of the material can also be adversely affected.

Table 2.1: Tungsten Carbide Grain Sizes Denotations

Grain Size	**Classifications**
$<=$ 0.2 μm	Nano
0.2 - 0.5 μm	Ultra-fine
0.5 - 0.8 μm	Sub-Micron
0.8 - 1.3 μm	Fine
1.3 - 2.5 μm	Medium
2.5 - 6.0 μm	Coarse
$>$6.0 μm	Extra Coarse

Table 2.2: Cemented Carbides Physical- and Mechanical Properties Comparison. Adapted from (**?**)

	Physical Properties	**Mechanical Properties**			
Material	**Density [g/cc]**	**Micro-hardness [HV]**	**Tensile Strength [MPa]**	**Modulus Of Elasticity [GPa]**	**Compressive Strength [MPa]**
WC-6 wt% Co	14.95	1550	1440	600	5300-7000
Titanium Carbide	4.94	3200	258	450	2500
Tantalum Carbide	14.3	1790	291	722	2700
Tungsten Carbide	15.7	2200	344	600	2683
Vanadium Carbide	5.71	2950	800	420	607
Chromium Carbide	6.67	2280	NA	386	1039

2.2 Applications

Tungsten carbide cobalt can be used in any industry in which the three main characteristics: wear resistance, strength, and fracture toughness is desired. These characteristics are explored in section **??**. Figure **??** shows WC-Co's most desirable characteristics as well as the main application areas to date. From this figure, it is clear that the main application area for WC-Co is the tooling industry. In the tooling industry, the areas of use include but are not limited to drills, dies, burrs, cutters, tool blanks. Saw tips are commonly used in the construction, mining, and oil and gas sectors. (**?**)

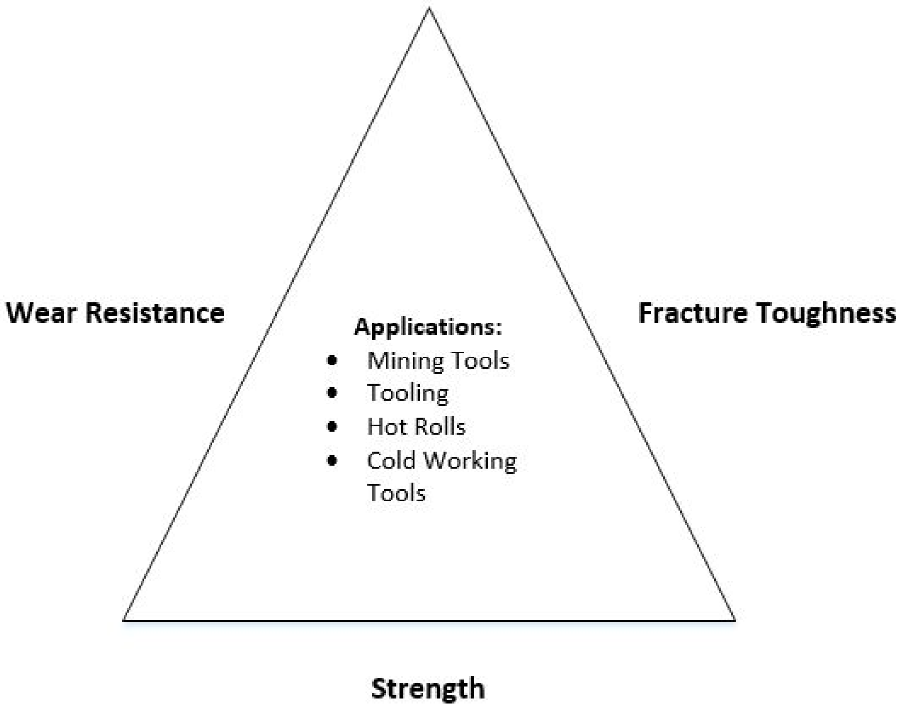

Figure 2.3: WC-Co Characteristics and Applications

WC-Co is primarily used to strengthen products that are exposed to intensive abrasion wear at extreme conditions such as high velocities, pressure, and cyclic load impact. (?). It is for this reason that WC-Co is well suited for the tooling industry which produces parts that work at the above-mentioned conditions. Figure **??** show the different application areas of different compositions WC-Co as well as different grain sizes of WC. **?** and **?** identified the following areas of applications for WC-Co:

- Tooling
- Aerospace components
- Automotive components
- Wear resistant nozzles
- Ammunition (Armor-piercing rounds)
- Coating of agricultural tools
- Jewellery
- Nuclear reflectors
- and surgical instruments

Figure **??** represents the whole lifecycle of tungsten from ores to end products showing the value added during each stage of the lifecycle. This figure shows that 65-95% of all tungsten ends up as Carbide Products.

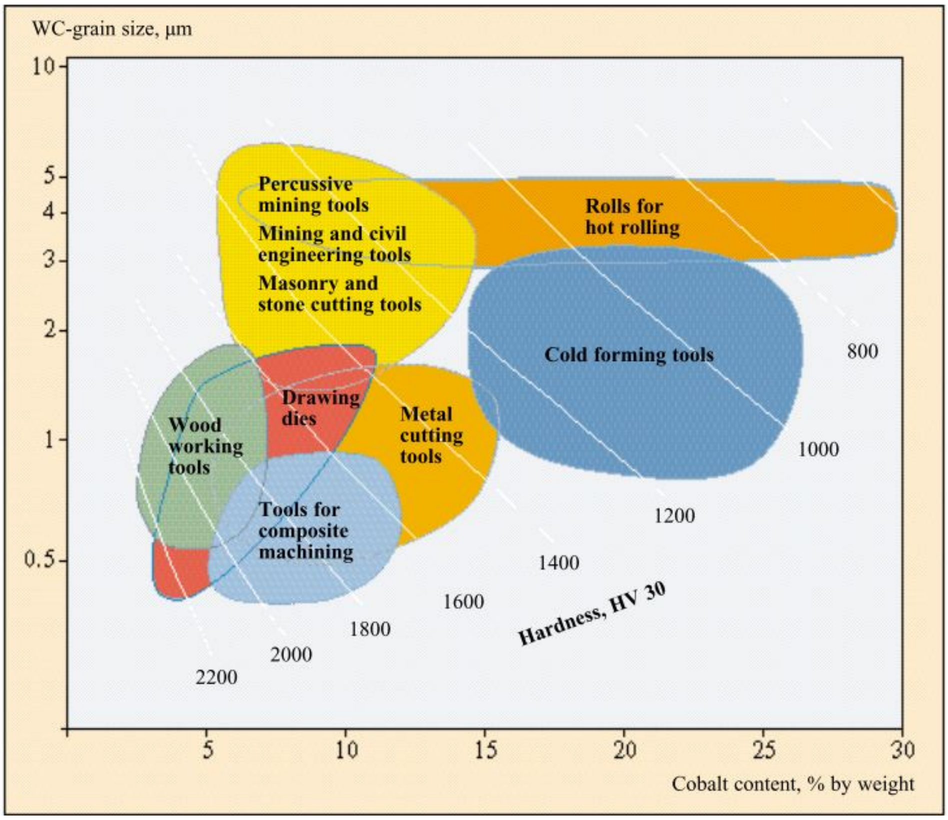

Figure 2.4: WC-Co Applications as Function of Cobalt content and WC grain size (?).

2.3 WC-Co Production Processes

This section explores the methods that are used to synthesise WC-Co from the raw ores. The production of WC powder is the first step and then the synthesis of WC-Co can be done.

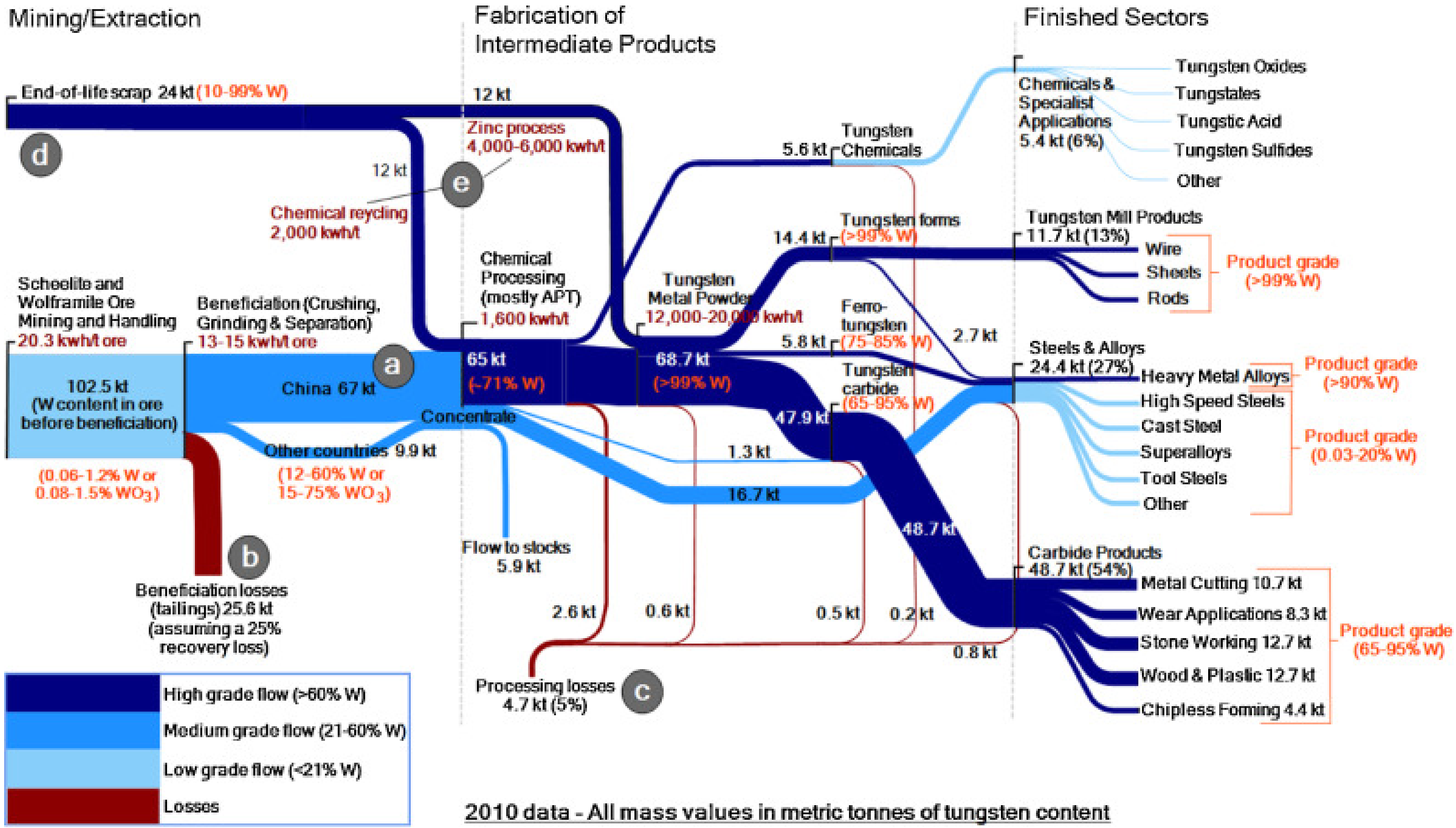

Figure 2.5: Global Mass Flow of Tungsten in 2010. Source: **?**

2.3.1 Producing Tungsten Powder

This section explains the process followed to produce tungsten from tungsten ores. Tungsten is one of the main constituents of WC-Co,
The ores that are primarily used to produce W is $FeMn(WO_4)_2$ (Wolframite) and CA_2WO_4 (Scheelite). These two ores are only two of thirteen tungsten ores available. The process of producing tungsten from the two primary ores can be seen in figure **??**. The APT that is formed during this process is also a popular state to which WC scrap is processed as there are different cemented carbides which can be produced from this state. The result of the process described in figure **??** is tungsten powder (**?**).

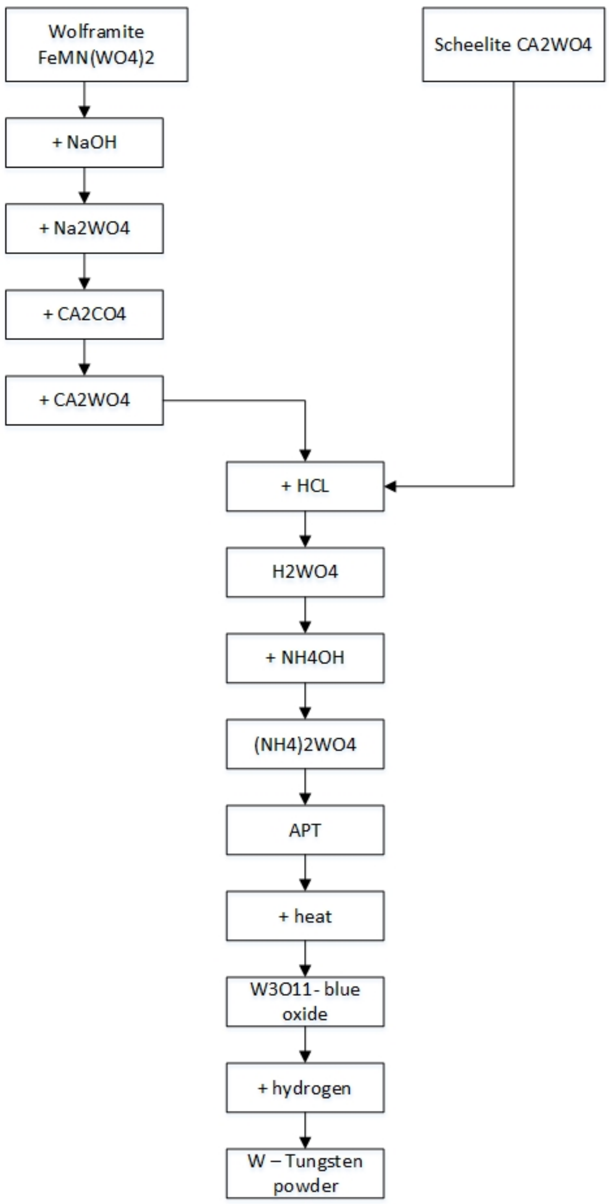

Figure 2.6: Production of W Powder from Ores. Adapted from (?)

2.3.2 Producing WC-Co

Tungsten carbide is produced from tungsten powder and carbon by mixing the two constituents using equipment such as V-blenders, double cone blenders, mixing ball mills, or high energy mixers. The mixture is consequently carburised by heating to temperatures of 1400-200°C in double stage rotary furnaces.

Tungsten carbide cobalt can be produced in a number of different ways. These methods are discussed in sections **??** to **??**. Some of the processes produce WC only and not WC-Co. These processes require an additional powder metallurgy step as discussed in section **??**. The spray conversion process (section **??**) is an exception as WC-Co and not WC is produced.

Figure **??** to **??** show the different processes used to synthesize WC and WC-Co powder.

2.3.2.1 Carburisation Processing

There are two possibilities of producing WC powder using this route. The process details will vary according to the needed output powder required. For fine submicron powders tungsten oxide and carbon black are mixed followed by either direct carburisation or the rapid carbothermal reduction (RCR) process.

The direct carburisation route makes use of two rotary furnaces operating at 1000-1600°C in an H_2 atmosphere and 1400-2000°C in an N_2 atmosphere respectively. The quality and the characteristics of the resulting powders are subject to the quality of the source materials and the process parameters.

The RCR process continuously synthesise WC powder through the carbothermal reduction of WO_3 in a graphite transport reactor. Two methods are used to prepare WC powders, it is the *entrainment method* and the *drop method*. A combination of these methods is used to produce WC precursor (WC_{1-x}) after which carbon is added by mixing. (**?**)

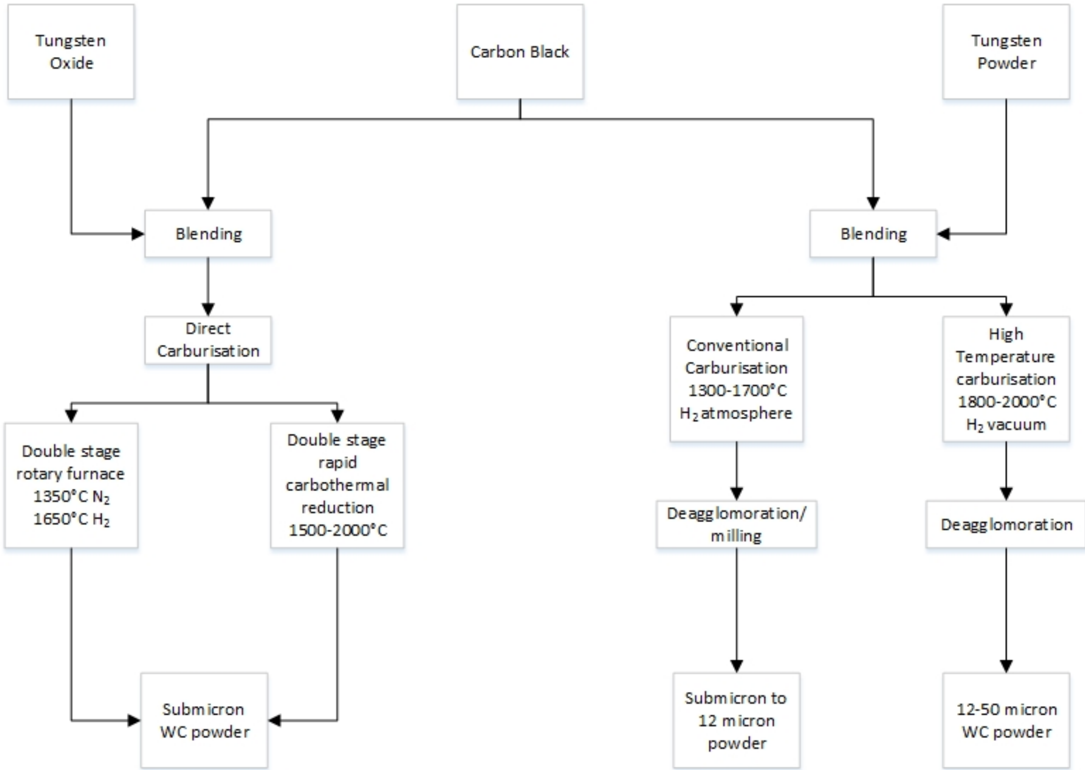

Figure 2.7: Process for the Carburisation of Tungsten Carbide Precursors

2.3.2.2 Spray Conversion Processing

? successfully produced WC-Co powders in the late 1980's via a spray conversion process. This process allows tungsten and cobalt particles to mix at molecular level, yielding true nano-structured WC-Co with WC grains smaller than 50 nm according to **?**.

The molecular mixing uses aqueous solution-phase reactions between certain WC-Co precursors such as ammonium metatungstate (AMT) and cobalt chloride. The solution is spray-dried, then the precursor powder is reduced and carbonized in a fluid-bed reactor to yield nano-phase WC-Co powder.(**?**). The fluid-bed carburisation process synthesise WC at lower temperatures by reacting tungsten metal or blue WO_3 with carbon dioxide or carbon monoxide and hydrogen at temperatures ranging from 900-1200°C or reacting hexafluoride with hydrogen and methanol at 350°C. The grain sizes of WC obtained lies in a range from 0.5-7.0μm (**?**).

The spray conversion process has the advantage of producing ultra-fine nano-crystalline powders according to **?**. This process has been the classic method to produce WC-Co powders, but the scale-up into commercial production becomes a real problem. (**?**)

Following the initial research by **?** many research groups such as Zhuzhou Cemented Carbide and Shao's group at Huazhong Science & Technology University of China performed extensive research in producing WC-Co powders. Efforts were made to improve the process so that uniform and large quantities WC-Co can be produced at significantly improved hardness and toughness levels (**?**). Figure **??** shows the spray conversion process.

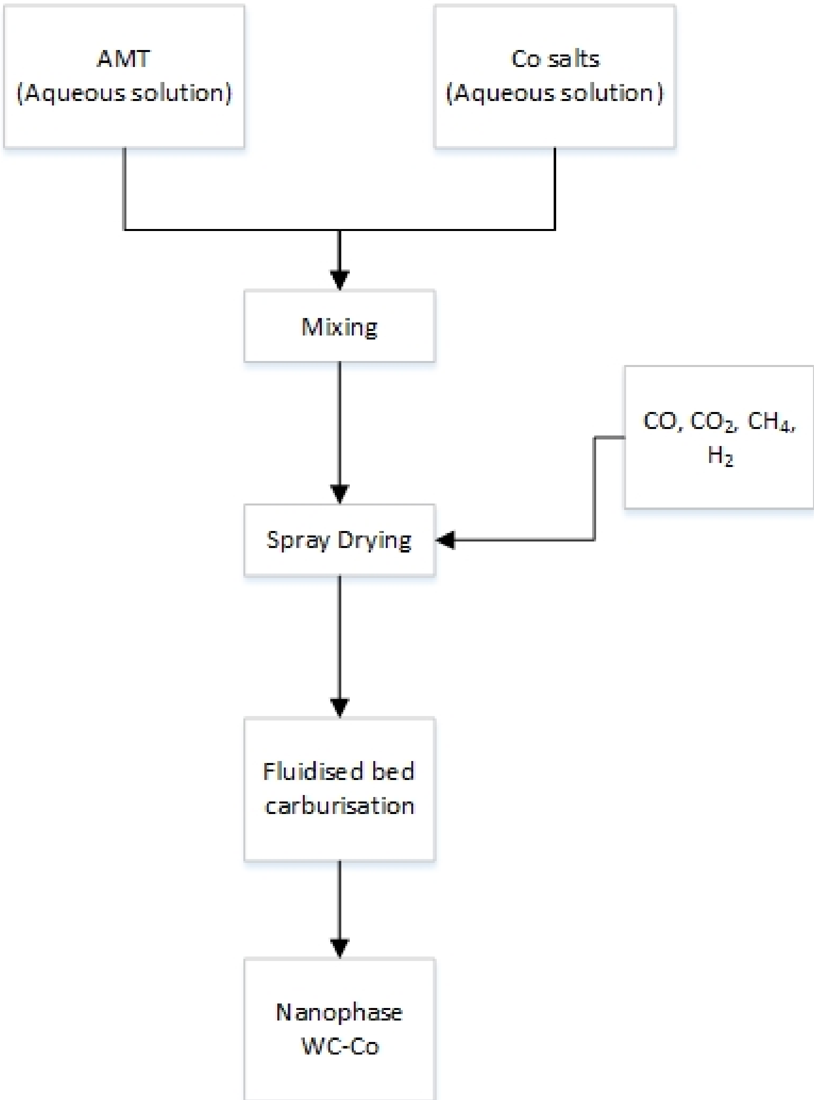

Figure 2.8: Spray Conversion Process of Aqueous WC Precursors. Adapted from **?**.

2.3.2.3 Melting Metallurgy Processing

This process is also called *menstruum tungsten carbide production*. It is unique in the sense that the process produces WC directly from ore concentrates. The mixture of ore concentrates, Fe_3O_4, Al, CaC_2 and C reacts exothermally to form WC and other metallic products. The metallic components would gather in the bottom of the melt. This process is an aluminothermic reduction of iron and tungsten oxides. The tungsten metals formed are carburised and the WC crystallises immediately. Figure **??** is a depiction of the process followed to produce WC with this method. (**?**)

The main problem with this process is that heavy metal salts such as $FeCl_3$ are formed. This presents environmental problems with the disposal of the salts.

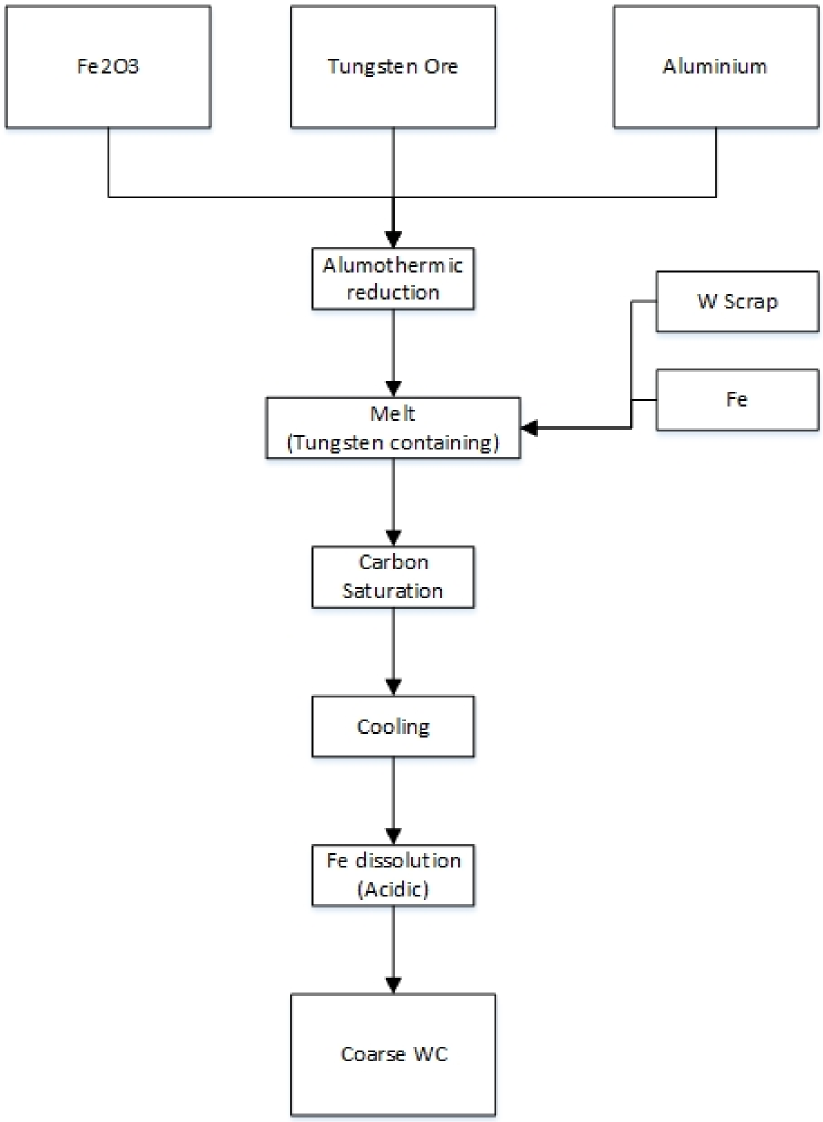

Figure 2.9: WC formation by Melting Metallurgy. Adapted from **?**.

2.3.2.4 Chemical Vapour Reaction Processing

Various chemical vapour reaction (CVR) techniques to produce WC are also described in literature (**?**). A CVR process is based on a chemical vapour reaction between a tungsten metal containing compound and a carbon-containing gas mixture. One CVR process includes reacting tungsten hexachloride (metal-containing compound) with hydrogen and methane (gas mixture) at 670°C.

The CVR process for WC powder production can be seen in Figure **??**.

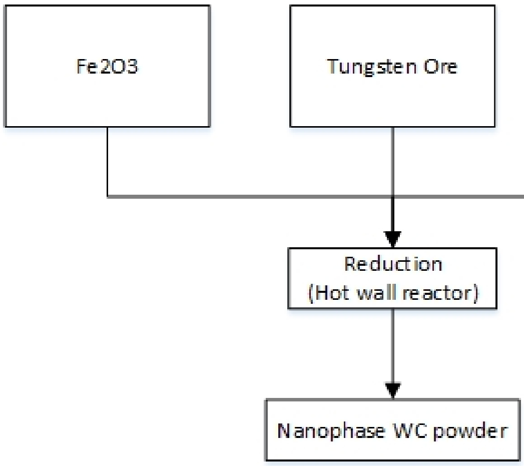

Figure 2.10: WC Formation by Chemical Vapour Reaction. Adapted from **?**.

2.3.3 Addition of Co to WC

WC-Co powders can be synthesised from WC and Co powders using powder metallurgical processes. These processes use the following steps to produce WC-Co powders for commercial use.

1. Mixing. After the production of WC, as discussed in section **??**, WC and cobalt is then weighed and mixed in different proportions as prescribed by the wanted characteristics of the final WC-Co powder. The total weight percentage cobalt ranges between 5%-30%.

2. Milling. This step is wet milling and is important as it have an effect on both the homogeneity of the slurry as well as the WC grain size, which will both have an effect on the mechanical properties of the sintered material.

3. Spray-drying. Because of the wet milling step, the slurry must be dried. This is done using the spray drying technique consisting of three steps. These steps are: Atomisation of the slurry into droplets, mixing the atomised spray with a drying gas in the drying chamber, and finally recovery of the powder.

This yields ready-to-press WC-Co powder. The WC grains obtained from this method is often in the order of several microns in size, thus hardness and toughness using this method is often limited according to **?**

2.4 Tungsten Carbide Cobalt Part Production

After the desired composition WC-Co powder is produced using the processes described in section **??**, the production of WC-Co parts can start.

The first step is to add additives such as binders and lubricants to the WC-Co. The addition of binders is to provide the part with green strength after compaction. This allows the unsintered part to be handled before sintering without the part falling apart (**?**).

Further, the powders are homogenised by forcing the powders through a screen to break up any lumps present in the mixture. Any mixing method can be used including high energy mixing (**?**).

The next step the powder is compacted into a near net shape, by either 1) hot compaction or 2) cold compaction. Hot compaction is limited to hot isostatic pressing, which is the process of sintering a part under high pressures for a certain time period. Parts produced through this method do not need a separate sintering step. Cold compaction can be done in various ways such as pressing, rolling or extrusion with compacting pressures for cemented carbides ranging from 140MPa to 400MPa. (**?**)

The next step is to sinter the green part. Cemented tungsten carbides are usually sintered between 1400°C and 1500°C for 20-30 minutes according to **?**. Sintering takes place in a vacuum or alternatively, an inert atmosphere to limit the amount of oxygen so as to prevent oxides from forming at high temperatures.

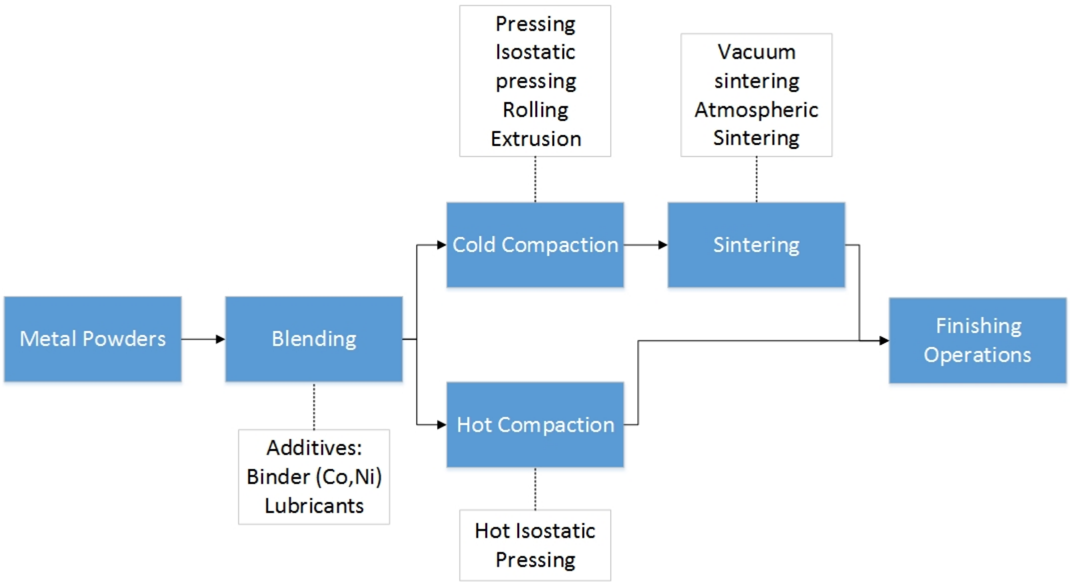

Figure 2.11: Process chain of conventional cemented carbide part production. Adapted from **?**.

This step is usually followed by a finishing step such as machining. One common problem with sintering is that it initiates grain growth which is an undesired effect.

2.5 Market Overview

The major reserves of tungsten in the world are shown in figure **??**. China is the largest producer of tungsten in the world. Due to tightening restrictions on exports in China, the cost of importing tungsten is increasing for emerging manufacturing countries such as South Africa. Compounding this problem is the decrease in tungsten production worldwide since 2012. With worldwide tungsten reserves expected to be depleted in 40 years, this material is at supply risk. (**?**)

According to **?** the drivers for the tungsten carbide market include:

- Remarkable material properties

- Cost Effectiveness
- High demand from various end use applications
- Tungsten recycling from scrap

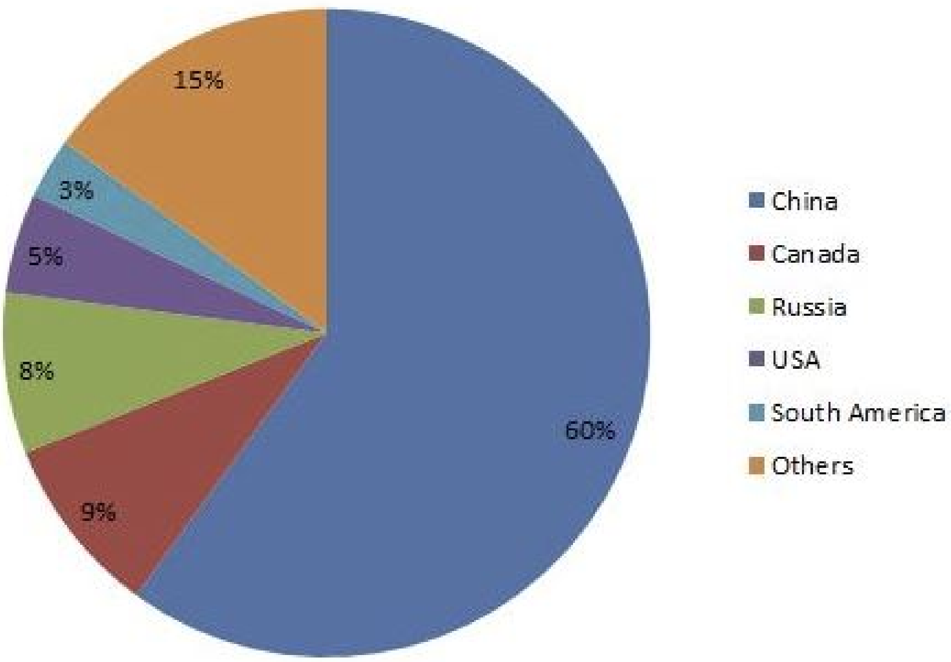

Figure 2.12: Tungsten Reserves (3 million tonnes, Tungsten content), Adapted from **?**.

The historical prices for tungsten in the USA can be seen in figure **??**. In 1981 a sharp recession in the price of tungsten came about because of increased exports from China. From 2006 China began to steadily decrease the annual export quotas, relating to a shortage of tungsten in the world and thus the steady increase in price till 2008 when a global financial crisis caused a decrease in tungsten consumption.

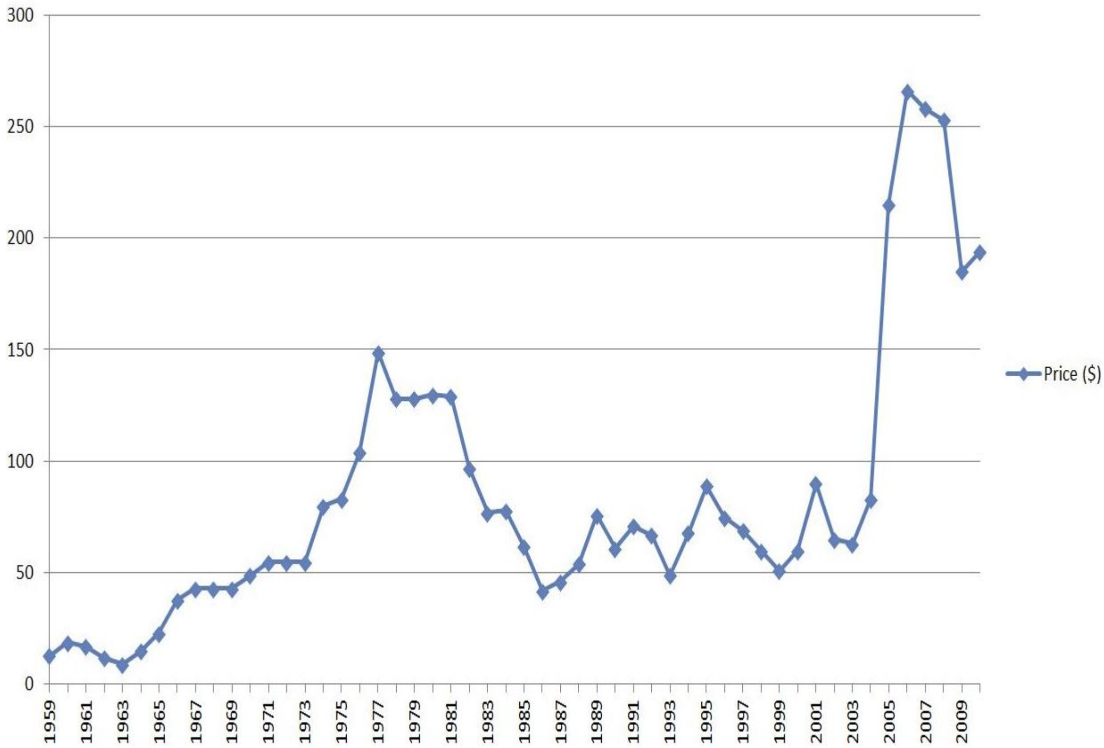

Figure 2.13: Historical Tungsten Prices. Source: **?**.

2.6 Beneficiation of WC in South Africa

South Africa's tungsten ore reserves are insignificant and inadequate for the demand caused by the mining industry, and therefore Boart established a plant in Springs for the production of tungsten carbide. The needs of the mining industry in South Africa served as the driver for the production of WC products in the late 1980's (**?**). It was during this period that the Boart International Springs Centre was established, they were the largest manufacturer of cemented tungsten carbide in the southern hemisphere during the 1990's. The South African WC industry is still dependent and based on imported intermediate-processed products such as APT and AMT to produce tungsten carbides **?**.

In 2002 the Integrated Manufacturing Strategy and the National Research and Development Strategy was developed by the Department of Trade and

Industry (DTI) and the Department of Science and Technology (DST) respectively. The South African government accepted these strategies in 2003 and this led to the Advanced Materials Initiative (AMI) to be established in 2005. From this the Centre of Excellence in Strong Materials (CoE-SM) at the University of the Witwatersrand started as support grew for the beneficiation of hard materials, including tungsten carbide beneficiation (**?**).

Various universities across South Africa are conducting research on WC-Co. Stellenbosch University (SU) is conducting research on the mechanical properties of additive manufactured WC-Co parts as well as the effect of machine parameters on the mechanical properties of additive manufactured WC-Co parts. The University of the Witwatersrand established the CoE-SM in 2004. This institution research various cemented carbides as well as sintered alloys or sprayed coatings of cemented WC. The University of Cape Town is doing research on powder consolidation techniques.

Chapter 3

Tungsten Carbide Cobalt Recycling Methods

This chapter provides an overview of the generation of WC-Co scrap as well as the recycling of this material. The challenges of WC-Co recycling are discussed. The current state of recycling in a global context is discussed. The recycling cycle is discussed from scrap sourcing to different intermediate materials or finished products are discussed and forms the basis of the feasibility model. A discussion of current and historical prices round out the chapter.

3.1 Sustainable Manufacturing

? described two opposing states of the world economy. The first is the so-called ”Cowboy economy” which was prevalent in the 19th century. The second state is the ”Spaceman economy” which he predicted we will reach by the latter stages of the 21st century. A ”Cowboy economy” is driven by exploitative mindsets and strategies, this is partly due to an abundance of available resources. Consumption and throughput rates serves as the measure of success in this economy.

Through the years environmental and economic incentives forced manufacturers to reinvent their systems to be more sustainable, thus moving towards the ”Spaceman economy” which is aimed at minimising throughput and maximising resource efficiency. The success of this economy is measured by the maintenance of current stock opposed to measuring by consumption and maximising throughput.

? defined sustainability as the capacity of ecosystems to be able to perform its processes and functions, while preserving diversity. This definition is based on an ecological model, but can be applied equally as well in business decision-making environments. The World Commission on Environment and Development (WCED) describe sustainability as using resources in such a way as to ensure that future generations will have the same ability as current generations to meet their needs. (**?**)

Sustainable manufacturing consist of the following key methodologies: the triple bottom line, the 6R's, and total life cycle focus. The tripple bottom line takes into account economic, environmental, and social impacts. The 6R's focus on a closed-loop system to reduce resource consumption. ant the total life cycle takes into account the effect on resources of every stage of a products life cycle.

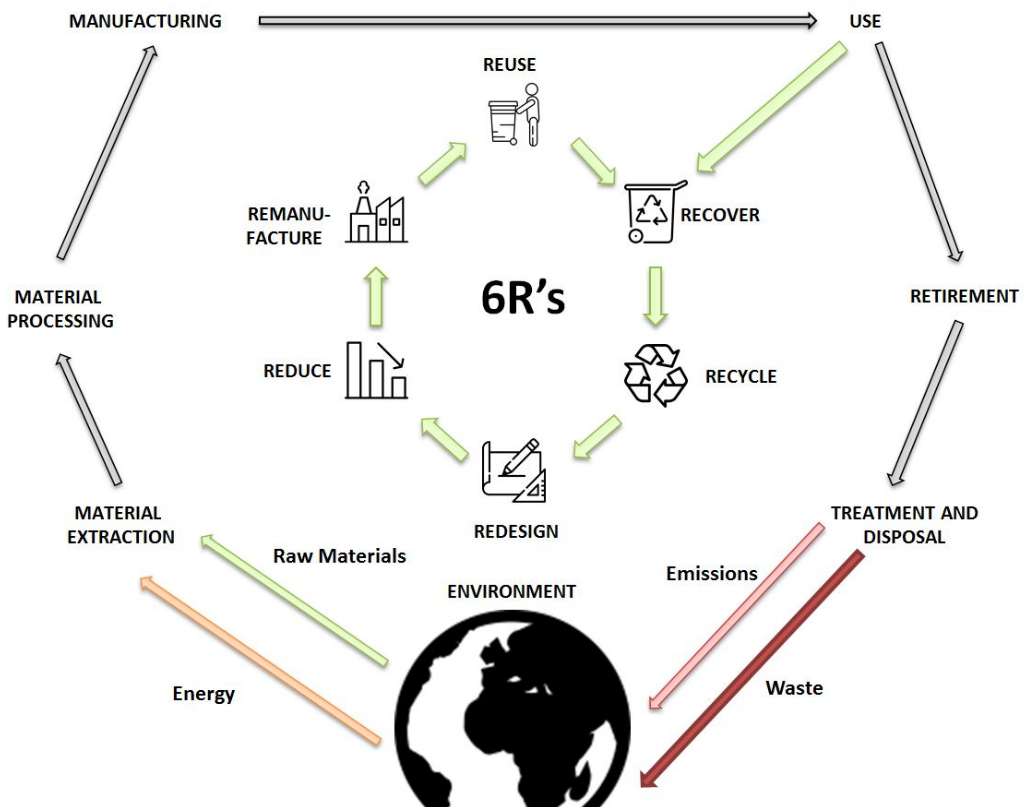

Figure 3.1: Closed Loop 6R Sustainable manufacturing Life-Cycle. Adapted from **?**.

According to **?** sustainable manufacturing is a holistic approach to manufacturing. Sustainable manufacturing includes the manufacturing of sustainable products as well as the sustainable manufacturing of products. The manufacturing of sustainable products includes renewable technologies and energy, building using "green" practices, and energy efficient products. The sustainable manufacturing of products considers the total life-cycle regarding the products that are manufactured. (**?**)

? proposed a closed-loop system by which a society can prioritise recycling. This system functions on the 6R approach. The 6R's are: Reduce, remanufacture, reuse, recover, recycle, and redesign. The model by **?** can be seen in Figure **??** and this waste-to-resource approach enables us to transform waste into a resource with a closed-loop system as seen in Figure **??**.

3.2 Cemented Carbides Recycling

One step of the total life-cycle is to determine what happens with products at the end of life. It is here that the 6R's is used to create value where the EoL product might have lost its value. Recycling is one of the 6R's and therefore recycling of carbides adds to the sustainability over the whole life-cycle of tungsten carbides.

The current world economical situation is still one of consumption, where large quantities of ores need to be extracted from the crust of the earth to produce small amounts of commodities. According to **?** the quality of ore is decreasing rapidly, therefore ever-increasing amounts of ore need to be removed for the same amount of material. This serves as drivers for industry to use the available resources on a more sustainable basis through recycling. This is a solution that helps the economy to move towards a more sustainable "Spaceman economy". According to **?**, the recycling of EoL products use less energy than primary production of new raw materials.

The targeted "spaceman economy" is, in essence, a closed-loop material cycle where all current stock stays in the system through recycling and maintenance of current systems. This cycle is represented in figure **??**. In this economic model all materials should be recycled to near 100% and all materials that are extracted from the crust of the earth regarded as potential waste. **?** identified three factors that influence recycling of materials. The factors are:

1. Collection and sorting of scrap.
2. Physical properties and the design of EoL products.
3. Recycling Processes, including the chemical and physical effect on the materials being processed.

All three factors are discussed in this study. New scrap is prevalent in any manufacturing industry and EoL products make up a big part of the industry in South Africa as the main use for WC-Co is as tools and coatings of tools. Opportunities for recycling exists in all parts of the materials flow cycle represented in figure **??**. The infrastructures identified by **?** that can assist with recycling are:

1. Policy making
2. Incentives
3. Knowledge
4. Best Available Technique (BAT) standards
5. Modelling

The above-mentioned opportunities and infrastructures are used as a basis when assessing the recycling of tungsten carbide cobalt.

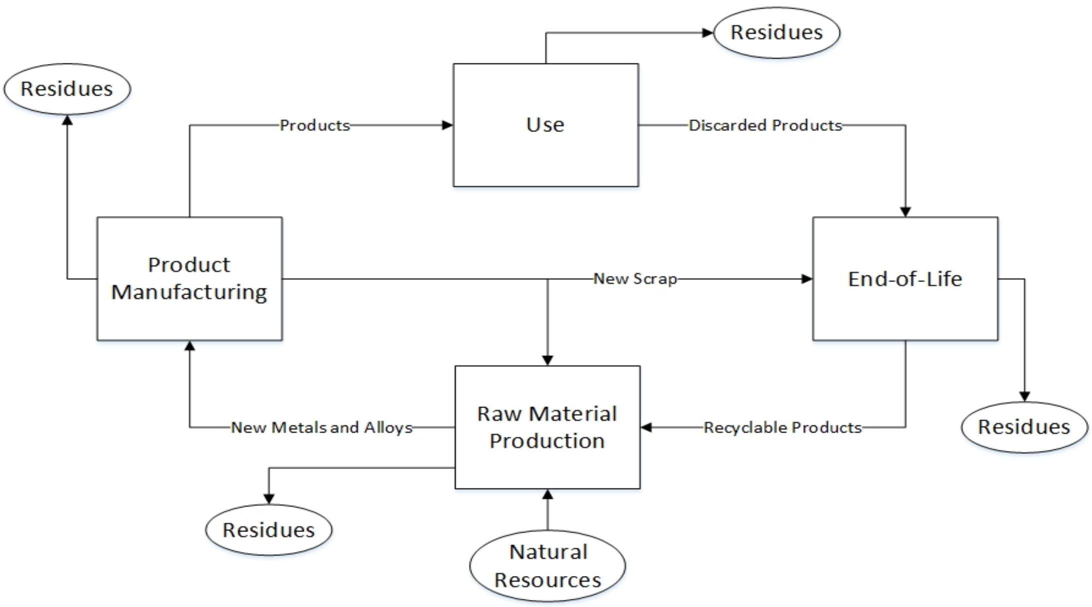

Figure 3.2: Closed-Loop Material Flow. Adapted from **?**

3.3 Recycling Rates

This section assesses the theory of recycling rates. This will help to identify the information needed to assess the feasibility of a recycling plant in South Africa. **?** identified six factors that influence recycling rates the most. These factors are:

1. Profitability
2. Public support
3. Organisation of infrastructure
4. Sortability
5. Legislative support
6. Scrap purity

One problem with defining recycling rates is the inconsistent ways it is defined. Many attempts have been made to rectify this situation (**?**, **?**, **?**, **?**, **?**). **?** suggested a more consistent approach to classify recycling rates. **?** classified two stages which needs to be analysed, namely: EoL efficiencies (collection, process efficiency, recycling rates) and production (recycling input rate, recycled content old scrap ratio). **?** identified three levels at EoL where recycling efficiencies can be measured. They are:

1. **Old Scrap collection Rate (CR).** How much of the material contained in discarded products is collected and enters the recycling chain.
2. **Recycling process Efficiency rate.** The efficiency in any recycling process. Also called recovery rate.
3. **EoL recycling rate (EoL-RR).** This refers to functional recycling including recycling as a pure material or as an alloy/combined material.

Non-functional recycling refers to EoL recycling where the material becomes an impurity.

During material production, **?** identified two other metrics which is of some importance. They are:

1. **Recycling input rate (RIR).** The fraction of secondary scrap metal in the total material input of material production. RIR is the same as recycled content (RC).

2. **Old Scrap Ratio (OSR).** The fraction of old scrap in the recycling flow.

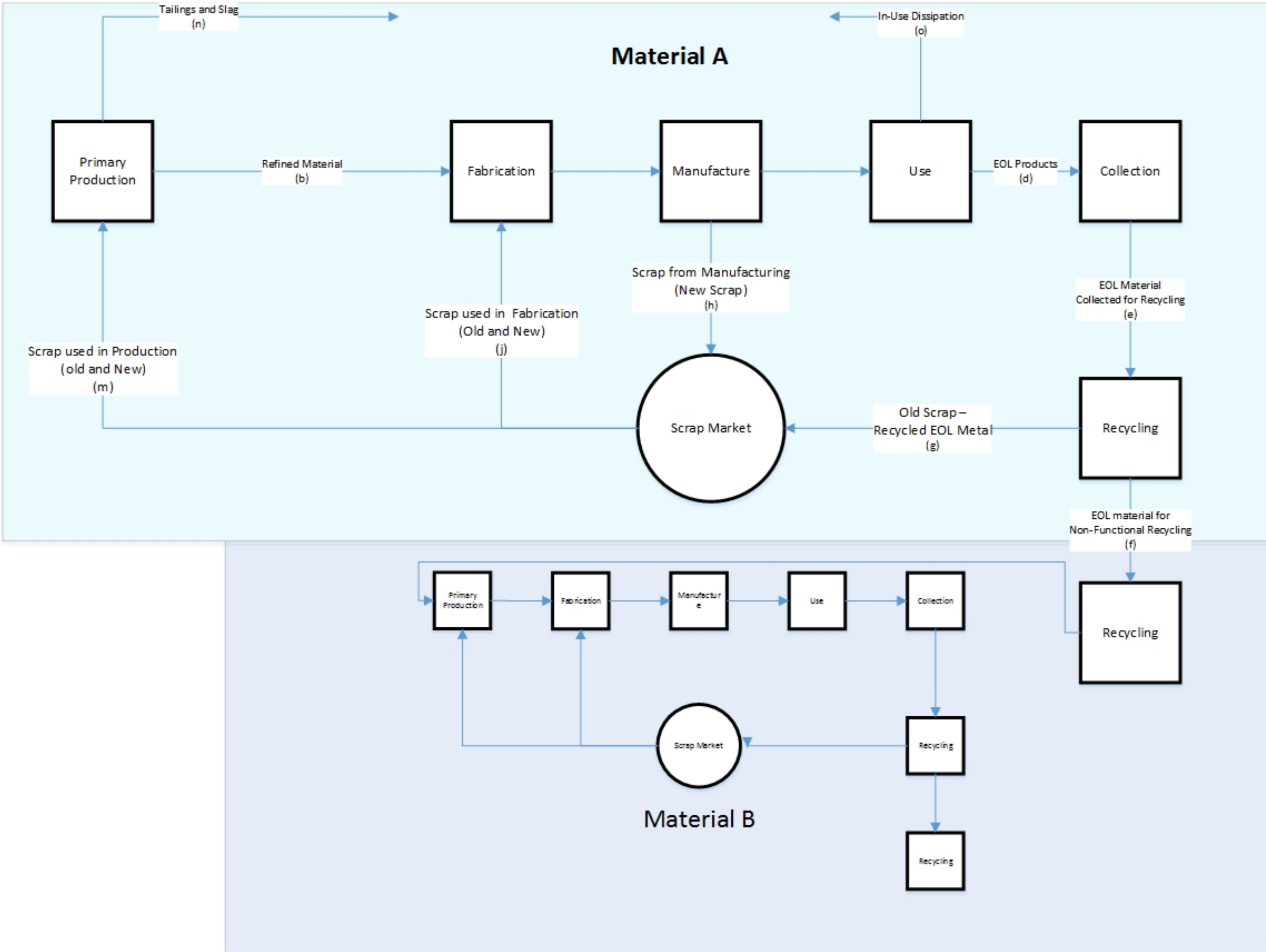

Figure 3.3: Material Recycling Flow Overview. Adapted from **?**

Figure **??** provides an overview of the material flow in a recycling process. The primary production (Alloys/combined materials and intermediates) of material is presented by the squares in this figure. New scrap is produced during the manufacturing step and can enter the scrap market. Old scrap from EoL products are also collected and enters the scrap market. From the scrap market, the metal can be used again in the primary production and manufacturing of intermediate products. Old scrap can also be recycled for non-functional uses and be used for the fabrication of other materials. An example in WC-Co is when grain growth inhibitors such as VC, TaC, and NbC is used in cemented tungsten carbides.

The formulas, using the letters in figure **??**, are calculated by the following equations:

$$\text{CR} = \frac{e}{d} \tag{3.3.1}$$

$$\text{Efficiency}Rate = \frac{g}{e} \tag{3.3.2}$$

$$\text{EoL-RR (Functional)} = \frac{g}{d} \tag{3.3.3}$$

$$\text{EoL-RR (Non-Functional)} = \frac{f}{d} \tag{3.3.4}$$

Other metrics that are applicable to material production is recycling input rate (RIR) and Old Scrap ratio (OSR) which is the fraction of old scrap in the recycling flow. The equations for these are:

$$\text{RC} = \frac{(j+m)}{(a+j+m)} \tag{3.3.5}$$

$$\text{OSR} = \frac{g}{(g+h)} \tag{3.3.6}$$

OSR is an indicator for the content of old scrap recycled as well as the quantity of old scrap in new products.

Using the equations for OSR, RC, and EoL-RR, **?** calculated the state of recycling for 60 materials. The data were obtained from different sources, resulting in different measurements, for these the USGS values were taken as final.

The results for the different equations can be seen in Figures **??** to **??**. Figure **??** shows that tungsten recycling is very high. This is in part because of the high recycling rate of old products such as mining and wear tools. These tools form a large portion of the total amount of old scrap.

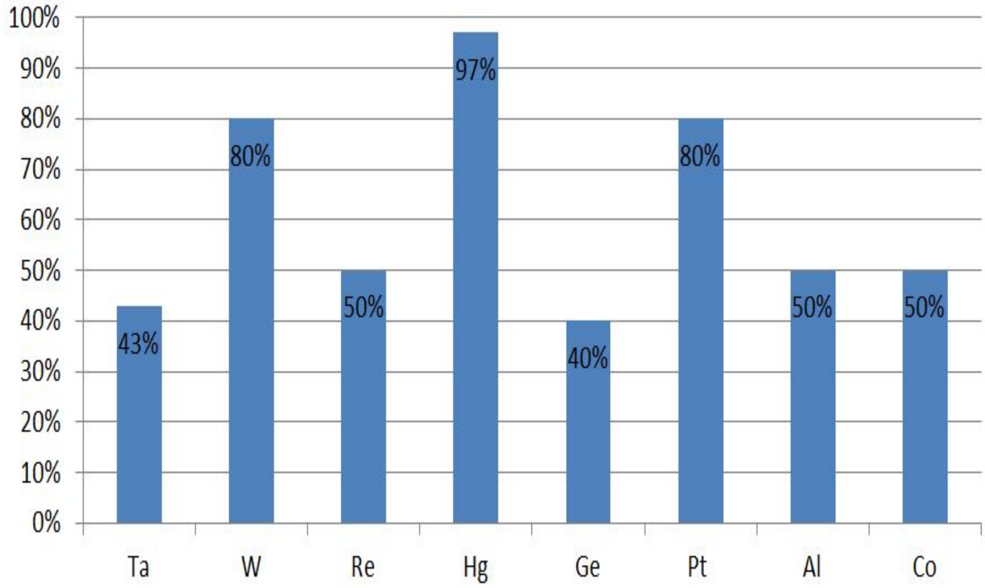

Figure 3.4: Old Scrap Rate of Selective Non-Ferrous Metals. Adapted from **?**

The recycled content for tungsten is 46%, which is above average for the sample chosen. **?** gave a reason for the number being this high, he stated that for every 1kg of tungsten carbide that was cast only 0.4kg to 0.6kg is contained in the product. This means that 40%-60% of tungsten used for castings can be recycled as new scrap.

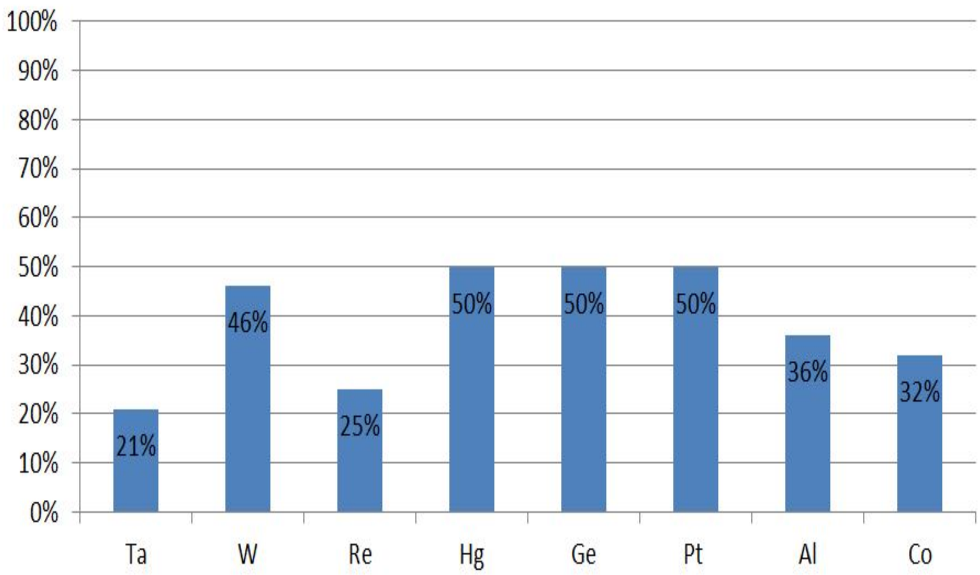

Figure 3.5: Recycled Content of Selected Non-Ferrous Metals. Adapted from **?**

The EoL-RR for tungsten is below average at 66% for functional recycling, leaving scope for new recycling efforts of EoL products such as cutting, drilling and milling inserts.

3.4 Challenges of Tungsten Carbide Recycling

This section discusses some generic problems and challenges faced across all fields of tungsten carbide recycling.

3.4.1 Available Scrap Volumes

? cites the lack of appropriate post-consumer collection systems as a limitation affecting tungsten carbide recycling. Andrew Salmo, the manager of Rend Lake Carbide, claim that one of the biggest challenges faced by companies recycling is not the process itself, but finding enough scrap material to sustainably recycle WC scrap. The problem is not the availability of scrap but rather the distribution of WC over large areas. The geographical density of available

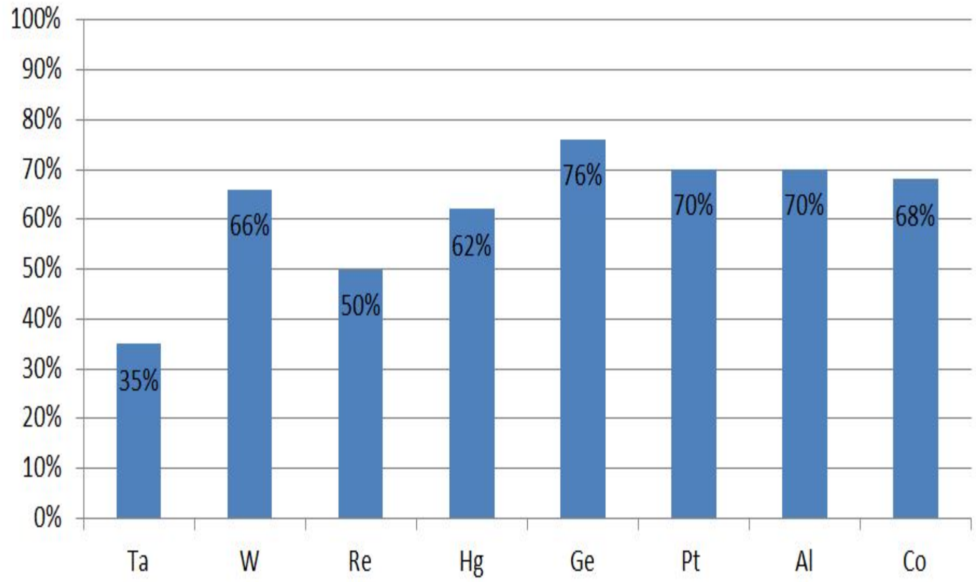

Figure 3.6: End-of-Life Recovery Rate of Selected Non-Ferrous Metals. Adapted from **?**

WC is thus low and the biggest challenge is a logistical one rather than a process challenge (**?**).

A solution to this problem is to source directly from scrap dealers who already consolidated high amounts of unsorted scrap. These dealers generally group tungsten with heavy metal scrap. By doing this the WC scrap is degraded to a less valuable group of scraps (**?**).

3.4.2 Impurities

One of the main advantages of WC-Co is the customisability of the material properties. By changing the cobalt content in WC-Co the material properties is manipulated to suit different needs. This, however, presents the problem that the sourcing of scrap becomes a problem as most old scrap will contain parts with differing cobalt content, influencing the cobalt content of final cobalt content. Sorting must take place before recycling if the powder composition and integrity is to be assured, or the recycling process may require additional steps or cycles such as mixing with virgin WC to maintain the wanted material properties. The high occurrence of different WC-Co grades, because of different WC grain sizes and Co content, make detail sorting of scrap strenuous and often infeasible. (**?**)

Other impurities such as lubricates and coolants commonly generated during the manufacturing of new products

3.5 Sourcing of scrap

? classified scrap into three categories. These categories are home scrap, old scrap, and new scrap. Home scrap is generated within a manufacturing plant and recycled and consumed within the same plant. Old scrap is scrap that is sourced from EoL products such as burs, drill bits, mills, cutters, etc. New scrap is scrap resulting from the manufacturing process, for cemented carbides this includes hardmetal sludge and machine swarf. New Scrap can be classified further as either hard scrap or soft scrap. Soft scrap consists of fine powder particles as well as cutting and grinding hardmetal sludge. Hard scrap is solid pieces of WC-Co such as out of specification parts (**?**).

The most common WC-Co scrap sources found in South Africa is old scrap due to the large amounts of EoL mining equipment, and to a lesser extent agricultural and toolmaking equipment. The tool manufacturing sector will also account for some new scrap during the manufacturing process of the tools. The main applications in South Africa for WC-Co is in the mining industry and it is therefore also the main source of scrap produced either as EoL mining products or during the manufacturing of the tools intended for the mining industry. This is because the WC industry was driven by the needs of the mining industry (**?**).

3.6 Tungsten Carbide Scrap Prices

The processed and unprocessed scrap prices can be seen in Figure **??**. In this figure it becomes apparent that there is a real value increase from unprocessed EoL products to a refined form such as APT or recycled WC which is recycled to a virgin equivalent quality.

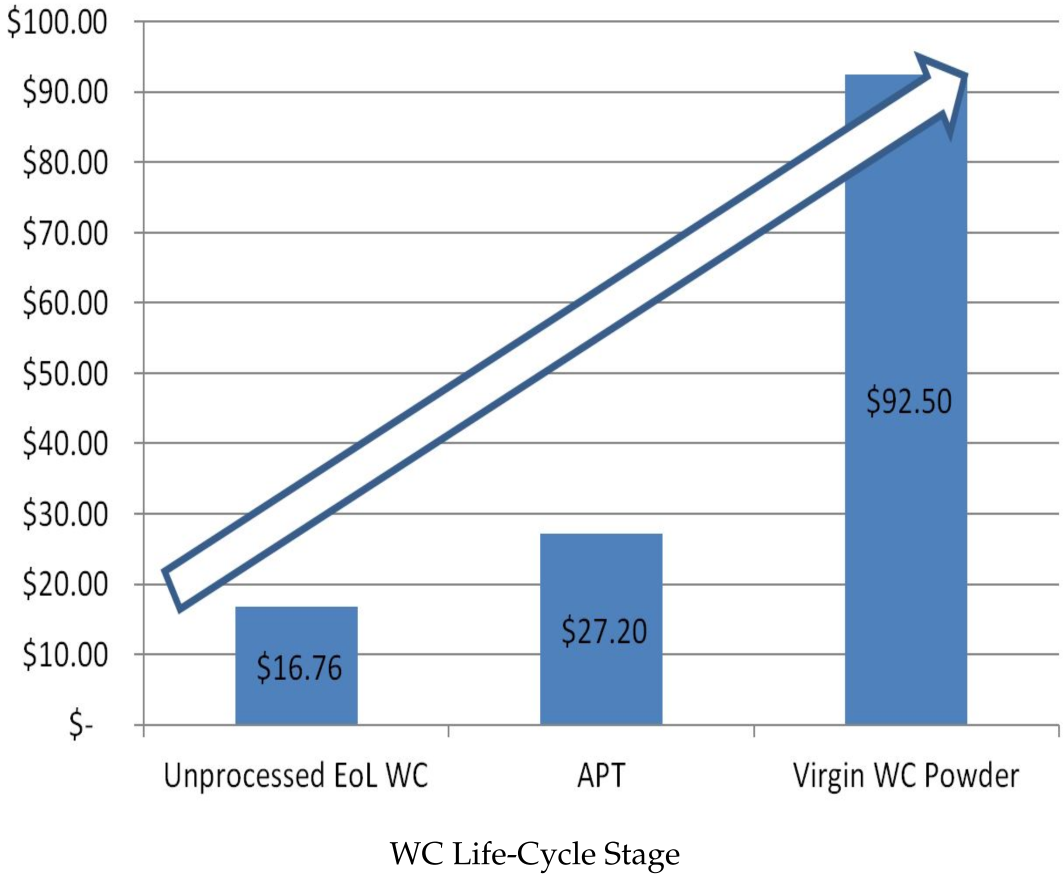

Figure 3.7: Tungsten Carbide Price ($) for Different Life-Cycle Stages .

3.7 Processing of Scrap

This section takes an in-depth look at the processing of WC-Co products. This study focus only on old scrap. In the old scrap classification, the study is limited to where the entire part consists of WC-Co, therefore excluding WC-Co coated EoL products.

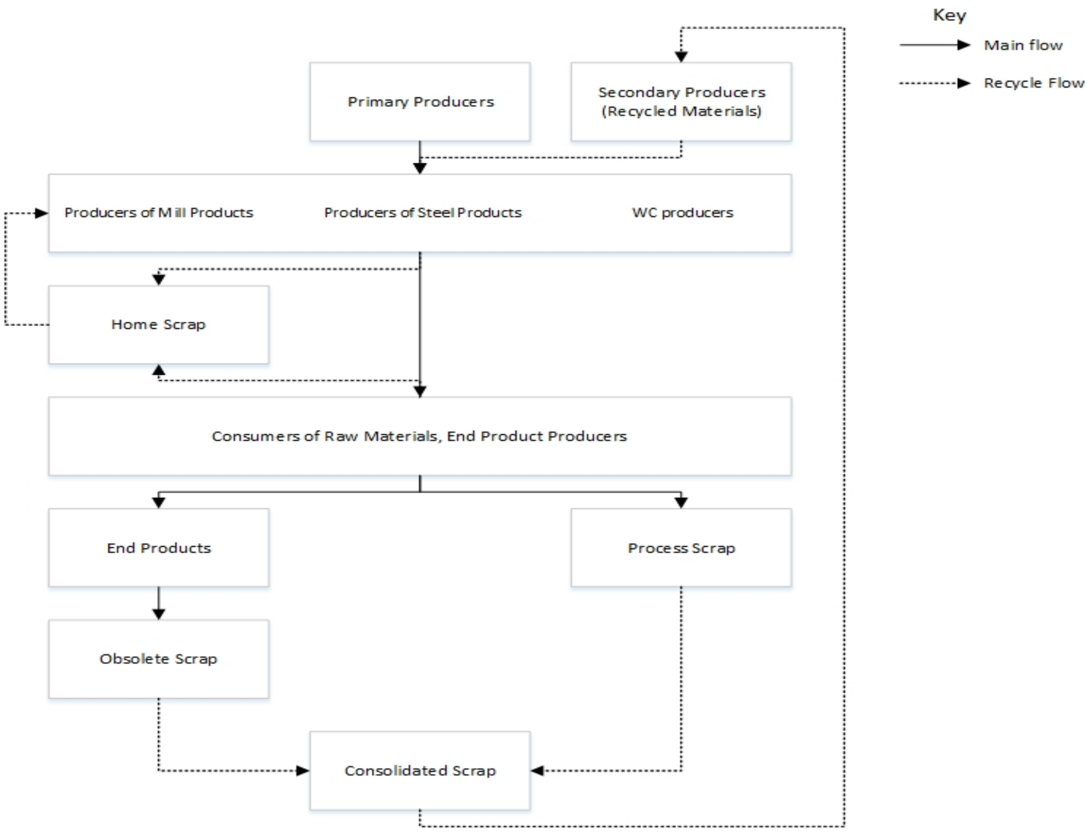

Figure 3.8: Tungsten Carbide Recycling Flow. Adapted from **?**.

Figure **??** shows the typical flow of virgin WC as well as recycled WC through the life of a typical product.

In the USA an estimated 35% of cemented carbide scrap was recycled using chemical processes, 25% was recycled using the zinc recycling process, 5% is recycled using various other methods, and the remaining 35% is not recycled at all (?).

The processes for recycling WC-Co can be classified into three categories, namely: direct methods, semi-direct methods, and indirect methods. Figure ?? shows the different recycling processes for tungsten carbide recycling.

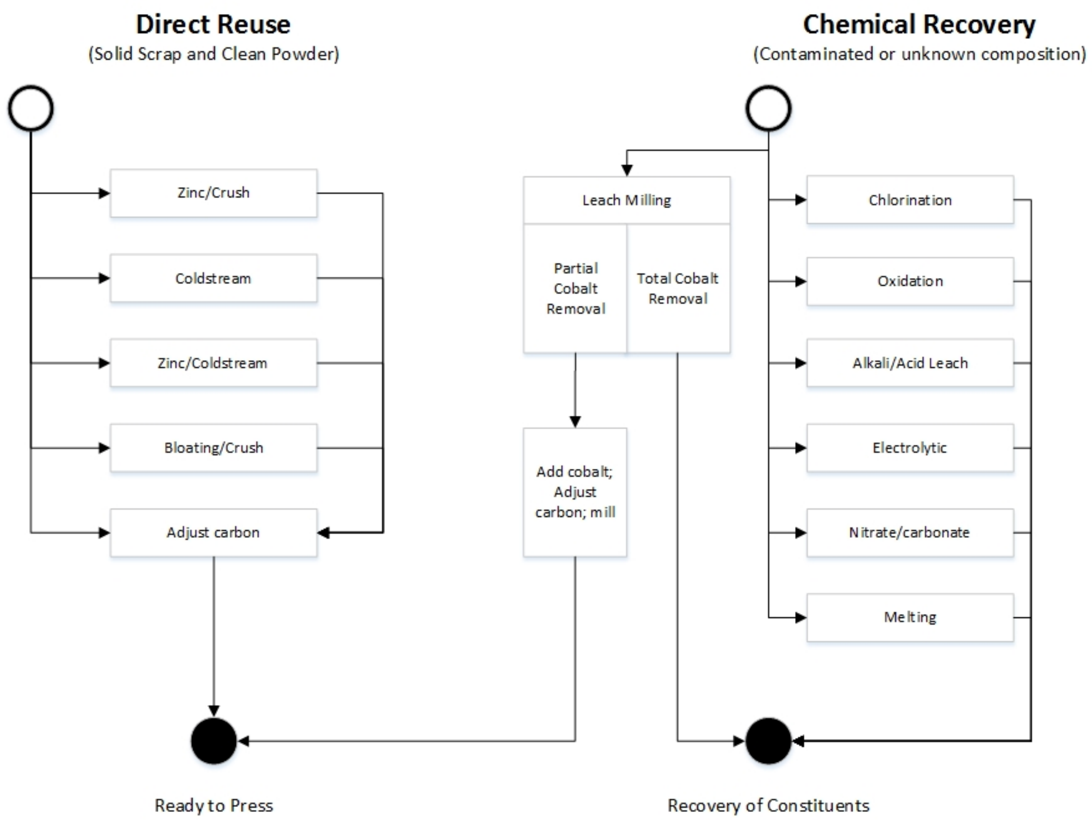

Figure 3.9: WC recovery material flow. Adapted from ?.

3.7.1 Direct Recycling

Direct recycling is understood as, the product obtained from the scrap source has the same composition as that of the initial scrap source.

The recycling process can be physical, chemical, or a combination of the two (?).

For a process to be considered a direct recycling method it must adhere to some prerequisites such as:

- The composition of product must be the same as the scrap.
- The scrap must not contain foreign substances and the grain sizes should fall within a small range.
- The process must be able to convert the scrap to a powder of acceptable form.
- There must be no contamination by other materials during the process.

Some processes for direct recycling of WC-Co include 1) Zinc reclamation process, 2) Coldstream Process, 3) Bloating/Crushing, and 4) A combination of process 1) and 2) where zinc infiltration is followed by the Coldstream crushing and finished with a zinc distillation step. The Zinc recycling process is the most widely used reclamation process of cemented carbides as it is the most cost-effective and environmentally friendly reclamation method (**?**)

According to **?**, barriers to direct recycling include:

- **Sorting**. Poor sorting or no sorting at all at the scrap source.
- **Impurities**. There is a possibility of heterogeneous impurity content in the recycled material.
- **Lack of Knowledge**. The lack of process knowledge, specifically process parameters in comparison to producing virgin equivalents.

Efforts to increase the amount of directly recycled material will have a direct improvement on the economy as well as the environment.

3.7.1.1 Zinc Recycling Process

This process, first invented by **?** and later improved by **?** is the most comprehensively used method in the world. This process recycles cemented carbide scrap by treating the scrap in molten zinc or zinc vapour. The zinc reacts with the cobalt binder to form a cobalt-zinc alloy. The reaction causes a volume increase of the cobalt binder, thus bloating the scrap. The next step is the vacuum distillation of the zinc at 0.06-0.13mbar and 1000-1050°C , the material is friable and can easily be disintegrated. From here the cooled material is crushed, ball milled and screened. The top screen (+200 Mesh) is recycled in the following batch. The last step may include a carbon adjustment step as there may be a depletion of carbon by approximately 0.12-0.15%.(**?**)

Table 3.1: Costs Associated with the Operation of a Zinc Recycling Plant

	Cost		
	Per Year	**Per Batch**	**Per kg**
Labour	**R 134 498.48**	**R 1 293.25**	**R 1.20**
Applied Labour	R 16 679.44	R 160.38	R 0.15
Wages	R 117 819.04	R 1 132.88	R 1.05
Utilities	**R 678 852.89**	**R 6 527.43**	**R 6.04**
Gas	R 1 560.26	R 15.00	R 0.01
Electricity	R 652 602.14	R 6 275.02	R 5.81
Water and Refuse	R 24 690.49	R 237.41	R 0.22
Raw Materials	**R 23 068 434**	**R 211 811.86**	**R 205.38**
Zinc	R 610 409.55	R 5 869.32	R 5.43
WC EoL Products	R 22 458 024.58	R 215 942.54	R 199.95
Maintenance	**R 253 876.68**	**R 2 441.12**	**R 2.26**
Buildings	R 7 528.94	R 72.39	R 0.07
Equipment	R 246 347.74	R 2 368.73	R 2.19

Information obtained from a South African company, Pilot Tools, can be seen in Table **??**. The process which is used at Pilot Tools is the normal Zinc recycling method implemented in a batch mode. The raw data can be seen in

Appendix ??. The replacement value for the machinery as of April 2018 is R10 million VAT inclusive.

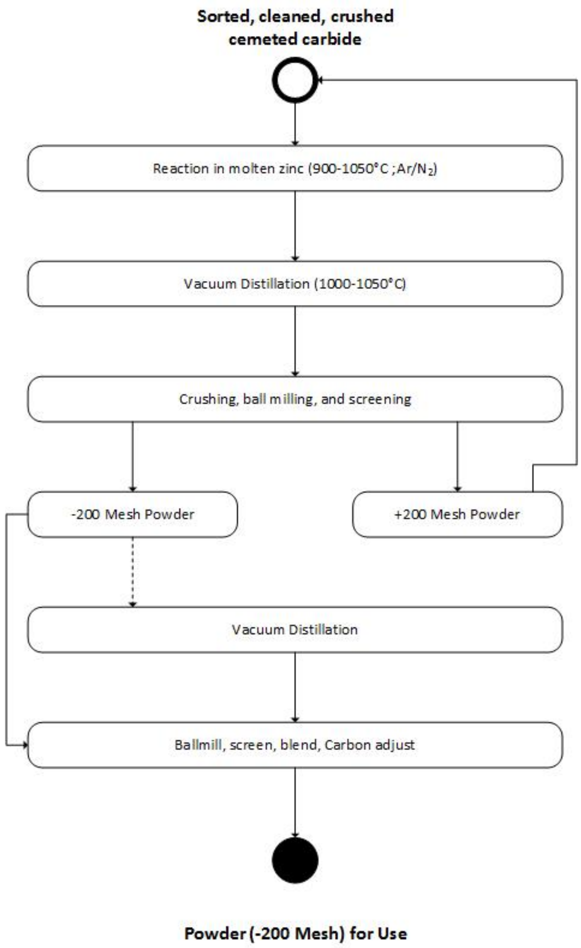

Figure 3.10: Flow diagram of the Zinc Recycling Process for WC-Co. Adapted from ?.

The energy consumption for producing WC-Co is approximately 4-6 kWh/kg which is better than the 12 kWh/kg needed for virgin WC-Co produced by the chemical route (?). Figure ?? shows the process flow for this recycling method while Figure ?? shows the different stages in the life of cemented tungsten carbide products recycled through the zinc recycling process. This process is prone to yield oversized products with grain sizes larger than 15mm.

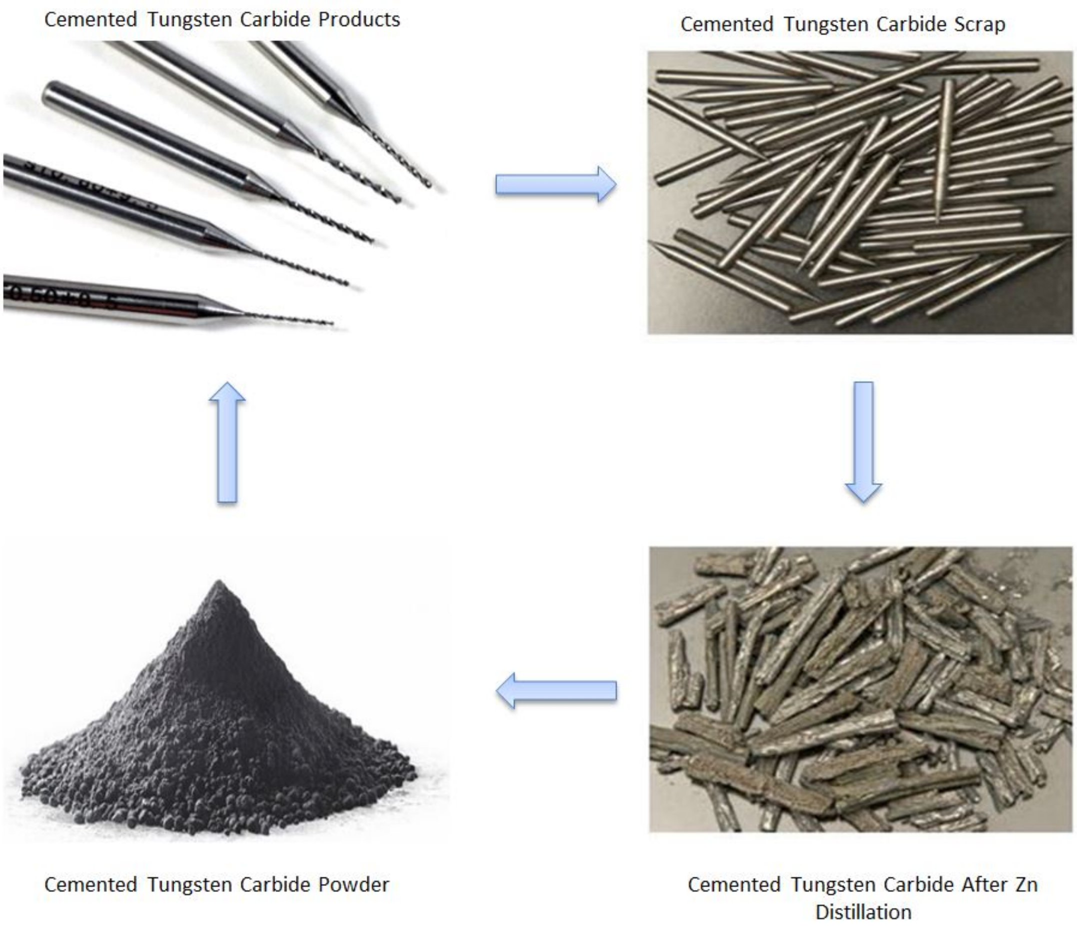

Figure 3.11: Cemented tungsten carbide lifecycle recycled through the zinc recycling method.

3.7.1.2 Coldstream Recycling Process

This process is a mechanical reduction method. The method uses air blasts to accelerate particles against a target with enough energy to fracture. The target can be an object such as an impact plate, but newer technologies collide particles against each other to achieve the same results, without the contamination which can happen if the impact plate is another material than the particles being reduced. The drop in pressure as the particles exit the nozzle (adiabatic air expansion) protects the scrap from oxidisation. The particles are accelerated to almost Mach 2. Oversized scrap is recycled to the start of this process (?). Figure **??** contains the process flow for this recycling method. Incomplete separation of the main WC constituent and the binding materials requires expensive and specialised equipment (?).

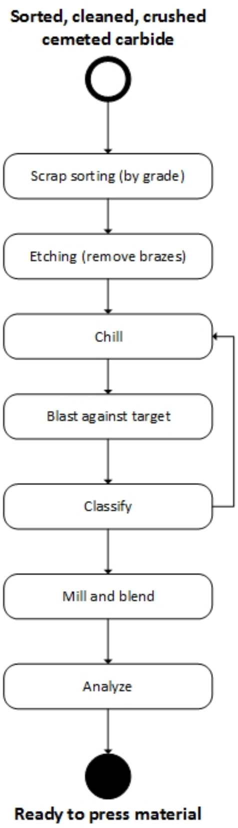

Figure 3.12: Flow diagram of the Coldstream Recycling Process for WC-Co. Adapted from **?**.

3.7.1.3 Bloating/Crushing Recycling Process

This process employs the embrittling effect of heating WC-Co to 1800°C followed by rapid quenching. The rapid grain growth and thermal stresses experienced during this process embrittle the particles and enables easier crushing of the scrap.

3.7.2 Indirect Recycling

Indirect recycling processes are where individual components are recovered from the original scrap and purified individually by using various chemical methods. Some of the processes for indirect recycling of WC-Co include 1) Alkali/Acid Leach and 2) Oxidation, 3) Chlorination, 4) Electrolytic conversion, 5) Nitrate/carbonate processes 6) Melting (**?**), (**?**). Melting can be better classified as a semi-direct process (See section **??**).

The advantages of indirect recycling of WC-Co scrap is that any scrap type can be used as input scrap. These methods are especially of importance when WC scrap is not pure enough to be recycled using direct methods. Also, the scrap can be recycled to virgin equivalent WC and do not necessarily need to have the same binder or binder content as most processes recycle the scrap to an intermediary such as ATP, which can be used as a precursor for various compositions cemented WC (**?**). In comparison to the 4-6 kWh/kg needed to recycle WC using the zinc recycling method, indirect recycling only need 2 kWh/kg of recycled materials. The main disadvantage of indirect recycling is that the recycling rates are very slow due to the extended contact times needed between the scrap and the recycling agents. According to **?** these methods are mostly used to recycle the large scraps which could not be recycled by direct methods.

3.7.2.1 Hydrometallurgy

Hydrometallurgy is a family of processes, which can theoretically convert most tungsten containing scraps into virgin ATP. **?** claims that these processes produce great quantities of chemical waste, are high in energy consumption, and are expensive to use.

To recycle the tungsten the scrap is oxidised by air, chemicals, or electrical energy, from here the same processes as for ore concentrates are used as described in section **??**.

These methods becomes viable when the input scrap is more polluted and cannot be processed by direct methods such as the coldstream process or the zinc recycling process (**?**). Table **??** contains as summary of the different hydrometallurgical recycling methods and their input as well as output materials as found in literature.

Table 3.2: Hydrometallurgical processes for WC Recycling. Adapted from **?**

	Leaching Agent	Input Waste	Recovered Material	Reference
1	Acetic Acid	EoL products	Co powder	**?**
		Sintered Carbides	WC powder	**?**
2	*HCl*	Waste Cermets	WC powder	**?**
		Sintered Carbides	Tungsten	**?**
3	Aqua Regia	WC sludge	APT	**?**
4	HNO_3	Sintered WC	Co powder	**?**
5	Amine Solution	Sintered WC powder	WC particles	**?**
6	*NaOH*	Metal Carbide	Tungsten	**?**

3.7.2.2 Oxidation

This is a family of chemical reclamation processes. It involves oxidisation followed by a secondary process, normally alkali/acid leaching or carburisation.

Tungsten bearing soft scrap is oxidised in air or oxygen-enriched air. The tungsten contained in the scrap is then oxidised at elevated temperatures. These processes takes around 12 hours to complete. Other constituents in the compound are oxidised to their respective oxides, this includes cobalt which forms cobalt tungstate. **?**

Table 3.3: Oxidation reclamation methods utilising secondary methods. Adapted from **?**.

	Input Material	**Oxidation Temperature**	**Secondary Process**	**Reference**
1	Sintered WC	1800°C	*HCl* leaching	**?**
2	Sintered WC	704-1093°C	*HCl* leaching	**?**
3	Cemented WC	825-850°C	*NaOH* leaching	**?**
4	Cemented WC	825°C	*NaOH* leaching	**?**
5	WC	600-1050°C	*NaOH* leaching, spray drying	**?**
6	Sintered WC	1600-1800°C	Oxidation at elevated temperatures	**?**
7	Cemented WC	760-870°C	Carburised, Sintered	**?**
8	WC Alloy	400-1000°C	Carbothermal reduction	**?**

This process is performed in either a push-type or a rotary furnace, followed by grinding and screening. The oxidised scrap is leached with sodium hydroxide to produce a sodium tungstate solution. This process is followed by a filtering step to remove byproduct sludge, including the cobalt tungstate and other metals recovered from the original scrap. This is followed by a purification step where the sodium tungstate solution is subjected to a liquid ion exchange process. This is done by contacting the sodium tungstate with an organic sulphate. The product is further reacted with aqueous ammonia and subsequent evaporation of ammonium tungstate take place, resulting in the intermediate substance of ATP (**?**). Table **??** is a summary of the different oxidation reclamation methods.

3.7.2.3 Chlorination

The Axel Johnson process of chlorination of tungsten-bearing scraps is a chemical method of treating WC-Co scrap. The process was developed by the Axel Johnson Institute of Industrial Research in Sweden. It includes the chlorination of tungsten scrap, treating the formed chlorides to prepare WCl_6. The last step includes a reduction by hydrogen to form tungsten powder. Through the use of this method, control over the grain size is facilitated. A problem with this method of recycling is that chlorine is absorbed creating unacceptable corrosion problems. This process first explored by **?**, is suitable for recovering highly polluted tungsten carbide, with a focus of recovering the constituents such as Co rather than the WC.

3.7.2.4 Electrolytic Recovery

? were the first to describe a hydrometallurgical way to recycle tungsten bearing scraps via an electrochemical method using nitric acid as the electrolyte. Elctrolytic recovery consists of applying a current to the scrap submerged in an electrolyte, sometimes at elevated temperatures. The drawback of these methods are the low energy efficiencies at laboratory levels with decreasing efficiency rates with increasing scales.

Table **??** is a summary of the different electrolytic recovery methods, The summary contains the input waste, the electrolyte used, and the output of the process.

Table 3.4: Electrolytic Recovery Methods. Adapted from **?**

	Electrolyte	Input Waste	Process Output	Reference
1	*NaOH*	Tungsten Alloys	W suspension	**?**
		Tungsten	tungstate	**?**
		Tungsten Alloys	APT	**?**
		Sintered WC	WC Powder and Co	**?**
2	H_2SO_4	WC-Ni	tungsten trioxide	**?**
		Toolgrade WC	tungstic acid	**?**
3	HNO_3	Hard alloys	tungsten trioxide	**?**
		Sintered WC	W, Co	**?**
		Cemented WC	W, Co	**?**
		WC scrap	tungsten trioxide	**?**
4	H_3PO_4	WC-Co	WC, Co	**?**
		WC-Co	W, Co	**?**
		WC-Co	WC, Co	**?**
		WC-Co	WC, Co	**?**
5	HCl	WC-Co	W, Co	**?**
		Cemented WC	WC, Co	**?**
		WC-15wt%Co	W, Co	**?**
6	NH_4OH	Heavy metal alloys	APT	**?**
		Cemented WC	APT	**?**
		WC scrap	WO3, Co	**?**

3.7.2.5 Nitrate Fusion

This method fuse cemented carbides and sodium nitrates to yield a soluble sodium tungstate which can be leached with water to recover tungsten. Scalability and environmental complications provide problems for the use of this recycling method in the current environmental and economic climate.

3.7.3 Semi-direct Recycling

Semi-direct processes are normally classified as either a direct or an indirect process, however, some processes contain certain factors from both types of processes, these processes are classified as semi-direct recycling methods by **?**. Semi-direct recycling methods are where one component of a compound is dissolved chemically, which leaves the other phase(s) intact. By the dissolution of the one component, the integrity of the remaining scrap is compromised and attrition can take place (**?**). Semi-direct recycling includes 1) Hydrothermal methods and 2) Menstruum Processing.

3.7.3.1 Hydrothermal Methods

In this method of WC-Co recycling, the cobalt binder phase is extracted through the addition of hydrochloric acid at 110 °C with a subsequent ball milling step (**?**). A negative effect of this process is that oxidation occurs on the material, which degrades the properties of the resulting materials. During this process WC-Co is with a 6N HCl treatment solution is hydrothermally treated in a autoclave for 24 hours. After which the resulting material is continually washed in a rotating drum and ball milled for a further 24 hours. After the wet ball milling step the material is briefly dried in a drying oven at 100 °C, resulting in a 1 µm - 5 µm particle size WC-Co powder. A 6N HCl solution consists of 216g HCl per litre of the solution. Approximately 1 litre of treatment solution is needed per kilogram of WC being recycled, this value take into account the constant readjustment of the pH by adding treatment solution as necessary.

3.7.3.2 Menstruum Processing

The melt bath technique as proposed by **?** is a suitable method for recycling tungsten bearing materials into WC powder. The process consists of dissolving tungsten scrap in a Fe-C or Co-C melt followed by leaching with concentrated HCl. If the dissolving agent is Zn, then the process would similar to the Zinc Recycling Process discussed in Section **??**. For methods not using zinc as dissolving agent, the tungsten in the scrap reacts with the Fe-C melt to form WC, which settles at the bottom of the melt. The melt is either crushed while the binder matrix is still liquid or crushed in the as-solidified condition.

Table 3.5: Comparison of direct and indirect WC-Co recycling methods. Adapted from **?**.

Recycling Method		
Direct Recycling		**Indirect Recycling**
Limited, sorted	**Scrap Type**	Any
Powders, same composition as scrap	**Final Recycled Content**	Virgin equivalent
High	**Energy Consumption**	Low
None or very little	**Chemical Consumption**	High
None	**Waste by Product**	High
Competitive	**Conversion Cost**	Higher than W-concentrate conversion

One advantage of this method is that it is effective in recycling large pieces of heavy metal scrap, a shortcoming of most other recycling methods discussed in this research. The main drawback of this process is the amount of pollution caused by the processing of the scrap. Due to the similarities to the zinc recycling method, the machinery is the same for both processes, and therefore the costs in Table **??** can be assumed to be relevant for this recycling method as well. The only amendment would be that Fe-C and also concentrated HCl is used as a raw material input instead of zinc. An additional rotating drum is also needed for the leaching process that follows.

Chapter 4

Financial Modelling

This chapter is a comprehensive literature study on the accepted methods for estimating investment costs of production plants. This study provides the basis on which the feasibility study in chapter **??** is based.

4.1 Feasibility Model Development Process

To develop a feasibility model, as well as a financial model, certain steps must be followed to reach an agreeable outcome. The steps in Figure **??** can be followed to build such a model. These steps were used as a basis for developing the financial model as per the objectives of this study. The financial model, and focus of this study, is a tool to make an investment decision and not a finance decision.

Figure 4.1: Financial Feasibility Model Development Process. Adapted from **?**

The concept of a feasibility study is a broad term, encompassing multiple types of studies. One such study is to determine the economic feasibility of a process or project. Economic feasibility of the recycling of tungsten carbide is the focus of this study. **?** identified eleven financial indicators needed to conduct an economic feasibility study. These indicators are:

- Fixed Capital Investment
- Working Capital Investment
- Total Capital Investment
- Total Manufacturing Expenses
- In-Plant Expenses
- Operating Expenses
- Marketing Data
- Cash Flow analysis
- Project Profitability
- Sensitivity Analysis
- Uncertainty Analysis

These indicators are used in this study as the basis for the financial model.

4.2 Capital Investment Cost Estimation Methods

Total capital investment costs include fixed capital investment, working capital, start-up expenses, offsite capital and allocated capital. **?** place estimates of capital investment costs into five classes. These classes are:

1. Order of Magnitude Estimate
2. Study Estimate
3. Preliminary Estimate
4. Definitive Estimate
5. Detailed Estimate

These classes can be used to predict how accurate estimates will be. **?** described the estimate classifications as set out by the Recommended Practice Nr. 17R-97 of the AACE as shown in Table **??**. The classification system shown in this table can be used to predict the accuracy of estimates. Each class of estimates has an accuracy range with class 1 estimates having a range of +6% and -4% accuracy. Using Class 1 estimates as a benchmark, an accuracy range for each class is obtained. Class 2, for example, has a range of 1 to 3, relative to the Class 1 index of 1. The lowest expected cost range will be +6% and -4%, while the highest expected cost range will be +18% and -12% of the total plant cost. In the context of this study it is important to get to as near as possible to the actual plant cost, thus as close as possible to a class 1 estimate as possible.

? provides requirements needed to make cost estimates with regards to a factored study estimate. They provide requirements for project scope, site, equipment, buildings. utilities, process flow, electrical, piping and insulation and work-hours. These requirements can be seen in Table **??**. The best practice, as described by **?**, for obtaining estimates is to use quotes from relevant vendors of specific pieces of equipment. This is not always possible to obtain. In the case of unavailability of quotes estimates based on past estimates of similar

Table 4.1: Cost Estimate Classification System (?)

Class of Estimate	**Project Completion [%]**	**Purpose of Estimate**	**Estimating Method**	**Accuracy Range [+/- Range relative to Best Index]**	**Preparation Effort [Relative to lowest index of 1]**
Class 5	0-2	Screening or Feasibility	Judgement	4-20	1
Class 4	1-15	Concept Study or Feasibility	Stochastic	3-12	2-4
Class 3	10-40	Budgeting	Primarily Stochastic	2-6	3-10
Class 2	30-70	Bid/Tender	Deterministic	1-3	5-20
Class 1	50-100	Check Estimate	Deterministic	1	10-100

equipment can be made. These estimates must be adjusted to reflect the situation invested, as the past studies seldom provide information that is precisely as needed for the current study.

Table 4.2: Factored Study Cost Estimate Requirements. Adapted from (**?**)

Capital Cost	**Requirements**
Project Scope	Product, Capacity, Location, and Utilities
Site	Location
Equipment	Size and Construction
Buildings	Size and Construction
Utilities	Estimated quantities
Process Flow	Rough Sketches
Electrical	Motor list and sizes
Piping and Insulation	Rough flow sheets
Work-Hours	Drafting and Engineering

4.2.1 Effect of Capacity on Equipment Cost

Differences in the capacity of equipment obtained from quotes and the needed capacity of equipment can be accounted for by adjusting the cost according to Equation **??**.

$$\frac{C_a}{C_b} = \left(\frac{A_a}{A_b}\right)^n \tag{4.2.1}$$

Where:

A = Equipment Cost Attribute

C = Purchase Cost

a = Equipment with Desired Attribute

b = Equipment with Initial Attribute

n = Cost Exponent

The attribute used most is the total plant capacity. The cost exponent differs for different equipment. **?** describes the six-tenths rule to reduce the amount of calculations. The rule states that the different cost exponent values of a plant cancel each other out to give a value of $n = 0.6$ for the entire plant. The six-tenths rule makes provision for economies of scale in equipment costs, as larger equipment usually leads to lower costs per unit of capacity.

4.2.2 Effect of Time on Equipment Cost

The age of previous quotes must be taken into account, due to costs obtained from past studies generally being a number of years old. Cost indexes can be used to account for inflation since the time of the previous estimate. Equation **??** is used to make this adjustment.

$$C_2 = C_1 \left(\frac{I_2}{I_1}\right) \tag{4.2.2}$$

Where:

$$\begin{aligned} C &= \text{Purchased Cost} \\ I &= \text{Cost Index} \\ 1 &= \text{Known cost time period} \\ 2 &= \text{Desired cost time period} \end{aligned}$$

Popular cost indexes include: the Marshall and Swift Equipment Cost Index, the Chemical Engineering Plant Cost Index (CEPCI), and Nelson-Farrar Cost Indexes. To use Equation **??** the desired time period index is divided by the available period index multiplied by the available period equipment costs. Table **??** contains a collection of CEPCI values since 1995. The CEPCI index takes 1959 = 100.

4.2.3 Effect of Inflation on a Project

While the CEPCI values can be used to account for inflation from previous dates to a current date, future projects present a problem for this index as it contains historical data. This section explains how to adjust plant costs for future dates. Equation **??** shows how to calculate the future inflated cost after a number of years.

$$C_{p+i} = (1 + f_1)(1 + f_2)....(1 + f_i)C_p \tag{4.2.3}$$

Table 4.3: CEPCI values from 1995 to 2016

Year	CEPCI Value	Year	CEPCI Value
1995	381.1	2007	525.4
1996	381.7	2008	575.4
1997	386.5	2009	521.9
1998	389.5	2010	550.8
1999	390.6	2011	585.7
2000	394.1	2012	584.8
2001	394.3	2013	587.3
2002	395.6	2014	576.1
2003	402	2015	556.8
2004	444.2	2016	541.7
2005	468.2	2017	567.5
2006	499.6	2018	574.0

Where:

$$C_i = \text{Inflated Cost after } i \text{ years}$$
$$f_1 = \text{Inflation rate in year 1}$$
$$f_2 = \text{Inflation rate in year 2}$$
$$f_i = \text{Inflation rate in year } i$$
$$C_p = \text{Cost in reference year}$$

4.2.4 Estimating Total Plant Cost

Equipment costs are but one category of many that contribute towards the total cost to build an entire production plant. Once equations **??** through **??** is applied, then the additional categories can be taken into account. **?** states that total plant costs are divided into four categories of direct expenses, indirect expenses, contingency and fees, and auxiliary expenses. These costs can be calculated using various techniques, including the module costing technique, the Lang factor technique or the bare module cost for equipment at base/non-base conditions. **?** argues that the Lang factor technique is an adequate method when estimating total plant costs. **?** further argues that more detailed techniques are infeasible for most research and development projects as both definitive and detailed cost estimates would be needed, these detailed estimates would range outside the scope of such projects. Therefore the Lang factor technique is used for this project. The Lang factor technique is described by Equation **??**.

Table **??** contains Lang factors for determining the total plant costs for a project.

$$C_{TM} = F_{Lang} \sum_{i=1}^{n} C_{p,i} \tag{4.2.4}$$

Where:

$$\begin{aligned} C_{TM} &= \text{Total Capital Cost of the Plant} \\ C_{p,i} &= \text{Purchased Cost of Major Equipment} \\ n &= \text{Number of Units} \\ F_{Lang} &= \text{Lang Factor} \end{aligned}$$

Table 4.4: Lang Factors for the Estimation of Capital Cost for Chemical Plants. Adapted from **?**

Type of Plant	**Lang Factor**
Fluid Processing	4.74
Solid-Fluid Processing	3.63
Solid Processing	3.10

Table **??** show Lang factors obtained from a South African metallurgical specific study by **?**. The study provides Lang factors, and a breakdown thereof, for different metallurgical plants.It should be noted that GST (VAT) has been changed from 13% to 15%.

Table 4.5: South African Metallurgical Plant Lang Factor Breakdown (?)

Type of Plant	**Solids**	**Hydrometallurgy**	**Chemical**
Equipment	1.00	1.00	1.00
Erection of items	0.11	0.17	0.11
Structural and Buildings	0.26	0.24	0.21
Civils	0.17	0.27	0.38
Piping and Ducting	0.14	0.35	0.59
Electrical	0.26	0.25	0.35
Instruments	0.10	0.20	0.27
Installed Plant	2.04	2.48	2.91
GST (15%) Site Preparation (5%) Construction Management (15%) Contingency (15%)			
	3.26	3.96	4.65

4.3 Cost Estimation Methods for Manufacturing

? identified three manufacturing cost sources. These are: Direct manufacturing costs, fixed costs, and general expenses. Direct manufacturing costs are defined as operating expenses that are directly proportionate to the production rate, while fixed costs occur whether or not production takes place. General expenses encompass the rest of the expenses needed to operate a business and are often associated with administrative and managerial functions. General expenses are not directly affected by the production rate, and are thus similar to fixed costs.

? described the total manufacturing cost of a plant using equation **??**.

$$COM = DMC + FMC + GE \tag{4.3.1}$$

Where:

$$COM = \text{Total Cost of Manufacture}$$
$$DMC = \text{Direct Manufacturing Costs}$$
$$FMC = \text{Fixed Manufacturing Costs}$$
$$GE = \text{General Expenses}$$

To use the above-mentioned formula a number of values need to be available. Table **??** contain the needed values and their descriptions. These values form the starting point to estimate all other manufacturing costs using multiplication factors, as provided by **?**.

Table 4.6: Required Values for Manufacturing Costs Calculation

Description	**Variable**
Fixed Capital Investment	C_{TM} (FCI)
Operating Labour Cost	C_{OL}
Utilies Cost	C_{UT}
Waste Treatment Cost	C_{WT}
Raw Material Cost	C_{RM}

4.3.1 Direct Manufacturing Expenses

? identifies the following direct manufacturing costs: raw materials, utilities, direct labour, clerical labour, supervisory labour, maintenance, patents and royalties, waste treatment, operating supplies, laboratory charges.

The raw material expense is the total amount paid for the feedstock of the recycling process. Raw material is often the biggest direct expense.

Utilities will form a large part of the direct manufacturing expenses. Utilities include electricity, fuel, refrigeration, compressed air, inert gas, water, and instrument air. These values can be calculated from mass balances for the recycling processes in conjunction with technical documents for relevant equipment.

Labour costs consist of operating labour, supervisory labour and clerical labour. Operating labour can be determined using a pre-determined shift table, which takes into account vacations and weekends. Supervisory labour is estimated as 1% to 25% of the operating labour.(**?**)

Maintenance costs can be broken down into two components namely, maintenance labour and materials. Materials contribute approximately 60% and labour 40% of the total maintenance cost. **?** states that maintenance costs should be approximately 6% to 10% of the fixed capital, while **?** believes it to be approximately 2% to 10% of the fixed capital. The labour component already includes all benefits such as compensation, unemployment tax, paid vacations, and insurance.

Table 4.7: Multiplication Factor Ranges for Estimating Direct Manufactruing Costs **?**

Direct Manufacturing Costs	**Estimate Range**
Raw Materials	C_{RM}
Waste Treatment	C_{WT}
Utilities	C_{UT}
Operating Labour	C_{OL}
Supervisory and Clerical Labour	$(0.1-0.25)C_{OL}$
Maintenance	$(0.02-0.1)FCI$
Operating Supplies	$(0.1-0.2)$(Maintenace and Repairs)
Laboratory Expenses	$(0.1-0.2)C_{OL}$
Royalties and Patents	$(0-0.06)COM$

Waste treatment must conform to environmental laws and regulation. The lubrication used in machines and acid used during processing are examples of a materials in need of waste treatment and disposal. **?** estimate operating supplies at 5% to 7% of operating labour. Laboratory expenses is estimated at 10% to 20% of operating labour. Royalties and patents are calculated at 1% to 5% of sales. **?** calculate the total direct manufacturing costs using Equation **??**. The constants used in the equation is obtained by using the midpoints from the estimates made by **?** and **?**. Table **??** contains a summary of the values as discussed in this section, where the values from **?** and **?** differs, the values from **?** will be used, as this is the most current values available.

$$DMC = C_{RM} + C_{UT} + 1.33C_{OL} + 0.03COM + 0.069FCI \tag{4.3.2}$$

4.3.2 Fixed Manufacturing Costs

Depreciation. taxes, insurance, and plant overhead costs are the components of fixed manufacturing costs. The loss of value from ageing assets is offset by accounting for depreciation. Table **??** contains the constants for Equation **??** as estimated by **?**.

$$FMC = 0.708C_{OL} + 0.068FCI + \text{Depreciation} \tag{4.3.3}$$

Table 4.8: Multiplication Factor Ranges for Estimating Direct Manufacturing Costs **?**

Fixed Manufacturing Costs	**Estimate Range**
Depreciation	$0.1FCI$
Taxes and Insurance	$(0.014 - 0.05)FCI$
Overhead Costs	$(0.5 - 0.7)(C_{OL} +$ Supervisory and Clerical Labour+Maintenace)

4.3.3 General Expenses

General expenses are the last factor needed to determine the total manufacturing cost of a plant. General expenses can be attributed to administration,

Table 4.9: Multiplication Factor Ranges for Estimating General Expenses **?**

General Expense	Estimated Range
Research and Development	$0.05COM$
Distribution and selling Costs	$(0.02-0.2)COM$
Administration	$0.15(C_{OL}+$ Supervisory and Clerical Labour $+$ Maintenance$)$

distribution and selling costs as well as research and development costs. Table **??** contains the multiplication factors to obtain these values as estimated by **?**.

Using the information in Table **??** Equation **??** is formulated to express the value of general expenses in relation to other notable variables.

$$GE = 0.177C_{OL} + 0.009FCI + 0.16COM \tag{4.3.4}$$

4.4 Factors influencing Economic Analysis

Different factors such as depreciation, taxes, exchange rates, inflation and the time value of money must be taken into account when determining the profitability of a plant. This section discusses these factors and the effect it has on the profitability of a plant.

4.4.1 Time Value of Money

The principle of time value of money rests on the fact that if money is borrowed or loaned then the money needs to be returned on a predetermined date with interest. The interest compensates the loaner for the risk taken. Thus, after a period of time has passed, the value of the money becomes greater. The initial amount of loaned money is known as the principal value, denoted as P. The future value of the money is denoted as F. In the current day and age compounded interest is used to calculate the future value of an investment.

Equation **??** is used to determine compounded interest (**?**). Compounded interest is where the interest earned throughout finite periods of the investment is reinvested.

$$F_n = P(1+i)^n \tag{4.4.1}$$

Where:

$$\begin{aligned} P &= \text{Present Value} \\ F &= \text{Future Value} \\ i_a &= \text{Simple Interest Rate} \\ n &= \text{Number of Years} \end{aligned}$$

In the case where the interest rate is not given as compounded yearly, the effective interest rate can be calculated. This calculates the effective annual interest rate from any compounded period. Equation **??** is used to accomplish this.

$$i_{eff} = \left[1 + \frac{i_{nom}}{m}\right]^m - 1 \tag{4.4.2}$$

Where:

$$\begin{aligned} i_{eff} &= \text{Effective Annual Interest Rate} \\ i_{nom} &= \text{Nominal Interest Rate} \\ m &= \text{Number of Compound Periods per Year} \end{aligned}$$

To finance a plant businesses often need to take out a loan, which must be paid back to the investing entity in monthly instalments. Equation **??** is used to determine these monthly payment amounts.

$$A = P\frac{r(1+r)^n}{(1+r)^n - 1} \tag{4.4.3}$$

Where:

$$A = \text{Installment Amount per Period}$$
$$P = \text{Loan Amount}$$
$$r = \text{Interets Rate per Compound Period}$$
$$n = \text{Number of payments per Period}$$

4.4.2 Depreciation

Depreciation is an allowance that is made to reflect the decreasing value of a property over a certain period of time. The value decreases due to the inevitable deterioration in the condition of the property in question. The depreciation period starts at the time when the property is put into service and ends once the asset is taken out of service, or the full value of the asset has been recovered. Depreciation is thus linked to taxation systems (**?**). In South Africa, the rate at which depreciation takes place is determined by the South African Revenue Service (SARS).

Of all the terms discussed under fixed capital, only land cannot be depreciated. Working capital is also not depreciable, because working capital is the amount of capital required to functionally operate a business for the first few years of existence. **?** estimates working capital at roughly 15% to 20% of the fixed capital investment.

Equation **??** is used to calculate the total capital for depreciation.

$$D = FCI_L - S \tag{4.4.4}$$

Where:

$$D = \text{Total Capital for Depreciation}$$
$$FCI_L = \text{Fixed Capital Investment minus the value of non-depreciable land.}$$
$$S = \text{Salvage Value } (FCI_L \text{at end of asset life})$$

The book value of an asset is calculated using Equation **??**.

$$BV_k = FCI_L - \sum_{j=1}^{k} d_j \tag{4.4.5}$$

Where:

$$BV_k = \text{Asset Book Value}$$
$$d_j = \text{Depreciation in j-th year}$$

Three methods for calculating depreciation exists. The methods are:

1. Straight-Line (SL) Method
2. Double-Declining Balance (DDB) Method
3. Sum-of-the-Years-Digits (SOYD) Method

When using the SL method an equal amount of depreciation is deducted each year. Equation **??** shows how the depreciation is calculated.

$$d_k^{SL} = \frac{[FCI_L - S]}{n} \tag{4.4.6}$$

The DDB method use a constant fraction of the book value. The DDB method use Equation **??** to calculate the yearly depreciation.

$$d_k^{DDB} = \frac{2}{n}\left[FCI_L - \sum_{j=0}^{j=k-1} d_j\right] \tag{4.4.7}$$

The SOYD, the yearly depreciation decrease by a set rate and it is calculated by using Equation **??**.

$$d_k^{SOYD} = \frac{[n + -k][FCI_L - S]}{\frac{n}{2}[n+1]} \tag{4.4.8}$$

4.4.3 Taxes

Income tax is the main form of deductible tax with which a company will be burdened (**?**). Income tax directly influences the net-profit and thus the after-tax cash flow of a business of a business. Equation **??** through **??** represents these values and how they are calculated.

$$IncomeTax = (R - COM_d - d)(t) \tag{4.4.9}$$

Where:

$$\begin{aligned} COM_d &= \text{Expenses (Cost of Manufacturing + Depreciation)} \\ d &= \text{Depreciation} \\ t &= \text{Income Tax Rate} \\ R &= \text{Sales Revenue} \end{aligned}$$

$$\text{Nett Profit} = (R - COM_d - d)(1 - t) \tag{4.4.10}$$

$$\text{Cash Flow (After Tax)} = (R - COM_d - d)(1 - t) + d \tag{4.4.11}$$

4.5 Profitability Analysis

Profitability can be measured as a function of cash, interest rate, or time. For each of these, the function can be discounted or not. In this case, the profitability factor will be discounted as non-discounted techniques fail to incorporate the time value of money as discussed in Section **??** and is thus not often used to evaluate large projects (**?**).

Profitability will be measured using the discounted payback period method (DPBP), which measures the amount of time it takes to pay back the discounted fixed capital investment (FCI_L). The best performing project will be the project that has the shortest payback period. The calculation for this can be seen in Equation **??** as described by **?**.

$$POP + I = \frac{\text{Depreciable FCI}}{\text{Cash Flow (After Tax)}} \tag{4.5.1}$$

Where:
POP + I = payback Period Plus Interest

The criteria used to measure the project is the Net Present Value (NPV). The NPV is a cash criterion while the DPBP is a time criterion. The Calculation for NPV can be seen in Equation **??**.

$$\text{NPV = PV of All Cash Inflows - PV of all Investment Outflows} \tag{4.5.2}$$

To evaluate profitability in terms of interest rates the Internal Rate of Return (IRR) is used. This provides an interest rate at the end of the project for an NPV equal to zero. This provides the biggest after-tax interest rate at which the project in question will break even.

DPBP, NPV, and IRR are all deterministic in nature, thus providing exact answers to the profitability of the respective projects.

4.6 Incorporating Uncertainty Factors

Section **??** discussed the different deterministic manners in which profitability will be measured. The NPV, IRR, and DPBP and provide exact answers, but **?** show in Table **??** how input values can vary over the course of a ten year period. The variation shown in Table **??** contributes to the accuracy of the estimates in Table **??**.

To account for uncertainty in a cost model a scenario analysis, sensitivity analysis, or Monte-Carlo simulation can be used. To introduce this variation into the proposed model the @Risk tool is used in this investigation, to facilitate a Monte-Carlo simulation.

Table 4.10: Probable Variation of Costs over a Ten Year Project (?)

Input Factor	Possible Variation [%]
Fixed Capital Investment	-10 to +25
Total Construction Time	-5 to +50
Start-up Costs	-10 to +100
Total Sales	-50 to +150
Product Price	-50 to +20
Plant Maintenance Cost	-10 to +100
Income Tax Rate	-5 to +15
Inflation Rate	-10 to +100
Interest Rate	-50 to +50
Raw Material Cost	-25 to +50
Profit	-100 to +10
Salvage Value	-100 to +10
Working Capital	-20 to +50

4.6.1 Scenario Analysis

A scenario analysis evaluates a variety of scenarios with a discreet uniform distribution between the minimum throughput to the maximum possible throughput for the process in question. The minimum throughput is decided by the minimum throughput needed for a process to become operable and the maximum throughput by the bottleneck throughput of the process.

The drawback of a scenario analysis is that the best (maximum throughput) and worst case (minimum throughput) scenarios have a small chance of occurring. To make up for the shortcomings of a scenario analysis a Monte-Carlo Simulation can be conducted, where output values are weighted according to their probability of occurring.

4.6.2 Sensitivity Analysis

A sensitivity analysis allows the user to gauge the effect that different variables will have on the overall output measure, profitability in the case of this investigation. In this case, profitability is measured as NPV, IRR, or DPBP. For example: If IRR was chosen as the output measure of profitability, then Equation **??** represents the sensitivity of a variable (x_1) if the output measure is affected by variables $x_1, x_2, ..., x_n$

$$S_1 = \left[\frac{\delta(IRR)}{\delta x_1}\right]_{x_1,x_2,...,x_n} \tag{4.6.1}$$

In Equation **??** the partial derivative must be calculated, which is often too cumbersome or too difficult to compute. Therefore S_1 is approximated in Equation **??**. By using this equation the sensitivity coefficients can be calculated.

$$S_1 \approx \left[\frac{\Delta(IRR)}{\Delta x_1}\right]_{x_1,x_2,...,x_n} \tag{4.6.2}$$

Once the coefficients are known, then Equation **??** is used to calculate the effect that the changes in parameters can have on the IRR. These formulas can be used to gauge the effect on the other two profitability factors (NPV and DPBP) as well.

$$\Delta IRR = S_1\Delta x_1 + S_2\Delta x_2 + ... + S_n\Delta x_n \tag{4.6.3}$$

4.6.3 Monte-Carlo Simulation

? defined eight sequential steps to be followed when conducting a Monte-Carlo Simulation. The steps are:

1. Identify and quantify all uncertainty parameters.

2. Assign probability distribution to the said parameters.

3. Assign random numbers to these parameters.

4. Assign a value to each parameter. The value is a function of the probability distribution and the random number assigned to it.

5. Estimate the NPV.

6. Repeat steps 3 through 5 a set number of times (1000 times or more).

7. From the resulting data: Construct a histogram and cumulative probability curve.

8. From the data obtained in step 7: Analyse the profitability of the project in question.

The @Risk tool analysis tool is used in this research product to automate the Monte-Carlo Simulation to a certain degree. The tool allows the user to fit different pre-set distributions to datasets, or create your own probability distributions by providing estimates of the mean, maximum and minimum value of the data.

Uniform, triangular, normal, lognormal, and trapezoidal distributions can all be used to represent different datasets. The @Risk software allows users to fit all of these distributions to datasets. This allows the user to represent datasets as accurately as possible given the uncertainty factors that must be incorporated. This allows the user to make informed decisions on the profitability of different projects while taking into account the risk involved in the said projects.

Chapter 5

Research Methodology

Figure **??** shows the methodology followed during this study. As shown in the figure a divergent approach is followed during the first part of the study, followed by a convergent approach in the second part of the study. The divergent part is where the author accumulated a broad knowledge base focussed on the recycling of cemented tungsten carbides.

In the next part of the study, all the alternatives will be evaluated with a feasibility study, in terms of the respective project's financial feasibility. The converging shape is seen in the second part of Figure **??** is due to the elimination of infeasible projects. Chapter **??** to **??** forms Phase 1 of Figure **??**, providing the background of the problem as well as the needed theoretical knowledge needed to address the problem.

Phase 2 consists of the development of a feasibility framework. In this phase, a cost model is developed to analyse the recycling alternatives against each other through a break-even analysis. The main output from the feasibility study is to identify the most suitable alternative, within a South African perspective, for cemented tungsten carbide recycling. The best-suited alternative is simulated with uncertainty factors in phase 3, through the use of a Monte-Carlo Simulation. By using this simulation the probability of this project being successful can be determined.

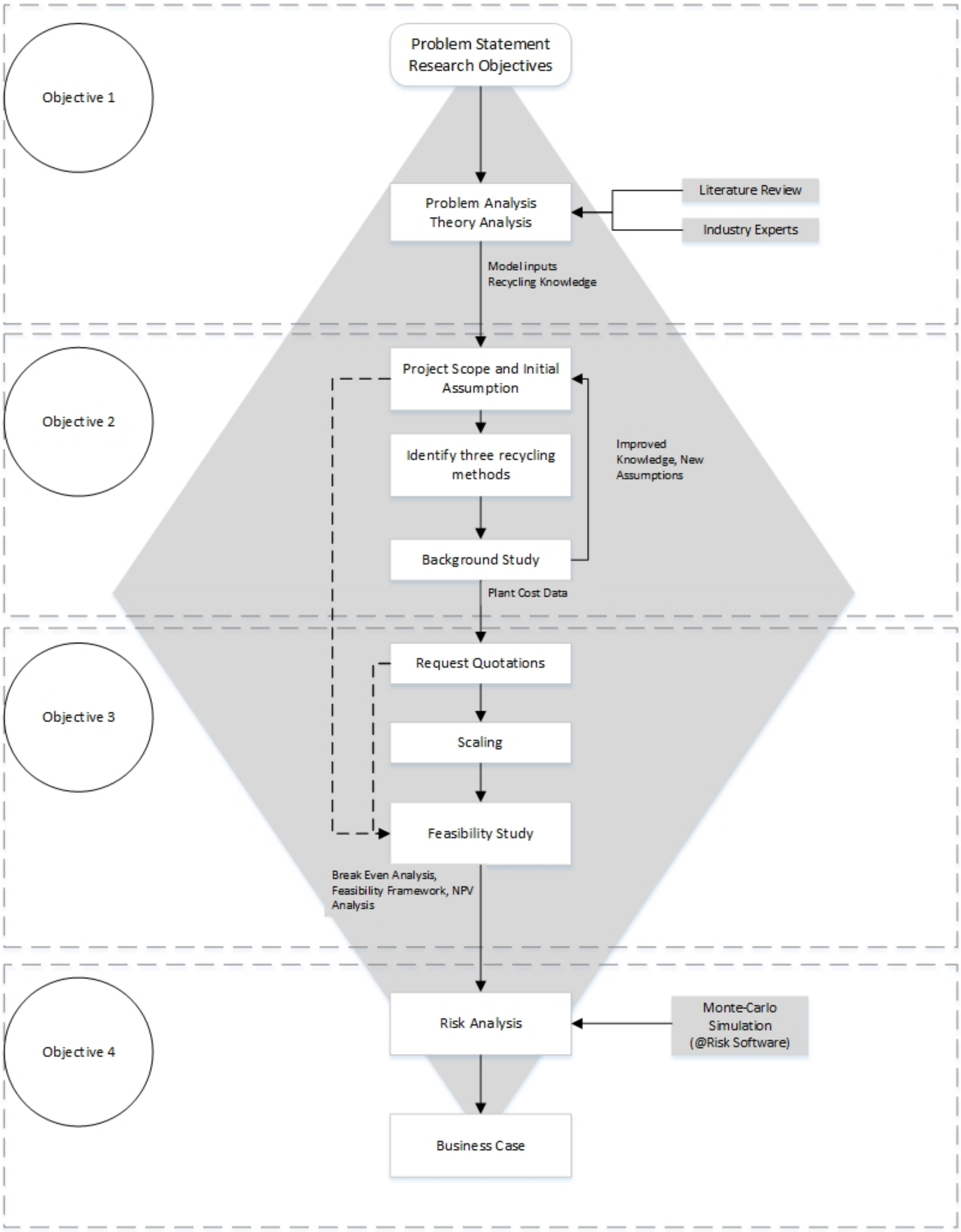

Figure 5.1: Research Methodology Followed to Conduct a Feasibility Study for Cemented Tungsten Carbides Recycling in South Africa to Support Investment Decisions

The Lang factors and other important costing data are obtained by conducting a background study and using the data obtained through this study in conjunction with the Lang factors and cost data obtained through the literature study. Using these data sources the feasibility framework is compiled. The break-even quantity is then expressed in terms of scrap throughput weight.

The feasibility study serves to identify many outputs. One of these outputs is to discover the most suitable tungsten carbide recycling method currently in use. This method is taken further in phase 3, where a Monte-Carlo Simulation is used to superimpose uncertainty into the model. By introducing this uncertainty into the model, the probability of a successful project can be simulated more accurately.

5.1 Feasibility Study

The methods used in Chapter **??** are used as a basis to conduct the feasibility study. This study is used to eliminate the processes which are infeasible at the current juncture in time. Figure **??** represents a summary of how the financial feasibility model will be created. The model inputs in conjunction with Lang factors are used to calculate the general expenses, fixed capital costs, direct manufacturing costs, as well as fixed manufacturing costs. These values form the basis of the break-even analysis and the scenario analysis. Lang factors are simply multiplication factors used to determine certain parameters from other known input values. Lang factors are determined and indexed, drawing on results from previous projects and studies.

Equipment data must be normalised to a certain capacity so as to adjust for inflation and capacity. Equations **??** and **??** are used to adjust for capacity and inflation respectively. The normalised equipment data can then be used to determine the total capital investment cost, which is calculated using the Lang factors in Table **??** which is specific to South Africa.

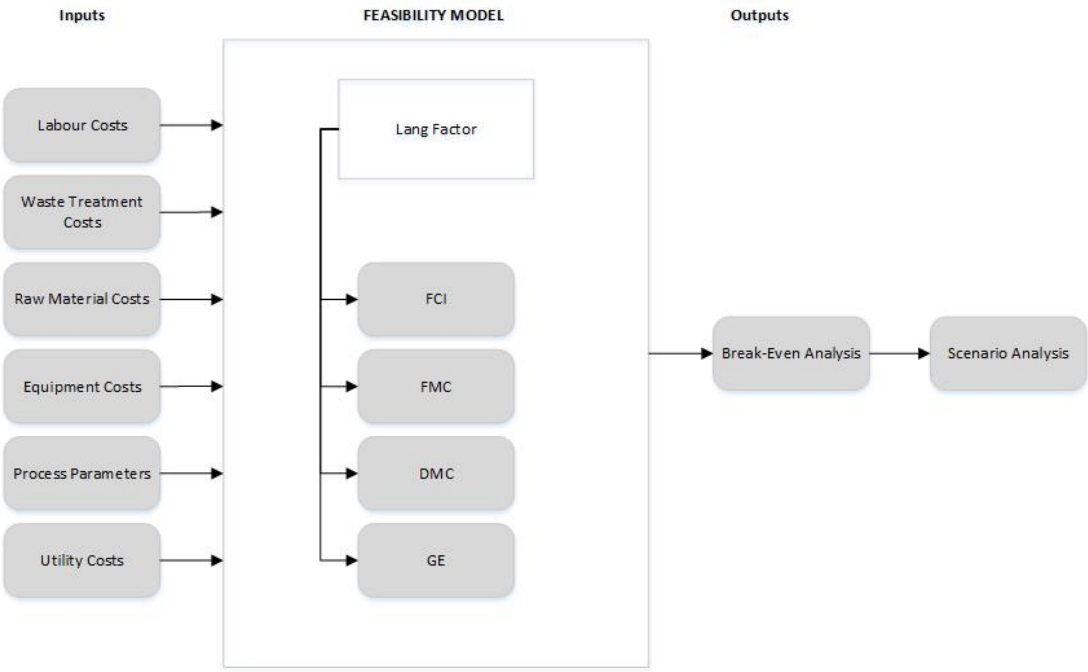

Figure 5.2: Summarised Feasibility Model Setup

The multiplication factors in Table **??** to Table **??** is used to determine the manufactruing costs. Depreciation is determined by using Equation **??**. Corporate income tax is calculated using Equation **??**. The yearly/monthly installments is determined using Equation **??**. Operating labour for a typical metallurgical plant was obtained through the information provided by Pilot Tools.

Due to the lack of the available scrap volumes in South Africa, a uniform distribution for input material throughput was used. The minimum and maximum throughput is determined by each processes' minimum start-up volume and bottleneck throughput respectively. The next step is to conduct a scenario analysis.

Microsoft Excel's Goal Seek function is used to conduct a break-even analysis. By varying the throughput of the respective recycling method's, a NPV of zero after ten years is found. This means that the throughput amount of scrap tungsten carbide for each recycling method, resulting in a positive NPV after

10 years, can be determined. The break even-analysis forms the basis of the decision-making framework.

Recycling process feasibility is determined by two factors establishing whether the break-even throughput is less than the maximum process capacity and whether the project have a positive NPV after 10 years. If these conditions are not met, then the process will have been adjudged to add too little value to scrap. Therefore, the costs involved with the project cannot be justified and the project would be deemed infeasible.

To build the model inputs are needed. These inputs include inputs that hold true for all processes, these inputs are called "global inputs". The inputs that are only applicable to certain processes are called "process specific inputs". The model inputs can be found in Appendix **??**.

5.1.1 Scenarios Considered

Each of the methods under consideration (Zinc recycling method, Acid leach method, and Coldstream process) are evaluated under three different scenarios. The first scenario is where the process has a maximum capacity according to the first bottleneck in the system. Scenario two and three is where, respectively the first and second bottlenecks in the system have been removed. This is done for all three processes. In the feasibility experiment, ten different throughputs, which are uniformly distributed from zero kg/h to the maximum capacity of the system, are used as input data for each scenario. Table **??** is a summary of the nine different scenarios under consideration. Each of the base scenarios have eleven throughputs (ten uniformly distributed throughputs, and one break-even throughput).

5.1.2 Universal Model Inputs

Available scrap volumes are the primary concern when determining the feasibility of metals recycling. According to an industry expert, who chose to

Table 5.1: Summary of Scenarios Evaluated

	Scenario	Maximum Capacity (kg/h)	ton/year
1	Zinc process	25	49.800
2		45.5	90.636
3		75	149.400
4	Acid Leach Process	22	43.824
5		44.5	88.644
6		68.75	136.950
7	Coldstream Process	25	49.800
8		44.5	88.644
9		75	149.400

stay anonymous tungsten carbide scrap in South Africa is in abundance and should not present a problem. However, in South Africa's case, low geological density of scrap might increase the cost of post-consumer collection efforts. Since the local metals industry in South Africa is unwilling to provide data on scrap production and volumes, scrap volumes will be estimated from available trade data for tungsten carbide. The simplest method for estimating the available scrap volumes is to assume that all available tungsten carbide scrap is available for recycling.

An alternative method to estimate available tungsten carbide scrap is to find the difference between imports and exports of tungsten carbide products. A disadvantage of this method is that a lot of WC is exported as scrap, making this method potentially inaccurate due to a large amount of assumptions.

The prime lending rate in South Africa at the time of the study is 10.25% and this rate will thus be taken as the interest rate for the initial loan. A discounting rate of 6.21% is used, which is the average inflation rate over 2017. SARS documents contain no relevant information on metal recycling equipment life durations, therefore a ten year depreciation period for all equipment involved are used.

Unprocessed WC EoL products can be sold/bought for $16.76 per kg, APT can be acquired for $27.20 per kg, while virgin WC powder is sold for $92.50 per kg.

The corporate tax rate for South Africa is 28%. For 2018 up until the conclusion of the study, the latest Rand to Dollar exchange rate was R12.47 per Dollar and the Rand to Euro exchange rate was taken as R14.60 per Euro.

5.1.3 Process Specific Inputs

For each of the three processes, a number of machine cost inputs is needed. This information was obtained using the methods described in Section **??**, which includes the procurement of quotes as well as using data from previous projects. Certain pieces of machinery can be used in more than one process and thus only one quote for that machine serves as input for multiple processes. Table **??** contains a summary of the different machines and their cost, capacity, and utility characteristics. The maximum capacity of the machines are based on a 1 hour batch time, thus batch times for each process will affect this value. Appendix **??** contains all the quotes for the machinery used in the processes. Table **??** contain the initial machine cost per process. Electricity usage process is aggregated across all the machines used for the process. The electricity usage per machine is sourced from the brochures supplied for the relevant machines.

5.1.3.1 Zinc Recycling Process Inputs

The zinc recycling process quotes were acquired for a basic line able to process 25 kg/h of input material. The wage for one worker amounts to R34.00 per hour, while two workers were used for the 25 kg/h line, three workers for the 45 kg/h line, and 4 workers for the 75kg/h line. The raw material input cost is R385.38 per kg. The raw materials include zinc and WC EoL parts. The utility costs for the different processes can be seen in table **??**.

Table 5.2: Total Machine Cost per Process

	Initial Machine Cost
Zinc (25 kg/h)	R 9 540 590.75
Zinc (45 kg/h)	R 13 631 657.28
Zinc (75 kg/h)	R 24 184 052.80
Acid(22 kg/h)	R 13 278 428.69
Acid(44 kg/h)	R 26 476 984.15
Acid(68 kg/h)	R 39 827 951.19
Coldstream (25 kg/h)	R 11 413 325.76
Coldstream (44 kg/h)	R 14 405 851.70
Coldstream(75 kg/h	R 25 831 744.99

5.1.3.2 Acid Leach Process Inputs

The acid leaching process quotes were acquired for a basic line able to process 22 kg/h of input material. The wage for one worker amounts to R 45.00 per hour. This is more than for the zinc recycling method due to the more technical nature of the machines used in this process. Three workers were used for the 22 kg/h line, Five workers for the 44.5 kg/h line, and seven workers for the 68.75 kg/h line. The raw material input cost amounts to R273.29, which include HCl and WC EoL parts. The utility costs for the different processes can be seen in table **??**. Waste treatment amounts to R2.01 per kg of input material. The waste treatment consists of neutralising and diluting the HCl

5.1.3.3 Coldstream Process Inputs

The coldstream process quotes were acquired for a basic line able to process 25 kg/h of input material. The wage for one worker amounts to R90.00 per hour. This is due to the extensive training needed to operate the system, which requires a highly qualified individual. Two workers were used for the 25 kg/h line, Three workers were used for the 44.5 kg/h line and five workers for the 75 kg/h line. The raw material input cost amounts to R199.95. The utility costs for the different processes can be seen in table **??**.

Table 5.3: Utility Cost per Process

	Capacity	Utility Cost (R/kg)
Zinc Recycle Process	25	R 6.04
	45.5	R 5.51
	75	R 4.50
Acid Leach Process	22	R 4.79
	44.5	R 2.69
	68.75	R3.31
Coldstream Process	25	R 2.32
	44.5	R 1.46
	75	R 1.42

5.2 Monte-Carlo Simulation

After the conclusion of the feasibility study, the best remaining recycling method will be subjected to a Monte-Carlo Simulation, allowing for uncertainty to be incorporated into the prediction model. The uncertainty is imposed on the multiplication factors. The ”best” method is selected as the process needing the lowest throughput weight to achieve a positive NPV after 10 years.

The Monte-Carlo simulation is applied with the @Risk software package as a Microsoft Excel add-in tool. The @Risk tool allows distributions to be fitted to the majority of input values. For inputs with reliable historical data, custom fit distributions can be used, for other inputs with less reliable historical data or insufficient data, triangular distributions are used. This method of introducing uncertainty allows one to analyse the probability of a project being profitable.

The next step is to conduct a sensitivity analysis, which allows one to determine the impact of each input variable on the resulting NPV. The sensitivity analysis is also conducted using the @Risk tool which use Equations **??** and **??**. The results are displayed in a tornado graph showing the biggest influence on

Table 5.4: Machine Financial Inputs and Utility Usage

Machine	**Cost**	**Max Capacity (kg/h)**	**Electricity (kW)**	**Gas**	**Data Age (year)**
Electric Induction Furnace	€607 000.00	1100	15kWh	5kg/h Ar	1998
Ball mill	$ 38 055.80	2140	18kWh	-	2018
Stainless Steel Bath	R 39 240.00	75	-	-	2018
Rotating Drum	R 225 000.00	75	0.25	-	2018
Crusher	R 650 000.00	2000	0.00135kWh	-	2016
Jet Mill	€230 000.00	25	1kWh	60m3 N2	2018
Spray drier	$ 10 000.00	25	60 kWh		2018
Cyclone	€410 000.00	500		-	1998
Drying Oven	R 150 000.00	50	170.56 kWh	-	2016

the NPV at the top of the graph.

For the chosen simulation, 10 000 iterations are completed. Appendix **??** contains a list of the model inputs for the simulation model.

5.2.1 Input Distributions

Inputs that have an expected significant variation in value over the analysis period are candidates for a distribution to be fitted to the values. Electricity costs, scrap prices, exchange rates, and tungsten carbide scrap volumes are some of the possible inputs that might need such a distribution due to significant variation.

? argues that the Akaike Information Criterion (AIC) score has several advantages over other similar best fit scoring systems and almost no disadvantages. It is also the best fit criterion used by the @Risk software. A lower AIC score denotes a better fit, and thus the distribution with the lowest AIC score is used for predictions.

To predict exchange rates, past data cannot be used by simply applying a distribution to the historic exchange rates. This is because a distribution of exchange rate values will result in all historical values affecting the probability of the forecasted rate. It is however clear that the future rate will, in the case of South Africa's largely depreciating currency, increase to a higher rate than any previous value. Thus the best way to predict the exchange rate is to fit a distribution to the monthly changes in the exchange rate and using this probability distribution to predict the rise or fall for the rate for the next month. Using this method the exchange rates will not be dependent on previous exchange rates. By using this method, the future rates are determined using the last known exchange rate and applying a simulated rise and fall for each consecutive month, using the probability distribution. This method allows a greater tendency for upwards movement in exchange rates, which is a more realistic approach.

The electricity costs for the industrial sector, as obtained from Eskom, was fitted a distribution in the same manner as the exchange rates. This allowed a similar model allowing for period-to-period changes in the electricity prices. The average yearly electricity prices since 2003 can be seen in Table **??**. To forecast the price of electricity, a probability distribution will be fitted to the year-on-year percentage change.

Table 5.5: Historic Industrial Electricity Costs

Year	Cost/kWh (c/kWh)	Year-on-year change(c/kWh)
2003/04	14.02047371	-
2004/05	13.97199458	-0.04847913
2005/06	14.63517208	0.663177492
2006/07	16.0105645	1.375392423
2007/08	17.28011705	1.269552556
2008/09	21.68566998	4.405552927
2009/10	27.03346711	5.347797125
2010/11	34.33762225	7.304155145
2011/12	40.11802429	5.780402036
2012/13	45.55974843	5.441724141
2013/14	51.78564894	6.225900517
2014/15	56.8144837	5.028834756
2015/16	62.63609172	5.821608025
2016/17	67.71094316	5.074851437

Interest rates since 2010, as obtained from the South African Reserve Bank, was used to fit a distribution to the yearly changes in the interest rate. Historically, the interest rate moves by a minimum of 25 basis points, or 0.25%. Due to this, the distribution is rounded to 0.25%. The distribution is them used to simulate the yearly interest rates by adding or subtracting the changes from the previous year's rate.

For the remaining inputs, triangular or uniform distributions is used to simulate the values over a minimum to maximum range, for the triangular the midpoint of these distributions was taken as the most likely value. The simulation were applied for each simulated year to prevent the use of the same set of values for each year. The output, relative to the input of each recycling method is varied between 60% and 90% due to the changes in efficiency of the different recycling methods as reported by **?**. For the zinc recycling method a process efficiency distribution of 82% to 97% with a most likely value of 87% is used. (**?**)

Chapter 6

Results and Discussion

This section reflects on the results of the feasibility analysis and the risk simulations. The aim of this chapter is to take into account all the information and knowledge obtained throughout this document and to put it together in such a manner as to provide meaningful insights into the feasibility of WC recycling, as well as the financial risks of such a venture. The end product is feasibility framework which will hopefully provide decision assistance for future endeavours aimed at establishing recycling programmes regarding WC in South Africa.

6.1 Feasibility Study Results

The feasibility analysis consists of a break-even analysis section and a scenario analysis section. These knowledge gained through these sections, along with knowledge gained through Chapter **??** to Chapter **??** is used as the basis for developing a feasibility framework.

To conduct the feasibility analysis, the Excel Goal Seek function is used. This function is utilised to determine the hourly throughput which will evaluate the model to a NPV of R 0.00 over a ten year period. A scenario analysis is conducted where firstly every process is evaluated over a uniformly distributed set of hourly throughputs,with the theoretical minimum equalling zero and the maximum being the maximum theoretical throughput of the process under evaluation. Further the processes are all evaluated against each other at set hourly throughputs. This provides a measurement of profitability for each process at the set hourly throughputs. Appendix **??** contains all the model inputs as well as calculations. The results of the break-even and scenario analysis are presented in Appendix **??**.

6.1.1 Break-Even Analysis

Chapter **??** contains all the inputs for the break-even analysis and these inputs are used to calculate the break-even throughput of each process under consideration. Figure **??** draws a comparison between the break-even throughputs and throughput capacity for each process. Only after the throughput exceeds the break-even bar will the process become profitable from a NPV calculation point of view. The throughput cannot exceed the maximum capacity denoted by the red bar. Therefore where the difference between the maximum capacity and the break-even throughput is bigger, the process has more leeway to become more profitable.

Figure **??** is a comparison of the NPV values over the ten year analysis period. The starting value at Year 0 is the amount of starting capital needed to launch the project in question, which can also be seen in Figure **??**. All the processes break even after the ten year analysis period, and the break-even throughputs are all lower than the maximum capacity of the respective processes, this can be seen in Figure **??**. Therefore, all the processes in question is theoretically feasible from a capability point of view.

The zinc process optimised for a 25 kg/h throughput has the lowest throughput required to break even. Followed by the coldstream process optimised for 25 kg/h. The acid leach process consistently ranks as the worst option at each interval of removing bottlenecks. Another drawback is that all three acid leaching cases have a comparatively small margin between the break-even throughput and the maximum throughput capacity, leaving little room for the process

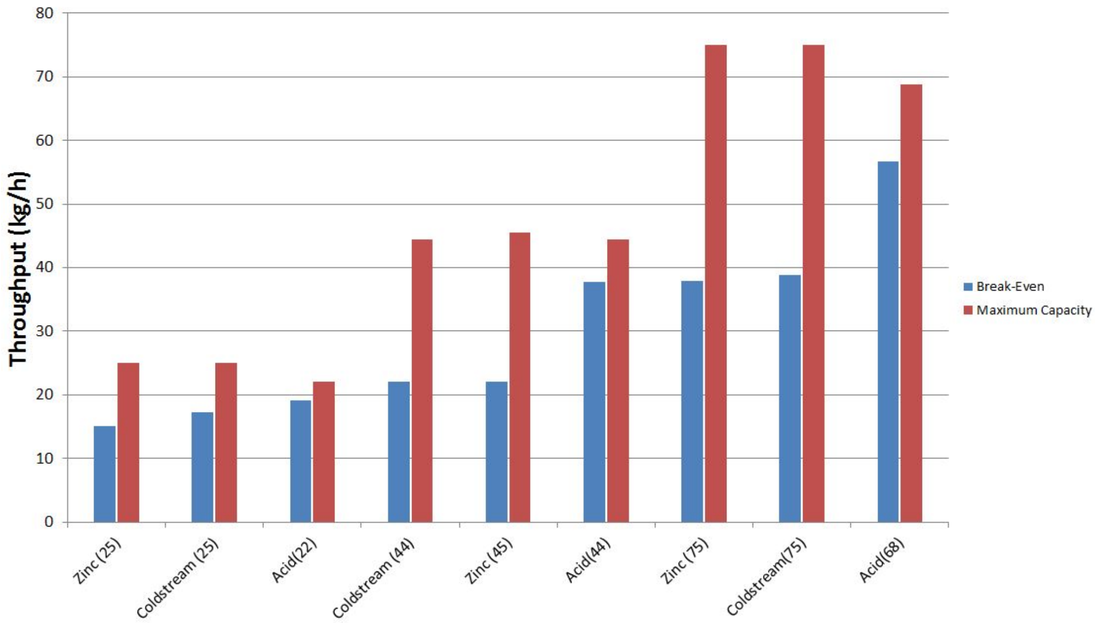

Figure 6.1: Comparison of Break-Even Recycling Rate and Maximum Throughput Capacity of Recycling Alternatives

to become profitable before the maximum process capacity is reached. This result ties in with the findings of **?**, where they concluded that the acid leach process is best used as a secondary, laboratory sized plant to process oversized material at the end of a primary process. Figure **??** to **??** in Appendix **??** contains all the NPV calculations for the break even cases.

Small break-even throughput increases from the 25 kg/h optimised zinc and coldstream processes to the larger 44.5 kg/h coldstream process and 45.5 kg/h zinc processes can be seen. This is indicative of the ease at which these two processes can be up-scaled at a future date and still be profitable without the need for a large rise in throughput for the process to break-even. This is not true for the acid leach process where up-scaling goes hand-in-hand with a comparatively large rise in the break-even throughput.

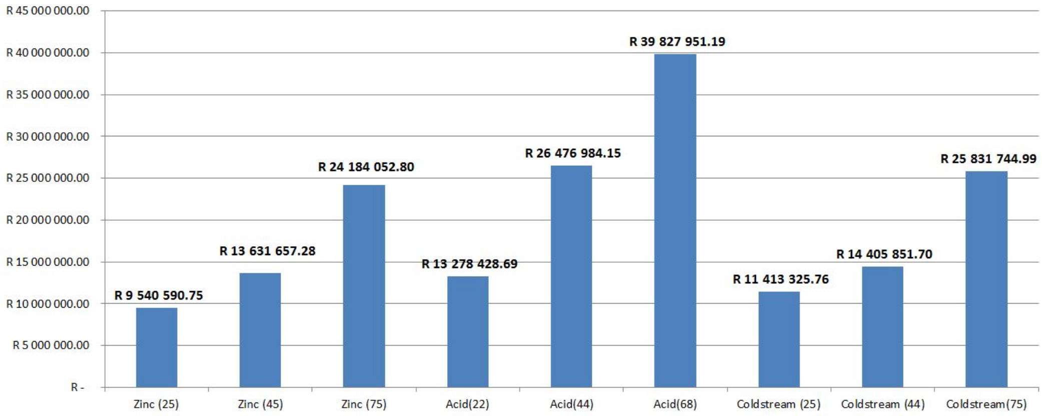

Figure 6.2: Equipment Cost for Each Process

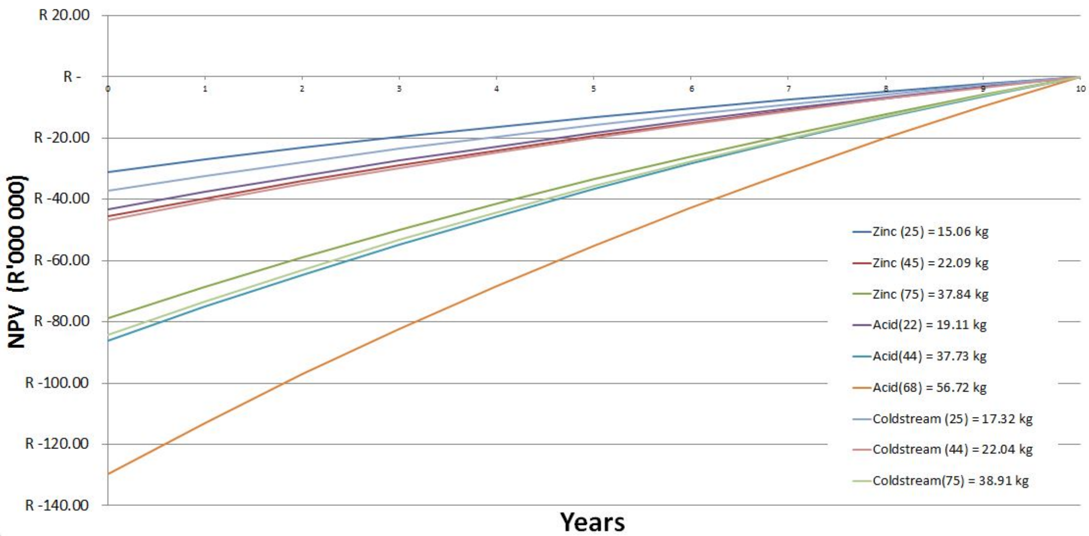

Figure 6.3: Ten Year NPV comparison for All Break-Even Cases

6.1.2 Scenario Analysis

In this section each recycling process will be discussed in terms of different throughput scenarios. The scenario analysis, consisting of a uniformly distributed throughput, will be done on all three processes as well as all three capacities for the respective processes. The cumulative discounted cash flow over the ten year period is taken as the first barrier to feasibility. If the cumulated cash flow is positive at the end of the period then the process is financially feasible. The second barrier is whether the break-even throughput is smaller than the maximum capacity of the process. If this is true then the process is feasible. In the NPV plots, a positive trend in the values indicates that the project's value is increasing, and a decreasing trend indicates that the project is losing money and will never break-even.

6.1.2.1 Zinc Recycling Scenario Analysis

In Figure **??** to Figure **??** the NPV plots for the ten different throughputs can be seen. For the 25 kg/h configuration, the process breaks even at 60.2% of the maximum process capacity. For the 45.5 kg/h configuration, the process breaks even at 48.5% of the maximum process capacity. For the 75 kg/h configuration, the process breaks even at 50.4% of the maximum process capacity. All of this indicates that there is 40-50% of improvement room after the process breaks even.

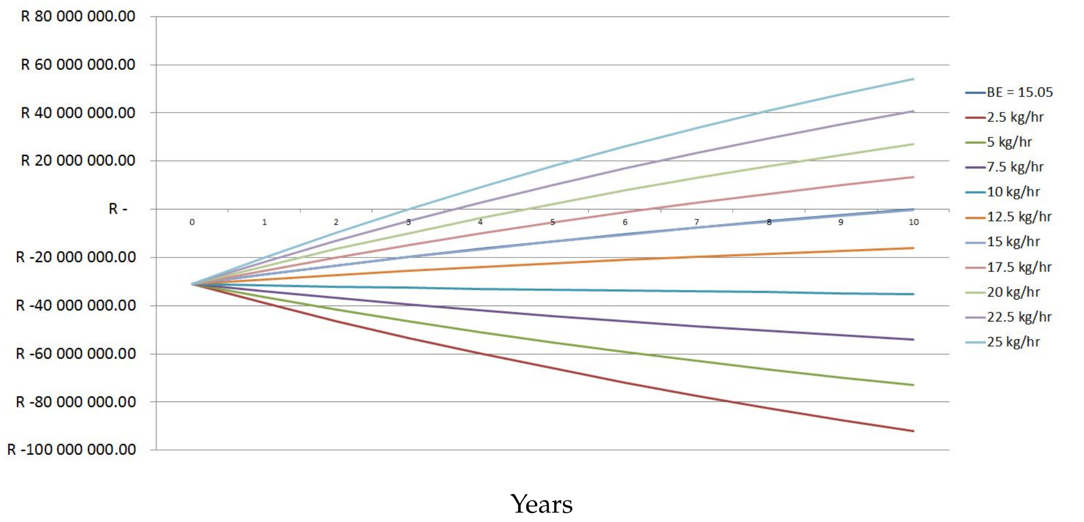

Figure 6.4: NPV (R) Analysis with Different Throughput Scenarios for the Zinc Recycling (25kg/h)

As seen in Figure **??**, 40% of the scenarios in the 25 kg/h zinc recycling process shows a decreasing trend, and will thus never show a positive NPV.

Only 10% of the scenarios show a positive trend, but doesn't reach a positive NPV in the ten year period. A maximum NPV of R54.25 million at an IRR of 35.92% can be reached if the process operates at its maximum capacity. The NPV analysis calculations can be seen in Figures **??** to **??**.

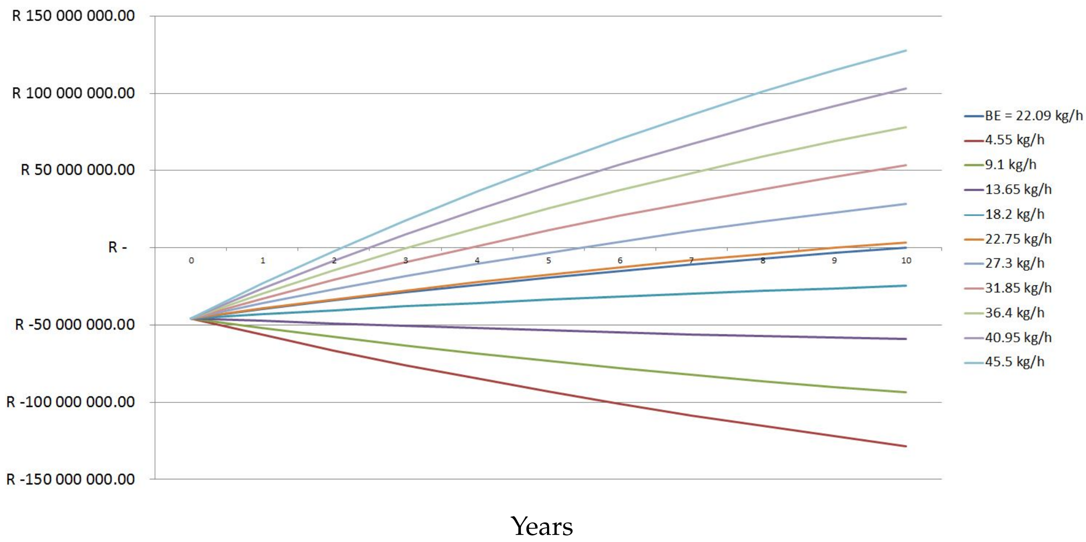

Figure 6.5: NPV (R) Analysis with Different Throughput Scenarios for the Zinc Recycling (45kg/h)

As seen in Figure **??**, 30% of the scenarios in the 45.5 kg/h zinc recycling process shows a decreasing trend, and will thus never show a positive NPV. Only 10% of the scenarios show a positive trend, but doesn't reach a positive NPV in the ten year period. A maximum NPV of R127.88 million at an IRR of 51.34% can be reached if the process operates at its maximum capacity.The NPV analysis calculations can be seen in Figures **??** to **??**.

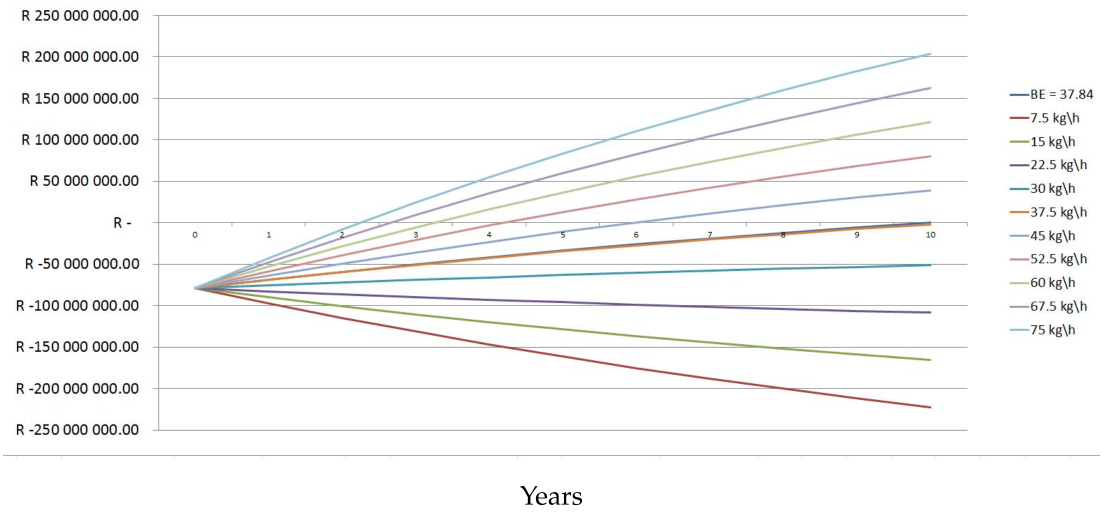

Figure 6.6: NPV (R) Analysis with Different Throughput Scenarios for the Zinc Recycling (75kg/h)

As seen in Figure **??**, 30% of the scenarios in the 75 kg/h zinc recycling process shows a decreasing trend, and will thus never show a positive NPV. 20% of the scenarios show a positive trend, but doesn't reach a positive NPV in the ten year period. A maximum NPV of R203.50 million at an IRR of 48.20% can be reached if the process operates at its maximum capacity.The NPV analysis calculations can be seen in Figures **??** to **??**.

6.1.2.2 Acid Leach Process Scenario Analysis

In Figure **??** to Figure **??** the NPV plots for the ten different throughputs can be seen. For the 22 kg/h configuration, the process breaks even at 86.86% of the maximum process capacity. For the 44.5 kg/h configuration, the process breaks even at 84.76% of the maximum process capacity. For the 68.75 kg/h configuration, the process breaks even at 82.50% of the maximum process capacity. This is an indication that the processes have to operate at a very high efficiency just to break even after the ten year period.

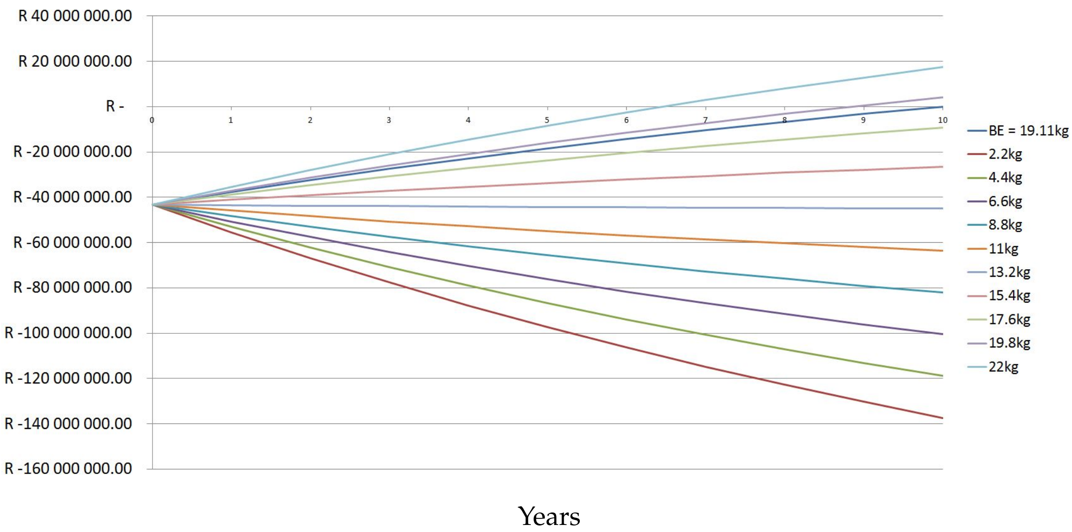

Figure 6.7: NPV (R) Analysis with Different Throughput Scenarios for the Acid Leach Process (22kg/h)

As seen in Figure **??**, 60% of the scenarios in the 22 kg/h acid leach process shows a decreasing trend, and will therefore never have a positive NPV. 20% of the scenarios show an upward trend, yet does not reach a positive NPV in the analysis period. A maximum NPV of R17.46 million at an IRR of 14.12% can be reached if the process operates at its maximum capacity.The NPV analysis calculations can be seen in Figures **??** to **??**.

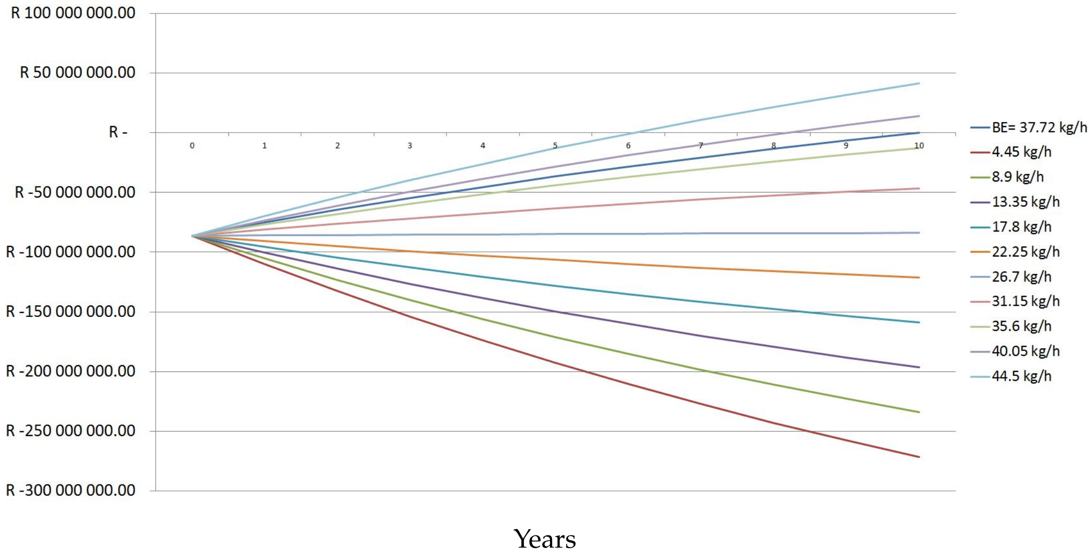

Figure 6.8: NPV (R) Analysis with Different Throughput Scenarios for the Acid Leach Process (44kg/h)

As seen in Figure **??**, 50% of the scenarios in the 44.5 kg/h acid leach process shows a decreasing trend, and will therefore never have a positive NPV. 30% of the scenarios show an upward trend, yet does not reach a positive NPV in the analysis period. A maximum NPV of R41.10 million at an IRR of 15.44% can be reached if the process operates at its maximum capacity.The NPV analysis calculations can be seen in Figures **??** to **??**.

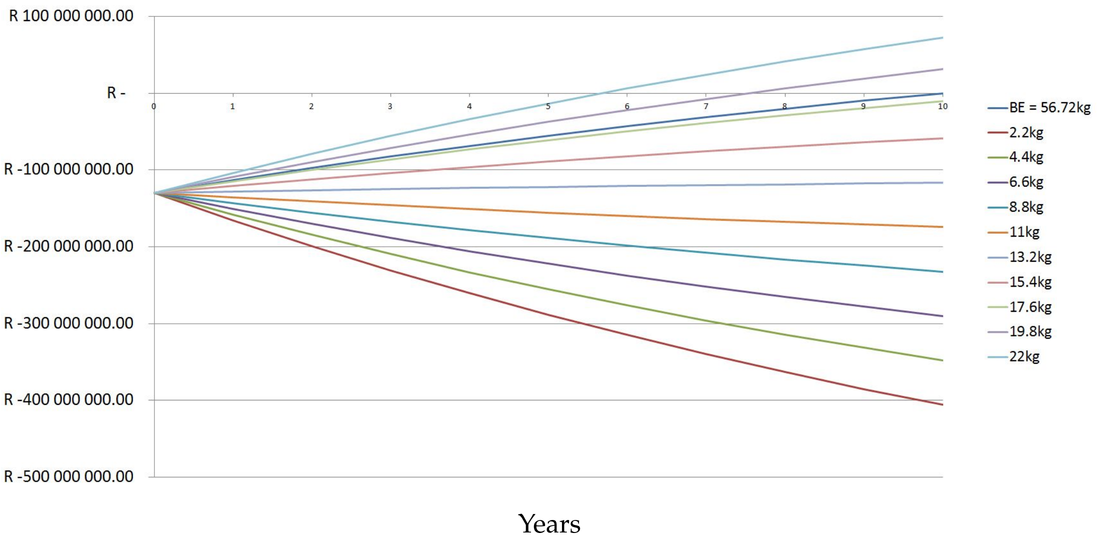

Figure 6.9: NPV (R) Analysis with Different Throughput Scenarios for the Acid Leach Process (68kg/h)

As seen in Figure **??**, 50% of the scenarios in the 68.75 kg/h acid leach process shows a decreasing trend, and will therefore never have a positive NPV. 30% of the scenarios show an upward trend, yet does not reach a positive NPV in the analysis period. A maximum NPV of R72.94 million at an IRR of 16.96% can be reached if the process operates at its maximum capacity.The NPV analysis calculations can be seen in Figures **??** to **??**.

6.1.2.3 Coldstream Process Scenario Analysis

In Figure **??** to Figure **??** the NPV plots for the ten different throughputs can be seen. For the 25 kg/h configuration, the process breaks even at 69.28% of the maximum process capacity. For the 44.5 kg/h configuration, the process breaks even at 49.5% of the maximum process capacity. For the 75 kg/h configuration, the process breaks even at 51.88% of the maximum process capacity. All of this indicates that there is 30-50% of improvement room after the processes breaks even.

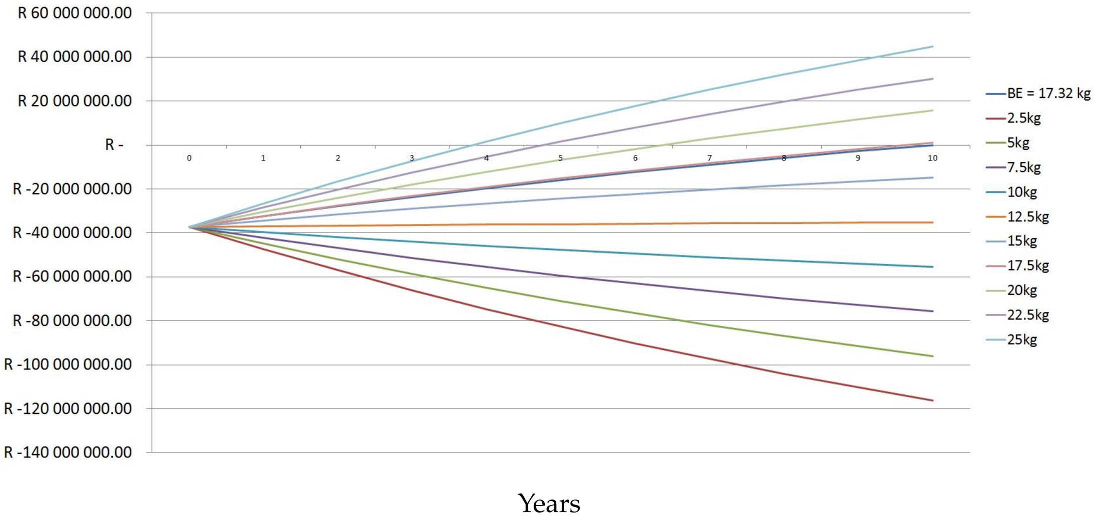

Figure 6.10: NPV (R) Analysis with Different Throughput Scenarios for the Coldstream Process (25kg/h)

As seen in Figure **??**, 40% of the scenarios in the 25 kg/h coldstream process shows a decreasing trend, and will therefore never have a positive NPV. 20% of the scenarios show an upward trend, yet does not reach a positive NPV in the analysis period. A maximum NPV of R44.82 million at an IRR of 27.62% can be reached if the process operates at its maximum capacity. The NPV analysis calculations can be seen in Figures **??** to **??**.

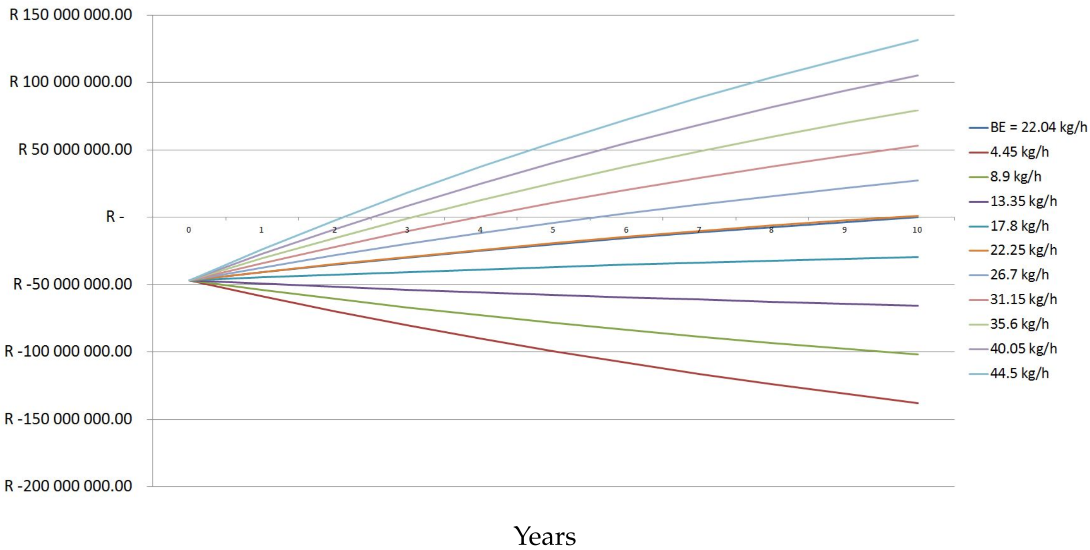

Figure 6.11: NPV (R) Analysis with Different Throughput Scenarios for the Coldstream Process (44kg/h)

As seen in Figure **??**, 30% of the scenarios in the 44.5 kg/h coldstream process shows a decreasing trend, and will therefore never have a positive NPV. 10% of the scenarios show an upward trend, yet does not reach a positive NPV in the analysis period. A maximum NPV of R131.39 million at an IRR of 51.31% can be reached if the process operates at its maximum capacity.The NPV analysis calculations can be seen in Figures **??** to **??**.

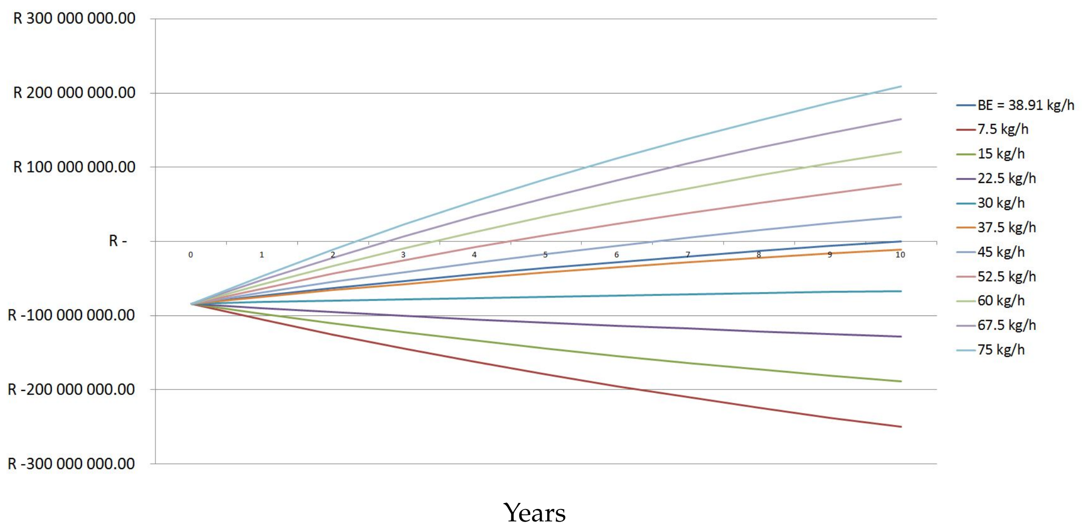

Figure 6.12: NPV (R) Analysis with Different Throughput Scenarios for the Coldstream Process (75kg/h)

As seen in Figure **??**, 30% of the scenarios in the 75 kg/h coldstream process shows a decreasing trend, and will therefore never have a positive NPV. 20% of the scenarios show an upward trend, yet does not reach a positive NPV in the analysis period. A maximum NPV of R208.59 million at an IRR of 46.70% can be reached if the process operates at its maximum capacity.The NPV analysis calculations can be seen in Figures **??** to **??**.

6.1.2.4 Comparative Analysis

This section aims to compare the different processes at set throughput intervals. By doing this a direct comparison of the processes can be made regarding the NPV at certain throughputs. Figure **??** to Figure **??** contains the ten year NPV analysis at 25 kg/h, 44 kg/h, 68 kg/h, and the maximum throughput per process respectively.

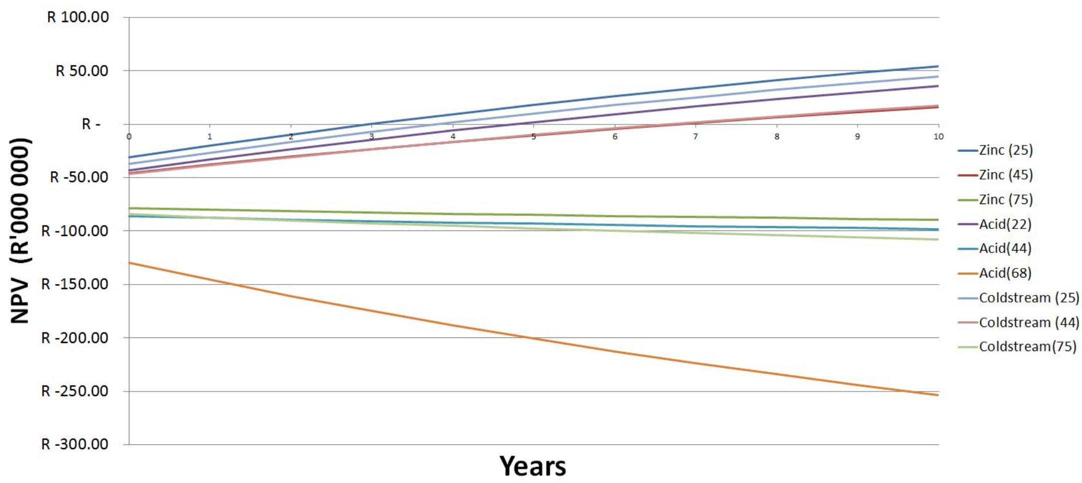

Figure 6.13: Process NPV Comparison @ 25kg/h Throughput

Figure **??** shows the NPV at 25 kg/h, and from this figure it can be seen that the Zinc (75 kg/h) process , the acid leach (44 kg/h) process, acid leach (68 kg/h) process, and the coldstream process (75 kg/h) never breaks even. The negative slope of these processes also indicates that this process will never be profitable at this throughput.

The Zinc (25 kg/h) process have the highest NPV (R 54 251 329) at this throughput with an IRR of 35.92%. The coldstream (25 kg/h) has the second highest NPV at R 44 817 027 with an IRR of 27.62%.

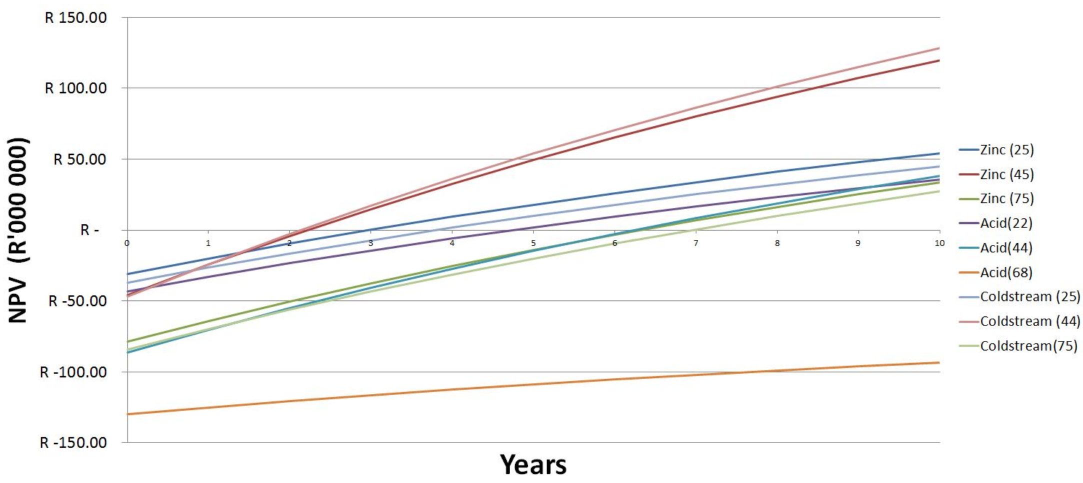

Figure 6.14: Process NPV Comparison @ 44kg/h Throughput

Figure **??** shows the NPV at 44 kg/h. The processes that are only capable of a lower throughput due to system constraints is assumed to operate at that maximum capacity. From this figure it can be seen that only the acid (68 kg/h) process has a negative NPV after ten years. Although the slope is positive at the moment this process will likely never break-even as the process NPV will even out somewhere in the future.

The coldstream (44 kg/h) process has the highest NPV after ten years at R 128 462 618 at an IRR of 50.42%. The zinc (45kg/h) process has the second highest ten year NPV of R 119 680 721 at an IRR of 48.77%.

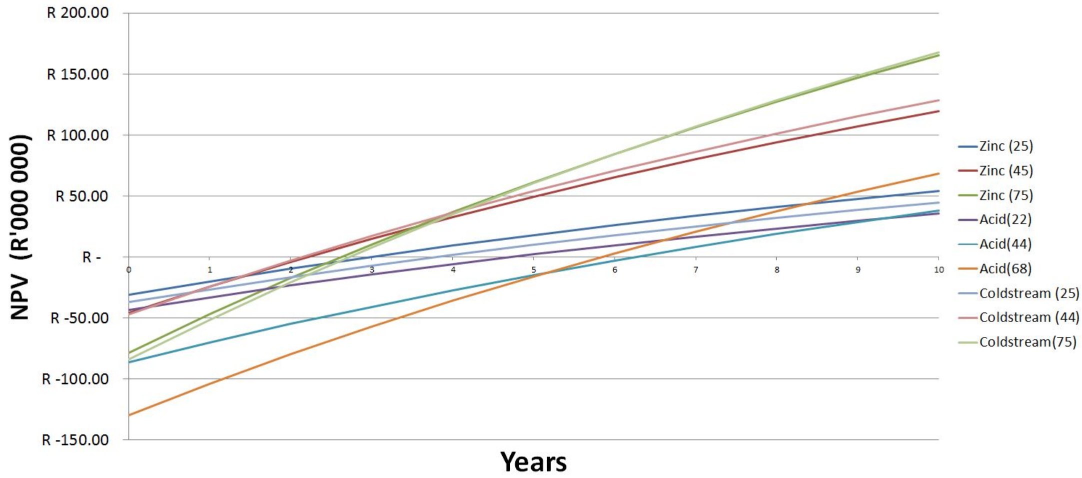

Figure 6.15: Process NPV Comparison @ 68kg/h Throughput

Figure ?? shows the NPV at 68 kg/h. The processes that are only capable of a lower throughput due to system constraints is assumed to operate at that maximum capacity. At this throughput all the processes have a positive NPV after the ten year analysis period, however it is the coldstream (75 kg/h) process at a NPV of R 167 637 025 and zinc (75 kg/h) process at an NPV of R 165 160 362 with IRR's of 39.60% and 41.13%.

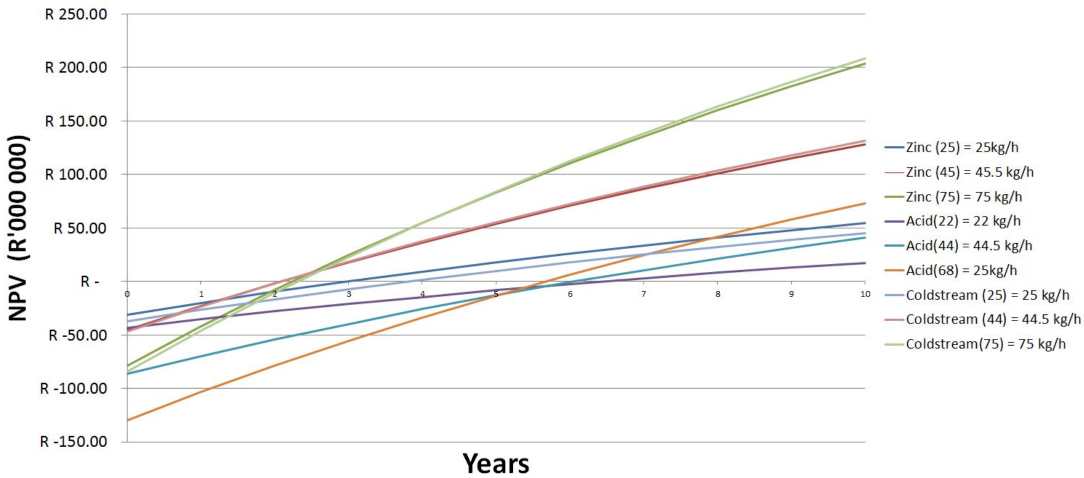

Figure 6.16: Process NPV Comparison @ Maximum Throughput

Figure ?? shows the NPV after ten years at the maximum throughput of each process. As with the 658 kg/h throughput, the processes with the highest NPV after ten years are the coldstream (75 kg/h) process and zinc (75 kg/h) process. The coldstream (75 kg/h) process has a NPV of R 208 590 277 and an IRR of 46.70%. The zinc (75 kg/h) process has a NPV of R 203 495 710 with an IRR of 48.20%.

Table **??** is an illustration of the NPV after ten years and the break-even year for each throughput of every process and its different configurations. A red cell indicates a scenario where the the process will not break even within the ten year analysis period. A green cell indicates that the process will break even within 6 years, which is favourable for projects of this magnitude. A yellow cell indicates where a process will break even at that throughput, but only after seven to ten years.

From Table **??** it can be deducted that a measured degree of economy of scale enables proportionate increases in the NPV as well as decreases in the payback period. However, for both the zinc process and the coldstream process there exists a tipping point, where larger process capacities will result in longer payback periods.

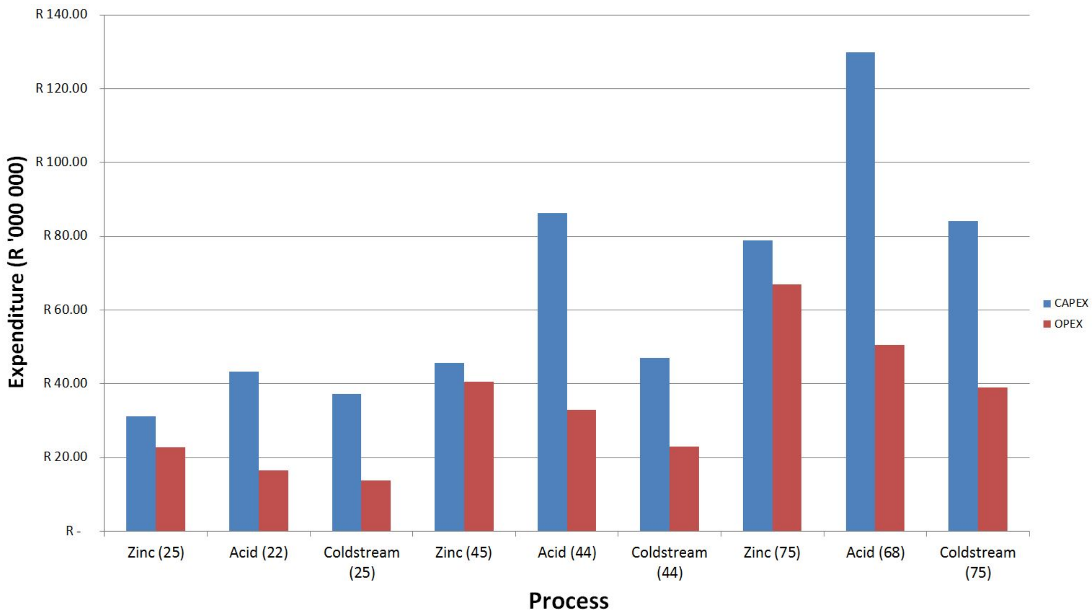

Figure 6.17: Capex and Opex Comparison per Process

Figure **??** represents a comparison of the Capex and Opex values for the maximum throughput per process. The zinc process is consistently the process with the lowest Capex value, but it is also the process which consistently have the highest Opex value, this is due to the high raw material inputs associated with this process. The acid leach process has the highest Capex values across the different throughput brackets. The coldstream process consistently has the lowest Opex values across the different throughput brackets.

Table 6.1: Process Financial Analysis Results Summary

Process	Capacity (kg/h)		Throughput 1	Throughput 2	Throughput 3	Throughput 4	Throughput 5	Throughput 6	Throughput 7	Throughput 8	Throughput 9	Throughput 10
Zinc Process	25	Rate	2.5 kg/h	5 kg/h	7.5 kg/h	10 kg/h	12.5 kg/h	15 kg/h	17.5 kg/h	20 kg/h	22.5 kg/h	25 kg/h
		NPV	R -91 893 289.34	R -72 946 508.30	R -53 999 727.26	R -35 052 946.22	R -16 106 165.18	R -315 400.15	R 13 326 282.20	R 26 967 964.55	R 40 609 646.90	R 54 251 329.25
		PBP	Never	Never	Never	Never	Never	Year 11	Year 7	Year 5	Year 4	Year 3
	45.5	Rate	4.55 kg/h	9.1 kg/h	13.65 kg/h	18.2 kg/h	22.75 kg/h	27.3 kg/h	31.85 kg/h	36.4 kg/h	40.95 kg/h	45.5 kg/h
		NPV	R -128 312 773.20	R -93 786 949.43	R -59 261 125.67	R -24 735 301.91	R 3 582 896.64	R 28 441 489.75	R 53 300 082.86	R 78 158 675.97	R 103 017 269.08	R 127 875 862.19
		PBP	Never	Never	Never	Never	Year 10	Year 6	Year 4	Year 4	Year 3	Year 3
	75	Rate	7.5 kg/h	15 kg/h	22.5 kg/h	30 kg/h	37.5 kg/h	45 kg/h	52.5 kg/h	60 kg/h	67.5 kg/h	75 kg/h
		NPV	R -222 475 942.56	R -165 429 293.14	R -108 382 643.71	R -51 335 994.29	R -1 872 227.01	R 39 201 360.58	R 80 274 948.16	R 121 348 535.75	R 162 422 123.33	R 203 495 710.92
		PBP	Never	Never	Never	Never	Never	Year 6	Year 5	Year 4	Year 3	Year 3
Acid Leach Process	22	Rate	2.2 kg/h	4.4 kg/h	6.6 kg/h	8.8 kg/h	11 kg/h	13.2 kg/h	15.4 kg/h	17.6 kg/h	19.8 kg/h	22 kg/h
		NPV	R -137 396 543.13	R -118 928 445.04	R -100 460 415.22	R -81 992 453.67	R -63 524 560.40	R -45 056 735.40	R -26 588 978.68	R -9 132 831.73	R 4 163 854.79	R 17 460 492.15
		PBP	Never	Never	Never	Never	Never	Never	Never	Never	Year 9	Year 7
	44.5	Rate	4.45 kg/h	8.9 kg/h	13.35 kg/h	17.8 kg/h	22.25 kg/h	26.7 kg/h	31.15 kg/h	35.6 kg/h	40.05 kg/h	44.5 kg/h
		NPV	R -271 516 895.93	R -233 993 391.76	R -196 470 166.93	R -158 947 221.45	R -121 424 555.31	R -83 902 168.51	R -46 380 061.05	R -12 929 170.08	R 14 086 345.04	R 41 101 659.03
		PBP	Never	Never	Never	Never	Never	Never	Never	Never	Year 9	Year 7
	68.75	Rate	6.875 kg/h	13.75 kg/h	20.625 kg/h	27.5 kg/h	34.375 kg/h	41.25 kg/h	48.125 kg/h	55 kg/h	61.875 kg/h	68.75 kg/h
		NPV	R -406 048 059.99	R -348 152 510.16	R -290 257 627.09	R -232 363 410.77	R -174 469 861.20	R -116 576 978.37	R -58 684 762.30	R -10 425 806.75	R 31 255 628.70	R 72 936 584.10
		PBP	Never	Never	Never	Never	Never	Never	Never	Never	Year 8	Year 6
Coldstream Process	25	Rate	2.5 kg/h	5 kg/h	7.5 kg/h	10 kg/h	12.5 kg/h	15 kg/h	17.5 kg/h	20 kg/h	22.5 kg/h	25 kg/h
		NPV	R -116 297 328.64	R -96 023 390.12	R -75 749 451.59	R -55 475 513.06	R -35 201 574.54	R -14 927 636.01	R 1 025 320.44	R 15 622 556.17	R 30 219 791.91	R 44 817 027.65
		PBP	Never	Never	Never	Never	Never	Never	Year 10	Year 7	Year 5	Year 4
	44.5	Rate	4.45 kg/h	8.9 kg/h	13.35 kg/h	17.8 kg/h	22.25 kg/h	26.7 kg/h	31.15 kg/h	35.6 kg/h	40.05 kg/h	44.5 kg/h
		NPV	R -137 968 027.58	R -101 812 314.93	R -65 656 602.28	R -29 500 889.63	R 1 227 009.73	R 27 259 122.84	R 53 291 235.95	R 79 323 349.05	R 105 355 462.16	R 131 387 575.26
		PBP	Never	Never	Never	Never	Year 10	Year 6	Year 4	Year 4	Year 3	Year 3
	75	Rate	7.5 kg/h	15 kg/h	22.5 kg/h	30 kg/h	37.5 kg/h	45 kg/h	52.5 kg/h	60 kg/h	67.5 kg/h	75 kg/h
		NPV	R -249 895 124.77	R -188 952 785.77	R -128 010 446.78	R -67 068 107.79	R -10 802 143.34	R 33 076 340.73	R 76 954 824.81	R 120 833 308.88	R 164 711 792.96	R 208 590 277.04
		PBP	Never	Never	Never	Never	Never	Year 7	Year 5	Year 4	Year 3	Year 3

6.2 Monte-Carlo Simulation

One of the objectives of this study is to evaluate the financial feasibility of tungsten carbide recycling methods. To better understand the effect of the different model inputs on the outcome of the feasibility models. To evaluate the risks carried by the variability of the inputs, a Monte-Carlo simulation is executed using the @Risk software described in Chapter **??**.

For the input distributions several of the Lang factors are given as a triangular distribution with a minimum, maximum, and most-likely value provided, as shown in Figure **??**. The blue line indicates the fitted distribution, and the red bars indicate the actual values assigned to the distribution during the simulation. The rest of the inputs can be seen in Section **??** of Appendix **??**. For the feasibility part of the study the most-likely value was used. The other input variables are fitted with relevant distributions as determined by the "Distribution Fitting" function of the @Risk software.

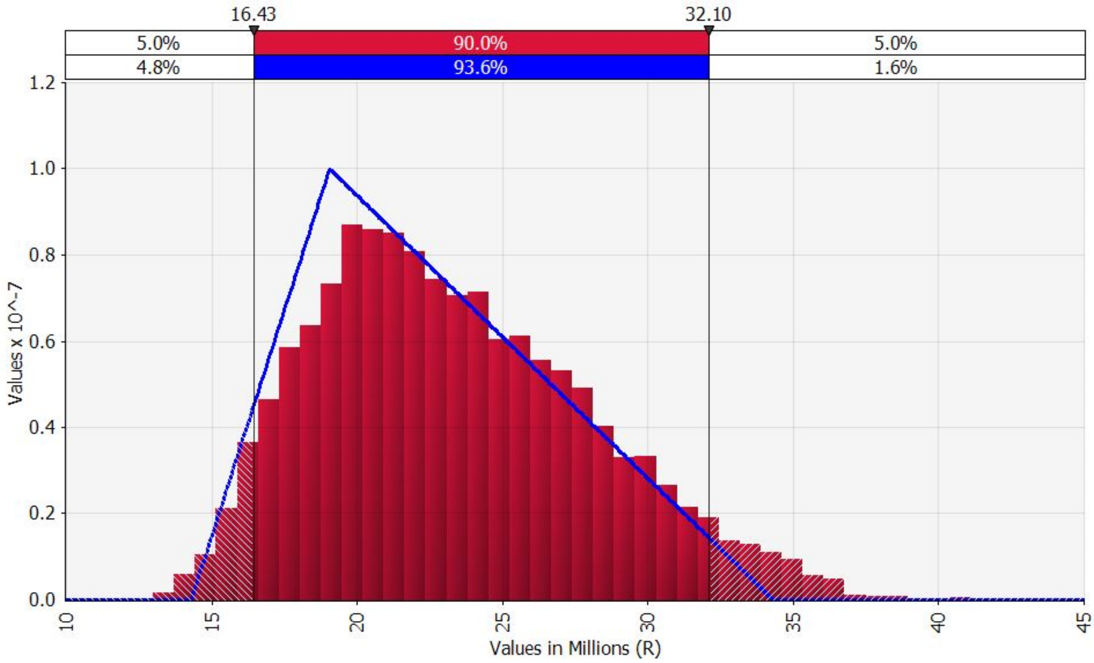

Figure 6.18: Triangular Distribution of Raw Material Costs

Three simulation, one for each process evaluated, was run with 10 000 iterations in each run. At the conclusion of the simulations, the probability of profitability for each process were assessed. Further, the effect of the different inputs on the NPV were assessed for each process and displayed using tornado graphs. Appendix **??** contains a complete summary of the simulation inputs.

All the processes was run with a throughput of 35 kg/h in order to account for possible process downtime, as this is a factor that the Lang factor method does not take into account. During the analysis of the simulation results, two types of graphs were used to display the results. These graphs are: 1) Probability density graphs and 2) Tornado graphs. The probability density graphs display the probability that certain NPV or IRR values can occur. In the case of the NPV analysis, the probability that the NPV will be bigger than 0, is determined. In the case of the IRR analysis, the probability of an IRR bigger than 15% is determined. The tornado graph displays the sensitivity of the model to certain input factors.

The input distributions was determined using the strategy outlined in Section **??** to Section **??**.

6.2.1 Zinc Process Results

The zinc process, optimised for 45.5 kg/h was used for the simulation. According to the simulation, the zinc process has an 88.7% probability of having a positive NPV value. This can be seen in Figure **??**. Therefore, there is an 11.3% probability of the project failing. The mean value for the process is positive at R63 896 666. Figure **??** shows that there is an 81.8% chance that this process will have a IRR of more than 15%. A mean value of 30.55% is obtained. Figure **??** indicates that the biggest influence on the NPV of this process is the process efficiency. It is also the only input which can drive the NPV to a negative value. The raw material costs also has a significant effect on the model.

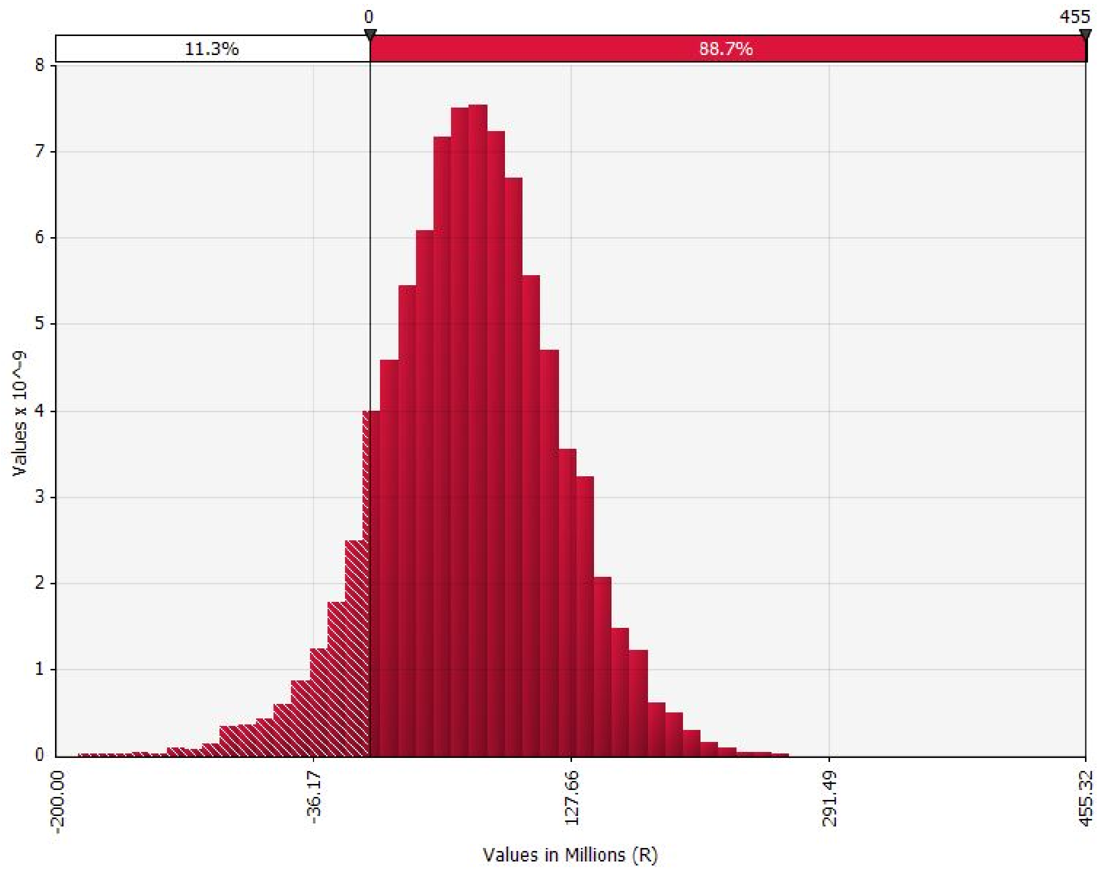

Figure 6.19: Zinc Process NPV Probability Density Function

Equipment cost, labour as well as electricity input costs predictably have a relatively large effect on the NPV. It should be noted that the yearly discount rates each have a relatively small effect on the output, but collectively the effect might be significant over the course of the ten years.

6.2.2 Coldstream Process Results

The coldstream process, optimised for 44.5 kg/h was used for the simulation. Figure **??** indicates that the coldstream process has a probability of 92.2% of having a positive NPV after 10 years. The mean NPV for this scenario is R51 508 084. This scenario has the largest probability of having a positive NPV all the scenarios evaluated.

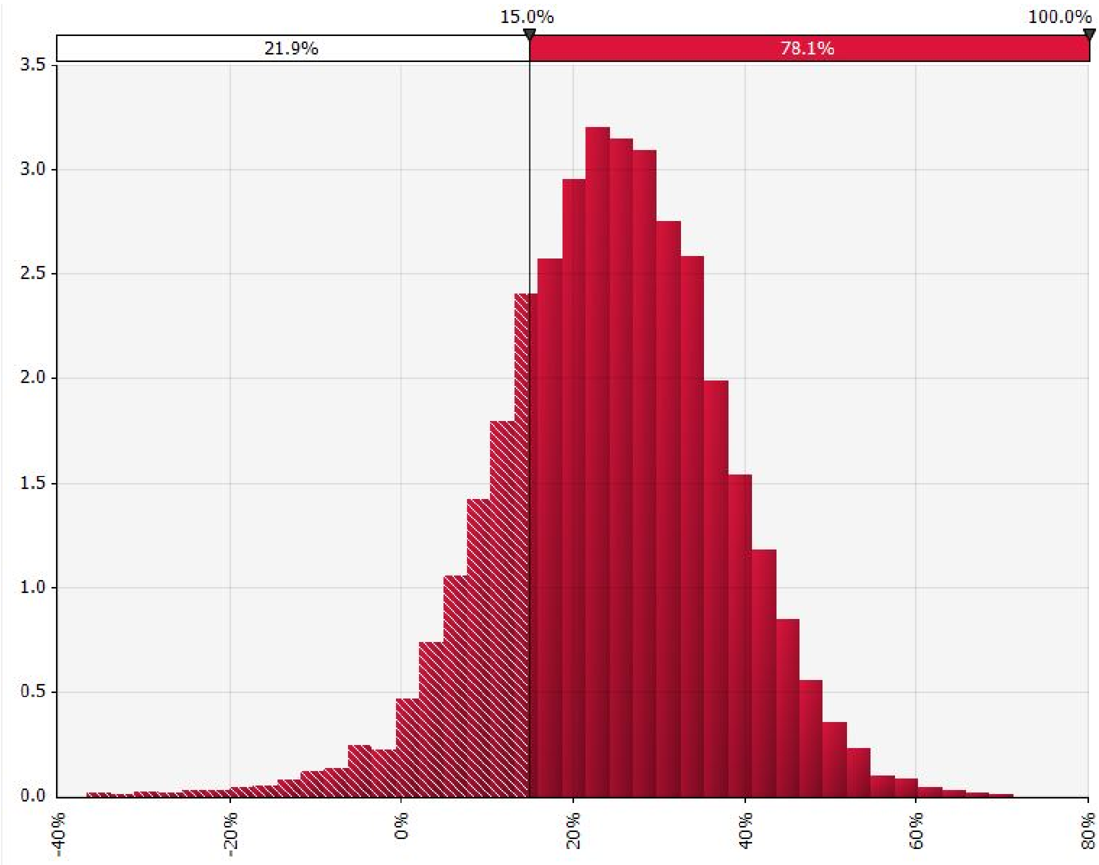

Figure 6.20: Coldstream Process IRR Probability Density Function

As can be seen in Figure **??**, this scenario has a 78.1% probability of having an IRR larger than 15%. The mean value is 24.48%. Both of these values are notably smaller than that of the zinc process, indicating that a smaller return on investment can be expected from the coldstream process than that of the zinc process.

Figure **??** shows that process efficiency is again the input with the greatest effect on the model, and the only input with the possibility of driving the NPV to a negative value on its own. It is followed by raw material, equipment, and labour costs. As noted in the previous section, the discount rates again has a relatively small effect on the model on its own, but collectively it can possibly have a large effect on the scenario outcome.

6.2.3 Acid Leaching Process Results

The acid leach process, optimised for 44.5 kg/h, was used for the simulation. This process has the smallest probability (20.4%) of having a positive NPV after ten years of all the scenarios evaluated as can be seen in Figure **??**. This is the only scenario with a negative mean value, the value being -R58 074 468.

As shown in Figure **??** this scenario has a probability of 8.4% of having an IRR value of 15% or higher, leaving this an extremely risky scenario to pursue as an investment option, and it is clearly the worst scenario to consider as an investment option.As shown in Figure **??**, the process efficiency has the biggest effect on the model, with the equipment costs coming in at a close second. Both of these inputs, along with raw material costs can drive the NPV well below zero, but if managed properly this is the inputs which can make this scenario profitable, however unlikely.

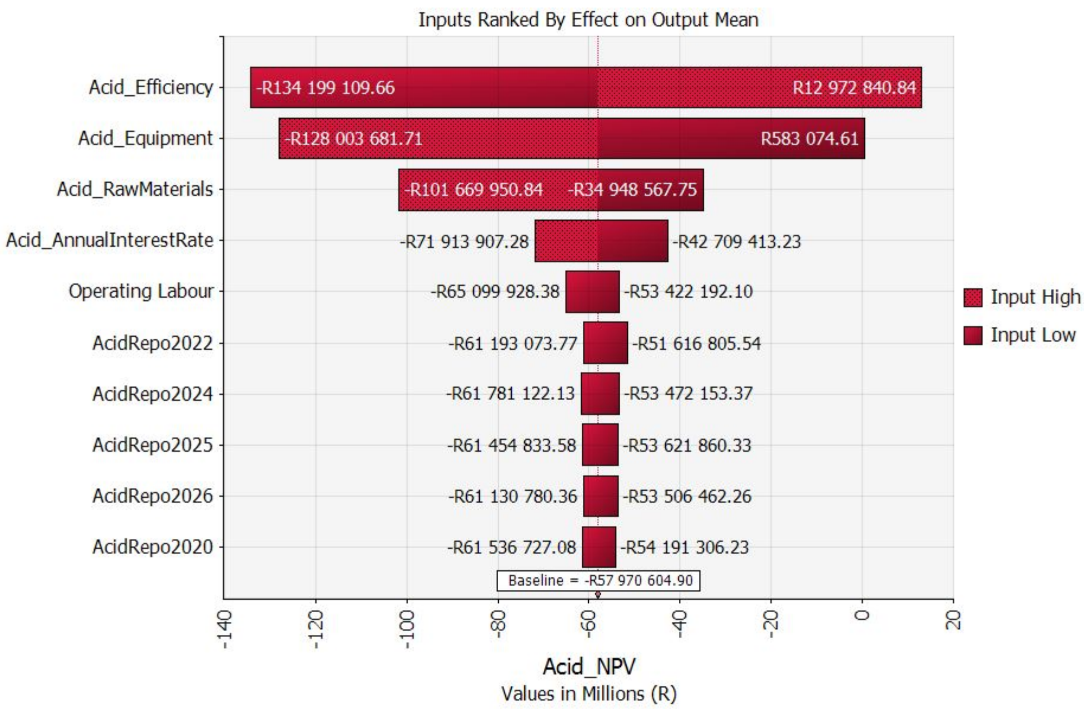

Figure 6.21: Acid Leach Process NPV Tornado Graph

6.2.4 Feasibility Framework

In this section a feasibility framework is compiled, utilising the knowledge gained throughout this study. This knowledge includes, but is not limited to the information as shown in Section **??** and Section **??**. The framework is depicted in Figure **??**.

The feasibility framework process starts with the generation of WC scrap from EoL WC products. From here the total hourly available scrap is used as a starting point to determine the appropriate process to use. If the available scrap volume is less than 15 kg/h, then no scenario is feasible, and the scrap must be sold to a scrap dealer or a WC recycling plant.

The next step is to decide whether to apply a filter. The filter is a decision criteria from the investor. The decision criteria includes whether or not future scale-up is desired, and if the project will be capital constrained. Both filters can be applied or none at all.

The minimum throughput for a process to become feasible is 15.07 kg/h. At this scrap availability the zinc process (25kg/h) becomes feasible. In Figure **??** the coloured lines in the 'Decision Criteria' section represents the coloured blocks in the 'Available Scrap Quantity' section after the chosen filters are applied.

If the zinc recycling process or coldstream process is feasible, then recycled WC-Co powder is sold to end-users, typically powder resellers, or to tooling manufacturers. During no scenario is Acid leaching a better option than the other recycling methods.

In Figure **??** the coloured lines in the *Decision Criteria* section represents the routes to follow depending on the scrap availability as depicted in the *Available Scrap Quantity* section.

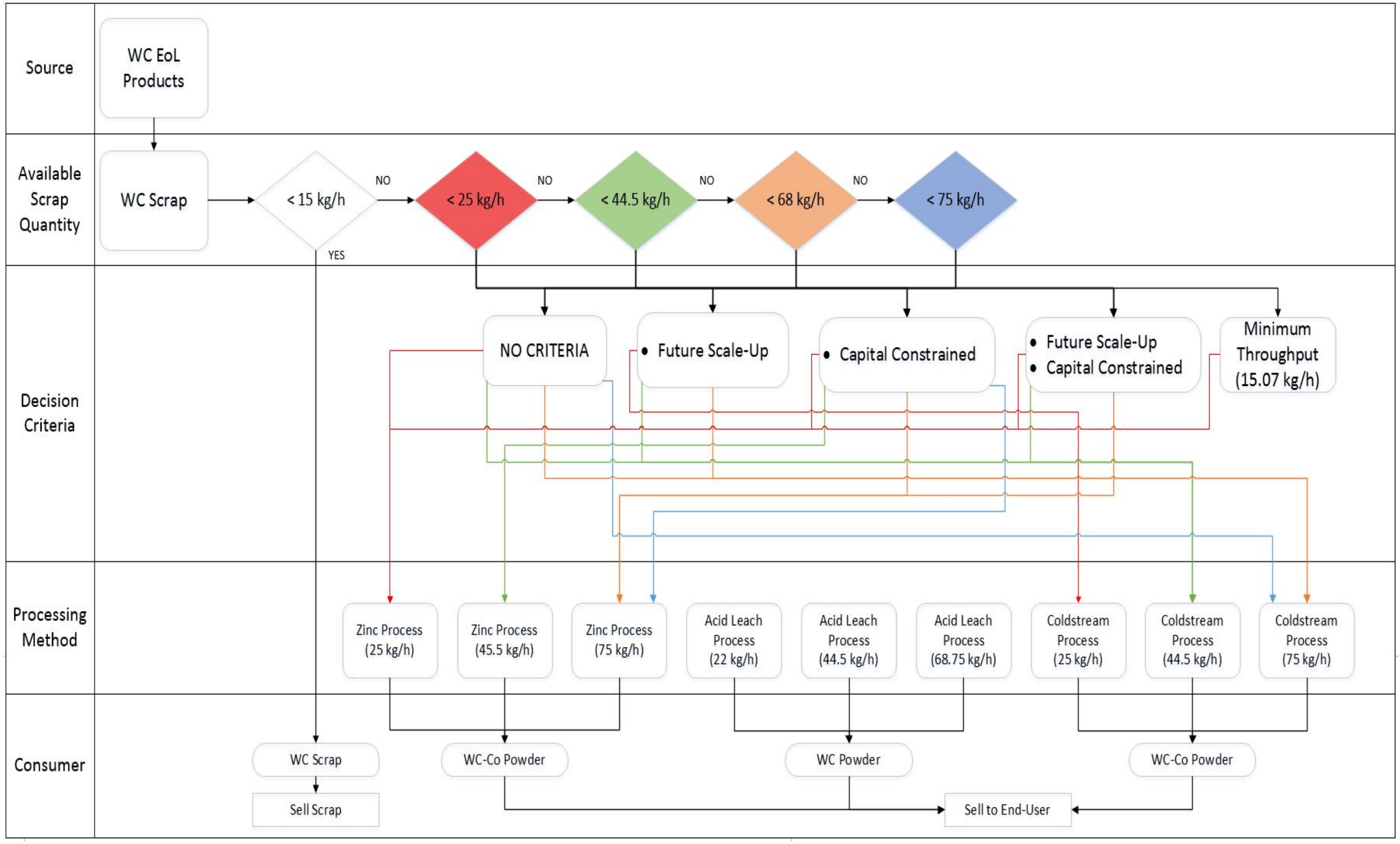

Figure 6.22: Acid Leach Process NPV Tornado Graph

Chapter 7

Conclusion and Recommendations

This chapter aims to discuss how the project met the initial findings, by discussing the initial goals and how this project went about to meet these goals. In Section **??** possible future work, based on this study, is briefly discussed.

7.1 Research Findings

The study set out to determine whether the possibility of recycling tungsten carbide in South Africa existed. This research endeavours to create a tool, assisting industry to make sound investment choices regarding recycling of tungsten carbide.

The first goal was to identify, research, and map the different methods available for the recycling of tungsten carbide scrap. Chapter **??** conducted the literature study regarding the different available WC recycling methods. After evaluating and comparing the different processes and with guidance from the project leader three process were selected. The three processes chosen were: the zinc recycling method, the acid leach process, and the coldstream process.

The second goal was to identify the key elements influencing the three selected recycling methods. To do this, comprehensive literature studies were conducted in Chapter **??** to Chapter **??**. During the exploration of this influencing factors, assumptions were made, based on the research from these chapters. The challenges faced by the WC recycling industry were identified through literature and by consulting industry experts. A market review provided the prices of the different forms and intermediary products of tungsten carbide.

The third goal was to create cost models to evaluate the financial feasibility of selected tungsten carbide recycling methods in South Africa. Through the thorough literature study in Chapter **??**, a financial model were created evaluating the financial feasibility of the three identified processes at different capacities. The challenges identified during the pursuit of the second goal were incorporated in the model. The financial feasibility study evaluated three different capacities for each process. Each of these nine scenarios were evaluated using a uniformly distributed throughput as well as a break-even throughput, resulting in 99 scenarios across the nine different financial models.

The models were based on a high level project estimation method typical for these types of investment decision studies. Lang factors were extensively used to estimate costs based on the equipment costs. Quotations were obtained from the recycling industry to determine these equipment costs. The quotations served as reference value and were adjusted for each of the nine base scenarios. To obtain these quotations proved to be challenging. Industry were not interested in providing quotations when they suspected that the quotations would probably not lead to any monetary advantage for them.

The feasibility analysis evaluated the profitability measures using measures such as the net present value and internal rate of return to gauge the profitability of the projects. The project with the highest NPV were the Coldstream process optimised for 75 kg/h with an NPV of R208.59 million. The project with the highest IRR were the Coldstream process optimised for 44.5 kg/h with an IRR of 50.42%. A risk analysis, using a Monte-Carlo simulation, were conducted on the different models to determine the inputs that have the biggest influence on the NPV and IRR. During this analysis distributions were fitted to different Lang factors as well as other inputs such as exchange rates, process efficiencies, scrap prices, utilities and inflation. The risk analysis and feasibility analysis showed that all nine models could prove profitable, but that the supply of scrap would have a major influence on whether a project is successful. The zinc recycling and coldstream processes proves to be much more robust in terms of the available scrap. The simulations were run for the three different processes and it was found that the zinc process had a 88.7% chance of having a positive NPV after ten years. The coldstream process had a 92.2% chance of having a positive NPV after ten years. This stands in stark contrast to the acid leach process, which has only a 20.4% chance of having a positive NPV after ten years.

The last goal was to create a business case for tungsten carbide recycling. The different literature studies, as well as information obtained from satisfying the first three objectives were used as inputs to ultimately satisfy this last goal. The IRR achieved formed an important part in determining the best course of action given certain circumstances. The business case was built with certain decision criteria in mind, namely: The option for future scale-up, capital availability, and any combination of these two, including none at all or both. It was shown that both the zinc recycling process and the coldstream process could be the best choice in certain circumstances.

The objectives of this study were achieved. The literature studies managed to map the available recycling methods for tungsten carbide. The information obtained from the studies were used to build a feasibility framework. Using the feasibility study, and the risk analysis, a business case is built to help potential investors with their decision making.

7.2 Future Work

The estimate level is a class 4 study. The accuracy of the results can be improved by stepping up the level of the estimate to a class 1 estimate by obtaining a bid. This is recommended if any commercial recycling project is to be attempted. The current class 4 estimate has the potential of being 48% under budget and 72% over budget. A class 1 estimate will stay between 6% over budget and 4% under budget.

The study only focussed on three processes. Future studies might provide further insights and improve the scope of the study by investigating more processes not considered in this study and completing feasibility studies for them. As **?** noted, the post-consumer collection efforts of tungsten carbide remains problem and studies addressing this problem can be undertaken.

This study serves as a solid body of knowledge on the current state of tungsten carbide recycling in South Africa, and can serve as a starting point for future work in the field.

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Appendix A

FEASIBILITY MODEL CALCULATIONS AND INPUTS

Capital Investment		
Equipment (excl VAT)	R	9 540 590.75
Erection of Items	R	1 049 464.98
Buildings and Structural	R	2 480 553.60
Civils	R	1 621 900.43
Piping and Ducts	R	1 335 682.71
Electrical	R	2 480 553.60
Instrumentation	R	954 059.08
	R	19 462 805.14
Installed Plant		
VAT @15%	R	2 919 420.77
Site Preperation	R	1 119 111.30
Contruction Management	R	3 525 200.58
Contingency	R	4 053 980.67
	R	11 617 713.32
Fixed Capital Investment (FCI)	R	31 080 518.46
Initial Loan	R	31 080 518.46
Annual Interest Rate		10.25%
Payback Period (Years)		10
Compounding Periods Per Year		12
Total Compounding Periods (Months)		120
Effective Annual Interest Rate		10.75%
Future Value	R	86 248 129.78
Monthly Installment	R	415 046.14
Yearly Total	R	4 980 553.69
Discounting Factor		6%
Depreciation		
Fixed Capital Investment	R	31 080 518.46
Salvage Value		0
Life of Equipment		10

Figure A.1: Zinc Process (25 kg/h) Capital Investment Cost

	BE	Throughput 1	Throughput 2	Throughput 3	Throughput 4	Throughput 5	Throughput 6	Throughput 7	Throughput 8	Throughput 9	Throughput 10
Throughput (kg/hr)	15.05	2.5	5	7.5	10	12.5	15	17.5	20	22.5	25
Manufacturing Costs											
Raw Materials	R 11 559 567.49	R 1 919 199.16	R 3 838 398.33	R 5 757 597.49	R 7 676 796.65	R 9 595 995.81	R 11 515 194.98	R 13 434 394.14	R 15 353 593.30	R 17 272 792.46	R 19 191 991.63
Operating Labour	R 135 456.00	R 135 456.00	R 135 456.00	R 135 456.00	R 135 456.00	R 135 456.00	R 135 456.00	R 135 456.00	R 135 456.00	R 135 456.00	R 135 456.00
Utilities	R 181 170.64	R 30 079.20	R 60 158.40	R 90 237.60	R 120 316.80	R 150 396.00	R 180 475.20	R 210 554.40	R 240 633.60	R 270 712.80	R 300 792.00
Waste Treatment	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Clerical and Supervisory Labour	R 23 704.80	R 23 704.80	R 23 704.80	R 23 704.80	R 23 704.80	R 23 704.80	R 23 704.80	R 23 704.80	R 23 704.80	R 23 704.80	R 23 704.80
Maintenance	R 1 864 831.11	R 1 864 831.11	R 1 864 831.11	R 1 864 831.11	R 1 864 831.11	R 1 864 831.11	R 1 864 831.11	R 1 864 831.11	R 1 864 831.11	R 1 864 831.11	R 1 864 831.11
Operating Supplies	R 279 724.67	R 279 724.67	R 279 724.67	R 279 724.67	R 279 724.67	R 279 724.67	R 279 724.67	R 279 724.67	R 279 724.67	R 279 724.67	R 279 724.67
Laboratory Charges	R 20 318.40	R 20 318.40	R 20 318.40	R 20 318.40	R 20 318.40	R 20 318.40	R 20 318.40	R 20 318.40	R 20 318.40	R 20 318.40	R 20 318.40
Patents & Royalties	R 705 403.44	R 344 098.57	R 416 026.94	R 487 955.32	R 559 883.69	R 631 812.06	R 703 740.43	R 775 668.80	R 847 597.17	R 919 525.55	R 991 453.92
Direct Manufacturing Costs (DMC)	R 14 770 176.54	R 4 617 411.91	R 6 638 618.64	R 8 659 825.38	R 10 681 032.11	R 12 702 238.85	R 14 723 445.58	R 16 744 652.31	R 18 765 859.05	R 20 787 065.78	R 22 808 272.52
Depreciation	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85
Local Taxes	R 994 576.59	R 994 576.59	R 994 576.59	R 994 576.59	R 994 576.59	R 994 576.59	R 994 576.59	R 994 576.59	R 994 576.59	R 994 576.59	R 994 576.59
Overhead Costs	R 1 133 121.54	R 1 133 121.54	R 1 133 121.54	R 1 133 121.54	R 1 133 121.54	R 1 133 121.54	R 1 133 121.54	R 1 133 121.54	R 1 133 121.54	R 1 133 121.54	R 1 133 121.54
FMC	R 5 235 749.98	R 5 235 749.98	R 5 235 749.98	R 5 235 749.98	R 5 235 749.98	R 5 235 749.98	R 5 235 749.98	R 5 235 749.98	R 5 235 749.98	R 5 235 749.98	R 5 235 749.98
Administration	R 303 598.79	R 303 598.79	R 303 598.79	R 303 598.79	R 303 598.79	R 303 598.79	R 303 598.79	R 303 598.79	R 303 598.79	R 303 598.79	R 303 598.79
Distribution	R 2 586 479.27	R 1 261 694.77	R 1 525 432.13	R 1 789 169.49	R 2 052 906.86	R 2 316 644.22	R 2 580 381.58	R 2 844 118.94	R 3 107 856.30	R 3 371 593.67	R 3 635 331.03
Research and Development	R 1 175 672.40	R 573 497.62	R 693 378.24	R 813 258.86	R 933 139.48	R 1 053 020.10	R 1 172 900.72	R 1 292 781.34	R 1 412 661.96	R 1 532 542.58	R 1 652 423.20
GE	R 4 065 750.46	R 2 138 791.18	R 2 522 409.16	R 2 906 027.14	R 3 289 645.12	R 3 673 263.10	R 4 056 881.08	R 4 440 499.07	R 4 824 117.05	R 5 207 735.03	R 5 591 353.01
COM	R 23 513 447.95	R 11 469 952.43	R 13 867 564.82	R 16 265 177.21	R 18 662 789.59	R 21 060 401.98	R 23 458 014.36	R 25 855 626.75	R 28 253 239.14	R 30 650 851.52	R 33 048 463.91
COM_d	R 20 405 396.10	R 8 361 900.59	R 10 759 512.97	R 13 157 125.36	R 15 554 737.75	R 17 952 350.13	R 20 349 962.52	R 22 747 574.90	R 25 145 187.29	R 27 542 799.68	R 29 940 412.06
INCOME	R 30 100 819.60	R 4 997 545.79	R 9 995 091.57	R 14 992 637.36	R 19 990 183.14	R 24 987 728.93	R 29 985 274.71	R 34 982 820.50	R 39 980 366.28	R 44 977 912.07	R 49 975 457.85

Figure A.2: Zinc Process (25 kg/h) Manufacturing Cost

	BE Throughput	Throughput 1:	Throughput 2:	Throughput 3	Throughput 4	Throughput 5	Throughput 6	Throughput 7:	Throughput 8:	Throughput 9:	Throughput 10:	UNITS
Throughput	15.05780082	2.5	5	7.5	10	12.5	15	17.5	20	22.5	25	kg/hr
Workdays	249	249	249	249	249	249	249	249	249	249	249	Days
Shift Length	8	8	8	8	8	8	8	8	8	8	8	hrs
Shifts/Day	1	1	1	1	1	1	1	1	1	1	1	Shifts
Theoretical Output	29995.13923	4980	9960	14940	19920	24900	29880	34860	39840	44820	49800	kg/yr
Wage	34	34	34	34	34	34	34	R 34.00	34	34	34	R/hr
Nr of workers	2	2	2	2	2	2	2	2	2	2	2	# Workers
Yearly Wage	135456	135456	135456	135456	135456	135456	135456	135456	135456	135456	135456	R
Waste Treatment Cost	0	0	0	0	0	0	0	0	0	0	0	R
Electricity Use	174277.885	28934.8171	57869.63421	86804.45131	115739.2684	144674.0855	173608.9026	R 202 543.72	231478.5368	260413.3539	289348.171	R
Gas Use	416.6685891	69.17819444	138.3563889	207.5345833	276.7127778	345.8909722	415.0691667	R 484.25	553.4255556	622.60375	691.7819444	R
Water use	6593.61365	1094.717238	2189.434476	3284.151715	4378.868953	5473.586191	6568.303429	R 7 663.02	8757.737906	9852.455144	10947.17238	R

Figure A.3: Zinc Process (25 kg/h) Process Inputs

Capital Investment	
Equipment (excl VAT)	R 14 009 040.04
Erection of Items	R 1 540 994.40
Buildings and Structural	R 3 642 350.41
Civils	R 2 381 536.81
Piping and Ducts	R 1 961 265.61
Electrical	R 3 642 350.41
Instrumentation	R 1 400 904.00
	R 28 578 441.67
Installed Plant	
VAT @15%	R 4 286 766.25
Site Preperation	R 1 643 260.40
Contruction Management	R 5 176 270.25
Contingency	R 5 952 710.79
	R 17 059 007.68
Fixed Capital Investment (FCI)	R 45 637 449.36
Initial Loan	R 45 637 449.36
Annual Interest Rate	10.25%
Payback Period (Years)	10
Compounding Periods Per Year	12
Total Compounding Periods (Months)	120
Effective Annual Interest Rate	10.75%
Future Value	R 126 643 468.33
Monthly Installment	R 609 437.94
Yearly Total	R 7 313 255.32
Discounting Factor	6%
Depreciation	
Fixed Capital Investment	R 45 637 449.36
Salvage Value	0
Life of Equipment	10

Figure A.4: Zinc Process (45 kg/h) Capital Investment Cost

	BE	Throughput 1	Throughput 2	Throughput 3	Throughput 4	Throughput 5	Throughput 6	Throughput 7	Throughput 8	Throughput 9	Throughput 10
Throughput (kg/hr)	22.09	4.55	9.1	13.65	18.2	22.75	27.3	31.85	36.4	40.95	45.5
Manufacturing Costs											
Raw Materials	R 16 961 270.70	R 3 492 942.48	R 6 985 884.95	R 10 478 827.43	R 13 971 769.90	R 17 464 712.38	R 20 957 654.86	R 24 450 597.33	R 27 943 539.81	R 31 436 482.28	R 34 929 424.76
Operating Labour	R 203 184.00	R 203 184.00	R 203 184.00	R 203 184.00	R 203 184.00	R 203 184.00	R 203 184.00	R 203 184.00	R 203 184.00	R 203 184.00	R 203 184.00
Utilities	R 242 707.81	R 49 982.37	R 99 964.73	R 149 947.10	R 199 929.46	R 249 911.83	R 299 894.19	R 349 876.56	R 399 858.92	R 449 841.29	R 499 823.66
Waste Treatment	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Clerical and Supervisory Labour	R 35 557.20	R 35 557.20	R 35 557.20	R 35 557.20	R 35 557.20	R 35 557.20	R 35 557.20	R 35 557.20	R 35 557.20	R 35 557.20	R 35 557.20
Maintenance	R 2 738 246.96	R 2 738 246.96	R 2 738 246.96	R 2 738 246.96	R 2 738 246.96	R 2 738 246.96	R 2 738 246.96	R 2 738 246.96	R 2 738 246.96	R 2 738 246.96	R 2 738 246.96
Operating Supplies	R 410 737.04	R 410 737.04	R 410 737.04	R 410 737.04	R 410 737.04	R 410 737.04	R 410 737.04	R 410 737.04	R 410 737.04	R 410 737.04	R 410 737.04
Laboratory Charges	R 30 477.60	R 30 477.60	R 30 477.60	R 30 477.60	R 30 477.60	R 30 477.60	R 30 477.60	R 30 477.60	R 30 477.60	R 30 477.60	R 30 477.60
Patents & Royalties	R 1 034 822.15	R 530 729.27	R 661 463.20	R 792 197.12	R 922 931.05	R 1 053 664.98	R 1 184 398.90	R 1 315 132.83	R 1 445 866.76	R 1 576 600.68	R 1 707 334.61
Direct Manufacturing Costs (DMC)	R 21 657 003.47	R 7 491 856.92	R 11 165 515.69	R 14 839 174.45	R 18 512 833.22	R 22 186 491.99	R 25 860 150.76	R 29 533 809.53	R 33 207 468.30	R 36 881 127.06	R 40 554 785.83
Depreciation	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94
Local Taxes	R 1 460 398.38	R 1 460 398.38	R 1 460 398.38	R 1 460 398.38	R 1 460 398.38	R 1 460 398.38	R 1 460 398.38	R 1 460 398.38	R 1 460 398.38	R 1 460 398.38	R 1 460 398.38
Overhead Costs	R 1 664 282.50	R 1 664 282.50	R 1 664 282.50	R 1 664 282.50	R 1 664 282.50	R 1 664 282.50	R 1 664 282.50	R 1 664 282.50	R 1 664 282.50	R 1 664 282.50	R 1 664 282.50
FMC	R 7 688 425.81	R 7 688 425.81	R 7 688 425.81	R 7 688 425.81	R 7 688 425.81	R 7 688 425.81	R 7 688 425.81	R 7 688 425.81	R 7 688 425.81	R 7 688 425.81	R 7 688 425.81
Administration	R 446 548.22	R 446 548.22	R 446 548.22	R 446 548.22	R 446 548.22	R 446 548.22	R 446 548.22	R 446 548.22	R 446 548.22	R 446 548.22	R 446 548.22
Distribution	R 3 794 347.89	R 1 946 007.33	R 2 425 365.06	R 2 904 722.79	R 3 384 080.52	R 3 863 438.25	R 4 342 795.98	R 4 822 153.71	R 5 301 511.44	R 5 780 869.17	R 6 260 226.91
Research and Development	R 1 724 703.59	R 884 548.78	R 1 102 438.66	R 1 320 328.54	R 1 538 218.42	R 1 756 108.30	R 1 973 998.17	R 2 191 888.05	R 2 409 777.93	R 2 627 667.81	R 2 845 557.68
GE	R 5 965 599.70	R 3 277 104.34	R 3 974 351.94	R 4 671 599.55	R 5 368 847.16	R 6 066 094.77	R 6 763 342.38	R 7 460 589.99	R 8 157 837.60	R 8 855 085.21	R 9 552 332.81
COM	R 34 494 071.71	R 17 690 975.69	R 22 048 773.25	R 26 406 570.81	R 30 764 368.36	R 35 122 165.92	R 39 479 963.47	R 43 837 761.03	R 48 195 558.58	R 52 553 356.14	R 56 911 153.69
COM_d	R 29 930 326.78	R 13 127 230.76	R 17 485 028.31	R 21 842 825.87	R 26 200 623.42	R 30 558 420.98	R 34 916 218.54	R 39 274 016.09	R 43 631 813.65	R 47 989 611.20	R 52 347 408.76
INCOME	R 44 166 717.32	R 9 095 533.33	R 18 191 066.66	R 27 286 599.99	R 36 382 133.31	R 45 477 666.64	R 54 573 199.97	R 63 668 733.30	R 72 764 266.63	R 81 859 799.96	R 90 955 333.29

Figure A.5: Zinc Process (45 kg/h) Manufacturing Cost

	BE Throughput	**Throughput 1:**	**Throughput 2:**	**Throughput 3**	**Throughput 4**	**Throughput 5**	**Throughput 6**	**Throughput 7:**	**Throughput 8:**	**Throughput 9:**	**Throughput 10:**	**UNITS**
Throughput	22.09420344	4.55	9.1	13.65	18.2	22.75	27.3	31.85	36.4	40.95	45.5	kg/hr
Workdays	249	249	249	249	249	249	249	249	249	249	249	Days
Shift Length	8	8	8	8	8	8	8	8	8	8	8	hrs
Shifts/Day	1	1	1	1	1	1	1	1	1	1	1	Shifts
Theoretical Output	44011.65326	9063.6	18127.2	27190.8	36254.4	45318	54381.6	63445.2	72508.8	81572.4	90636	kg/yr
Wage	34	34	34	34	34	34	34	34	34	34	34	R/hr
Nr of workers	3	3	3	3	3	3	3	3	3	3	3	# Workers
Yearly Wage	203184	203184	203184	203184	203184	203184	203184	203184	203184	203184	203184	R
Waste Treatment Cost	0	0	0	0	0	0	0	0	0	0	0	R
Electricity Use	255716.6943	52661.36713	105322.7343	157984.1014	210645.4685	263306.8357	315968.2028	368629.5699	421290.937	473952.3042	526613.6713	R
Gas Use	611.3748408	125.9043139	251.8086278	377.7129417	503.6172556	629.5215694	755.4258833	881.3301972	1007.234511	1133.138825	1259.043139	R
Water use	9674.762151	1992.385374	3984.770747	5977.156121	7969.541494	9961.926868	11954.31224	13946.69762	15939.08299	17931.46836	19923.85374	R

Figure A.6: Zinc Process (45 kg/h) Process Inputs

Capital Investment		
Equipment (excl VAT)	R	24 184 052.80
Erection of Items	R	2 660 245.81
Buildings and Structural	R	6 287 853.73
Civils	R	4 111 288.98
Piping and Ducts	R	3 385 767.39
Electrical	R	6 287 853.73
Instrumentation	R	2 418 405.28
	R	49 335 467.70
Installed Plant		
VAT @15%	R	7 400 320.16
Site Preperation	R	2 836 789.39
Contruction Management	R	8 935 886.59
Contingency	R	10 276 269.58
	R	29 449 265.71
Fixed Capital Investment (FCI)	R	78 784 733.42
Initial Loan	R	78 784 733.42
Annual Interest Rate		10.25%
Payback Period (Years)		10
Compounding Periods Per Year		12
Total Compounding Periods (Months)		120
Effective Annual Interest Rate		10.75%
Future Value	R	218 626 852.12
Monthly Installment	R	1 052 083.47
Yearly Total	R	12 625 001.60
Discounting Factor		6%
Depreciation		
Fixed Capital Investment	R	78 784 733.42
Salvage Value		0
Life of Equipment		10

Figure A.7: Zinc Process (75 kg/h) Capital Investment Cost

	BE	Throughput 1	Throughput 2	Throughput 3	Throughput 4	Throughput 5	Throughput 6	Throughput 7	Throughput 8	Throughput 9	Throughput 10
Throughput (kg/hr)	37.84	7.5	15	22.5	30	37.5	45	52.5	60	67.5	75
Manufacturing Costs											
Raw Materials	R 29 050 431.75	R 5 757 597.49	R 11 515 194.98	R 17 272 792.46	R 23 030 389.95	R 28 787 987.44	R 34 545 584.93	R 40 303 182.42	R 46 060 779.90	R 51 818 377.39	R 57 575 974.88
Operating Labour	R 270 912.00	R 270 912.00	R 270 912.00	R 270 912.00	R 270 912.00	R 270 912.00	R 270 912.00	R 270 912.00	R 270 912.00	R 270 912.00	R 270 912.00
Utilities	R 339 170.96	R 67 221.37	R 134 442.74	R 201 664.11	R 268 885.48	R 336 106.85	R 403 328.22	R 470 549.60	R 537 770.97	R 604 992.34	R 672 213.71
Waste Treatment	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Clerical and Supervisory Labour	R 47 409.60	R 47 409.60	R 47 409.60	R 47 409.60	R 47 409.60	R 47 409.60	R 47 409.60	R 47 409.60	R 47 409.60	R 47 409.60	R 47 409.60
Maintenance	R 4 727 084.00	R 4 727 084.00	R 4 727 084.00	R 4 727 084.00	R 4 727 084.00	R 4 727 084.00	R 4 727 084.00	R 4 727 084.00	R 4 727 084.00	R 4 727 084.00	R 4 727 084.00
Operating Supplies	R 709 062.60	R 709 062.60	R 709 062.60	R 709 062.60	R 709 062.60	R 709 062.60	R 709 062.60	R 709 062.60	R 709 062.60	R 709 062.60	R 709 062.60
Laboratory Charges	R 40 636.80	R 40 636.80	R 40 636.80	R 40 636.80	R 40 636.80	R 40 636.80	R 40 636.80	R 40 636.80	R 40 636.80	R 40 636.80	R 40 636.80
Patents & Royalties	R 1 768 455.79	R 898 915.27	R 1 113 851.09	R 1 328 786.90	R 1 543 722.72	R 1 758 658.53	R 1 973 594.35	R 2 188 530.16	R 2 403 465.98	R 2 618 401.80	R 2 833 337.61
Direct Manufacturing Costs (DMC)	R 36 953 163.51	R 12 518 839.13	R 18 558 593.81	R 24 598 348.48	R 30 638 103.16	R 36 677 857.83	R 42 717 612.51	R 48 757 367.18	R 54 797 121.86	R 60 836 876.53	R 66 876 631.21
Depreciation	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34
Local Taxes	R 2 521 111.47	R 2 521 111.47	R 2 521 111.47	R 2 521 111.47	R 2 521 111.47	R 2 521 111.47	R 2 521 111.47	R 2 521 111.47	R 2 521 111.47	R 2 521 111.47	R 2 521 111.47
Overhead Costs	R 2 864 696.16	R 2 864 696.16	R 2 864 696.16	R 2 864 696.16	R 2 864 696.16	R 2 864 696.16	R 2 864 696.16	R 2 864 696.16	R 2 864 696.16	R 2 864 696.16	R 2 864 696.16
FMC	R 13 264 280.97	R 13 264 280.97	R 13 264 280.97	R 13 264 280.97	R 13 264 280.97	R 13 264 280.97	R 13 264 280.97	R 13 264 280.97	R 13 264 280.97	R 13 264 280.97	R 13 264 280.97
Administration	R 756 810.84	R 756 810.84	R 756 810.84	R 756 810.84	R 756 810.84	R 756 810.84	R 756 810.84	R 756 810.84	R 756 810.84	R 756 810.84	R 756 810.84
Distribution	R 6 484 337.91	R 3 296 022.65	R 4 084 120.65	R 4 872 218.64	R 5 660 316.63	R 6 448 414.62	R 7 236 512.61	R 8 024 610.60	R 8 812 708.60	R 9 600 806.59	R 10 388 904.58
Research and Development	R 2 947 426.32	R 1 498 192.12	R 1 856 418.48	R 2 214 644.84	R 2 572 871.20	R 2 931 097.55	R 3 289 323.91	R 3 647 550.27	R 4 005 776.63	R 4 364 002.99	R 4 722 229.35
GE	R 10 188 575.07	R 5 551 025.61	R 6 697 349.96	R 7 843 674.31	R 8 989 998.66	R 10 136 323.02	R 11 282 647.37	R 12 428 971.72	R 13 575 296.07	R 14 721 620.42	R 15 867 944.77
COM	R 58 948 526.45	R 29 963 842.31	R 37 128 369.51	R 44 292 896.71	R 51 457 423.90	R 58 621 951.10	R 65 786 478.29	R 72 951 005.49	R 80 115 532.69	R 87 280 059.88	R 94 444 587.08
COM_d	R 51 070 053.11	R 22 085 368.97	R 29 249 896.17	R 36 414 423.36	R 43 578 950.56	R 50 743 477.76	R 57 908 004.95	R 65 072 532.15	R 72 237 059.34	R 79 401 586.54	R 86 566 113.74
INCOME	R 75 646 585.09	R 14 992 637.36	R 29 985 274.71	R 44 977 912.07	R 59 970 549.42	R 74 963 186.78	R 89 955 824.13	R 104 948 461.49	R 119 941 098.84	R 134 933 736.20	R 149 926 373.55

Figure A.8: Zinc Process (75 kg/h) Manufacturing Cost

	BE Throughput	**Throughput 1:**	**Throughput 2:**	**Throughput 3**	**Throughput 4**	**Throughput 5**	**Throughput 6**	**Throughput 7:**	**Throughput 8:**	**Throughput 9:**	**Throughput 10:**	**UNITS**
Throughput	37.84186696	7.5	15	22.5	30	37.5	45	52.5	60	67.5	75	kg/hr
Workdays	249	249	249	249	249	249	249	249	249	249	249	Days
Shift Length	8	8	8	8	8	8	8	8	8	8	8	hrs
Shifts/Day	1	1	1	1	1	1	1	1	1	1	1	Shifts
Theoretical Output	75380.99899	14940	29880	44820	59760	74700	89640	104580	119520	134460	149400	kg/yr
Wage	34	34	34	34	34	34	34	R 34.00	34	34	34	R/hr
Nr of workers	4	4	4	4	4	4	4	4	4	4	4	# Workers
Yearly Wage	270912	270912	270912	270912	270912	270912	270912	270912	270912	270912	270912	R
Waste Treatment Cost	0	0	0	0	0	0	0	0	0	0	0	R
Electricity Use	0	86804.45131	173608.9026	260413.3539	347217.8053	434022.2566	520826.7079	R 607 631.16	694435.6105	781240.0618	868044.5131	R
Gas Use	0	207.5345833	415.0691667	622.60375	830.1383333	1037.672917	1245.2075	R 1 452.74	1660.276667	1867.81125	2075.345833	R
Water use	0	3284.151715	6568.303429	9852.455144	13136.60686	16420.75857	19704.91029	R 22 989.06	26273.21372	29557.36543	32841.51715	R

Figure A.9: Zinc Process (75 kg/h) Process Inputs

Capital Investment		
Equipment (excl VAT)	R	13 278 428.69
Erection of Items	R	1 460 627.16
Buildings and Structural	R	3 452 391.46
Civils	R	2 257 332.88
Piping and Ducts	R	1 858 980.02
Electrical	R	3 452 391.46
Instrumentation	R	1 327 842.87
	R	27 087 994.52
Installed Plant		
VAT @15%	R	4 063 199.18
Site Preperation	R	1 557 559.69
Contruction Management	R	4 906 313.01
Contingency	R	5 642 259.96
	R	16 169 331.83
Fixed Capital Investment (FCI)	R	43 257 326.35
Initial Loan	R	43 257 326.35
Annual Interest Rate		10.3%
Payback Period (Years)		10
Compounding Periods Per Year		12
Total Compounding Periods (Months)		120
Effective Annual Interest Rate		10.75%
Future Value	R	120 038 650.65
Monthly Installment	R	577 654.02
Yearly Total	R	6 931 848.22
Discounting Factor		6%
Depreciation		
Fixed Capital Investment	R	43 257 326.35
Salvage Value		0
Life of Equipment		10

Figure A.10: Acid Leach Process (22 kg/h) Capital Investment Cost

	BE	Throughput 1	Throughput 2	Throughput 3	Throughput 4	Throughput 5	Throughput 6	Throughput 7	Throughput 8	Throughput 9	Throughput 10
Throughput (kg/hr)	19.11	2.2	4.4	6.6	8.8	11	13.2	15.4	17.6	19.8	22
Manufacturing Costs											
Raw Materials	R 11 976 538.25	R 1 197 653.83	R 2 395 307.65	R 3 592 961.48	R 4 790 615.30	R 5 988 269.13	R 7 185 922.95	R 8 383 576.78	R 9 581 230.60	R 10 778 884.43	R 11 976 538.25
Operating Labour	R 268 920.00	R 268 920.00	R 268 920.00	R 268 920.00	R 268 920.00	R 268 920.00	R 268 920.00	R 268 920.00	R 268 920.00	R 268 920.00	R 268 920.00
Utilities	R 209 851.80	R 20 950.90	R 41 909.42	R 62 875.56	R 83 849.32	R 104 830.69	R 125 819.68	R 146 816.28	R 167 820.51	R 188 832.35	R 209 851.80
Waste Treatment	R 88 217.71	R 8 821.77	R 17 643.54	R 26 465.31	R 35 287.08	R 44 108.86	R 52 930.63	R 61 752.40	R 70 574.17	R 79 395.94	R 88 217.71
Clerical and Supervisory Labour	R 47 061.00	R 47 061.00	R 47 061.00	R 47 061.00	R 47 061.00	R 47 061.00	R 47 061.00	R 47 061.00	R 47 061.00	R 47 061.00	R 47 061.00
Maintenance	R 2 595 439.58	R 2 595 439.58	R 2 595 439.58	R 2 595 439.58	R 2 595 439.58	R 2 595 439.58	R 2 595 439.58	R 2 595 439.58	R 2 595 439.58	R 2 595 439.58	R 2 595 439.58
Operating Supplies	R 389 315.94	R 389 315.94	R 389 315.94	R 389 315.94	R 389 315.94	R 389 315.94	R 389 315.94	R 389 315.94	R 389 315.94	R 389 315.94	R 389 315.94
Laboratory Charges	R 40 338.00	R 40 338.00	R 40 338.00	R 40 338.00	R 40 338.00	R 40 338.00	R 40 338.00	R 40 338.00	R 40 338.00	R 40 338.00	R 40 338.00
Patents & Royalties	R 838 319.12	R 430 678.13	R 475 970.45	R 521 263.05	R 566 555.93	R 611 849.09	R 657 142.53	R 702 436.26	R 747 730.26	R 793 024.55	R 838 319.12
Direct Manufacturing Costs (DMC)	R 16 454 001.40	R 4 999 179.15	R 6 271 905.58	R 7 544 639.92	R 8 817 382.15	R 10 090 132.28	R 11 362 890.31	R 12 635 656.23	R 13 908 430.06	R 15 181 211.78	R 16 454 001.40
Depreciation	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64
Local Taxes	R 1 384 234.44	R 1 384 234.44	R 1 384 234.44	R 1 384 234.44	R 1 384 234.44	R 1 384 234.44	R 1 384 234.44	R 1 384 234.44	R 1 384 234.44	R 1 384 234.44	R 1 384 234.44
Overhead Costs	R 1 585 500.35	R 1 585 500.35	R 1 585 500.35	R 1 585 500.35	R 1 585 500.35	R 1 585 500.35	R 1 585 500.35	R 1 585 500.35	R 1 585 500.35	R 1 585 500.35	R 1 585 500.35
FMC	R 7 295 467.43	R 7 295 467.43	R 7 295 467.43	R 7 295 467.43	R 7 295 467.43	R 7 295 467.43	R 7 295 467.43	R 7 295 467.43	R 7 295 467.43	R 7 295 467.43	R 7 295 467.43
Administration	R 436 713.09	R 436 713.09	R 436 713.09	R 436 713.09	R 436 713.09	R 436 713.09	R 436 713.09	R 436 713.09	R 436 713.09	R 436 713.09	R 436 713.09
Distribution	R 3 073 836.76	R 1 579 153.13	R 1 745 224.97	R 1 911 297.84	R 2 077 371.73	R 2 243 446.66	R 2 409 522.62	R 2 575 599.61	R 2 741 677.63	R 2 907 756.68	R 3 073 836.76
Research and Development	R 1 397 198.53	R 717 796.88	R 793 284.08	R 868 771.74	R 944 259.88	R 1 019 748.48	R 1 095 237.55	R 1 170 727.09	R 1 246 217.10	R 1 321 707.58	R 1 397 198.53
GE	R 4 907 748.37	R 2 733 663.10	R 2 975 222.13	R 3 216 782.67	R 3 458 344.70	R 3 699 908.23	R 3 941 473.26	R 4 183 039.79	R 4 424 607.82	R 4 666 177.35	R 4 907 748.37
COM	R 27 943 970.53	R 14 355 937.57	R 15 865 681.54	R 17 375 434.87	R 18 885 197.57	R 20 394 969.64	R 21 904 751.08	R 23 414 541.89	R 24 924 342.07	R 26 434 151.62	R 27 943 970.53
COM_d	R 23 618 237.90	R 10 030 204.94	R 11 539 948.90	R 13 049 702.24	R 14 559 464.94	R 16 069 237.01	R 17 579 018.45	R 19 088 809.26	R 20 598 609.43	R 22 108 418.98	R 23 618 237.90
INCOME	R 40 439 910.72	R 4 043 991.07	R 8 087 982.14	R 12 131 973.22	R 16 175 964.29	R 20 219 955.36	R 24 263 946.43	R 28 307 937.50	R 32 351 928.58	R 36 395 919.65	R 40 439 910.72

Figure A.11: Acid Leach Process (22 kg/h) Manufacturing Cost

	BE Throughput	**Throughput 1:**	**Throughput 2:**	**Throughput 3**	**Throughput 4**	**Throughput 5**	**Throughput 6**	**Throughput 7:**	**Throughput 8:**	**Throughput 9:**	**Throughput 10:**	**UNITS**
Throughput	19.11106955	2.2	4.4	6.6	8.8	11	13.2	15.4	17.6	19.8	22	kg/hr
Workdays	249	249	249	249	249	249	249	249	249	249	249	Days
Shift Length	8	8	8	8	8	8	8	8	8	8	8	hrs
Shifts/Day	1	1	1	1	1	1	1	1	1	1	1	Shifts
Theoretical Output	38069.25055	4382.4	8764.8	13147.2	17529.6	21912	26294.4	30676.8	35059.2	39441.6	43824	kg/yr
Wage	45	45	45	45	45	45	45	45	45	45	45	R/hr
Nr of workers	3	3	3	3	3	3	3	3	3	3	3	# Workers
Yearly Wage	268920	268920	268920	268920	268920	268920	268920	268920	268920	268920	268920	R
Waste Treatment Cost	76633.40136	8821.7712	17643.5424	26465.3136	35287.0848	44108.856	52930.6272	61752.3984	70574.1696	79395.9408	88217.712	R
Electricity Use	173595.7825	19983.744	39967.488	59951.232	79934.976	99918.72	119902.464	139886.208	159869.952	179853.696	199837.44	R
Gas Use	528.8277143	60.87681111	121.7536222	182.6304333	243.5072444	304.3840556	365.2608667	426.1376778	487.0144889	547.8913	608.7681111	R
Water use	8460.524192	973.9461818	1947.892364	2921.838545	3895.784727	4869.730909	5843.677091	6817.623272	7791.569454	8765.515636	9739.461818	R
HCl use	2447660.39	281766.1692	563532.3383	845298.5075	1127064.677	1408830.846	1690597.015	1972363.184	2254129.353	2535895.522	2817661.692	

Figure A.12: Acid Leach Process (22 kg/h) Process Inputs

Capital Investment		
Equipment (excl VAT)	R	26 476 984.15
Erection of Items	R	2 912 468.26
Buildings and Structural	R	6 884 015.88
Civils	R	4 501 087.31
Piping and Ducts	R	3 706 777.78
Electrical	R	6 884 015.88
Instrumentation	R	2 647 698.42
	R	54 013 047.67
Installed Plant		
VAT @15%	R	8 101 957.15
Site Preperation	R	3 105 750.24
Contruction Management	R	9 783 113.26
Contingency	R	11 250 580.25
	R	32 241 400.90
Fixed Capital Investment (FCI)	R	86 254 448.58
Initial Loan	R	86 254 448.58
Annual Interest Rate		10.25%
Payback Period (Years)		10
Compounding Periods Per Year		12
Total Compounding Periods (Months)		120
Effective Annual Interest Rate		10.75%
Future Value	R	239 355 237.44
Monthly Installment	R	1 151 833.30
Yearly Total	R	13 821 999.56
Discounting Factor		6%
Depreciation		
Fixed Capital Investment	R	86 254 448.58
Salvage Value		0
Life of Equipment		10

Figure A.13: Acid Leach Process (44 kg/h) Capital Investment Cost

	BE	Throughput 1	Throughput 2	Throughput 3	Throughput 4	Throughput 5	Throughput 6	Throughput 7	Throughput 8	Throughput 9	Throughput 10
Throughput (kg/hr)	37.73	4.45	8.9	13.35	17.8	22.25	26.7	31.15	35.6	40.05	44.5
Manufacturing Costs											
Raw Materials	R 20 539 594.80	R 2 422 527.06	R 4 845 054.11	R 7 267 581.17	R 9 690 108.22	R 12 112 635.28	R 14 562 381.74	R 16 957 689.39	R 19 380 216.45	R 21 802 743.50	R 24 225 270.56
Operating Labour	R 448 200.00	R 448 200.00	R 448 200.00	R 448 200.00	R 448 200.00	R 448 200.00	R 448 200.00	R 448 200.00	R 448 200.00	R 448 200.00	R 448 200.00
Utilities	R 201 647.12	R 23 666.59	R 47 364.33	R 71 093.25	R 94 853.33	R 118 644.57	R 142 734.82	R 166 320.55	R 190 205.29	R 214 121.19	R 238 068.25
Waste Treatment	R 151 292.14	R 17 844.04	R 35 688.07	R 53 532.11	R 71 376.15	R 89 220.19	R 107 264.72	R 124 908.26	R 142 752.30	R 160 596.33	R 178 440.37
Clerical and Supervisory Labour	R 78 435.00	R 78 435.00	R 78 435.00	R 78 435.00	R 78 435.00	R 78 435.00	R 78 435.00	R 78 435.00	R 78 435.00	R 78 435.00	R 78 435.00
Maintenance	R 5 175 266.91	R 5 175 266.91	R 5 175 266.91	R 5 175 266.91	R 5 175 266.91	R 5 175 266.91	R 5 175 266.91	R 5 175 266.91	R 5 175 266.91	R 5 175 266.91	R 5 175 266.91
Operating Supplies	R 776 290.04	R 776 290.04	R 776 290.04	R 776 290.04	R 776 290.04	R 776 290.04	R 776 290.04	R 776 290.04	R 776 290.04	R 776 290.04	R 776 290.04
Laboratory Charges	R 67 230.00	R 67 230.00	R 67 230.00	R 67 230.00	R 67 230.00	R 67 230.00	R 67 230.00	R 67 230.00	R 67 230.00	R 67 230.00	R 67 230.00
Patents & Royalties	R 1 532 179.45	R 852 167.94	R 943 092.08	R 1 034 017.37	R 1 124 943.81	R 1 215 871.40	R 1 307 821.82	R 1 397 730.03	R 1 488 661.07	R 1 579 593.26	R 1 670 526.60
Direct Manufacturing Costs (DMC)	R 28 970 135.47	R 9 861 627.57	R 12 416 620.55	R 14 971 645.85	R 17 526 703.46	R 20 081 793.39	R 22 665 625.05	R 25 192 070.18	R 27 747 257.05	R 30 302 476.23	R 32 857 727.73
Depreciation	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86
Local Taxes	R 2 760 142.35	R 2 760 142.35	R 2 760 142.35	R 2 760 142.35	R 2 760 142.35	R 2 760 142.35	R 2 760 142.35	R 2 760 142.35	R 2 760 142.35	R 2 760 142.35	R 2 760 142.35
Overhead Costs	R 3 152 221.15	R 3 152 221.15	R 3 152 221.15	R 3 152 221.15	R 3 152 221.15	R 3 152 221.15	R 3 152 221.15	R 3 152 221.15	R 3 152 221.15	R 3 152 221.15	R 3 152 221.15
FMC	R 14 537 808.36	R 14 537 808.36	R 14 537 808.36	R 14 537 808.36	R 14 537 808.36	R 14 537 808.36	R 14 537 808.36	R 14 537 808.36	R 14 537 808.36	R 14 537 808.36	R 14 537 808.36
Administration	R 855 285.29	R 855 285.29	R 855 285.29	R 855 285.29	R 855 285.29	R 855 285.29	R 855 285.29	R 855 285.29	R 855 285.29	R 855 285.29	R 855 285.29
Distribution	R 5 617 991.33	R 3 124 615.77	R 3 458 004.29	R 3 791 397.02	R 4 124 793.97	R 4 458 195.13	R 4 795 346.66	R 5 125 010.11	R 5 458 423.92	R 5 791 841.95	R 6 125 264.20
Research and Development	R 2 553 632.42	R 1 420 279.90	R 1 571 820.13	R 1 723 362.28	R 1 874 906.35	R 2 026 452.33	R 2 179 703.03	R 2 329 550.05	R 2 481 101.78	R 2 632 655.43	R 2 784 211.00
GE	R 9 026 909.05	R 5 400 180.96	R 5 885 109.71	R 6 370 044.59	R 6 854 985.60	R 7 339 932.75	R 7 830 334.98	R 8 309 845.44	R 8 794 810.99	R 9 279 782.67	R 9 764 760.49
COM	R 51 072 648.50	R 28 405 597.95	R 31 436 402.62	R 34 467 245.63	R 37 498 126.97	R 40 529 046.64	R 43 594 060.57	R 46 591 000.99	R 49 622 035.66	R 52 653 108.66	R 55 684 219.99
COM_d	R 42 447 203.64	R 19 780 153.09	R 22 810 957.76	R 25 841 800.77	R 28 872 682.11	R 31 903 601.79	R 34 968 615.72	R 37 965 556.13	R 40 996 590.80	R 44 027 663.80	R 47 058 775.13
INCOME	R 69 353 878.60	R 8 179 891.03	R 16 359 782.06	R 24 539 673.10	R 32 719 564.13	R 40 899 455.16	R 49 171 255.08	R 57 259 237.22	R 65 439 128.26	R 73 619 019.29	R 81 798 910.32

Figure A.14: Acid Leach Process (44 kg/h) Manufacturing Cost

	BE Throughput	Throughput 1:	Throughput 2:	Throughput 3	Throughput 4	Throughput 5	Throughput 6	Throughput 7:	Throughput 8:	Throughput 9:	Throughput 10:	UNITS
Throughput	37.72969084	4.45	8.9	13.35	17.8	22.25	26.7	31.15	35.6	40.05	44.5	kg/hr
Workdays	249	249	249	249	249	249	249	249	249	249	249	Days
Shift Length	8	8	8	8	8	8	8	8	8	8	8	hrs
Shifts/Day	1	1	1	1	1	1	1	1	1	1	1	Shifts
Theoretical Output	75157.54416	8864.4	17728.8	26593.2	35457.6	44322	53186.4	62050.8	70915.2	79779.6	88644	kg/yr
Wage	45	45	45	45	45	45	45	45	45	45	45	R/hr
Nr of workers	5	5	5	5	5	5	5	5	5	5	5	# Workers
Yearly Wage	448200	448200	448200	448200	448200	448200	448200	448200	448200	448200	448200	R
Waste Treatment Cost	151292.1364	17844.0372	35688.0744	53532.1116	71376.1488	89220.186	107064.2232	124908.2604	142752.2976	160596.3348	178440.372	R
Electricity Use	342718.4014	40421.664	80843.328	121264.992	161686.656	202108.32	242529.984	282951.648	323373.312	363794.976	404216.64	R
Gas Use	1044.028756	123.1371861	246.2743722	369.4115583	492.5487444	615.6859306	738.8231167	861.9603028	985.0974889	1108.234675	1231.371861	R
Water use	16703.04015	1970.027504	3940.055008	5910.082512	7880.110016	9850.13752	11820.16502	13790.19253	15760.22003	17730.24754	19700.27504	R
HCl use	4832250.206	569936.1149	1139872.23	1709808.345	2279744.46	2849680.574	3419616.689	3989552.804	4559488.919	5129425.034	5699361.149	

Figure A.15: Acid Leach Process (44 kg/h) Process Inputs

Capital Investment		
Equipment (excl VAT)	R	39 827 951.19
Erection of Items	R	4 381 074.63
Buildings and Structural	R	10 355 267.31
Civils	R	6 770 751.70
Piping and Ducts	R	5 575 913.17
Electrical	R	10 355 267.31
Instrumentation	R	3 982 795.12
	R	81 249 020.44
Installed Plant		
VAT @15%	R	12 187 353.07
Site Preperation	R	4 671 818.68
Contruction Management	R	14 716 228.83
Contingency	R	16 923 663.15
	R	48 499 063.72
Fixed Capital Investment (FCI)	R	129 748 084.16
Initial Loan	R	129 748 084.16
Annual Interest Rate		10.3%
Payback Period (Years)		10
Compounding Periods Per Year		12
Total Compounding Periods (Months)		120
Effective Annual Interest Rate		10.75%
Future Value	R	360 049 643.85
Monthly Installment	R	1 732 642.97
Yearly Total	R	20 791 715.58
Discounting Factor		6%
Depreciation		
Fixed Capital Investment	R	129 748 084.16
Salvage Value		0
Life of Equipment		10

Figure A.16: Acid Leach Process (68 kg/h) Capital Investment Cost

	BE	Throughput 1	Throughput 2	Throughput 3	Throughput 4	Throughput 5	Throughput 6	Throughput 7	Throughput 8	Throughput 9	Throughput 10
Throughput (kg/hr)	56.72	6.875	13.75	20.625	27.5	34.375	41.25	48.125	55	61.875	68.75
Manufacturing Costs											
Raw Materials	R 30 877 497.82	R 3 742 668.20	R 7 485 336.41	R 11 228 004.61	R 14 970 672.82	R 18 713 341.02	R 22 456 009.22	R 26 198 677.43	R 29 941 345.63	R 33 684 013.84	R 37 426 682.04
Operating Labour	R 627 480.00	R 627 480.00	R 627 480.00	R 627 480.00	R 627 480.00	R 627 480.00	R 627 480.00	R 627 480.00	R 627 480.00	R 627 480.00	R 627 480.00
Utilities	R 373 757.15	R 45 033.53	R 90 141.45	R 135 323.76	R 180 580.45	R 225 911.52	R 271 316.98	R 316 796.82	R 362 351.05	R 407 979.67	R 453 682.66
Waste Treatment	R 227 439.86	R 27 568.04	R 55 136.07	R 82 704.11	R 110 272.14	R 137 840.18	R 165 408.21	R 192 976.25	R 220 544.28	R 248 112.32	R 275 680.35
Clerical and Supervisory Labour	R 109 809.00	R 109 809.00	R 109 809.00	R 109 809.00	R 109 809.00	R 109 809.00	R 109 809.00	R 109 809.00	R 109 809.00	R 109 809.00	R 109 809.00
Maintenance	R 7 784 885.05	R 7 784 885.05	R 7 784 885.05	R 7 784 885.05	R 7 784 885.05	R 7 784 885.05	R 7 784 885.05	R 7 784 885.05	R 7 784 885.05	R 7 784 885.05	R 7 784 885.05
Operating Supplies	R 1 167 732.76	R 1 167 732.76	R 1 167 732.76	R 1 167 732.76	R 1 167 732.76	R 1 167 732.76	R 1 167 732.76	R 1 167 732.76	R 1 167 732.76	R 1 167 732.76	R 1 167 732.76
Laboratory Charges	R 94 122.00	R 94 122.00	R 94 122.00	R 94 122.00	R 94 122.00	R 94 122.00	R 94 122.00	R 94 122.00	R 94 122.00	R 94 122.00	R 94 122.00
Patents & Royalties	R 2 302 838.36	R 1 282 057.97	R 1 422 844.17	R 1 563 633.12	R 1 704 424.81	R 1 845 219.24	R 1 986 016.42	R 2 126 816.34	R 2 267 619.01	R 2 408 424.42	R 2 549 232.58
Direct Manufacturing Costs (DMC)	R 43 565 561.99	R 14 881 356.55	R 18 837 486.91	R 22 793 694.40	R 26 749 979.02	R 30 706 340.76	R 34 662 779.64	R 38 619 295.65	R 42 575 888.78	R 46 532 559.05	R 50 489 306.44
Depreciation	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42
Local Taxes	R 4 151 938.69	R 4 151 938.69	R 4 151 938.69	R 4 151 938.69	R 4 151 938.69	R 4 151 938.69	R 4 151 938.69	R 4 151 938.69	R 4 151 938.69	R 4 151 938.69	R 4 151 938.69
Overhead Costs	R 4 736 816.43	R 4 736 816.43	R 4 736 816.43	R 4 736 816.43	R 4 736 816.43	R 4 736 816.43	R 4 736 816.43	R 4 736 816.43	R 4 736 816.43	R 4 736 816.43	R 4 736 816.43
FMC	R 21 863 563.54	R 21 863 563.54	R 21 863 563.54	R 21 863 563.54	R 21 863 563.54	R 21 863 563.54	R 21 863 563.54	R 21 863 563.54	R 21 863 563.54	R 21 863 563.54	R 21 863 563.54
Administration	R 1 278 326.11	R 1 278 326.11	R 1 278 326.11	R 1 278 326.11	R 1 278 326.11	R 1 278 326.11	R 1 278 326.11	R 1 278 326.11	R 1 278 326.11	R 1 278 326.11	R 1 278 326.11
Distribution	R 8 443 740.65	R 4 700 879.24	R 5 217 095.30	R 5 733 321.43	R 6 249 557.62	R 6 765 803.88	R 7 282 060.20	R 7 798 326.59	R 8 314 603.04	R 8 830 889.55	R 9 347 186.13
Research and Development	R 3 838 063.93	R 2 136 763.29	R 2 371 406.96	R 2 606 055.20	R 2 840 708.01	R 3 075 365.40	R 3 310 027.36	R 3 544 693.90	R 3 779 365.02	R 4 014 040.71	R 4 248 720.97
GE	R 13 560 130.68	R 8 115 968.63	R 8 866 828.36	R 9 617 702.73	R 10 368 591.74	R 11 119 495.39	R 11 870 413.67	R 12 621 346.60	R 13 372 294.16	R 14 123 256.37	R 14 874 233.21
COM	R 76 761 278.60	R 42 735 265.79	R 47 428 139.10	R 52 121 103.91	R 56 814 160.21	R 61 507 308.01	R 66 200 547.29	R 70 893 878.08	R 75 587 300.35	R 80 280 814.12	R 84 974 419.38
COM_d	R 63 786 470.18	R 29 760 457.37	R 34 453 330.68	R 39 146 295.49	R 43 839 351.79	R 48 532 499.59	R 53 225 738.88	R 57 919 069.66	R 62 612 491.94	R 67 306 005.70	R 71 999 610.97
INCOME	R 104 260 782.93	R 12 637 472.10	R 25 274 944.20	R 37 912 416.30	R 50 549 888.40	R 63 187 360.50	R 75 824 832.60	R 88 462 304.70	R 101 099 776.80	R 113 737 248.90	R 126 374 721.00

Figure A.17: Acid Leach Process (68 kg/h) Manufacturing Cost

	BE Throughput	Throughput 1:	Throughput 2:	Throughput 3	Throughput 4	Throughput 5	Throughput 6	Throughput 7:	Throughput 8:	Throughput 9:	Throughput 10:	UNITS
Throughput	56.71964116	6.875	13.75	20.625	27.5	34.375	41.25	48.125	55	61.875	68.75	kg/hr
Workdays	249	249	249	249	249	249	249	249	249	249	249	Days
Shift Length	8	8	8	8	8	8	8	8	8	8	8	hrs
Shifts/Day	1	1	1	1	1	1	1	1	1	1	1	Shifts
Theoretical Output	112985.5252	13695	27390	41085	54780	68475	82170	95865	109560	123255	136950	kg/yr
Wage	45	45	45	45	45	45	45	45	45	45	45	R/hr
Nr of workers	7	7	7	7	7	7	7	7	7	7	7	# Workers
Yearly Wage	627480	627480	627480	627480	627480	627480	627480	627480	627480	627480	627480	R
Waste Treatment Cost	227439.8622	27568.035	55136.07	82704.105	110272.14	137840.175	165408.21	192976.245	220544.28	248112.315	275680.35	R
Electricity Use	515213.9948	62449.2	124898.4	187347.6	249796.8	312246	374695.2	437144.4	499593.6	562042.8	624492	R
Gas Use	1569.504946	190.2400347	380.4800694	570.7201042	760.9601389	951.2001736	1141.440208	1331.680243	1521.920278	1712.160313	1902.400347	R
Water use	25109.94452	3043.581818	6087.163636	9130.745454	12174.32727	15217.90909	18261.49091	21305.07273	24348.65454	27392.23636	30435.81818	R
HCl use	7264398.184	880519.2786	1761038.557	2641557.836	3522077.114	4402596.393	5283115.672	6163634.95	7044154.229	7924673.508	8805192.786	

Figure A.18: Acid Leach Process (68 kg/h) Process Inputs

Capital Investment		
Equipment (excl VAT)	R	11 413 325.76
Erection of Items	R	1 255 465.83
Buildings and Structural	R	2 967 464.70
Civils	R	1 940 265.38
Piping and Ducts	R	1 597 865.61
Electrical	R	2 967 464.70
Instrumentation	R	1 141 332.58
	R	23 283 184.55
Installed Plant		
VAT @15%	R	3 492 477.68
Site Preperation	R	1 338 783.11
Contruction Management	R	4 217 166.80
Contingency	R	4 849 741.82
	R	13 898 169.42
Fixed Capital Investment (FCI)	R	37 181 353.98
Initial Loan	R	37 181 353.98
Annual Interest Rate		10.3%
Payback Period (Years)		10
Compounding Periods Per Year		12
Total Compounding Periods (Months)		120
Effective Annual Interest Rate		10.75%
Future Value	R	103 177 887.70
Monthly Installment	R	496 516.09
Yearly Total	R	5 958 193.08
Discounting Factor		6%
Depreciation		
Fixed Capital Investment	R	37 181 353.98
Salvage Value		0
Life of Equipment		10

Figure A.19: Coldstream Process (25 kg/h) Capital Investment Cost

	BE	Throughput 1	Throughput 2	Throughput 3	Throughput 4	Throughput 5	Throughput 6	Throughput 7	Throughput 8	Throughput 9	Throughput 10
Throughput (kg/hr)	17.34	2.5	5	7.5	10	12.5	15	17.5	20	22.5	25
Manufacturing Costs											
Raw Materials	R 6 900 204.29	R 995 735.06	R 1 991 470.13	R 2 987 205.19	R 3 982 940.26	R 4 978 675.32	R 5 974 410.38	R 6 970 145.45	R 7 965 880.51	R 8 961 615.58	R 9 957 350.64
Operating Labour	R 358 560.00	R 358 560.00	R 358 560.00	R 358 560.00	R 358 560.00	R 358 560.00	R 358 560.00	R 358 560.00	R 358 560.00	R 358 560.00	R 358 560.00
Utilities	R 87 271.05	R 18 766.22	R 30 318.93	R 41 871.65	R 53 424.37	R 64 977.09	R 76 529.80	R 88 082.52	R 99 635.24	R 111 187.96	R 122 740.67
Waste Treatment	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Clerical and Supervisory Labour	R 62 748.00	R 62 748.00	R 62 748.00	R 62 748.00	R 62 748.00	R 62 748.00	R 62 748.00	R 62 748.00	R 62 748.00	R 62 748.00	R 62 748.00
Maintenance	R 2 230 881.24	R 2 230 881.24	R 2 230 881.24	R 2 230 881.24	R 2 230 881.24	R 2 230 881.24	R 2 230 881.24	R 2 230 881.24	R 2 230 881.24	R 2 230 881.24	R 2 230 881.24
Operating Supplies	R 334 632.19	R 334 632.19	R 334 632.19	R 334 632.19	R 334 632.19	R 334 632.19	R 334 632.19	R 334 632.19	R 334 632.19	R 334 632.19	R 334 632.19
Laboratory Charges	R 53 784.00	R 53 784.00	R 53 784.00	R 53 784.00	R 53 784.00	R 53 784.00	R 53 784.00	R 53 784.00	R 53 784.00	R 53 784.00	R 53 784.00
Patents & Royalties	R 599 527.28	R 379 124.53	R 416 293.45	R 453 462.37	R 490 631.29	R 527 800.21	R 564 969.13	R 602 138.05	R 639 306.97	R 676 475.89	R 713 644.81
Direct Manufacturing Costs (DMC)	R 10 627 608.05	R 4 434 231.24	R 5 478 687.94	R 6 523 144.64	R 7 567 601.34	R 8 612 058.04	R 9 656 514.74	R 10 700 971.44	R 11 745 428.14	R 12 789 884.84	R 13 834 341.54
Depreciation	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40
Local Taxes	R 1 189 803.33	R 1 189 803.33	R 1 189 803.33	R 1 189 803.33	R 1 189 803.33	R 1 189 803.33	R 1 189 803.33	R 1 189 803.33	R 1 189 803.33	R 1 189 803.33	R 1 189 803.33
Overhead Costs	R 1 376 177.54	R 1 376 177.54	R 1 376 177.54	R 1 376 177.54	R 1 376 177.54	R 1 376 177.54	R 1 376 177.54	R 1 376 177.54	R 1 376 177.54	R 1 376 177.54	R 1 376 177.54
FMC	R 6 284 116.27	R 6 284 116.27	R 6 284 116.27	R 6 284 116.27	R 6 284 116.27	R 6 284 116.27	R 6 284 116.27	R 6 284 116.27	R 6 284 116.27	R 6 284 116.27	R 6 284 116.27
Administration	R 397 828.39	R 397 828.39	R 397 828.39	R 397 828.39	R 397 828.39	R 397 828.39	R 397 828.39	R 397 828.39	R 397 828.39	R 397 828.39	R 397 828.39
Distribution	R 2 198 266.68	R 1 390 123.29	R 1 526 409.33	R 1 662 695.37	R 1 798 981.40	R 1 935 267.44	R 2 071 553.48	R 2 207 839.51	R 2 344 125.55	R 2 480 411.59	R 2 616 697.63
Research and Development	R 999 212.13	R 631 874.22	R 693 822.42	R 755 770.62	R 817 718.82	R 879 667.02	R 941 615.22	R 1 003 563.42	R 1 065 511.61	R 1 127 459.81	R 1 189 408.01
GE	R 3 595 307.20	R 2 419 825.90	R 2 618 060.14	R 2 816 294.37	R 3 014 528.61	R 3 212 762.85	R 3 410 997.08	R 3 609 231.32	R 3 807 465.55	R 4 005 699.79	R 4 203 934.02
COM	R 19 984 242.59	R 12 637 484.49	R 13 876 448.46	R 15 115 412.43	R 16 354 376.40	R 17 593 340.37	R 18 832 304.34	R 20 071 268.31	R 21 310 232.29	R 22 549 196.26	R 23 788 160.23
COM_d	R 16 266 107.19	R 8 919 349.09	R 10 158 313.06	R 11 397 277.03	R 12 636 241.00	R 13 875 204.98	R 15 114 168.95	R 16 353 132.92	R 17 592 096.89	R 18 831 060.86	R 20 070 024.83
INCOME	R 27 864 658.02	R 4 021 013.85	R 8 042 027.70	R 12 063 041.55	R 16 084 055.40	R 20 105 069.25	R 24 126 083.10	R 28 147 096.95	R 32 168 110.80	R 36 189 124.65	R 40 210 138.50

Figure A.20: Coldstream Process (25 kg/h) Manufacturing Cost

	BE Throughput	Throughput 1:	Throughput 2:	Throughput 3	Throughput 4	Throughput 5	Throughput 6	Throughput 7:	Throughput 8:	Throughput 9:	Throughput 10:	UNITS
Throughput	17.32439819	2.5	5	7.5	10	12.5	15	17.5	20	22.5	25	kg/hr
Workdays	249	249	249	249	249	249	249	249	249	249	249	Days
Shift Length	8	8	8	8	8	8	8	8	8	8	8	hrs
Shifts/Day	1	1	1	1	1	1	1	1	1	1	1	Shifts
Theoretical Output	34510.20118	4980	9960	14940	19920	24900	29880	34860	39840	44820	49800	kg/yr
Wage	R 90.00	90	90	90	90	90	90	90	90	90	90	R/hr
Nr of workers	2	2	2	2	2	2	2	2	2	2	2	# Workers
Yearly Wage	R 358 560.00	358560	358560	358560	358560	358560	358560	358560	358560	358560	358560	R
Waste Treatment Cost	R -	0	0	0	0	0	0	0	0	0	0	R
Electricity Use	R 72 471.42	10458	20916	31374	41832	52290	62748	73206	83664	94122	104580	R
Gas Use	R -	0	0	0	0	0	0	0	0	0	0	R
Water use	R 7 586.13	1094.717238	2189.434476	3284.151715	4378.868953	5473.586191	6568.303429	7663.020668	8757.737906	9852.455144	10947.17238	R
Nitrogen Gas Use	R 7 213.50	7213.5	7213.5	7213.5	7213.5	7213.5	7213.5	7213.5	7213.5	7213.5	7213.5	

Figure A.21: Coldstream Process (25 kg/h) Process Inputs

Capital Investment		
Equipment (excl VAT)	R	14 405 851.70
Erection of Items	R	1 584 643.69
Buildings and Structural	R	3 745 521.44
Civils	R	2 448 994.79
Piping and Ducts	R	2 016 819.24
Electrical	R	3 745 521.44
Instrumentation	R	1 440 585.17
	R	29 387 937.46
Installed Plant		
VAT @15%	R	4 408 190.62
Site Preperation	R	1 689 806.40
Contruction Management	R	5 322 890.17
Contingency	R	6 121 323.70
	R	17 542 210.89
Fixed Capital Investment (FCI)	R	46 930 148.36
Initial Loan	R	46 930 148.36
Annual Interest Rate		10.3%
Payback Period (Years)		10
Compounding Periods Per Year		12
Total Compounding Periods (Months)		120
Effective Annual Interest Rate		10.75%
Future Value	R	130 230 695.21
Monthly Installment	R	626 700.52
Yearly Total	R	7 520 406.20
Discounting Factor		6%
Depreciation		
Fixed Capital Investment	R	46 930 148.36
Salvage Value		0
Life of Equipment		10

Figure A.22: Coldstream Process (44 kg/h) Capital Investment Cost

	BE	Throughput 1	Throughput 2	Throughput 3	Throughput 4	Throughput 5	Throughput 6	Throughput 7	Throughput 8	Throughput 9	Throughput 10
Throughput (kg/hr)	22.04	4.45	8.9	13.35	17.8	22.25	26.7	31.15	35.6	40.05	44.5
Manufacturing Costs											
Raw Materials	R 8 778 500.55	R 1 772 408.41	R 3 544 816.83	R 5 317 225.24	R 7 089 633.66	R 8 862 042.07	R 10 634 450.48	R 12 406 858.90	R 14 179 267.31	R 15 951 675.73	R 17 724 084.14
Operating Labour	R 537 840.00	R 537 840.00	R 537 840.00	R 537 840.00	R 537 840.00	R 537 840.00	R 537 840.00	R 537 840.00	R 537 840.00	R 537 840.00	R 537 840.00
Utilities	R 78 646.54	R 27 393.14	R 40 359.28	R 53 325.42	R 66 291.56	R 79 257.70	R 92 223.84	R 105 189.98	R 118 156.11	R 131 122.25	R 144 088.39
Waste Treatment	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Clerical and Supervisory Labour	R 94 122.00	R 94 122.00	R 94 122.00	R 94 122.00	R 94 122.00	R 94 122.00	R 94 122.00	R 94 122.00	R 94 122.00	R 94 122.00	R 94 122.00
Maintenance	R 2 815 808.90	R 2 815 808.90	R 2 815 808.90	R 2 815 808.90	R 2 815 808.90	R 2 815 808.90	R 2 815 808.90	R 2 815 808.90	R 2 815 808.90	R 2 815 808.90	R 2 815 808.90
Operating Supplies	R 422 371.34	R 422 371.34	R 422 371.34	R 422 371.34	R 422 371.34	R 422 371.34	R 422 371.34	R 422 371.34	R 422 371.34	R 422 371.34	R 422 371.34
Laboratory Charges	R 80 676.00	R 80 676.00	R 80 676.00	R 80 676.00	R 80 676.00	R 80 676.00	R 80 676.00	R 80 676.00	R 80 676.00	R 80 676.00	R 80 676.00
Patents & Royalties	R 765 091.07	R 504 675.02	R 570 555.34	R 636 435.66	R 702 315.98	R 768 196.30	R 834 076.62	R 899 956.95	R 965 837.27	R 1 031 717.59	R 1 097 597.91
Direct Manufacturing Costs (DMC)	R 13 573 056.40	R 6 255 294.81	R 8 106 549.68	R 9 957 804.56	R 11 809 059.43	R 13 660 314.31	R 15 511 569.18	R 17 362 824.05	R 19 214 078.93	R 21 065 333.80	R 22 916 588.68
Depreciation	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84
Local Taxes	R 1 501 764.75	R 1 501 764.75	R 1 501 764.75	R 1 501 764.75	R 1 501 764.75	R 1 501 764.75	R 1 501 764.75	R 1 501 764.75	R 1 501 764.75	R 1 501 764.75	R 1 501 764.75
Overhead Costs	R 1 745 958.54	R 1 745 958.54	R 1 745 958.54	R 1 745 958.54	R 1 745 958.54	R 1 745 958.54	R 1 745 958.54	R 1 745 958.54	R 1 745 958.54	R 1 745 958.54	R 1 745 958.54
FMC	R 7 940 738.12	R 7 940 738.12	R 7 940 738.12	R 7 940 738.12	R 7 940 738.12	R 7 940 738.12	R 7 940 738.12	R 7 940 738.12	R 7 940 738.12	R 7 940 738.12	R 7 940 738.12
Administration	R 517 165.64	R 517 165.64	R 517 165.64	R 517 165.64	R 517 165.64	R 517 165.64	R 517 165.64	R 517 165.64	R 517 165.64	R 517 165.64	R 517 165.64
Distribution	R 2 805 333.92	R 1 850 475.07	R 2 092 036.25	R 2 333 597.43	R 2 575 158.60	R 2 816 719.78	R 3 058 280.96	R 3 299 842.13	R 3 541 403.31	R 3 782 964.49	R 4 024 525.66
Research and Development	R 1 275 151.78	R 841 125.03	R 950 925.57	R 1 060 726.10	R 1 170 526.64	R 1 280 327.17	R 1 390 127.71	R 1 499 928.24	R 1 609 728.78	R 1 719 529.31	R 1 829 329.85
GE	R 4 597 651.34	R 3 208 765.74	R 3 560 127.45	R 3 911 489.16	R 4 262 850.88	R 4 614 212.59	R 4 965 574.30	R 5 316 936.01	R 5 668 297.72	R 6 019 659.44	R 6 371 021.15
COM	R 25 503 035.66	R 16 822 500.65	R 19 018 511.35	R 21 214 522.05	R 23 410 532.75	R 25 606 543.45	R 27 802 554.15	R 29 998 564.85	R 32 194 575.55	R 34 390 586.25	R 36 586 596.95
COM_d	R 20 810 020.83	R 12 129 485.81	R 14 325 496.52	R 16 521 507.22	R 18 717 517.92	R 20 913 528.62	R 23 109 539.32	R 25 305 550.02	R 27 501 560.72	R 29 697 571.42	R 31 893 582.12
INCOME	R 35 449 662.82	R 7 157 404.65	R 14 314 809.31	R 21 472 213.96	R 28 629 618.61	R 35 787 023.27	R 42 944 427.92	R 50 101 832.57	R 57 259 237.22	R 64 416 641.88	R 71 574 046.53

Figure A.23: Coldstream Process (44 kg/h) Manufacturing Cost

	BE Throughput	Throughput 1:	Throughput 2:	Throughput 3	Throughput 4	Throughput 5	Throughput 6	Throughput 7:	Throughput 8:	Throughput 9:	Throughput 10:	UNITS
Throughput	22.04025163	4.45	8.9	13.35	17.8	22.25	26.7	31.15	35.6	40.05	44.5	kg/hr
Workdays	249	249	249	249	249	249	249	249	249	249	249	Days
Shift Length	8	8	8	8	8	8	8	8	8	8	8	hrs
Shifts/Day	1	1	1	1	1	1	1	1	1	1	1	Shifts
Theoretical Output	43904.18125	8864.4	17728.8	26593.2	35457.6	44322	53186.4	62050.8	70915.2	79779.6	88644	kg/yr
Wage	90	90	90	90	90	90	90	90	90	90	90	R/hr
Nr of workers	3	3	3	3	3	3	3	3	3	3	3	# Workers
Yearly Wage	537840	537840	537840	537840	537840	537840	537840	537840	537840	537840	537840	R
Waste Treatment Cost	0	0	0	0	0	0	0	0	0	0	0	R
Electricity Use	92198.78061	18615.24	37230.48	55845.72	74460.96	93076.2	111691.44	130306.68	148921.92	167537.16	186152.4	R
Gas Use	0	0	0	0	0	0	0	0	0	0	0	R
Water use	9651.137357	1948.596684	3897.193368	5845.790052	7794.386736	9742.98342	11691.5801	13640.17679	15588.77347	17537.37016	19485.96684	R
Nitrogen Gas Use	28854	28854	28854	28854	28854	28854	28854	28854	28854	28854	28854	R

Figure A.24: Coldstream Process (44 kg/h) Process Inputs

Capital Investment		
Equipment (excl VAT)	R	25 831 744.99
Erection of Items	R	2 841 491.95
Buildings and Structural	R	6 716 253.70
Civils	R	4 391 396.65
Piping and Ducts	R	3 616 444.30
Electrical	R	6 716 253.70
Instrumentation	R	2 583 174.50
	R	52 696 759.77
Installed Plant		
VAT @15%	R	7 904 513.97
Site Preperation	R	3 030 063.69
Contruction Management	R	9 544 700.61
Contingency	R	10 976 405.71
	R	31 455 683.97
Fixed Capital Investment (FCI)	R	84 152 443.74
Initial Loan	R	84 152 443.74
Annual Interest Rate		10.3%
Payback Period (Years)		10
Compounding Periods Per Year		12
Total Compounding Periods (Months)		120
Effective Annual Interest Rate		10.75%
Future Value	R	233 522 194.91
Monthly Installment	R	1 123 763.33
Yearly Total	R	13 485 160.01
Discounting Factor		6%
Depreciation		
Fixed Capital Investment	R	84 152 443.74
Salvage Value		0
Life of Equipment		10

Figure A.25: Coldstream Process (75 kg/h) Capital Investment Cost

	BE	Throughput 1	Throughput 2	Throughput 3	Throughput 4	Throughput 5	Throughput 6	Throughput 7	Throughput 8	Throughput 9	Throughput 10
Throughput (kg/hr)	38.91	7.5	15	22.5	30	37.5	45	52.5	60	67.5	75
Manufacturing Costs											
Raw Materials	R 15 496 596.47	R 2 987 205.19	R 5 974 410.38	R 8 961 615.58	R 11 948 820.77	R 14 936 025.96	R 17 923 231.15	R 20 910 436.34	R 23 897 641.54	R 26 884 846.73	R 29 872 051.92
Operating Labour	R 896 400.00	R 896 400.00	R 896 400.00	R 896 400.00	R 896 400.00	R 896 400.00	R 896 400.00	R 896 400.00	R 896 400.00	R 896 400.00	R 896 400.00
Utilities	R 131 681.87	R 42 852.65	R 64 064.80	R 85 276.96	R 106 489.11	R 127 701.26	R 148 913.41	R 170 125.56	R 191 337.71	R 212 549.87	R 233 762.02
Waste Treatment	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Clerical and Supervisory Labour	R 156 870.00	R 156 870.00	R 156 870.00	R 156 870.00	R 156 870.00	R 156 870.00	R 156 870.00	R 156 870.00	R 156 870.00	R 156 870.00	R 156 870.00
Maintenance	R 5 049 146.62	R 5 049 146.62	R 5 049 146.62	R 5 049 146.62	R 5 049 146.62	R 5 049 146.62	R 5 049 146.62	R 5 049 146.62	R 5 049 146.62	R 5 049 146.62	R 5 049 146.62
Operating Supplies	R 757 371.99	R 757 371.99	R 757 371.99	R 757 371.99	R 757 371.99	R 757 371.99	R 757 371.99	R 757 371.99	R 757 371.99	R 757 371.99	R 757 371.99
Laboratory Charges	R 134 460.00	R 134 460.00	R 134 460.00	R 134 460.00	R 134 460.00	R 134 460.00	R 134 460.00	R 134 460.00	R 134 460.00	R 134 460.00	R 134 460.00
Patents & Royalties	R 1 356 979.16	R 892 104.82	R 1 003 115.42	R 1 114 126.02	R 1 225 136.62	R 1 336 147.22	R 1 447 157.82	R 1 558 168.42	R 1 669 179.02	R 1 780 189.62	R 1 891 200.22
Direct Manufacturing Costs (DMC)	R 23 979 506.12	R 10 916 411.28	R 14 035 839.23	R 17 155 267.17	R 20 274 695.11	R 23 394 123.06	R 26 513 551.00	R 29 632 978.95	R 32 752 406.89	R 35 871 834.83	R 38 991 262.78
Depreciation	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37
Local Taxes	R 2 692 878.20	R 2 692 878.20	R 2 692 878.20	R 2 692 878.20	R 2 692 878.20	R 2 692 878.20	R 2 692 878.20	R 2 692 878.20	R 2 692 878.20	R 2 692 878.20	R 2 692 878.20
Overhead Costs	R 3 123 609.97	R 3 123 609.97	R 3 123 609.97	R 3 123 609.97	R 3 123 609.97	R 3 123 609.97	R 3 123 609.97	R 3 123 609.97	R 3 123 609.97	R 3 123 609.97	R 3 123 609.97
FMC	R 14 231 732.55	R 14 231 732.55	R 14 231 732.55	R 14 231 732.55	R 14 231 732.55	R 14 231 732.55	R 14 231 732.55	R 14 231 732.55	R 14 231 732.55	R 14 231 732.55	R 14 231 732.55
Administration	R 915 362.49	R 915 362.49	R 915 362.49	R 915 362.49	R 915 362.49	R 915 362.49	R 915 362.49	R 915 362.49	R 915 362.49	R 915 362.49	R 915 362.49
Distribution	R 4 975 590.25	R 3 271 051.01	R 3 678 089.88	R 4 085 128.75	R 4 492 167.61	R 4 899 206.48	R 5 306 245.35	R 5 713 284.21	R 6 120 323.08	R 6 527 361.95	R 6 934 400.81
Research and Development	R 2 261 631.93	R 1 486 841.37	R 1 671 859.04	R 1 856 876.70	R 2 041 894.37	R 2 226 912.04	R 2 411 929.70	R 2 596 947.37	R 2 781 965.04	R 2 966 982.70	R 3 152 000.37
GE	R 8 152 584.67	R 5 673 254.88	R 6 265 311.41	R 6 857 367.94	R 7 449 424.48	R 8 041 481.01	R 8 633 537.54	R 9 225 594.08	R 9 817 650.61	R 10 409 707.14	R 11 001 763.68
COM	R 45 232 638.61	R 29 736 827.40	R 33 437 180.73	R 37 137 534.06	R 40 837 887.39	R 44 538 240.73	R 48 238 594.06	R 51 938 947.39	R 55 639 300.72	R 59 339 654.06	R 63 040 007.39
COM_d	R 36 817 394.23	R 21 321 583.02	R 25 021 936.35	R 28 722 289.69	R 32 422 643.02	R 36 122 996.35	R 39 823 349.68	R 43 523 703.02	R 47 224 056.35	R 50 924 409.68	R 54 624 763.02
INCOME	R 62 578 924.14	R 12 063 041.55	R 24 126 083.10	R 36 189 124.65	R 48 252 166.20	R 60 315 207.75	R 72 378 249.30	R 84 441 290.85	R 96 504 332.40	R 108 567 373.95	R 120 630 415.50

Figure A.26: Coldstream Process (475 kg/h) Manufacturing Cost

	BE Throughput	Throughput 1:	Throughput 2:	Throughput 3	Throughput 4	Throughput 5	Throughput 6	Throughput 7:	Throughput 8:	Throughput 9:	Throughput 10:	UNITS
Throughput	38.90742887	7.5	15	22.5	30	37.5	45	52.5	60	67.5	75	kg/hr
Workdays	249	249	249	249	249	249	249	249	249	249	249	Days
Shift Length	8	8	8	8	8	8	8	8	8	8	8	hrs
Shifts/Day	1	1	1	1	1	1	1	1	1	1	1	Shifts
Theoretical Output	77503.59831	14940	29880	44820	59760	74700	89640	104580	119520	134460	149400	kg/yr
Wage	90	90	90	90	90	90	90	90	90	90	90	R/hr
Nr of workers	4	5	5	5	5	5	5	5	5	5	5	# Workers
Yearly Wage	717120	896400	896400	896400	896400	896400	896400	896400	896400	896400	896400	R
Waste Treatment Cost	0	0	0	0	0	0	0	0	0	0	0	R
Electricity Use	162757.5565	31374	62748	94122	125496	156870	188244	219618	250992	282366	313740	R
Gas Use	0	0	0	0	0	0	0	0	0	0	0	R
Water use	17037.05323	3284.151715	6568.303429	9852.455144	13136.60686	16420.75857	19704.91029	22989.062	26273.21372	29557.36543	32841.51715	R
Nitrogen Gas Use	43281	43281	43281	43281	43281	43281	43281	43281	43281	43281	43281	

Figure A.27: Coldstream Process (75 kg/h) Process Inputs

Appendix B

NPV Analysis Results

B.1 NPV Calculations Break-Even Cases

Throughput: BE		kg/hr									
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		R 30 100 819.60	30100819.6	30100819.6	30100819.6	30100819.6	30100819.6	30100819.6	30100819.6	30100819.6	30100819.6
Total Annual Expense		R 25 385 949.79	R 25 385 949.79	R 25 385 949.79	R 25 385 949.79	R 25 385 949.79	R 25 385 949.79	R 25 385 949.79	R 25 385 949.79	R 25 385 949.79	R 25 385 949.79
Annual Cash Flow		R 4 714 869.81	R 4 714 869.81	R 4 714 869.81	R 4 714 869.81	R 4 714 869.81	R 4 714 869.81	R 4 714 869.81	R 4 714 869.81	R 4 714 869.81	R 4 714 869.81
Annual Depreciation and Other Tax Allowances		R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85
Amount of Tax		449909.0289	449909.0289	449909.0289	449909.0289	449909.0289	449909.0289	449909.0289	449909.0289	449909.0289	449909.0289
Total Annual Capital Expenditure	R 31 080 518.46	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -31 080 518.46	R 4 264 960.78	R 4 264 960.78	R 4 264 960.78	R 4 264 960.78	R 4 264 960.78	R 4 264 960.78	R 4 264 960.78	R 4 264 960.78	R 4 264 960.78	R 4 264 960.78
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -31 080 518.46	R 4 015 592.48	R 3 780 804.52	R 3 559 744.40	R 3 351 609.45	R 3 155 643.96	R 2 971 136.39	R 2 797 416.81	R 2 633 854.44	R 2 479 855.42	R 2 334 860.58
Net Present Value	R -31 080 518.46	R -27 064 925.97	R -23 284 121.45	R -19 724 377.05	R -16 372 767.60	R -13 217 123.64	R -10 245 987.25	R -7 448 570.45	R -4 814 716.00	R -2 334 860.58	R -0.00

Figure B.1: NPV Calculations for Zinc Process (25 kg/h) Break-Even Case

Throughput: BE											
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		44166717.32	44166717.32	44166717.32	44166717.32	44166717.32	44166717.32	44166717.32	44166717.32	44166717.32	44166717.32
Total Annual Expense		R 37 243 582.10	R 37 243 582.10	R 37 243 582.10	R 37 243 582.10	R 37 243 582.10	R 37 243 582.10	R 37 243 582.10	R 37 243 582.10	R 37 243 582.10	R 37 243 582.10
Annual Cash Flow		R 6 923 135.22	R 6 923 135.22	R 6 923 135.22	R 6 923 135.22	R 6 923 135.22	R 6 923 135.22	R 6 923 135.22	R 6 923 135.22	R 6 923 135.22	R 6 923 135.22
Annual Depreciation and Other Tax Allowances		R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94
Amount of Tax		660629.2798	660629.2798	660629.2798	660629.2798	660629.2798	660629.2798	660629.2798	660629.2798	660629.2798	660629.2798
Total Annual Capital Expenditure	R 45 637 449.36	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -45 637 449.36	R 6 262 505.94	R 6 262 505.94	R 6 262 505.94	R 6 262 505.94	R 6 262 505.94	R 6 262 505.94	R 6 262 505.94	R 6 262 505.94	R 6 262 505.94	R 6 262 505.94
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -45 637 449.36	R 5 896 343.04	R 5 551 589.34	R 5 226 993.07	R 4 921 375.64	R 4 633 627.38	R 4 362 703.50	R 4 107 620.28	R 3 867 451.54	R 3 641 325.24	R 3 428 420.34
Net Present Value	R -45 637 449.36	R -39 741 106.32	R -34 189 516.98	R -28 962 523.91	R -24 041 148.26	R -19 407 520.88	R -15 044 817.39	R -10 937 197.11	R -7 069 745.57	R -3 428 420.34	R 0.00

Figure B.2: NPV Calculations for Zinc Process (45.5 kg/h) Break-Even Case

Throughput: BE		kg/hr									
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		R 30 100 819.60	30100819.6	30100819.6	30100819.6	30100819.6	30100819.6	30100819.6	30100819.6	30100819.6	30100819.6
Total Annual Expense		R 25 385 949.79	R 25 385 949.79	R 25 385 949.79	R 25 385 949.79	R 25 385 949.79	R 25 385 949.79	R 25 385 949.79	R 25 385 949.79	R 25 385 949.79	R 25 385 949.79
Annual Cash Flow		R 4 714 869.81	R 4 714 869.81	R 4 714 869.81	R 4 714 869.81	R 4 714 869.81	R 4 714 869.81	R 4 714 869.81	R 4 714 869.81	R 4 714 869.81	R 4 714 869.81
Annual Depreciation and Other Tax Allowances		R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85
Amount of Tax		449909.0289	449909.0289	449909.0289	449909.0289	449909.0289	449909.0289	449909.0289	449909.0289	449909.0289	449909.0289
Total Annual Capital Expenditure	R 31 080 518.46	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -31 080 518.46	R 4 264 960.78	R 4 264 960.78	R 4 264 960.78	R 4 264 960.78	R 4 264 960.78	R 4 264 960.78	R 4 264 960.78	R 4 264 960.78	R 4 264 960.78	R 4 264 960.78
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -31 080 518.46	R 4 015 592.48	R 3 780 804.52	R 3 559 744.40	R 3 351 609.45	R 3 155 643.96	R 2 971 136.39	R 2 797 416.81	R 2 633 854.44	R 2 479 855.42	R 2 334 860.58
Net Present Value	R -31 080 518.46	R -27 064 925.97	R -23 284 121.45	R -19 724 377.05	R -16 372 767.60	R -13 217 123.64	R -10 245 987.25	R -7 448 570.45	R -4 814 716.00	R -2 334 860.58	R -0.00

Figure B.3: NPV Calculations for Zinc Process (75 kg/h) Break-Even Case

Throughput 1: BE

	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		35129543.03	35129543.03	35129543.03	35129543.03	35129543.03	35129543.03	35129543.03	35129543.03	35129543.03	35129543.03
Total Annual Expense		R 28 567 469.03	R 28 567 469.03	R 28 567 469.03	R 28 567 469.03	R 28 567 469.03	R 28 567 469.03	R 28 567 469.03	R 28 567 469.03	R 28 567 469.03	R 28 567 469.03
Annual Cash Flow		R 6 562 074.00	R 6 562 074.00	R 6 562 074.00	R 6 562 074.00	R 6 562 074.00	R 6 562 074.00	R 6 562 074.00	R 6 562 074.00	R 6 562 074.00	R 6 562 074.00
Annual Depreciation and Other Tax Allowances		R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64
Amount of Tax		626175.5807	626175.5807	626175.5807	626175.5807	626175.5807	626175.5807	626175.5807	626175.5807	626175.5807	626175.5807
Total Annual Capital Expenditure	R 43 257 326.35	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -43 257 326.35	R 5 935 898.41	R 5 935 898.41	R 5 935 898.41	R 5 935 898.41	R 5 935 898.41	R 5 935 898.41	R 5 935 898.41	R 5 935 898.41	R 5 935 898.41	R 5 935 898.41
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -43 257 326.35	R 5 588 831.95	R 5 262 058.14	R 4 954 390.49	R 4 664 711.88	R 4 391 970.51	R 4 135 176.08	R 3 893 396.18	R 3 665 752.92	R 3 451 419.75	R 3 249 618.45
Net Present Value	R -43 257 326.35	R -37 668 494.40	R -32 406 436.26	R -27 452 045.77	R -22 787 333.89	R -18 395 363.38	R -14 260 187.30	R -10 366 791.12	R -6 701 038.20	R -3 249 618.45	R 0.00

Figure B.4: NPV Calculations for Acid Leach Process (22 kg/h) Break-Even Case

Throughput 1: BE

	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		69353878.6	69353878.6	69353878.6	69353878.6	69353878.6	69353878.6	69353878.6	69353878.6	69353878.6	69353878.6
Total Annual Expense		R 56 269 203.20	R 56 269 203.20	R 56 269 203.20	R 56 269 203.20	R 56 269 203.20	R 56 269 203.20	R 56 269 203.20	R 56 269 203.20	R 56 269 203.20	R 56 269 203.20
Annual Cash Flow		R 13 084 675.40	R 13 084 675.40	R 13 084 675.40	R 13 084 675.40	R 13 084 675.40	R 13 084 675.40	R 13 084 675.40	R 13 084 675.40	R 13 084 675.40	R 13 084 675.40
Annual Depreciation and Other Tax Allowances		R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86
Amount of Tax		1248584.552	1248584.552	1248584.552	1248584.552	1248584.552	1248584.552	1248584.552	1248584.552	1248584.552	1248584.552
Total Annual Capital Expenditure	R 86 254 448.58	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -86 254 448.58	R 11 836 090.85	R 11 836 090.85	R 11 836 090.85	R 11 836 090.85	R 11 836 090.85	R 11 836 090.85	R 11 836 090.85	R 11 836 090.85	R 11 836 090.85	R 11 836 090.85
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -86 254 448.58	R 11 144 045.61	R 10 492 463.62	R 9 878 979.03	R 9 301 364.30	R 8 757 522.18	R 8 245 477.99	R 7 763 372.56	R 7 309 455.38	R 6 882 078.31	R 6 479 689.59
Net Present Value	R -86 254 448.58	R -75 110 402.96	R -64 617 939.34	R -54 738 960.31	R -45 437 596.01	R -36 680 073.83	R -28 434 595.84	R -20 671 223.28	R -13 361 767.91	R -6 479 689.59	R 0.00

Figure B.5: NPV Calculations for Acid Leach Process (44.5 kg/h) Break-Even Case

Throughput 1: BE 55.87 kg/h

	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		104260782.9	104260782.9	104260782.9	104260782.9	104260782.9	104260782.9	104260782.9	104260782.9	104260782.9	104260782.9
Total Annual Expense		R 84 578 185.77	R 84 578 185.77	R 84 578 185.77	R 84 578 185.77	R 84 578 185.77	R 84 578 185.77	R 84 578 185.77	R 84 578 185.77	R 84 578 185.77	R 84 578 185.77
Annual Cash Flow		R 19 682 597.16	R 19 682 597.16	R 19 682 597.16	R 19 682 597.16	R 19 682 597.16	R 19 682 597.16	R 19 682 597.16	R 19 682 597.16	R 19 682 597.16	R 19 682 597.16
Annual Depreciation and Other Tax Allowances		R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42
Amount of Tax		1878180.849	1878180.849	1878180.849	1878180.849	1878180.849	1878180.849	1878180.849	1878180.849	1878180.849	1878180.849
Total Annual Capital Expenditure	R 129 748 084.16	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -129 748 084.16	R 17 804 416.31	R 17 804 416.31	R 17 804 416.31	R 17 804 416.31	R 17 804 416.31	R 17 804 416.31	R 17 804 416.31	R 17 804 416.31	R 17 804 416.31	R 17 804 416.31
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -129 748 084.16	R 16 763 408.64	R 15 783 267.71	R 14 860 434.72	R 13 991 558.91	R 13 173 485.46	R 12 403 244.01	R 11 678 037.86	R 10 995 233.84	R 10 352 352.73	R 9 747 060.29
Net Present Value	R -129 748 084.16	R -112 984 675.52	R -97 201 407.81	R -82 340 973.09	R -68 349 414.18	R -55 175 928.72	R -42 772 684.71	R -31 094 646.85	R -20 099 413.02	R -9 747 060.29	R 0.00

Figure B.6: NPV Calculations for Acid Leach Process (68.75 kg/h) Break-Even Case

Throughput: BE	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		27864658.02	27864658.02	27864658.02	27864658.02	27864658.02	27864658.02	27864658.02	27864658.02	27864658.02	27864658.02
Total Annual Expense		R 22 224 300.27	R 22 224 300.27	R 22 224 300.27	R 22 224 300.27	R 22 224 300.27	R 22 224 300.27	R 22 224 300.27	R 22 224 300.27	R 22 224 300.27	R 22 224 300.27
Annual Cash Flow		R 5 640 357.75	R 5 640 357.75	R 5 640 357.75	R 5 640 357.75	R 5 640 357.75	R 5 640 357.75	R 5 640 357.75	R 5 640 357.75	R 5 640 357.75	R 5 640 357.75
Annual Depreciation and Other Tax Allowances		R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40
Amount of Tax		538222.2592	538222.2592	538222.2592	538222.2592	538222.2592	538222.2592	538222.2592	538222.2592	538222.2592	538222.2592
Total Annual Capital Expenditure	R 37 181 353.98	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -37 181 353.98	R 5 102 135.49	R 5 102 135.49	R 5 102 135.49	R 5 102 135.49	R 5 102 135.49	R 5 102 135.49	R 5 102 135.49	R 5 102 135.49	R 5 102 135.49	R 5 102 135.49
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -37 181 353.98	R 4 803 818.37	R 4 522 943.58	R 4 258 491.27	R 4 009 501.24	R 3 775 069.43	R 3 554 344.63	R 3 346 525.40	R 3 150 857.17	R 2 966 629.48	R 2 793 173.41
Net Present Value	R -37 181 353.98	R -32 377 535.60	R -27 854 592.03	R -23 596 100.76	R -19 586 599.52	R -15 811 530.09	R -12 257 185.46	R -8 910 660.06	R -5 759 802.89	R -2 793 173.41	R -0.00

Figure B.7: NPV Calculations for Coldstream Process (25 kg/h) Break-Even Case

Throughput: BE	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		35449662.82	35449662.82	35449662.82	35449662.82	35449662.82	35449662.82	35449662.82	35449662.82	35449662.82	35449662.82
Total Annual Expense		R 28 330 427.03	R 28 330 427.03	R 28 330 427.03	R 28 330 427.03	R 28 330 427.03	R 28 330 427.03	R 28 330 427.03	R 28 330 427.03	R 28 330 427.03	R 28 330 427.03
Annual Cash Flow		R 7 119 235.79	R 7 119 235.79	R 7 119 235.79	R 7 119 235.79	R 7 119 235.79	R 7 119 235.79	R 7 119 235.79	R 7 119 235.79	R 7 119 235.79	R 7 119 235.79
Annual Depreciation and Other Tax Allowances		R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84
Amount of Tax		679341.8683	679341.8683	679341.8683	679341.8683	679341.8683	679341.8683	679341.8683	679341.8683	679341.8683	679341.8683
Total Annual Capital Expenditure	R 46 930 148.36	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -46 930 148.36	R 6 439 893.93	R 6 439 893.93	R 6 439 893.93	R 6 439 893.93	R 6 439 893.93	R 6 439 893.93	R 6 439 893.93	R 6 439 893.93	R 6 439 893.93	R 6 439 893.93
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -46 930 148.36	R 6 063 359.31	R 5 708 840.33	R 5 375 049.74	R 5 060 775.58	R 4 764 876.73	R 4 486 278.82	R 4 223 970.26	R 3 976 998.65	R 3 744 467.23	R 3 525 531.71
Net Present Value	R -46 930 148.36	R -40 866 789.04	R -35 157 948.72	R -29 782 898.98	R -24 722 123.40	R -19 957 246.67	R -15 470 967.85	R -11 246 997.59	R -7 269 998.94	R -3 525 531.71	R -0.00

Figure B.8: NPV Calculations for Coldstream Process (44.5 kg/h) Break-Even Case

Throughput: BE	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		62578924.14	62578924.14	62578924.14	62578924.14	62578924.14	62578924.14	62578924.14	62578924.14	62578924.14	62578924.14
Total Annual Expense		R 49 813 119.85	R 49 813 119.85	R 49 813 119.85	R 49 813 119.85	R 49 813 119.85	R 49 813 119.85	R 49 813 119.85	R 49 813 119.85	R 49 813 119.85	R 49 813 119.85
Annual Cash Flow		R 12 765 804.30	R 12 765 804.30	R 12 765 804.30	R 12 765 804.30	R 12 765 804.30	R 12 765 804.30	R 12 765 804.30	R 12 765 804.30	R 12 765 804.30	R 12 765 804.30
Annual Depreciation and Other Tax Allowances		R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37
Amount of Tax		1218156.779	1218156.779	1218156.779	1218156.779	1218156.779	1218156.779	1218156.779	1218156.779	1218156.779	1218156.779
Total Annual Capital Expenditure	R 84 152 443.74	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -84 152 443.74	R 11 547 647.52	R 11 547 647.52	R 11 547 647.52	R 11 547 647.52	R 11 547 647.52	R 11 547 647.52	R 11 547 647.52	R 11 547 647.52	R 11 547 647.52	R 11 547 647.52
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -84 152 443.74	R 10 872 467.30	R 10 236 764.24	R 9 638 230.15	R 9 074 691.79	R 8 544 102.99	R 8 044 537.23	R 7 574 180.61	R 7 131 325.31	R 6 714 363.35	R 6 321 780.76
Net Present Value	R -84 152 443.74	R -73 279 976.44	R -63 043 212.20	R -53 404 982.05	R -44 330 290.26	R -35 786 187.27	R -27 741 650.04	R -20 167 469.42	R -13 036 144.11	R -6 321 780.76	R 0.00

Figure B.9: NPV Calculations for Coldstream Process (75 kg/h) Break-Even Case

B.2 NPV Calculations Zinc Process (25 kg/h)

Throughput 1:	2.5 kg/hr										
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		4997545.785	4997545.785	4997545.785	4997545.785	4997545.785	4997545.785	4997545.785	4997545.785	4997545.785	4997545.785
Total Annual Expense		R 13 342 454.28	R 13 342 454.28	R 13 342 454.28	R 13 342 454.28	R 13 342 454.28	R 13 342 454.28	R 13 342 454.28	R 13 342 454.28	R 13 342 454.28	R 13 342 454.28
Annual Cash Flow		R -8 344 908.50	R -8 344 908.50	R -8 344 908.50	R -8 344 908.50	R -8 344 908.50	R -8 344 908.50	R -8 344 908.50	R -8 344 908.50	R -8 344 908.50	R -8 344 908.50
Annual Depreciation and Other Tax Allowances		R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85
Amount of Tax		0	0	0	0	0	0	0	0	0	0
Total Annual Capital Expenditure	R 31 080 518.46	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -31 080 518.46	R -8 344 908.50	R -8 344 908.50	R -8 344 908.50	R -8 344 908.50	R -8 344 908.50	R -8 344 908.50	R -8 344 908.50	R -8 344 908.50	R -8 344 908.50	R -8 344 908.50
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -31 080 518.46	R -7 856 989.45	R -7 397 598.58	R -6 965 067.87	R -6 557 826.82	R -6 174 396.78	R -5 813 385.54	R -5 473 482.29	R -5 153 452.87	R -4 852 135.27	R -4 568 435.43
Net Present Value	R -31 080 518.46	R -38 937 507.91	R -46 335 106.49	R -53 300 174.36	R -59 858 001.18	R -66 032 397.96	R -71 845 783.50	R -77 319 265.79	R -82 472 718.65	R -87 324 853.92	R -91 893 289.34

Figure B.10: NPV Calculations for Zinc Process (25 kg/h) Throughput 1

Throughput 2:	5 kg/hr										
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		R 9 995 091.57	9995091.57	9995091.57	9995091.57	9995091.57	9995091.57	9995091.57	9995091.57	9995091.57	9995091.57
Total Annual Expense		R 15 740 066.67	R 15 740 066.67	R 15 740 066.67	R 15 740 066.67	R 15 740 066.67	R 15 740 066.67	R 15 740 066.67	R 15 740 066.67	R 15 740 066.67	R 15 740 066.67
Annual Cash Flow		R -5 744 975.10	R -5 744 975.10	R -5 744 975.10	R -5 744 975.10	R -5 744 975.10	R -5 744 975.10	R -5 744 975.10	R -5 744 975.10	R -5 744 975.10	R -5 744 975.10
Annual Depreciation and Other Tax Allowances		R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85
Amount of Tax		0	0	0	0	0	0	0	0	0	0
Total Annual Capital Expenditure	R 31 080 518.46	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -31 080 518.46	R -5 744 975.10	R -5 744 975.10	R -5 744 975.10	R -5 744 975.10	R -5 744 975.10	R -5 744 975.10	R -5 744 975.10	R -5 744 975.10	R -5 744 975.10	R -5 744 975.10
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -31 080 518.46	R -5 409 071.74	R -5 092 808.35	R -4 795 036.57	R -4 514 675.24	R -4 250 706.38	R -4 002 171.52	R -3 768 168.27	R -3 547 846.98	R -3 340 407.66	R -3 145 097.13
Net Present Value	R -31 080 518.46	R -36 489 590.20	R -41 582 398.54	R -46 377 435.12	R -50 892 110.36	R -55 142 816.74	R -59 144 988.26	R -62 913 156.53	R -66 461 003.51	R -69 801 411.17	R -72 946 508.30

Figure B.11: NPV Calculations for Zinc Process (25 kg/h) Throughput 2

Throughput 3:	7.5 kg/hr										
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		14992637.36	14992637.36	14992637.36	14992637.36	14992637.36	14992637.36	14992637.36	14992637.36	14992637.36	14992637.36
Total Annual Expense		R 18 137 679.06	R 18 137 679.06	R 18 137 679.06	R 18 137 679.06	R 18 137 679.06	R 18 137 679.06	R 18 137 679.06	R 18 137 679.06	R 18 137 679.06	R 18 137 679.06
Annual Cash Flow		R -3 145 041.70	R -3 145 041.70	R -3 145 041.70	R -3 145 041.70	R -3 145 041.70	R -3 145 041.70	R -3 145 041.70	R -3 145 041.70	R -3 145 041.70	R -3 145 041.70
Annual Depreciation and Other Tax Allowances		R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85
Amount of Tax		0	0	0	0	0	0	0	0	0	0
Total Annual Capital Expenditure	R 31 080 518.46	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -31 080 518.46	R -3 145 041.70	R -3 145 041.70	R -3 145 041.70	R -3 145 041.70	R -3 145 041.70	R -3 145 041.70	R -3 145 041.70	R -3 145 041.70	R -3 145 041.70	R -3 145 041.70
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -31 080 518.46	R -2 961 154.03	R -2 788 018.11	R -2 625 005.28	R -2 471 523.66	R -2 327 015.97	R -2 190 957.51	R -2 062 854.26	R -1 942 241.09	R -1 828 680.06	R -1 721 758.83
Net Present Value	R -31 080 518.46	R -34 041 672.49	R -36 829 690.60	R -39 454 695.88	R -41 926 219.54	R -44 253 235.51	R -46 444 193.02	R -48 507 047.28	R -50 449 288.37	R -52 277 968.43	R -53 999 727.26

Figure B.12: NPV Calculations for Zinc Process (25 kg/h) Throughput 3

Throughput 4:	10 kg/hr										
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		19990183.14	19990183.14	19990183.14	19990183.14	19990183.14	19990183.14	19990183.14	19990183.14	19990183.14	19990183.14
Total Annual Expense		R 20 535 291.44	R 20 535 291.44	R 20 535 291.44	R 20 535 291.44	R 20 535 291.44	R 20 535 291.44	R 20 535 291.44	R 20 535 291.44	R 20 535 291.44	R 20 535 291.44
Annual Cash Flow		R -545 108.30	R -545 108.30	R -545 108.30	R -545 108.30	R -545 108.30	R -545 108.30	R -545 108.30	R -545 108.30	R -545 108.30	R -545 108.30
Annual Depreciation and Other Tax Allowances		R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85
Amount of Tax		0	0	0	0	0	0	0	0	0	0
Total Annual Capital Expenditure	R 31 080 518.46	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -31 080 518.46	R -545 108.30	R -545 108.30	R -545 108.30	R -545 108.30	R -545 108.30	R -545 108.30	R -545 108.30	R -545 108.30	R -545 108.30	R -545 108.30
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -31 080 518.46	R -513 236.33	R -483 227.87	R -454 973.99	R -428 372.08	R -403 325.57	R -379 743.49	R -357 540.25	R -336 635.20	R -316 952.45	R -298 420.54
Net Present Value	R -31 080 518.46	R -31 593 754.78	R -32 076 982.66	R -32 531 956.64	R -32 960 328.73	R -33 363 654.29	R -33 743 397.79	R -34 100 938.03	R -34 437 573.23	R -34 754 525.68	R -35 052 946.22

Figure B.13: NPV Calculations for Zinc Process (25 kg/h) Throughput 4

Throughput 5:	12.5 kg/hr										
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		24987728.93	24987728.93	24987728.93	24987728.93	24987728.93	24987728.93	24987728.93	24987728.93	24987728.93	24987728.93
Total Annual Expense		R 22 932 903.83	R 22 932 903.83	R 22 932 903.83	R 22 932 903.83	R 22 932 903.83	R 22 932 903.83	R 22 932 903.83	R 22 932 903.83	R 22 932 903.83	R 22 932 903.83
Annual Cash Flow		R 2 054 825.10	R 2 054 825.10	R 2 054 825.10	R 2 054 825.10	R 2 054 825.10	R 2 054 825.10	R 2 054 825.10	R 2 054 825.10	R 2 054 825.10	R 2 054 825.10
Annual Depreciation and Other Tax Allowances		R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85
Amount of Tax		0	0	0	0	0	0	0	0	0	0
Total Annual Capital Expenditure	R 31 080 518.46	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -31 080 518.46	R 2 054 825.10	R 2 054 825.10	R 2 054 825.10	R 2 054 825.10	R 2 054 825.10	R 2 054 825.10	R 2 054 825.10	R 2 054 825.10	R 2 054 825.10	R 2 054 825.10
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -31 080 518.46	R 1 934 681.38	R 1 821 562.36	R 1 715 057.30	R 1 614 779.50	R 1 520 364.84	R 1 431 470.52	R 1 347 773.77	R 1 268 970.69	R 1 194 775.15	R 1 124 917.76
Net Present Value	R -31 080 518.46	R -29 145 837.07	R -27 324 274.71	R -25 609 217.41	R -23 994 437.91	R -22 474 073.07	R -21 042 602.55	R -19 694 828.78	R -18 425 858.09	R -17 231 082.94	R -16 106 165.18

Figure B.14: NPV Calculations for Zinc Process (25 kg/h) Throughput 5

Throughput 6:	15 kg/hr										
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		29985274.71	29985274.71	29985274.71	29985274.71	29985274.71	29985274.71	29985274.71	29985274.71	29985274.71	29985274.71
Total Annual Expense		R 25 330 516.21	R 25 330 516.21	R 25 330 516.21	R 25 330 516.21	R 25 330 516.21	R 25 330 516.21	R 25 330 516.21	R 25 330 516.21	R 25 330 516.21	R 25 330 516.21
Annual Cash Flow		R 4 654 758.50	R 4 654 758.50	R 4 654 758.50	R 4 654 758.50	R 4 654 758.50	R 4 654 758.50	R 4 654 758.50	R 4 654 758.50	R 4 654 758.50	R 4 654 758.50
Annual Depreciation and Other Tax Allowances		R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85
Amount of Tax		433077.8624	433077.8624	433077.8624	433077.8624	433077.8624	433077.8624	433077.8624	433077.8624	433077.8624	433077.8624
Total Annual Capital Expenditure	R 31 080 518.46	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -31 080 518.46	R 4 221 680.63	R 4 221 680.63	R 4 221 680.63	R 4 221 680.63	R 4 221 680.63	R 4 221 680.63	R 4 221 680.63	R 4 221 680.63	R 4 221 680.63	R 4 221 680.63
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -31 080 518.46	R 3 974 842.89	R 3 742 437.52	R 3 523 620.68	R 3 317 597.85	R 3 123 620.99	R 2 940 985.77	R 2 769 029.07	R 2 607 126.51	R 2 454 690.25	R 2 311 166.79
Net Present Value	R -31 080 518.46	R -27 105 675.56	R -23 363 238.04	R -19 839 617.37	R -16 522 019.52	R -13 398 398.53	R -10 457 412.76	R -7 688 383.69	R -5 081 257.18	R -2 626 566.94	R -315 400.15

Figure B.15: NPV Calculations for Zinc Process (25 kg/h) Throughput 6

Throughput 7:	17.5 kg/hr										
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		34982820.5	34982820.5	34982820.5	34982820.5	34982820.5	34982820.5	34982820.5	34982820.5	34982820.5	34982820.5
Total Annual Expense		R 27 728 128.60	R 27 728 128.60	R 27 728 128.60	R 27 728 128.60	R 27 728 128.60	R 27 728 128.60	R 27 728 128.60	R 27 728 128.60	R 27 728 128.60	R 27 728 128.60
Annual Cash Flow		R 7 254 691.90	R 7 254 691.90	R 7 254 691.90	R 7 254 691.90	R 7 254 691.90	R 7 254 691.90	R 7 254 691.90	R 7 254 691.90	R 7 254 691.90	R 7 254 691.90
Annual Depreciation and Other Tax Allowances		R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85
Amount of Tax		1161059.214	1161059.214	1161059.214	1161059.214	1161059.214	1161059.214	1161059.214	1161059.214	1161059.214	1161059.214
Total Annual Capital Expenditure	R 31 080 518.46	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -31 080 518.46	R 6 093 632.68	R 6 093 632.68	R 6 093 632.68	R 6 093 632.68	R 6 093 632.68	R 6 093 632.68	R 6 093 632.68	R 6 093 632.68	R 6 093 632.68	R 6 093 632.68
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -31 080 518.46	R 5 737 343.64	R 5 401 886.49	R 5 086 043.21	R 4 788 666.99	R 4 508 678.08	R 4 245 059.86	R 3 996 855.16	R 3 763 162.75	R 3 543 134.12	R 3 335 970.36
Net Present Value	R -31 080 518.46	R -25 343 174.81	R -19 941 288.32	R -14 855 245.12	R -10 066 578.13	R -5 557 900.05	R -1 312 840.19	R 2 684 014.97	R 6 447 177.72	R 9 990 311.84	R 13 326 282.20

Figure B.16: NPV Calculations for Zinc Process (25 kg/h) Throughput 7

Throughput 8:	20 kg/hr										
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		39980366.28	39980366.28	39980366.28	39980366.28	39980366.28	39980366.28	39980366.28	39980366.28	39980366.28	39980366.28
Total Annual Expense		R 30 125 740.99	R 30 125 740.99	R 30 125 740.99	R 30 125 740.99	R 30 125 740.99	R 30 125 740.99	R 30 125 740.99	R 30 125 740.99	R 30 125 740.99	R 30 125 740.99
Annual Cash Flow		R 9 854 625.29	R 9 854 625.29	R 9 854 625.29	R 9 854 625.29	R 9 854 625.29	R 9 854 625.29	R 9 854 625.29	R 9 854 625.29	R 9 854 625.29	R 9 854 625.29
Annual Depreciation and Other Tax Allowances		R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85
Amount of Tax		1889040.566	1889040.566	1889040.566	1889040.566	1889040.566	1889040.566	1889040.566	1889040.566	1889040.566	1889040.566
Total Annual Capital Expenditure	R 31 080 518.46	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -31 080 518.46	R 7 965 584.73	R 7 965 584.73	R 7 965 584.73	R 7 965 584.73	R 7 965 584.73	R 7 965 584.73	R 7 965 584.73	R 7 965 584.73	R 7 965 584.73	R 7 965 584.73
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -31 080 518.46	R 7 499 844.39	R 7 061 335.46	R 6 648 465.74	R 6 259 736.12	R 5 893 735.17	R 5 549 133.95	R 5 224 681.25	R 4 919 198.99	R 4 631 578.00	R 4 360 773.93
Net Present Value	R -31 080 518.46	R -23 580 674.06	R -16 519 338.60	R -9 870 872.87	R -3 611 136.74	R 2 282 598.43	R 7 831 732.38	R 13 056 413.63	R 17 975 612.62	R 22 607 190.61	R 26 967 964.55

Figure B.17: NPV Calculations for Zinc Process (25 kg/h) Throughput 8

Throughput 9:	22.5 kg/hr										
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		44977912.07	44977912.07	44977912.07	44977912.07	44977912.07	44977912.07	44977912.07	44977912.07	44977912.07	44977912.07
Total Annual Expense		R 32 523 353.37	R 32 523 353.37	R 32 523 353.37	R 32 523 353.37	R 32 523 353.37	R 32 523 353.37	R 32 523 353.37	R 32 523 353.37	R 32 523 353.37	R 32 523 353.37
Annual Cash Flow		R 12 454 558.69	R 12 454 558.69	R 12 454 558.69	R 12 454 558.69	R 12 454 558.69	R 12 454 558.69	R 12 454 558.69	R 12 454 558.69	R 12 454 558.69	R 12 454 558.69
Annual Depreciation and Other Tax Allowances		R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85
Amount of Tax		2617021.917	2617021.917	2617021.917	2617021.917	2617021.917	2617021.917	2617021.917	2617021.917	2617021.917	2617021.917
Total Annual Capital Expenditure	R 31 080 518.46	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -31 080 518.46	R 9 837 536.78	R 9 837 536.78	R 9 837 536.78	R 9 837 536.78	R 9 837 536.78	R 9 837 536.78	R 9 837 536.78	R 9 837 536.78	R 9 837 536.78	R 9 837 536.78
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -31 080 518.46	R 9 262 345.14	R 8 720 784.43	R 8 210 888.27	R 7 730 805.26	R 7 278 792.26	R 6 853 208.04	R 6 452 507.34	R 6 075 235.23	R 5 720 021.87	R 5 385 577.51
Net Present Value	R -31 080 518.46	R -21 818 173.31	R -13 097 388.88	R -4 886 500.61	R 2 844 304.65	R 10 123 096.91	R 16 976 304.95	R 23 428 812.29	R 29 504 047.52	R 35 224 069.39	R 40 609 646.90

Figure B.18: NPV Calculations for Zinc Process (25 kg/h) Throughput 9

Throughput 10:	25 kg/hr										
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		49975457.85	49975457.85	49975457.85	49975457.85	49975457.85	49975457.85	49975457.85	49975457.85	49975457.85	49975457.85
Total Annual Expense		R 34 920 965.76	R 34 920 965.76	R 34 920 965.76	R 34 920 965.76	R 34 920 965.76	R 34 920 965.76	R 34 920 965.76	R 34 920 965.76	R 34 920 965.76	R 34 920 965.76
Annual Cash Flow		R 15 054 492.09	R 15 054 492.09	R 15 054 492.09	R 15 054 492.09	R 15 054 492.09	R 15 054 492.09	R 15 054 492.09	R 15 054 492.09	R 15 054 492.09	R 15 054 492.09
Annual Depreciation and Other Tax Allowances		R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85	R 3 108 051.85
Amount of Tax		3345003.269	3345003.269	3345003.269	3345003.269	3345003.269	3345003.269	3345003.269	3345003.269	3345003.269	3345003.269
Total Annual Capital Expenditure	R 31 080 518.46	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -31 080 518.46	R 11 709 488.82	R 11 709 488.82	R 11 709 488.82	R 11 709 488.82	R 11 709 488.82	R 11 709 488.82	R 11 709 488.82	R 11 709 488.82	R 11 709 488.82	R 11 709 488.82
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -31 080 518.46	R 11 024 845.89	R 10 380 233.40	R 9 773 310.80	R 9 201 874.40	R 8 663 849.35	R 8 157 282.13	R 7 680 333.43	R 7 231 271.47	R 6 808 465.75	R 6 410 381.08
Net Present Value	R -31 080 518.46	R -20 055 672.56	R -9 675 439.16	R 97 871.64	R 9 299 746.03	R 17 963 595.39	R 26 120 877.52	R 33 801 210.95	R 41 032 482.42	R 47 840 948.16	R 54 251 329.25

Figure B.19: NPV Calculations for Zinc Process (25 kg/h) Throughput 10

B.3 NPV Calculations Zinc Process (45.5 kg/h)

Throughput 1:	4.55 kg/h										
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		9095533.329	9095533.329	9095533.329	9095533.329	9095533.329	9095533.329	9095533.329	9095533.329	9095533.329	9095533.329
Total Annual Expense		R 20 440 486.08	R 20 440 486.08	R 20 440 486.08	R 20 440 486.08	R 20 440 486.08	R 20 440 486.08	R 20 440 486.08	R 20 440 486.08	R 20 440 486.08	R 20 440 486.08
Annual Cash Flow		R -11 344 952.75	R -11 344 952.75	R -11 344 952.75	R -11 344 952.75	R -11 344 952.75	R -11 344 952.75	R -11 344 952.75	R -11 344 952.75	R -11 344 952.75	R -11 344 952.75
Annual Depreciation and Other Tax Allowances		R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94
Amount of Tax		0	0	0	0	0	0	0	0	0	0
Total Annual Capital Expenditure	R 45 637 449.36	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -45 637 449.36	R -11 344 952.75	R -11 344 952.75	R -11 344 952.75	R -11 344 952.75	R -11 344 952.75	R -11 344 952.75	R -11 344 952.75	R -11 344 952.75	R -11 344 952.75	R -11 344 952.75
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -45 637 449.36	R -10 681 623.91	R -10 057 079.28	R -9 469 051.20	R -8 915 404.58	R -8 394 129.16	R -7 903 332.23	R -7 441 231.74	R -7 006 149.83	R -6 596 506.76	R -6 210 815.14
Net Present Value	R -45 637 449.36	R -56 319 073.26	R -66 376 152.55	R -75 845 203.75	R -84 760 608.33	R -93 154 737.49	R -101 058 069.72	R -108 499 301.46	R -115 505 451.29	R -122 101 958.05	R -128 312 773.20

Figure B.20: NPV Calculations for Zinc Process (45 kg/h) Throughput 1

Throughput 2:	9.1 kg/h										
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		18191066.66	18191066.66	18191066.66	18191066.66	18191066.66	18191066.66	18191066.66	18191066.66	18191066.66	18191066.66
Total Annual Expense		R 24 798 283.64	R 24 798 283.64	R 24 798 283.64	R 24 798 283.64	R 24 798 283.64	R 24 798 283.64	R 24 798 283.64	R 24 798 283.64	R 24 798 283.64	R 24 798 283.64
Annual Cash Flow		R -6 607 216.98	R -6 607 216.98	R -6 607 216.98	R -6 607 216.98	R -6 607 216.98	R -6 607 216.98	R -6 607 216.98	R -6 607 216.98	R -6 607 216.98	R -6 607 216.98
Annual Depreciation and Other Tax Allowances		R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94
Amount of Tax		0	0	0	0	0	0	0	0	0	0
Total Annual Capital Expenditure	R 45 637 449.36	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -45 637 449.36	R -6 607 216.98	R -6 607 216.98	R -6 607 216.98	R -6 607 216.98	R -6 607 216.98	R -6 607 216.98	R -6 607 216.98	R -6 607 216.98	R -6 607 216.98	R -6 607 216.98
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -45 637 449.36	R -6 220 899.14	R -5 857 168.95	R -5 514 705.73	R -5 192 266.01	R -4 888 679.04	R -4 602 842.52	R -4 333 718.59	R -4 080 330.09	R -3 841 756.99	R -3 617 133.02
Net Present Value	R -45 637 449.36	R -51 858 348.50	R -57 715 517.45	R -63 230 223.17	R -68 422 489.18	R -73 311 168.22	R -77 914 010.74	R -82 247 729.33	R -86 328 059.42	R -90 169 816.41	R -93 786 949.43

Figure B.21: NPV Calculations for Zinc Process (45 kg/h) Throughput 2

Throughput 3:	13.65 kg/h										
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		27286599.99	27286599.99	27286599.99	27286599.99	27286599.99	27286599.99	27286599.99	27286599.99	27286599.99	27286599.99
Total Annual Expense		R 29 156 081.19	R 29 156 081.19	R 29 156 081.19	R 29 156 081.19	R 29 156 081.19	R 29 156 081.19	R 29 156 081.19	R 29 156 081.19	R 29 156 081.19	R 29 156 081.19
Annual Cash Flow		R -1 869 481.21	R -1 869 481.21	R -1 869 481.21	R -1 869 481.21	R -1 869 481.21	R -1 869 481.21	R -1 869 481.21	R -1 869 481.21	R -1 869 481.21	R -1 869 481.21
Annual Depreciation and Other Tax Allowances		R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94
Amount of Tax		0	0	0	0	0	0	0	0	0	0
Total Annual Capital Expenditure	R 45 637 449.36	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -45 637 449.36	R -1 869 481.21	R -1 869 481.21	R -1 869 481.21	R -1 869 481.21	R -1 869 481.21	R -1 869 481.21	R -1 869 481.21	R -1 869 481.21	R -1 869 481.21	R -1 869 481.21
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -45 637 449.36	R -1 760 174.38	R -1 657 258.62	R -1 560 360.25	R -1 469 127.43	R -1 383 228.92	R -1 302 352.81	R -1 226 205.45	R -1 154 510.36	R -1 087 007.21	R -1 023 450.91
Net Present Value	R -45 637 449.36	R -47 397 623.73	R -49 054 882.35	R -50 615 242.60	R -52 084 370.03	R -53 467 598.94	R -54 769 951.75	R -55 996 157.20	R -57 150 667.55	R -58 237 674.76	R -59 261 125.67

Figure B.22: NPV Calculations for Zinc Process (45 kg/h) Throughput 3

Throughput 4:	18.2 kg/h										
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		36382133.31	36382133.31	36382133.31	36382133.31	36382133.31	36382133.31	36382133.31	36382133.31	36382133.31	36382133.31
Total Annual Expense		R 33 513 878.75	R 33 513 878.75	R 33 513 878.75	R 33 513 878.75	R 33 513 878.75	R 33 513 878.75	R 33 513 878.75	R 33 513 878.75	R 33 513 878.75	R 33 513 878.75
Annual Cash Flow		R 2 868 254.57	R 2 868 254.57	R 2 868 254.57	R 2 868 254.57	R 2 868 254.57	R 2 868 254.57	R 2 868 254.57	R 2 868 254.57	R 2 868 254.57	R 2 868 254.57
Annual Depreciation and Other Tax Allowances		R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94
Amount of Tax		0	0	0	0	0	0	0	0	0	0
Total Annual Capital Expenditure	R 45 637 449.36	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -45 637 449.36	R 2 868 254.57	R 2 868 254.57	R 2 868 254.57	R 2 868 254.57	R 2 868 254.57	R 2 868 254.57	R 2 868 254.57	R 2 868 254.57	R 2 868 254.57	R 2 868 254.57
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -45 637 449.36	R 2 700 550.39	R 2 542 651.72	R 2 393 985.23	R 2 254 011.14	R 2 122 221.21	R 1 998 136.90	R 1 881 307.70	R 1 771 309.38	R 1 667 742.57	R 1 570 231.21
Net Present Value	R -45 637 449.36	R -42 936 898.97	R -40 394 247.25	R -38 000 262.02	R -35 746 250.87	R -33 624 029.67	R -31 625 892.77	R -29 744 585.07	R -27 973 275.69	R -26 305 533.12	R -24 735 301.91

Figure B.23: NPV Calculations for Zinc Process (45 kg/h) Throughput 4

Throughput 5:	22.75 kg/h										
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		45477666.64	45477666.64	45477666.64	45477666.64	45477666.64	45477666.64	45477666.64	45477666.64	45477666.64	45477666.64
Total Annual Expense		R 37 871 676.30	R 37 871 676.30	R 37 871 676.30	R 37 871 676.30	R 37 871 676.30	R 37 871 676.30	R 37 871 676.30	R 37 871 676.30	R 37 871 676.30	R 37 871 676.30
Annual Cash Flow		R 7 605 990.34	R 7 605 990.34	R 7 605 990.34	R 7 605 990.34	R 7 605 990.34	R 7 605 990.34	R 7 605 990.34	R 7 605 990.34	R 7 605 990.34	R 7 605 990.34
Annual Depreciation and Other Tax Allowances		R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94
Amount of Tax		851828.7136	851828.7136	851828.7136	851828.7136	851828.7136	851828.7136	851828.7136	851828.7136	851828.7136	851828.7136
Total Annual Capital Expenditure	R 45 637 449.36	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -45 637 449.36	R 6 754 161.63	R 6 754 161.63	R 6 754 161.63	R 6 754 161.63	R 6 754 161.63	R 6 754 161.63	R 6 754 161.63	R 6 754 161.63	R 6 754 161.63	R 6 754 161.63
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -45 637 449.36	R 6 359 252.07	R 5 987 432.51	R 5 637 352.90	R 5 307 742.11	R 4 997 403.37	R 4 705 209.83	R 4 430 100.59	R 4 171 076.72	R 3 927 197.74	R 3 697 578.14
Net Present Value	R -45 637 449.36	R -39 278 197.28	R -33 290 764.77	R -27 653 411.87	R -22 345 669.75	R -17 348 266.39	R -12 643 056.55	R -8 212 955.96	R -4 041 879.24	R -114 681.50	R 3 582 896.64

Figure B.24: NPV Calculations for Zinc Process (45 kg/h) Throughput 5

Throughput 6:	27.3 kg/h										
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		54573199.97	54573199.97	54573199.97	54573199.97	54573199.97	54573199.97	54573199.97	54573199.97	54573199.97	54573199.97
Total Annual Expense		R 42 229 473.86	R 42 229 473.86	R 42 229 473.86	R 42 229 473.86	R 42 229 473.86	R 42 229 473.86	R 42 229 473.86	R 42 229 473.86	R 42 229 473.86	R 42 229 473.86
Annual Cash Flow		R 12 343 726.11	R 12 343 726.11	R 12 343 726.11	R 12 343 726.11	R 12 343 726.11	R 12 343 726.11	R 12 343 726.11	R 12 343 726.11	R 12 343 726.11	R 12 343 726.11
Annual Depreciation and Other Tax Allowances		R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94
Amount of Tax		2178394.73	2178394.73	2178394.73	2178394.73	2178394.73	2178394.73	2178394.73	2178394.73	2178394.73	2178394.73
Total Annual Capital Expenditure	R 45 637 449.36	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -45 637 449.36	R 10 165 331.38	R 10 165 331.38	R 10 165 331.38	R 10 165 331.38	R 10 165 331.38	R 10 165 331.38	R 10 165 331.38	R 10 165 331.38	R 10 165 331.38	R 10 165 331.38
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -45 637 449.36	R 9 570 973.91	R 9 011 367.96	R 8 484 481.64	R 7 988 401.89	R 7 521 327.45	R 7 081 562.43	R 6 667 510.05	R 6 277 666.94	R 5 910 617.58	R 5 565 029.27
Net Present Value	R -45 637 449.36	R -36 066 475.45	R -27 055 107.50	R -18 570 625.85	R -10 582 223.96	R -3 060 896.51	R 4 020 665.92	R 10 688 175.97	R 16 965 842.90	R 22 876 460.49	R 28 441 489.75

Figure B.25: NPV Calculations for Zinc Process (45 kg/h) Throughput 6

Throughput 7:	31.85 kg/h										
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		63668733.3	63668733.3	63668733.3	63668733.3	63668733.3	63668733.3	63668733.3	63668733.3	63668733.3	63668733.3
Total Annual Expense		R 46 587 271.41	R 46 587 271.41	R 46 587 271.41	R 46 587 271.41	R 46 587 271.41	R 46 587 271.41	R 46 587 271.41	R 46 587 271.41	R 46 587 271.41	R 46 587 271.41
Annual Cash Flow		R 17 081 461.89	R 17 081 461.89	R 17 081 461.89	R 17 081 461.89	R 17 081 461.89	R 17 081 461.89	R 17 081 461.89	R 17 081 461.89	R 17 081 461.89	R 17 081 461.89
Annual Depreciation and Other Tax Allowances		R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94
Amount of Tax		3504960.747	3504960.747	3504960.747	3504960.747	3504960.747	3504960.747	3504960.747	3504960.747	3504960.747	3504960.747
Total Annual Capital Expenditure	R 45 637 449.36	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -45 637 449.36	R 13 576 501.14	R 13 576 501.14	R 13 576 501.14	R 13 576 501.14	R 13 576 501.14	R 13 576 501.14	R 13 576 501.14	R 13 576 501.14	R 13 576 501.14	R 13 576 501.14
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -45 637 449.36	R 12 782 695.74	R 12 035 303.40	R 11 331 610.39	R 10 669 061.66	R 10 045 251.54	R 9 457 915.02	R 8 904 919.52	R 8 384 257.15	R 7 894 037.42	R 7 432 480.39
Net Present Value	R -45 637 449.36	R -32 854 753.62	R -20 819 450.22	R -9 487 839.83	R 1 181 221.83	R 11 226 473.37	R 20 684 388.39	R 29 589 307.90	R 37 973 565.05	R 45 867 602.47	R 53 300 082.86

Figure B.26: NPV Calculations for Zinc Process (45 kg/h) Throughput 7

Throughput 8:	36.4 kg/h										
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		72764266.63	72764266.63	72764266.63	72764266.63	72764266.63	72764266.63	72764266.63	72764266.63	72764266.63	72764266.63
Total Annual Expense		R 50 945 068.97	R 50 945 068.97	R 50 945 068.97	R 50 945 068.97	R 50 945 068.97	R 50 945 068.97	R 50 945 068.97	R 50 945 068.97	R 50 945 068.97	R 50 945 068.97
Annual Cash Flow		R 21 819 197.66	R 21 819 197.66	R 21 819 197.66	R 21 819 197.66	R 21 819 197.66	R 21 819 197.66	R 21 819 197.66	R 21 819 197.66	R 21 819 197.66	R 21 819 197.66
Annual Depreciation and Other Tax Allowances		R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94
Amount of Tax		4831526.763	4831526.763	4831526.763	4831526.763	4831526.763	4831526.763	4831526.763	4831526.763	4831526.763	4831526.763
Total Annual Capital Expenditure	R 45 637 449.36	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -45 637 449.36	R 16 987 670.90	R 16 987 670.90	R 16 987 670.90	R 16 987 670.90	R 16 987 670.90	R 16 987 670.90	R 16 987 670.90	R 16 987 670.90	R 16 987 670.90	R 16 987 670.90
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -45 637 449.36	R 15 994 417.57	R 15 059 238.84	R 14 178 739.14	R 13 349 721.43	R 12 569 175.63	R 11 834 267.61	R 11 142 328.98	R 10 490 847.36	R 9 877 457.26	R 9 299 931.52
Net Present Value	R -45 637 449.36	R -29 643 031.79	R -14 583 792.95	R -405 053.82	R 12 944 667.62	R 25 513 843.25	R 37 348 110.85	R 48 490 439.83	R 58 981 287.19	R 68 858 744.46	R 78 158 675.97

Figure B.27: NPV Calculations for Zinc Process (45 kg/h) Throughput 8

Throughput 9:	40.95	kg/h									
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		81859799.96	81859799.96	81859799.96	81859799.96	81859799.96	81859799.96	81859799.96	81859799.96	81859799.96	81859799.96
Total Annual Expense		R 55 302 866.52	R 55 302 866.52	R 55 302 866.52	R 55 302 866.52	R 55 302 866.52	R 55 302 866.52	R 55 302 866.52	R 55 302 866.52	R 55 302 866.52	R 55 302 866.52
Annual Cash Flow		R 26 556 933.44	R 26 556 933.44	R 26 556 933.44	R 26 556 933.44	R 26 556 933.44	R 26 556 933.44	R 26 556 933.44	R 26 556 933.44	R 26 556 933.44	R 26 556 933.44
Annual Depreciation and Other Tax Allowances		R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94
Amount of Tax		6158092.78	6158092.78	6158092.78	6158092.78	6158092.78	6158092.78	6158092.78	6158092.78	6158092.78	6158092.78
Total Annual Capital Expenditure	R 45 637 449.36	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -45 637 449.36	R 20 398 840.66	R 20 398 840.66	R 20 398 840.66	R 20 398 840.66	R 20 398 840.66	R 20 398 840.66	R 20 398 840.66	R 20 398 840.66	R 20 398 840.66	R 20 398 840.66
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -45 637 449.36	R 19 206 139.40	R 18 083 174.28	R 17 025 867.88	R 16 030 381.21	R 15 093 099.72	R 14 210 620.20	R 13 379 738.44	R 12 597 437.57	R 11 860 877.10	R 11 167 382.64
Net Present Value	R -45 637 449.36	R -26 431 309.96	R -8 348 135.68	R 8 677 732.20	R 24 708 113.41	R 39 801 213.12	R 54 011 833.32	R 67 391 571.77	R 79 989 009.34	R 91 849 886.44	R 103 017 269.08

Figure B.28: NPV Calculations for Zinc Process (45 kg/h) Throughput 9

Throughput 10:		kg/h									
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		90955333.29	90955333.29	90955333.29	90955333.29	90955333.29	90955333.29	90955333.29	90955333.29	90955333.29	90955333.29
Total Annual Expense		R 59 660 664.08	R 59 660 664.08	R 59 660 664.08	R 59 660 664.08	R 59 660 664.08	R 59 660 664.08	R 59 660 664.08	R 59 660 664.08	R 59 660 664.08	R 59 660 664.08
Annual Cash Flow		R 31 294 669.21	R 31 294 669.21	R 31 294 669.21	R 31 294 669.21	R 31 294 669.21	R 31 294 669.21	R 31 294 669.21	R 31 294 669.21	R 31 294 669.21	R 31 294 669.21
Annual Depreciation and Other Tax Allowances		R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94	R 4 563 744.94
Amount of Tax		7484658.797	7484658.797	7484658.797	7484658.797	7484658.797	7484658.797	7484658.797	7484658.797	7484658.797	7484658.797
Total Annual Capital Expenditure	R 45 637 449.36	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -45 637 449.36	R 23 810 010.41	R 23 810 010.41	R 23 810 010.41	R 23 810 010.41	R 23 810 010.41	R 23 810 010.41	R 23 810 010.41	R 23 810 010.41	R 23 810 010.41	R 23 810 010.41
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -45 637 449.36	R 22 417 861.23	R 21 107 109.72	R 19 872 996.63	R 18 711 040.98	R 17 617 023.80	R 16 586 972.79	R 15 617 147.91	R 14 704 027.78	R 13 844 296.94	R 13 034 833.77
Net Present Value	R -45 637 449.36	R -23 219 588.13	R -2 112 478.41	R 17 760 518.22	R 36 471 559.20	R 54 088 583.00	R 70 675 555.79	R 86 292 703.70	R 100 996 731.48	R 114 841 028.43	R 127 875 862.19

Figure B.29: NPV Calculations for Zinc Process (45 kg/h) Throughput 10

B.4 NPV Calculations Zinc Process (75 kg/h)

Throughput 1:	7.5	kg/hr									
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		14992637.36	14992637.36	14992637.36	14992637.36	14992637.36	14992637.36	14992637.36	14992637.36	14992637.36	14992637.36
Total Annual Expense		R 34 710 370.57	R 34 710 370.57	R 34 710 370.57	R 34 710 370.57	R 34 710 370.57	R 34 710 370.57	R 34 710 370.57	R 34 710 370.57	R 34 710 370.57	R 34 710 370.57
Annual Cash Flow		R -19 717 733.21	R -19 717 733.21	R -19 717 733.21	R -19 717 733.21	R -19 717 733.21	R -19 717 733.21	R -19 717 733.21	R -19 717 733.21	R -19 717 733.21	R -19 717 733.21
Annual Depreciation and Other Tax Allowances		R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34
Amount of Tax		0	0	0	0	0	0	0	0	0	0
Total Annual Capital Expenditure	R 78 784 733.42	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -78 784 733.42	R -19 717 733.21	R -19 717 733.21	R -19 717 733.21	R -19 717 733.21	R -19 717 733.21	R -19 717 733.21	R -19 717 733.21	R -19 717 733.21	R -19 717 733.21	R -19 717 733.21
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -78 784 733.42	R -18 564 855.68	R -17 479 385.82	R -16 457 382.37	R -15 495 134.52	R -14 589 148.40	R -13 736 134.45	R -12 932 995.44	R -12 176 815.21	R -11 464 848.14	R -10 794 509.12
Net Present Value	R -78 784 733.42	R -97 349 589.09	R -114 828 974.91	R -131 286 357.28	R -146 781 491.79	R -161 370 640.20	R -175 106 774.65	R -188 039 770.08	R -200 216 585.29	R -211 681 433.44	R -222 475 942.56

Figure B.30: NPV Calculations for Zinc Process (75 kg/h) Throughput 1

Throughput 2:	15 kg/hr										
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		R 29 985 274.71	29985274.71	29985274.71	29985274.71	29985274.71	29985274.71	29985274.71	29985274.71	29985274.71	29985274.71
Total Annual Expense		R 41 874 897.76	R 41 874 897.76	R 41 874 897.76	R 41 874 897.76	R 41 874 897.76	R 41 874 897.76	R 41 874 897.76	R 41 874 897.76	R 41 874 897.76	R 41 874 897.76
Annual Cash Flow (net Income before tax)		R -11 889 623.05	R -11 889 623.05	R -11 889 623.05	R -11 889 623.05	R -11 889 623.05	R -11 889 623.05	R -11 889 623.05	R -11 889 623.05	R -11 889 623.05	R -11 889 623.05
Annual Depreciation and Other Tax Allowances		R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34
Amount of Tax		0	0	0	0	0	0	0	0	0	0
Total Annual Capital Expenditure	R 78 784 733.42	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow (Net Income after tax)	R -78 784 733.42	R -11 889 623.05	R -11 889 623.05	R -11 889 623.05	R -11 889 623.05	R -11 889 623.05	R -11 889 623.05	R -11 889 623.05	R -11 889 623.05	R -11 889 623.05	R -11 889 623.05
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -78 784 733.42	R -11 194 447.84	R -10 539 918.88	R -9 923 659.62	R -9 343 432.46	R -8 797 130.65	R -8 282 770.59	R -7 798 484.70	R -7 342 514.54	R -6 913 204.54	R -6 508 995.90
Net Present Value	R -78 784 733.42	R -89 979 181.26	R -100 519 100.14	R -110 442 759.76	R -119 786 192.22	R -128 583 322.87	R -136 866 093.46	R -144 664 578.16	R -152 007 092.70	R -158 920 297.24	R -165 429 293.14

Figure B.31: NPV Calculations for Zinc Process (75 kg/h) Throughput 2

Throughput 3:	22.5 kg/hr										
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		44977912.07	44977912.07	44977912.07	44977912.07	44977912.07	44977912.07	44977912.07	44977912.07	44977912.07	44977912.07
Total Annual Expense		R 49 039 424.96	R 49 039 424.96	R 49 039 424.96	R 49 039 424.96	R 49 039 424.96	R 49 039 424.96	R 49 039 424.96	R 49 039 424.96	R 49 039 424.96	R 49 039 424.96
Annual Cash Flow		R -4 061 512.89	R -4 061 512.89	R -4 061 512.89	R -4 061 512.89	R -4 061 512.89	R -4 061 512.89	R -4 061 512.89	R -4 061 512.89	R -4 061 512.89	R -4 061 512.89
Annual Depreciation and Other Tax Allowances		R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34
Amount of Tax		0	0	0	0	0	0	0	0	0	0
Total Annual Capital Expenditure	R 78 784 733.42	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -78 784 733.42	R -4 061 512.89	R -4 061 512.89	R -4 061 512.89	R -4 061 512.89	R -4 061 512.89	R -4 061 512.89	R -4 061 512.89	R -4 061 512.89	R -4 061 512.89	R -4 061 512.89
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -78 784 733.42	R -3 824 040.01	R -3 600 451.94	R -3 389 936.87	R -3 191 730.41	R -3 005 112.90	R -2 829 406.74	R -2 663 973.96	R -2 508 213.87	R -2 361 560.94	R -2 223 482.67
Net Present Value	R -78 784 733.42	R -82 608 773.43	R -86 209 225.37	R -89 599 162.24	R -92 790 892.64	R -95 796 005.54	R -98 625 412.28	R -101 289 386.23	R -103 797 600.11	R -106 159 161.04	R -108 382 643.71

Figure B.32: NPV Calculations for Zinc Process (75 kg/h) Throughput 3

Throughput 4:	30 kg/hr										
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		59970549.42	59970549.42	59970549.42	59970549.42	59970549.42	59970549.42	59970549.42	59970549.42	59970549.42	59970549.42
Total Annual Expense		R 56 203 952.16	R 56 203 952.16	R 56 203 952.16	R 56 203 952.16	R 56 203 952.16	R 56 203 952.16	R 56 203 952.16	R 56 203 952.16	R 56 203 952.16	R 56 203 952.16
Annual Cash Flow		R 3 766 597.26	R 3 766 597.26	R 3 766 597.26	R 3 766 597.26	R 3 766 597.26	R 3 766 597.26	R 3 766 597.26	R 3 766 597.26	R 3 766 597.26	R 3 766 597.26
Annual Depreciation and Other Tax Allowances		R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34
Amount of Tax		0	0	0	0	0	0	0	0	0	0
Total Annual Capital Expenditure	R 78 784 733.42	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -78 784 733.42	R 3 766 597.26	R 3 766 597.26	R 3 766 597.26	R 3 766 597.26	R 3 766 597.26	R 3 766 597.26	R 3 766 597.26	R 3 766 597.26	R 3 766 597.26	R 3 766 597.26
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -78 784 733.42	R 3 546 367.82	R 3 339 014.99	R 3 143 785.89	R 2 959 971.65	R 2 786 904.86	R 2 623 957.12	R 2 470 536.79	R 2 326 086.80	R 2 190 082.66	R 2 062 030.56
Net Present Value	R -78 784 733.42	R -75 238 365.59	R -71 899 350.60	R -68 755 564.72	R -65 795 593.07	R -63 008 688.21	R -60 384 731.09	R -57 914 194.31	R -55 588 107.51	R -53 398 024.85	R -51 335 994.29

Figure B.33: NPV Calculations for Zinc Process (75 kg/h) Throughput 4

Throughput 5:	37.5	kg/hr									
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		74963186.78	74963186.78	74963186.78	74963186.78	74963186.78	74963186.78	74963186.78	74963186.78	74963186.78	74963186.78
Total Annual Expense		R 63 368 479.35	R 63 368 479.35	R 63 368 479.35	R 63 368 479.35	R 63 368 479.35	R 63 368 479.35	R 63 368 479.35	R 63 368 479.35	R 63 368 479.35	R 63 368 479.35
Annual Cash Flow		R 11 594 707.42	R 11 594 707.42	R 11 594 707.42	R 11 594 707.42	R 11 594 707.42	R 11 594 707.42	R 11 594 707.42	R 11 594 707.42	R 11 594 707.42	R 11 594 707.42
Annual Depreciation and Other Tax Allowances		R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34
Amount of Tax		1040545.543	1040545.543	1040545.543	1040545.543	1040545.543	1040545.543	1040545.543	1040545.543	1040545.543	1040545.543
Total Annual Capital Expenditure	R 78 784 733.42	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -78 784 733.42	R 10 554 161.88	R 10 554 161.88	R 10 554 161.88	R 10 554 161.88	R 10 554 161.88	R 10 554 161.88	R 10 554 161.88	R 10 554 161.88	R 10 554 161.88	R 10 554 161.88
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -78 784 733.42	R 9 937 069.84	R 9 356 058.60	R 8 809 018.55	R 8 293 963.42	R 7 809 023.09	R 7 352 436.77	R 6 922 546.62	R 6 517 791.75	R 6 136 702.53	R 5 777 895.23
Net Present Value	R -78 784 733.42	R -68 847 663.57	R -59 491 604.97	R -50 682 586.42	R -42 388 623.00	R -34 579 599.91	R -27 227 163.14	R -20 304 616.52	R -13 786 824.77	R -7 650 122.24	R -1 872 227.01

Figure B.34: NPV Calculations for Zinc Process (75 kg/h) Throughput 5

Throughput 6:	45	kg/hr									
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		89955824.13	89955824.13	89955824.13	89955824.13	89955824.13	89955824.13	89955824.13	89955824.13	89955824.13	89955824.13
Total Annual Expense		R 70 533 006.55	R 70 533 006.55	R 70 533 006.55	R 70 533 006.55	R 70 533 006.55	R 70 533 006.55	R 70 533 006.55	R 70 533 006.55	R 70 533 006.55	R 70 533 006.55
Annual Cash Flow		R 19 422 817.58	R 19 422 817.58	R 19 422 817.58	R 19 422 817.58	R 19 422 817.58	R 19 422 817.58	R 19 422 817.58	R 19 422 817.58	R 19 422 817.58	R 19 422 817.58
Annual Depreciation and Other Tax Allowances		R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34
Amount of Tax		3232416.387	3232416.387	3232416.387	3232416.387	3232416.387	3232416.387	3232416.387	3232416.387	3232416.387	3232416.387
Total Annual Capital Expenditure	R 78 784 733.42	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -78 784 733.42	R 16 190 401.19	R 16 190 401.19	R 16 190 401.19	R 16 190 401.19	R 16 190 401.19	R 16 190 401.19	R 16 190 401.19	R 16 190 401.19	R 16 190 401.19	R 16 190 401.19
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -78 784 733.42	R 15 243 763.48	R 14 352 474.80	R 13 513 298.93	R 12 723 188.90	R 11 979 275.87	R 11 278 858.74	R 10 619 394.35	R 9 998 488.23	R 9 413 885.92	R 8 863 464.76
Net Present Value	R -78 784 733.42	R -63 540 969.93	R -49 188 495.14	R -35 675 196.20	R -22 952 007.30	R -10 972 731.43	R 306 127.31	R 10 925 521.67	R 20 924 009.90	R 30 337 895.82	R 39 201 360.58

Figure B.35: NPV Calculations for Zinc Process (75 kg/h) Throughput 6

Throughput 7:	52.5	kg/hr									
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		104948461.5	104948461.5	104948461.5	104948461.5	104948461.5	104948461.5	104948461.5	104948461.5	104948461.5	104948461.5
Total Annual Expense		R 77 697 533.74	R 77 697 533.74	R 77 697 533.74	R 77 697 533.74	R 77 697 533.74	R 77 697 533.74	R 77 697 533.74	R 77 697 533.74	R 77 697 533.74	R 77 697 533.74
Annual Cash Flow		R 27 250 927.74	R 27 250 927.74	R 27 250 927.74	R 27 250 927.74	R 27 250 927.74	R 27 250 927.74	R 27 250 927.74	R 27 250 927.74	R 27 250 927.74	R 27 250 927.74
Annual Depreciation and Other Tax Allowances		R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34
Amount of Tax		5424287.232	5424287.232	5424287.232	5424287.232	5424287.232	5424287.232	5424287.232	5424287.232	5424287.232	5424287.232
Total Annual Capital Expenditure	R 78 784 733.42	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -78 784 733.42	R 21 826 640.51	R 21 826 640.51	R 21 826 640.51	R 21 826 640.51	R 21 826 640.51	R 21 826 640.51	R 21 826 640.51	R 21 826 640.51	R 21 826 640.51	R 21 826 640.51
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -78 784 733.42	R 20 550 457.12	R 19 348 890.99	R 18 217 579.32	R 17 152 414.38	R 16 149 528.65	R 15 205 280.72	R 14 316 242.09	R 13 479 184.72	R 12 691 069.31	R 11 949 034.28
Net Present Value	R -78 784 733.42	R -58 234 276.30	R -38 885 385.30	R -20 667 805.99	R -3 515 391.61	R 12 634 137.05	R 27 839 417.77	R 42 155 659.85	R 55 634 844.57	R 68 325 913.88	R 80 274 948.16

Figure B.36: NPV Calculations for Zinc Process (75 kg/h) Throughput 7

Throughput 8:	60	kg/hr									
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		119941098.8	119941098.8	119941098.8	119941098.8	119941098.8	119941098.8	119941098.8	119941098.8	119941098.8	119941098.8
Total Annual Expense		R 84 862 060.94	R 84 862 060.94	R 84 862 060.94	R 84 862 060.94	R 84 862 060.94	R 84 862 060.94	R 84 862 060.94	R 84 862 060.94	R 84 862 060.94	R 84 862 060.94
Annual Cash Flow		R 35 079 037.90	R 35 079 037.90	R 35 079 037.90	R 35 079 037.90	R 35 079 037.90	R 35 079 037.90	R 35 079 037.90	R 35 079 037.90	R 35 079 037.90	R 35 079 037.90
Annual Depreciation and Other Tax Allowances		R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34
Amount of Tax		7616158.076	7616158.076	7616158.076	7616158.076	7616158.076	7616158.076	7616158.076	7616158.076	7616158.076	7616158.076
Total Annual Capital Expenditure	R 78 784 733.42	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -78 784 733.42	R 27 462 879.82	R 27 462 879.82	R 27 462 879.82	R 27 462 879.82	R 27 462 879.82	R 27 462 879.82	R 27 462 879.82	R 27 462 879.82	R 27 462 879.82	R 27 462 879.82
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -78 784 733.42	R 25 857 150.76	R 24 345 307.18	R 22 921 859.70	R 21 581 639.86	R 20 319 781.43	R 19 131 702.70	R 18 013 089.82	R 16 959 881.20	R 15 968 252.70	R 15 034 603.81
Net Present Value	R -78 784 733.42	R -52 927 582.66	R -28 582 275.47	R -5 660 415.77	R 15 921 224.09	R 36 241 005.52	R 55 372 708.22	R 73 385 798.04	R 90 345 679.24	R 106 313 931.94	R 121 348 535.75

Figure B.37: NPV Calculations for Zinc Process (75 kg/h) Throughput 8

Throughput 9:	67.5	kg/hr									
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		134933736.2	134933736.2	134933736.2	134933736.2	134933736.2	134933736.2	134933736.2	134933736.2	134933736.2	134933736.2
Total Annual Expense		R 92 026 588.14	R 92 026 588.14	R 92 026 588.14	R 92 026 588.14	R 92 026 588.14	R 92 026 588.14	R 92 026 588.14	R 92 026 588.14	R 92 026 588.14	R 92 026 588.14
Annual Cash Flow		R 42 907 148.06	R 42 907 148.06	R 42 907 148.06	R 42 907 148.06	R 42 907 148.06	R 42 907 148.06	R 42 907 148.06	R 42 907 148.06	R 42 907 148.06	R 42 907 148.06
Annual Depreciation and Other Tax Allowances		R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34
Amount of Tax		9808028.92	9808028.92	9808028.92	9808028.92	9808028.92	9808028.92	9808028.92	9808028.92	9808028.92	9808028.92
Total Annual Capital Expenditure	R 78 784 733.42	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -78 784 733.42	R 33 099 119.14	R 33 099 119.14	R 33 099 119.14	R 33 099 119.14	R 33 099 119.14	R 33 099 119.14	R 33 099 119.14	R 33 099 119.14	R 33 099 119.14	R 33 099 119.14
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -78 784 733.42	R 31 163 844.40	R 29 341 723.38	R 27 626 140.08	R 26 010 865.34	R 24 490 034.22	R 23 058 124.67	R 21 709 937.55	R 20 440 577.68	R 19 245 436.10	R 18 120 173.33
Net Present Value	R -78 784 733.42	R -47 620 889.02	R -18 279 165.64	R 9 346 974.44	R 35 357 839.78	R 59 847 874.00	R 82 905 998.67	R 104 615 936.23	R 125 056 513.90	R 144 301 950.00	R 162 422 123.33

Figure B.38: NPV Calculations for Zinc Process (75 kg/h) Throughput 9

Throughput 10:	75	kg/hr									
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		149926373.6	149926373.6	149926373.6	149926373.6	149926373.6	149926373.6	149926373.6	149926373.6	149926373.6	149926373.6
Total Annual Expense		R 99 191 115.33	R 99 191 115.33	R 99 191 115.33	R 99 191 115.33	R 99 191 115.33	R 99 191 115.33	R 99 191 115.33	R 99 191 115.33	R 99 191 115.33	R 99 191 115.33
Annual Cash Flow		R 50 735 258.22	R 50 735 258.22	R 50 735 258.22	R 50 735 258.22	R 50 735 258.22	R 50 735 258.22	R 50 735 258.22	R 50 735 258.22	R 50 735 258.22	R 50 735 258.22
Annual Depreciation and Other Tax Allowances		R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34	R 7 878 473.34
Amount of Tax		11999899.76	11999899.76	11999899.76	11999899.76	11999899.76	11999899.76	11999899.76	11999899.76	11999899.76	11999899.76
Total Annual Capital Expenditure	R 78 784 733.42	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -78 784 733.42	R 38 735 358.45	R 38 735 358.45	R 38 735 358.45	R 38 735 358.45	R 38 735 358.45	R 38 735 358.45	R 38 735 358.45	R 38 735 358.45	R 38 735 358.45	R 38 735 358.45
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -78 784 733.42	R 36 470 538.04	R 34 338 139.57	R 32 330 420.46	R 30 440 090.82	R 28 660 287.00	R 26 984 546.65	R 25 406 785.29	R 23 921 274.16	R 22 522 619.49	R 21 205 742.86
Net Present Value	R -78 784 733.42	R -42 314 195.38	R -7 976 055.81	R 24 354 364.66	R 54 794 455.48	R 83 454 742.48	R 110 439 289.13	R 135 846 074.41	R 159 767 348.57	R 182 289 968.06	R 203 495 710.92

Figure B.39: NPV Calculations for Zinc Process (75 kg/h) Throughput 10

B.5 NPV Calculations Acid Leach Process (22 kg/h)

Throughput 1:	2.2	kg/hr									
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		4043991.072	4043991.072	4043991.072	4043991.072	4043991.072	4043991.072	4043991.072	4043991.072	4043991.072	4043991.072
Total Annual Expense		R 16 962 053.16	R 16 962 053.16	R 16 962 053.16	R 16 962 053.16	R 16 962 053.16	R 16 962 053.16	R 16 962 053.16	R 16 962 053.16	R 16 962 053.16	R 16 962 053.16
Annual Cash Flow		R -12 918 062.09	R -12 918 062.09	R -12 918 062.09	R -12 918 062.09	R -12 918 062.09	R -12 918 062.09	R -12 918 062.09	R -12 918 062.09	R -12 918 062.09	R -12 918 062.09
Annual Depreciation and Other Tax Allowances		R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64
Amount of Tax		0	0	0	0	0	0	0	0	0	0
Total Annual Capital Expenditure	R 43 257 326.35	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -43 257 326.35	R -12 918 062.09	R -12 918 062.09	R -12 918 062.09	R -12 918 062.09	R -12 918 062.09	R -12 918 062.09	R -12 918 062.09	R -12 918 062.09	R -12 918 062.09	R -12 918 062.09
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -43 257 326.35	R -12 162 755.00	R -11 451 610.02	R -10 782 045.02	R -10 151 628.87	R -9 558 072.57	R -8 999 220.94	R -8 473 044.86	R -7 977 633.80	R -7 511 188.97	R -7 072 016.73
Net Present Value	R -43 257 326.35	R -55 420 081.36	R -66 871 691.38	R -77 653 736.40	R -87 805 365.27	R -97 363 437.84	R -106 362 658.78	R -114 835 703.64	R -122 813 337.44	R -130 324 526.41	R -137 396 543.13

Figure B.40: NPV Calculations for Acid Leach Process (22 kg/h) Throughput 1

Throughput 2:	4.4	kg/hr									
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		8087982.144	8087982.144	8087982.144	8087982.144	8087982.144	8087982.144	8087982.144	8087982.144	8087982.144	8087982.144
Total Annual Expense		R 18 471 797.12	R 18 471 797.12	R 18 471 797.12	R 18 471 797.12	R 18 471 797.12	R 18 471 797.12	R 18 471 797.12	R 18 471 797.12	R 18 471 797.12	R 18 471 797.12
Annual Cash Flow		R -10 383 814.98	R -10 383 814.98	R -10 383 814.98	R -10 383 814.98	R -10 383 814.98	R -10 383 814.98	R -10 383 814.98	R -10 383 814.98	R -10 383 814.98	R -10 383 814.98
Annual Depreciation and Other Tax Allowances		R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64
Amount of Tax		0	0	0	0	0	0	0	0	0	0
Total Annual Capital Expenditure	R 43 257 326.35	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -43 257 326.35	R -10 383 814.98	R -10 383 814.98	R -10 383 814.98	R -10 383 814.98	R -10 383 814.98	R -10 383 814.98	R -10 383 814.98	R -10 383 814.98	R -10 383 814.98	R -10 383 814.98
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -43 257 326.35	R -9 776 682.97	R -9 205 049.40	R -8 666 838.72	R -8 160 096.71	R -7 682 983.44	R -7 233 766.54	R -6 810 814.93	R -6 412 592.91	R -6 037 654.56	R -5 684 638.51
Net Present Value	R -43 257 326.35	R -53 034 009.32	R -62 239 058.72	R -70 905 897.44	R -79 065 994.15	R -86 748 977.59	R -93 982 744.12	R -100 793 559.05	R -107 206 151.96	R -113 243 806.53	R -118 928 445.04

Figure B.41: NPV Calculations for Acid Leach Process (22 kg/h) Throughput 2

Throughput 3:	6.6	kg/hr									
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		12131973.22	12131973.22	12131973.22	12131973.22	12131973.22	12131973.22	12131973.22	12131973.22	12131973.22	12131973.22
Total Annual Expense		R 19 981 550.46	R 19 981 550.46	R 19 981 550.46	R 19 981 550.46	R 19 981 550.46	R 19 981 550.46	R 19 981 550.46	R 19 981 550.46	R 19 981 550.46	R 19 981 550.46
Annual Cash Flow		R -7 849 577.24	R -7 849 577.24	R -7 849 577.24	R -7 849 577.24	R -7 849 577.24	R -7 849 577.24	R -7 849 577.24	R -7 849 577.24	R -7 849 577.24	R -7 849 577.24
Annual Depreciation and Other Tax Allowances		R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64
Amount of Tax		0	0	0	0	0	0	0	0	0	0
Total Annual Capital Expenditure	R 43 257 326.35	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -43 257 326.35	R -7 849 577.24	R -7 849 577.24	R -7 849 577.24	R -7 849 577.24	R -7 849 577.24	R -7 849 577.24	R -7 849 577.24	R -7 849 577.24	R -7 849 577.24	R -7 849 577.24
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -43 257 326.35	R -7 390 619.75	R -6 958 497.09	R -6 551 640.23	R -6 168 571.91	R -5 807 901.24	R -5 468 318.66	R -5 148 591.15	R -4 847 557.81	R -4 564 125.61	R -4 297 265.42
Net Present Value	R -43 257 326.35	R -50 647 946.11	R -57 606 443.19	R -64 158 083.42	R -70 326 655.33	R -76 134 556.58	R -81 602 875.23	R -86 751 466.38	R -91 599 024.19	R -96 163 149.79	R -100 460 415.22

Figure B.42: NPV Calculations for Acid Leach Process (22 kg/h) Throughput 3

Throughput 4:	8.8	kg/hr									
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		16175964.29	16175964.29	16175964.29	16175964.29	16175964.29	16175964.29	16175964.29	16175964.29	16175964.29	16175964.29
Total Annual Expense		R 21 491 313.16	R 21 491 313.16	R 21 491 313.16	R 21 491 313.16	R 21 491 313.16	R 21 491 313.16	R 21 491 313.16	R 21 491 313.16	R 21 491 313.16	R 21 491 313.16
Annual Cash Flow		R -5 315 348.87	R -5 315 348.87	R -5 315 348.87	R -5 315 348.87	R -5 315 348.87	R -5 315 348.87	R -5 315 348.87	R -5 315 348.87	R -5 315 348.87	R -5 315 348.87
Annual Depreciation and Other Tax Allowances		R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64
Amount of Tax		0	0	0	0	0	0	0	0	0	0
Total Annual Capital Expenditure	R 43 257 326.35	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -43 257 326.35	R -5 315 348.87	R -5 315 348.87	R -5 315 348.87	R -5 315 348.87	R -5 315 348.87	R -5 315 348.87	R -5 315 348.87	R -5 315 348.87	R -5 315 348.87	R -5 315 348.87
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -43 257 326.35	R -5 004 565.36	R -4 711 953.08	R -4 436 449.56	R -4 177 054.48	R -3 932 825.98	R -3 702 877.30	R -3 486 373.51	R -3 282 528.49	R -3 090 602.10	R -2 909 897.47
Net Present Value	R -43 257 326.35	R -48 261 891.72	R -52 973 844.79	R -57 410 294.35	R -61 587 348.83	R -65 520 174.81	R -69 223 052.11	R -72 709 425.62	R -75 991 954.11	R -79 082 556.20	R -81 992 453.67

Figure B.43: NPV Calculations for Acid Leach Process (22 kg/h) Throughput 4

Throughput 5:	11	kg/hr									
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		20219955.36	20219955.36	20219955.36	20219955.36	20219955.36	20219955.36	20219955.36	20219955.36	20219955.36	20219955.36
Total Annual Expense		R 23 001 085.23	R 23 001 085.23	R 23 001 085.23	R 23 001 085.23	R 23 001 085.23	R 23 001 085.23	R 23 001 085.23	R 23 001 085.23	R 23 001 085.23	R 23 001 085.23
Annual Cash Flow		R -2 781 129.87	R -2 781 129.87	R -2 781 129.87	R -2 781 129.87	R -2 781 129.87	R -2 781 129.87	R -2 781 129.87	R -2 781 129.87	R -2 781 129.87	R -2 781 129.87
Annual Depreciation and Other Tax Allowances		R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64
Amount of Tax		0	0	0	0	0	0	0	0	0	0
Total Annual Capital Expenditure	R 43 257 326.35	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -43 257 326.35	R -2 781 129.87	R -2 781 129.87	R -2 781 129.87	R -2 781 129.87	R -2 781 129.87	R -2 781 129.87	R -2 781 129.87	R -2 781 129.87	R -2 781 129.87	R -2 781 129.87
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -43 257 326.35	R -2 618 519.79	R -2 465 417.37	R -2 321 266.71	R -2 185 544.40	R -2 057 757.65	R -1 937 442.47	R -1 824 162.01	R -1 717 504.96	R -1 617 084.04	R -1 522 534.64
Net Present Value	R -43 257 326.35	R -45 875 846.14	R -48 341 263.52	R -50 662 530.23	R -52 848 074.63	R -54 905 832.28	R -56 843 274.76	R -58 667 436.77	R -60 384 941.73	R -62 002 025.76	R -63 524 560.40

Figure B.44: NPV Calculations for Acid Leach Process (22 kg/h) Throughput 5

Throughput 6:	13.2	kg/hr									
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		24263946.43	24263946.43	24263946.43	24263946.43	24263946.43	24263946.43	24263946.43	24263946.43	24263946.43	24263946.43
Total Annual Expense		R 24 510 866.67	R 24 510 866.67	R 24 510 866.67	R 24 510 866.67	R 24 510 866.67	R 24 510 866.67	R 24 510 866.67	R 24 510 866.67	R 24 510 866.67	R 24 510 866.67
Annual Cash Flow		R -246 920.24	R -246 920.24	R -246 920.24	R -246 920.24	R -246 920.24	R -246 920.24	R -246 920.24	R -246 920.24	R -246 920.24	R -246 920.24
Annual Depreciation and Other Tax Allowances		R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64
Amount of Tax		0	0	0	0	0	0	0	0	0	0
Total Annual Capital Expenditure	R 43 257 326.35	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -43 257 326.35	R -246 920.24	R -246 920.24	R -246 920.24	R -246 920.24	R -246 920.24	R -246 920.24	R -246 920.24	R -246 920.24	R -246 920.24	R -246 920.24
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -43 257 326.35	R -232 483.04	R -218 889.97	R -206 091.68	R -194 041.69	R -182 696.25	R -172 014.17	R -161 956.67	R -152 487.21	R -143 571.42	R -135 176.94
Net Present Value	R -43 257 326.35	R -43 489 809.39	R -43 708 699.37	R -43 914 791.05	R -44 108 832.74	R -44 291 528.99	R -44 463 543.17	R -44 625 499.83	R -44 777 987.04	R -44 921 558.47	R -45 056 735.40

Figure B.45: NPV Calculations for Acid Leach Process (22 kg/h) Throughput 6

Throughput 7:	15.4	kg/hr									
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		28307937.5	28307937.5	28307937.5	28307937.5	28307937.5	28307937.5	28307937.5	28307937.5	28307937.5	28307937.5
Total Annual Expense		R 26 020 657.48	R 26 020 657.48	R 26 020 657.48	R 26 020 657.48	R 26 020 657.48	R 26 020 657.48	R 26 020 657.48	R 26 020 657.48	R 26 020 657.48	R 26 020 657.48
Annual Cash Flow		R 2 287 280.03	R 2 287 280.03	R 2 287 280.03	R 2 287 280.03	R 2 287 280.03	R 2 287 280.03	R 2 287 280.03	R 2 287 280.03	R 2 287 280.03	R 2 287 280.03
Annual Depreciation and Other Tax Allowances		R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64
Amount of Tax		0	0	0	0	0	0	0	0	0	0
Total Annual Capital Expenditure	R 43 257 326.35	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -43 257 326.35	R 2 287 280.03	R 2 287 280.03	R 2 287 280.03	R 2 287 280.03	R 2 287 280.03	R 2 287 280.03	R 2 287 280.03	R 2 287 280.03	R 2 287 280.03	R 2 287 280.03
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -43 257 326.35	R 2 153 544.89	R 2 027 629.12	R 1 909 075.53	R 1 797 453.66	R 1 692 358.21	R 1 593 407.60	R 1 500 242.54	R 1 412 524.75	R 1 329 935.74	R 1 252 175.63
Net Present Value	R -43 257 326.35	R -41 103 781.47	R -39 076 152.35	R -37 167 076.82	R -35 369 623.16	R -33 677 264.95	R -32 083 857.35	R -30 583 614.81	R -29 171 090.06	R -27 841 154.32	R -26 588 978.68

Figure B.46: NPV Calculations for Acid Leach Process (22 kg/h) Throughput 7

Throughput 8:	17.6	kg/hr									
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		32351928.58	32351928.58	32351928.58	32351928.58	32351928.58	32351928.58	32351928.58	32351928.58	32351928.58	32351928.58
Total Annual Expense		R 27 530 457.66	R 27 530 457.66	R 27 530 457.66	R 27 530 457.66	R 27 530 457.66	R 27 530 457.66	R 27 530 457.66	R 27 530 457.66	R 27 530 457.66	R 27 530 457.66
Annual Cash Flow		R 4 821 470.92	R 4 821 470.92	R 4 821 470.92	R 4 821 470.92	R 4 821 470.92	R 4 821 470.92	R 4 821 470.92	R 4 821 470.92	R 4 821 470.92	R 4 821 470.92
Annual Depreciation and Other Tax Allowances		R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64
Amount of Tax		138806.7196	138806.7196	138806.7196	138806.7196	138806.7196	138806.7196	138806.7196	138806.7196	138806.7196	138806.7196
Total Annual Capital Expenditure	R 43 257 326.35	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -43 257 326.35	R 4 682 664.20	R 4 682 664.20	R 4 682 664.20	R 4 682 664.20	R 4 682 664.20	R 4 682 664.20	R 4 682 664.20	R 4 682 664.20	R 4 682 664.20	R 4 682 664.20
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -43 257 326.35	R 4 408 873.18	R 4 151 090.46	R 3 908 380.06	R 3 679 860.71	R 3 464 702.67	R 3 262 124.73	R 3 071 391.32	R 2 891 809.93	R 2 722 728.49	R 2 563 533.08
Net Present Value	R -43 257 326.35	R -38 848 453.18	R -34 697 362.72	R -30 788 982.66	R -27 109 121.96	R -23 644 419.28	R -20 382 294.56	R -17 310 903.23	R -14 419 093.31	R -11 696 364.82	R -9 132 831.73

Figure B.47: NPV Calculations for Acid Leach Process (22 kg/h) Throughput 8

Throughput 9:	19.8	kg/hr									
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		36395919.65	36395919.65	36395919.65	36395919.65	36395919.65	36395919.65	36395919.65	36395919.65	36395919.65	36395919.65
Total Annual Expense		R 29 040 267.20	R 29 040 267.20	R 29 040 267.20	R 29 040 267.20	R 29 040 267.20	R 29 040 267.20	R 29 040 267.20	R 29 040 267.20	R 29 040 267.20	R 29 040 267.20
Annual Cash Flow		R 7 355 652.44	R 7 355 652.44	R 7 355 652.44	R 7 355 652.44	R 7 355 652.44	R 7 355 652.44	R 7 355 652.44	R 7 355 652.44	R 7 355 652.44	R 7 355 652.44
Annual Depreciation and Other Tax Allowances		R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64
Amount of Tax		848377.5467	848377.5467	848377.5467	848377.5467	848377.5467	848377.5467	848377.5467	848377.5467	848377.5467	848377.5467
Total Annual Capital Expenditure	R 43 257 326.35	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -43 257 326.35	R 6 507 274.90	R 6 507 274.90	R 6 507 274.90	R 6 507 274.90	R 6 507 274.90	R 6 507 274.90	R 6 507 274.90	R 6 507 274.90	R 6 507 274.90	R 6 507 274.90
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -43 257 326.35	R 6 126 800.58	R 5 768 572.25	R 5 431 289.19	R 5 113 726.76	R 4 814 731.90	R 4 533 219.00	R 4 268 165.90	R 4 018 610.21	R 3 783 645.80	R 3 562 419.55
Net Present Value	R -43 257 326.35	R -37 130 525.77	R -31 361 953.52	R -25 930 664.34	R -20 816 937.58	R -16 002 205.68	R -11 468 986.67	R -7 200 820.77	R -3 182 210.56	R 601 435.24	R 4 163 854.79

Figure B.48: NPV Calculations for Acid Leach Process (22 kg/h) Throughput 9

Throughput 10:	22 kg/hr										
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		40439910.72	40439910.72	40439910.72	40439910.72	40439910.72	40439910.72	40439910.72	40439910.72	40439910.72	40439910.72
Total Annual Expense		R 30 550 086.12	R 30 550 086.12	R 30 550 086.12	R 30 550 086.12	R 30 550 086.12	R 30 550 086.12	R 30 550 086.12	R 30 550 086.12	R 30 550 086.12	R 30 550 086.12
Annual Cash Flow		R 9 889 824.60	R 9 889 824.60	R 9 889 824.60	R 9 889 824.60	R 9 889 824.60	R 9 889 824.60	R 9 889 824.60	R 9 889 824.60	R 9 889 824.60	R 9 889 824.60
Annual Depreciation and Other Tax Allowances		R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64	R 4 325 732.64
Amount of Tax		1557945.751	1557945.751	1557945.751	1557945.751	1557945.751	1557945.751	1557945.751	1557945.751	1557945.751	1557945.751
Total Annual Capital Expenditure	R 43 257 326.35	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -43 257 326.35	R 8 331 878.85	R 8 331 878.85	R 8 331 878.85	R 8 331 878.85	R 8 331 878.85	R 8 331 878.85	R 8 331 878.85	R 8 331 878.85	R 8 331 878.85	R 8 331 878.85
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -43 257 326.35	R 7 844 721.64	R 7 386 048.05	R 6 954 192.69	R 6 547 587.50	R 6 164 756.15	R 5 804 308.58	R 5 464 936.05	R 5 145 406.32	R 4 844 559.20	R 4 561 302.32
Net Present Value	R -43 257 326.35	R -35 412 604.72	R -28 026 556.66	R -21 072 363.97	R -14 524 776.47	R -8 360 020.32	R -2 555 711.74	R 2 909 224.31	R 8 054 630.64	R 12 899 189.83	R 17 460 492.15

Figure B.49: NPV Calculations for Acid Leach Process (22 kg/h) Throughput 10

B.6 NPV Calculations Acid Leach Process (44.5 kg/h)

Throughput 1:	4.45 kg/h										
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		8179891.032	8179891.032	8179891.032	8179891.032	8179891.032	8179891.032	8179891.032	8179891.032	8179891.032	8179891.032
Total Annual Expense		R 33 602 152.65	R 33 602 152.65	R 33 602 152.65	R 33 602 152.65	R 33 602 152.65	R 33 602 152.65	R 33 602 152.65	R 33 602 152.65	R 33 602 152.65	R 33 602 152.65
Annual Cash Flow		R -25 422 261.62	R -25 422 261.62	R -25 422 261.62	R -25 422 261.62	R -25 422 261.62	R -25 422 261.62	R -25 422 261.62	R -25 422 261.62	R -25 422 261.62	R -25 422 261.62
Annual Depreciation and Other Tax Allowances		R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86
Amount of Tax		0	0	0	0	0	0	0	0	0	0
Total Annual Capital Expenditure	R 86 254 448.58	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -86 254 448.58	R -25 422 261.62	R -25 422 261.62	R -25 422 261.62	R -25 422 261.62	R -25 422 261.62	R -25 422 261.62	R -25 422 261.62	R -25 422 261.62	R -25 422 261.62	R -25 422 261.62
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -86 254 448.58	R -23 935 845.61	R -22 536 338.96	R -21 218 660.16	R -19 978 024.82	R -18 809 928.27	R -17 710 129.25	R -16 674 634.45	R -15 699 684.07	R -14 781 738.13	R -13 917 463.64
Net Present Value	R -86 254 448.58	R -110 190 294.18	R -132 726 633.14	R -153 945 293.30	R -173 923 318.12	R -192 733 246.40	R -210 443 375.65	R -227 118 010.10	R -242 817 694.17	R -257 599 432.30	R -271 516 895.93

Figure B.50: NPV Calculations for Acid Leach Process (44 kg/h) Throughput 1

Throughput 2:	8.9 kg/h										
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		16359782.06	16359782.06	16359782.06	16359782.06	16359782.06	16359782.06	16359782.06	16359782.06	16359782.06	16359782.06
Total Annual Expense		R 36 632 957.33	R 36 632 957.33	R 36 632 957.33	R 36 632 957.33	R 36 632 957.33	R 36 632 957.33	R 36 632 957.33	R 36 632 957.33	R 36 632 957.33	R 36 632 957.33
Annual Cash Flow		R -20 273 175.26	R -20 273 175.26	R -20 273 175.26	R -20 273 175.26	R -20 273 175.26	R -20 273 175.26	R -20 273 175.26	R -20 273 175.26	R -20 273 175.26	R -20 273 175.26
Annual Depreciation and Other Tax Allowances		R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86
Amount of Tax		0	0	0	0	0	0	0	0	0	0
Total Annual Capital Expenditure	R 86 254 448.58	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -86 254 448.58	R -20 273 175.26	R -20 273 175.26	R -20 273 175.26	R -20 273 175.26	R -20 273 175.26	R -20 273 175.26	R -20 273 175.26	R -20 273 175.26	R -20 273 175.26	R -20 273 175.26
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -86 254 448.58	R -19 087 821.55	R -17 971 774.36	R -16 920 981.41	R -15 931 627.35	R -15 000 119.91	R -14 123 076.84	R -13 297 313.66	R -12 519 832.09	R -11 787 809.14	R -11 098 586.89
Net Present Value	R -86 254 448.58	R -105 342 270.12	R -123 314 044.48	R -140 235 025.89	R -156 166 653.25	R -171 166 773.15	R -185 289 849.99	R -198 587 163.65	R -211 106 995.73	R -222 894 804.87	R -233 993 391.76

Figure B.51: NPV Calculations for Acid Leach Process (44 kg/h) Throughput 2

Throughput 3:	13.35 kg/h										
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		24539673.1	24539673.1	24539673.1	24539673.1	24539673.1	24539673.1	24539673.1	24539673.1	24539673.1	24539673.1
Total Annual Expense		R 39 663 800.34	R 39 663 800.34	R 39 663 800.34	R 39 663 800.34	R 39 663 800.34	R 39 663 800.34	R 39 663 800.34	R 39 663 800.34	R 39 663 800.34	R 39 663 800.34
Annual Cash Flow		R -15 124 127.24	R -15 124 127.24	R -15 124 127.24	R -15 124 127.24	R -15 124 127.24	R -15 124 127.24	R -15 124 127.24	R -15 124 127.24	R -15 124 127.24	R -15 124 127.24
Annual Depreciation and Other Tax Allowances		R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86
Amount of Tax		0	0	0	0	0	0	0	0	0	0
Total Annual Capital Expenditure	R 86 254 448.58	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -86 254 448.58	R -15 124 127.24	R -15 124 127.24	R -15 124 127.24	R -15 124 127.24	R -15 124 127.24	R -15 124 127.24	R -15 124 127.24	R -15 124 127.24	R -15 124 127.24	R -15 124 127.24
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -86 254 448.58	R -14 239 833.58	R -13 407 243.74	R -12 623 334.66	R -11 885 260.01	R -11 190 339.90	R -10 536 051.13	R -9 920 018.01	R -9 340 003.77	R -8 793 902.43	R -8 279 731.13
Net Present Value	R -86 254 448.58	R -100 494 282.15	R -113 901 525.89	R -126 524 860.55	R -138 410 120.56	R -149 600 460.46	R -160 136 511.59	R -170 056 529.60	R -179 396 533.37	R -188 190 435.80	R -196 470 166.93

Figure B.52: NPV Calculations for Acid Leach Process (44 kg/h) Throughput 3

Throughput 4:	17.8 kg/h										
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		32719564.13	32719564.13	32719564.13	32719564.13	32719564.13	32719564.13	32719564.13	32719564.13	32719564.13	32719564.13
Total Annual Expense		R 42 694 681.68	R 42 694 681.68	R 42 694 681.68	R 42 694 681.68	R 42 694 681.68	R 42 694 681.68	R 42 694 681.68	R 42 694 681.68	R 42 694 681.68	R 42 694 681.68
Annual Cash Flow		R -9 975 117.55	R -9 975 117.55	R -9 975 117.55	R -9 975 117.55	R -9 975 117.55	R -9 975 117.55	R -9 975 117.55	R -9 975 117.55	R -9 975 117.55	R -9 975 117.55
Annual Depreciation and Other Tax Allowances		R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86
Amount of Tax		0	0	0	0	0	0	0	0	0	0
Total Annual Capital Expenditure	R 86 254 448.58	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -86 254 448.58	R -9 975 117.55	R -9 975 117.55	R -9 975 117.55	R -9 975 117.55	R -9 975 117.55	R -9 975 117.55	R -9 975 117.55	R -9 975 117.55	R -9 975 117.55	R -9 975 117.55
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -86 254 448.58	R -9 391 881.70	R -8 842 747.10	R -8 325 719.90	R -7 838 922.79	R -7 380 588.26	R -6 949 052.12	R -6 542 747.50	R -6 160 199.14	R -5 800 018.02	R -5 460 896.35
Net Present Value	R -86 254 448.58	R -95 646 330.27	R -104 489 077.37	R -112 814 797.27	R -120 653 720.06	R -128 034 308.32	R -134 983 360.44	R -141 526 107.94	R -147 686 307.08	R -153 486 325.10	R -158 947 221.45

Figure B.53: NPV Calculations for Acid Leach Process (44 kg/h) Throughput 4

Throughput 5:	22.25 kg/h										
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		40899455.16	40899455.16	40899455.16	40899455.16	40899455.16	40899455.16	40899455.16	40899455.16	40899455.16	40899455.16
Total Annual Expense		R 45 725 601.35	R 45 725 601.35	R 45 725 601.35	R 45 725 601.35	R 45 725 601.35	R 45 725 601.35	R 45 725 601.35	R 45 725 601.35	R 45 725 601.35	R 45 725 601.35
Annual Cash Flow		R -4 826 146.19	R -4 826 146.19	R -4 826 146.19	R -4 826 146.19	R -4 826 146.19	R -4 826 146.19	R -4 826 146.19	R -4 826 146.19	R -4 826 146.19	R -4 826 146.19
Annual Depreciation and Other Tax Allowances		R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86
Amount of Tax		0	0	0	0	0	0	0	0	0	0
Total Annual Capital Expenditure	R 86 254 448.58	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -86 254 448.58	R -4 826 146.19	R -4 826 146.19	R -4 826 146.19	R -4 826 146.19	R -4 826 146.19	R -4 826 146.19	R -4 826 146.19	R -4 826 146.19	R -4 826 146.19	R -4 826 146.19
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -86 254 448.58	R -4 543 965.91	R -4 278 284.44	R -4 028 137.13	R -3 792 615.69	R -3 570 864.98	R -3 362 079.82	R -3 165 502.14	R -2 980 418.17	R -2 806 155.89	R -2 642 082.56
Net Present Value	R -86 254 448.58	R -90 798 414.48	R -95 076 698.93	R -99 104 836.05	R -102 897 451.75	R -106 468 316.72	R -109 830 396.55	R -112 995 898.68	R -115 976 316.85	R -118 782 472.74	R -121 424 555.31

Figure B.54: NPV Calculations for Acid Leach Process (44 kg/h) Throughput 5

Throughput 6:	26.7 kg/h										
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		49079346.19	49079346.19	49079346.19	49079346.19	49079346.19	49079346.19	49079346.19	49079346.19	49079346.19	49079346.19
Total Annual Expense		R 48 756 559.36	R 48 756 559.36	R 48 756 559.36	R 48 756 559.36	R 48 756 559.36	R 48 756 559.36	R 48 756 559.36	R 48 756 559.36	R 48 756 559.36	R 48 756 559.36
Annual Cash Flow		R 322 786.84	R 322 786.84	R 322 786.84	R 322 786.84	R 322 786.84	R 322 786.84	R 322 786.84	R 322 786.84	R 322 786.84	R 322 786.84
Annual Depreciation and Other Tax Allowances		R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86
Amount of Tax		0	0	0	0	0	0	0	0	0	0
Total Annual Capital Expenditure	R 86 254 448.58	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -86 254 448.58	R 322 786.84	R 322 786.84	R 322 786.84	R 322 786.84	R 322 786.84	R 322 786.84	R 322 786.84	R 322 786.84	R 322 786.84	R 322 786.84
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -86 254 448.58	R 303 913.79	R 286 144.23	R 269 413.65	R 253 661.28	R 238 829.94	R 224 865.78	R 211 718.08	R 199 339.12	R 187 683.95	R 176 710.24
Net Present Value	R -86 254 448.58	R -85 950 534.78	R -85 664 390.55	R -85 394 976.91	R -85 141 315.62	R -84 902 485.68	R -84 677 619.91	R -84 465 901.82	R -84 266 562.70	R -84 078 878.75	R -83 902 168.51

Figure B.55: NPV Calculations for Acid Leach Process (44 kg/h) Throughput 6

Throughput 7:	31.15 kg/h										
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		57259237.22	57259237.22	57259237.22	57259237.22	57259237.22	57259237.22	57259237.22	57259237.22	57259237.22	57259237.22
Total Annual Expense		R 51 787 555.69	R 51 787 555.69	R 51 787 555.69	R 51 787 555.69	R 51 787 555.69	R 51 787 555.69	R 51 787 555.69	R 51 787 555.69	R 51 787 555.69	R 51 787 555.69
Annual Cash Flow		R 5 471 681.53	R 5 471 681.53	R 5 471 681.53	R 5 471 681.53	R 5 471 681.53	R 5 471 681.53	R 5 471 681.53	R 5 471 681.53	R 5 471 681.53	R 5 471 681.53
Annual Depreciation and Other Tax Allowances		R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86
Amount of Tax		0	0	0	0	0	0	0	0	0	0
Total Annual Capital Expenditure	R 86 254 448.58	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -86 254 448.58	R 5 471 681.53	R 5 471 681.53	R 5 471 681.53	R 5 471 681.53	R 5 471 681.53	R 5 471 681.53	R 5 471 681.53	R 5 471 681.53	R 5 471 681.53	R 5 471 681.53
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -86 254 448.58	R 5 151 757.40	R 4 850 538.93	R 4 566 932.43	R 4 299 908.13	R 4 048 496.50	R 3 811 784.67	R 3 588 913.16	R 3 379 072.75	R 3 181 501.50	R 2 995 482.07
Net Present Value	R -86 254 448.58	R -81 102 691.18	R -76 252 152.25	R -71 685 219.82	R -67 385 311.69	R -63 336 815.19	R -59 525 030.52	R -55 936 117.36	R -52 557 044.62	R -49 375 543.11	R -46 380 061.05

Figure B.56: NPV Calculations for Acid Leach Process (44 kg/h) Throughput 7

Throughput 8:	35.6 kg/h										
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		65439128.26	65439128.26	65439128.26	65439128.26	65439128.26	65439128.26	65439128.26	65439128.26	65439128.26	65439128.26
Total Annual Expense		R 54 818 590.36	R 54 818 590.36	R 54 818 590.36	R 54 818 590.36	R 54 818 590.36	R 54 818 590.36	R 54 818 590.36	R 54 818 590.36	R 54 818 590.36	R 54 818 590.36
Annual Cash Flow		R 10 620 537.89	R 10 620 537.89	R 10 620 537.89	R 10 620 537.89	R 10 620 537.89	R 10 620 537.89	R 10 620 537.89	R 10 620 537.89	R 10 620 537.89	R 10 620 537.89
Annual Depreciation and Other Tax Allowances		R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86
Amount of Tax		558626.0501	558626.0501	558626.0501	558626.0501	558626.0501	558626.0501	558626.0501	558626.0501	558626.0501	558626.0501
Total Annual Capital Expenditure	R 86 254 448.58	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -86 254 448.58	R 10 061 911.84	R 10 061 911.84	R 10 061 911.84	R 10 061 911.84	R 10 061 911.84	R 10 061 911.84	R 10 061 911.84	R 10 061 911.84	R 10 061 911.84	R 10 061 911.84
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -86 254 448.58	R 9 473 601.21	R 8 919 688.55	R 8 398 162.65	R 7 907 129.88	R 7 444 807.35	R 7 009 516.38	R 6 599 676.47	R 6 213 799.52	R 5 850 484.44	R 5 508 412.05
Net Present Value	R -86 254 448.58	R -76 780 847.37	R -67 861 158.82	R -59 462 996.17	R -51 555 866.28	R -44 111 058.94	R -37 101 542.56	R -30 501 866.09	R -24 288 066.57	R -18 437 582.13	R -12 929 170.08

Figure B.57: NPV Calculations for Acid Leach Process (44 kg/h) Throughput 8

Throughput 9:	40.05	kg/h									
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		73619019.29	73619019.29	73619019.29	73619019.29	73619019.29	73619019.29	73619019.29	73619019.29	73619019.29	73619019.29
Total Annual Expense		R 57 849 663.36	R 57 849 663.36	R 57 849 663.36	R 57 849 663.36	R 57 849 663.36	R 57 849 663.36	R 57 849 663.36	R 57 849 663.36	R 57 849 663.36	R 57 849 663.36
Annual Cash Flow		R 15 769 355.92	R 15 769 355.92	R 15 769 355.92	R 15 769 355.92	R 15 769 355.92	R 15 769 355.92	R 15 769 355.92	R 15 769 355.92	R 15 769 355.92	R 15 769 355.92
Annual Depreciation and Other Tax Allowances		R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86
Amount of Tax		2000295.099	2000295.099	2000295.099	2000295.099	2000295.099	2000295.099	2000295.099	2000295.099	2000295.099	2000295.099
Total Annual Capital Expenditure	R 86 254 448.58	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -86 254 448.58	R 13 769 060.83	R 13 769 060.83	R 13 769 060.83	R 13 769 060.83	R 13 769 060.83	R 13 769 060.83	R 13 769 060.83	R 13 769 060.83	R 13 769 060.83	R 13 769 060.83
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -86 254 448.58	R 12 963 996.63	R 12 206 003.80	R 11 492 330.10	R 10 820 384.24	R 10 187 726.43	R 9 592 059.53	R 9 031 220.72	R 8 503 173.64	R 8 006 000.98	R 7 537 897.54
Net Present Value	R -86 254 448.58	R -73 290 451.94	R -61 084 448.14	R -49 592 118.04	R -38 771 733.81	R -28 584 007.38	R -18 991 947.85	R -9 960 727.12	R -1 457 553.48	R 6 548 447.49	R 14 086 345.04

Figure B.58: NPV Calculations for Acid Leach Process (44 kg/h) Throughput 9

Throughput 10:	44.5	kg/h									
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		81798910.32	81798910.32	81798910.32	81798910.32	81798910.32	81798910.32	81798910.32	81798910.32	81798910.32	81798910.32
Total Annual Expense		R 60 880 774.70	R 60 880 774.70	R 60 880 774.70	R 60 880 774.70	R 60 880 774.70	R 60 880 774.70	R 60 880 774.70	R 60 880 774.70	R 60 880 774.70	R 60 880 774.70
Annual Cash Flow		R 20 918 135.62	R 20 918 135.62	R 20 918 135.62	R 20 918 135.62	R 20 918 135.62	R 20 918 135.62	R 20 918 135.62	R 20 918 135.62	R 20 918 135.62	R 20 918 135.62
Annual Depreciation and Other Tax Allowances		R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86	R 8 625 444.86
Amount of Tax		3441953.414	3441953.414	3441953.414	3441953.414	3441953.414	3441953.414	3441953.414	3441953.414	3441953.414	3441953.414
Total Annual Capital Expenditure	R 86 254 448.58	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -86 254 448.58	R 17 476 182.21	R 17 476 182.21	R 17 476 182.21	R 17 476 182.21	R 17 476 182.21	R 17 476 182.21	R 17 476 182.21	R 17 476 182.21	R 17 476 182.21	R 17 476 182.21
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -86 254 448.58	R 16 454 366.07	R 15 492 294.58	R 14 586 474.51	R 13 733 616.90	R 12 930 625.09	R 12 174 583.45	R 11 462 746.87	R 10 792 530.72	R 10 161 501.47	R 9 567 367.93
Net Present Value	R -86 254 448.58	R -69 800 082.50	R -54 307 787.92	R -39 721 313.41	R -25 987 696.50	R -13 057 071.42	R -882 487.96	R 10 580 258.91	R 21 372 789.63	R 31 534 291.10	R 41 101 659.03

Figure B.59: NPV Calculations for Acid Leach Process (44 kg/h) Throughput 10

B.7 NPV Calculations Acid Leach Process (68.75 kg/h)

Throughput 1:	6.875	kg/hr									
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		12637472.1	12637472.1	12637472.1	12637472.1	12637472.1	12637472.1	12637472.1	12637472.1	12637472.1	12637472.1
Total Annual Expense		R 50 552 172.95	R 50 552 172.95	R 50 552 172.95	R 50 552 172.95	R 50 552 172.95	R 50 552 172.95	R 50 552 172.95	R 50 552 172.95	R 50 552 172.95	R 50 552 172.95
Annual Cash Flow		R -37 914 700.85	R -37 914 700.85	R -37 914 700.85	R -37 914 700.85	R -37 914 700.85	R -37 914 700.85	R -37 914 700.85	R -37 914 700.85	R -37 914 700.85	R -37 914 700.85
Annual Depreciation and Other Tax Allowances		R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42
Amount of Tax		0	0	0	0	0	0	0	0	0	0
Total Annual Capital Expenditure	R 129 748 084.16	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -129 748 084.16	R -37 914 700.85	R -37 914 700.85	R -37 914 700.85	R -37 914 700.85	R -37 914 700.85	R -37 914 700.85	R -37 914 700.85	R -37 914 700.85	R -37 914 700.85	R -37 914 700.85
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -129 748 084.16	R -35 697 863.53	R -33 610 642.62	R -31 645 459.58	R -29 795 178.97	R -28 053 082.54	R -26 412 844.88	R -24 868 510.38	R -23 414 471.69	R -22 045 449.29	R -20 756 472.35
Net Present Value	R -129 748 084.16	R -165 445 947.68	R -199 056 590.31	R -230 702 049.89	R -260 497 228.86	R -288 550 311.40	R -314 963 156.27	R -339 831 666.65	R -363 246 138.34	R -385 291 587.63	R -406 048 059.99

Figure B.60: NPV Calculations for Acid Leach Process (68 kg/h) Throughput 1

Throughput 2:	13.75	kg/hr									
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		R 25 274 944.20	25274944.2	25274944.2	25274944.2	25274944.2	25274944.2	25274944.2	25274944.2	25274944.2	25274944.2
Total Annual Expense		R 55 245 046.27	R 55 245 046.27	R 55 245 046.27	R 55 245 046.27	R 55 245 046.27	R 55 245 046.27	R 55 245 046.27	R 55 245 046.27	R 55 245 046.27	R 55 245 046.27
Annual Cash Flow		R -29 970 102.07	R -29 970 102.07	R -29 970 102.07	R -29 970 102.07	R -29 970 102.07	R -29 970 102.07	R -29 970 102.07	R -29 970 102.07	R -29 970 102.07	R -29 970 102.07
Annual Depreciation and Other Tax Allowances		R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42
Amount of Tax		0	0	0	0	0	0	0	0	0	0
Total Annual Capital Expenditure	R 129 748 084.16	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -129 748 084.16	R -29 970 102.07	R -29 970 102.07	R -29 970 102.07	R -29 970 102.07	R -29 970 102.07	R -29 970 102.07	R -29 970 102.07	R -29 970 102.07	R -29 970 102.07	R -29 970 102.07
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -129 748 084.16	R -28 217 778.05	R -26 567 910.79	R -25 014 509.74	R -23 551 934.60	R -22 174 874.87	R -20 878 330.54	R -19 657 593.96	R -18 508 232.71	R -17 426 073.54	R -16 407 187.21
Net Present Value	R -129 748 084.16	R -157 965 862.21	R -184 533 773.00	R -209 548 282.74	R -233 100 217.33	R -255 275 092.20	R -276 153 422.75	R -295 811 016.70	R -314 319 249.41	R -331 745 322.95	R -348 152 510.16

Figure B.61: NPV Calculations for Acid Leach Process (68 kg/h) Throughput 2

Throughput 3:	20.625	kg/hr									
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		R 37 912 416.30	37912416.3	37912416.3	37912416.3	37912416.3	37912416.3	37912416.3	37912416.3	37912416.3	37912416.3
Total Annual Expense		R 59 938 011.08	R 59 938 011.08	R 59 938 011.08	R 59 938 011.08	R 59 938 011.08	R 59 938 011.08	R 59 938 011.08	R 59 938 011.08	R 59 938 011.08	R 59 938 011.08
Annual Cash Flow		R -22 025 594.78	R -22 025 594.78	R -22 025 594.78	R -22 025 594.78	R -22 025 594.78	R -22 025 594.78	R -22 025 594.78	R -22 025 594.78	R -22 025 594.78	R -22 025 594.78
Annual Depreciation and Other Tax Allowances		R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42
Amount of Tax		0	0	0	0	0	0	0	0	0	0
Total Annual Capital Expenditure	R 129 748 084.16	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -129 748 084.16	R -22 025 594.78	R -22 025 594.78	R -22 025 594.78	R -22 025 594.78	R -22 025 594.78	R -22 025 594.78	R -22 025 594.78	R -22 025 594.78	R -22 025 594.78	R -22 025 594.78
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -129 748 084.16	R -20 737 778.72	R -19 525 260.07	R -18 383 636.26	R -17 308 762.13	R -16 296 734.89	R -15 343 879.95	R -14 446 737.55	R -13 602 050.23	R -12 806 750.99	R -12 057 952.16
Net Present Value	R -129 748 084.16	R -150 485 862.87	R -170 011 122.94	R -188 394 759.20	R -205 703 521.33	R -222 000 256.22	R -237 344 136.17	R -251 790 873.71	R -265 392 923.94	R -278 199 674.93	R -290 257 627.09

Figure B.62: NPV Calculations for Acid Leach Process (68 kg/h) Throughput 3

Throughput 4:	27.5	kg/hr									
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		50549888.4	50549888.4	50549888.4	50549888.4	50549888.4	50549888.4	50549888.4	50549888.4	50549888.4	50549888.4
Total Annual Expense		R 64 631 067.38	R 64 631 067.38	R 64 631 067.38	R 64 631 067.38	R 64 631 067.38	R 64 631 067.38	R 64 631 067.38	R 64 631 067.38	R 64 631 067.38	R 64 631 067.38
Annual Cash Flow		R -14 081 178.98	R -14 081 178.98	R -14 081 178.98	R -14 081 178.98	R -14 081 178.98	R -14 081 178.98	R -14 081 178.98	R -14 081 178.98	R -14 081 178.98	R -14 081 178.98
Annual Depreciation and Other Tax Allowances		R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42
Amount of Tax		0	0	0	0	0	0	0	0	0	0
Total Annual Capital Expenditure	R 129 748 084.16	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -129 748 084.16	R -14 081 178.98	R -14 081 178.98	R -14 081 178.98	R -14 081 178.98	R -14 081 178.98	R -14 081 178.98	R -14 081 178.98	R -14 081 178.98	R -14 081 178.98	R -14 081 178.98
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -129 748 084.16	R -13 257 865.53	R -12 482 690.45	R -11 752 839.14	R -11 065 661.56	R -10 418 662.61	R -9 809 493.09	R -9 235 941.14	R -8 695 924.25	R -8 187 481.64	R -7 708 767.20
Net Present Value	R -129 748 084.16	R -143 005 949.68	R -155 488 640.14	R -167 241 479.28	R -178 307 140.84	R -188 725 803.45	R -198 535 296.54	R -207 771 237.68	R -216 467 161.93	R -224 654 643.57	R -232 363 410.77

Figure B.63: NPV Calculations for Acid Leach Process (68 kg/h) Throughput 4

Throughput 5:	34.375	kg/hr								
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		63187360.5	63187360.5	63187360.5	63187360.5	63187360.5	63187360.5	63187360.5	63187360.5	63187360.5	63187360.5
Total Annual Expense		R 69 324 215.17	R 69 324 215.17	R 69 324 215.17	R 69 324 215.17	R 69 324 215.17	R 69 324 215.17	R 69 324 215.17	R 69 324 215.17	R 69 324 215.17	R 69 324 215.17
Annual Cash Flow		R -6 136 854.67	R -6 136 854.67	R -6 136 854.67	R -6 136 854.67	R -6 136 854.67	R -6 136 854.67	R -6 136 854.67	R -6 136 854.67	R -6 136 854.67	R -6 136 854.67
Annual Depreciation and Other Tax Allowances		R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42
Amount of Tax		0	0	0	0	0	0	0	0	0	0
Total Annual Capital Expenditure	R 129 748 084.16	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -129 748 084.16	R -6 136 854.67	R -6 136 854.67	R -6 136 854.67	R -6 136 854.67	R -6 136 854.67	R -6 136 854.67	R -6 136 854.67	R -6 136 854.67	R -6 136 854.67	R -6 136 854.67
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -129 748 084.16	R -5 778 038.48	R -5 440 201.94	R -5 122 118.39	R -4 822 632.89	R -4 540 658.03	R -4 275 169.97	R -4 025 204.76	R -3 789 854.77	R -3 568 265.49	R -3 359 632.32
Net Present Value	R -129 748 084.16	R -135 526 122.64	R -140 966 324.58	R -146 088 442.97	R -150 911 075.86	R -155 451 733.89	R -159 726 903.86	R -163 752 108.62	R -167 541 963.39	R -171 110 228.88	R -174 469 861.20

Figure B.64: NPV Calculations for Acid Leach Process (68 kg/h) Throughput 5

Throughput 6:	41.25	kg/hr								
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		75824832.6	75824832.6	75824832.6	75824832.6	75824832.6	75824832.6	75824832.6	75824832.6	75824832.6	75824832.6
Total Annual Expense		R 74 017 454.46	R 74 017 454.46	R 74 017 454.46	R 74 017 454.46	R 74 017 454.46	R 74 017 454.46	R 74 017 454.46	R 74 017 454.46	R 74 017 454.46	R 74 017 454.46
Annual Cash Flow		R 1 807 378.14	R 1 807 378.14	R 1 807 378.14	R 1 807 378.14	R 1 807 378.14	R 1 807 378.14	R 1 807 378.14	R 1 807 378.14	R 1 807 378.14	R 1 807 378.14
Annual Depreciation and Other Tax Allowances		R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42
Amount of Tax		0	0	0	0	0	0	0	0	0	0
Total Annual Capital Expenditure	R 129 748 084.16	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -129 748 084.16	R 1 807 378.14	R 1 807 378.14	R 1 807 378.14	R 1 807 378.14	R 1 807 378.14	R 1 807 378.14	R 1 807 378.14	R 1 807 378.14	R 1 807 378.14	R 1 807 378.14
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -129 748 084.16	R 1 701 702.42	R 1 602 205.46	R 1 508 525.99	R 1 420 323.88	R 1 337 278.86	R 1 259 089.41	R 1 185 471.62	R 1 116 158.20	R 1 050 897.47	R 989 452.47
Net Present Value	R -129 748 084.16	R -128 046 381.74	R -126 444 176.28	R -124 935 650.29	R -123 515 326.40	R -122 178 047.54	R -120 918 958.13	R -119 733 486.51	R -118 617 328.31	R -117 566 430.84	R -116 576 978.37

Figure B.65: NPV Calculations for Acid Leach Process (68 kg/h) Throughput 6

Throughput 7:	48.125	kg/hr								
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		88462304.7	88462304.7	88462304.7	88462304.7	88462304.7	88462304.7	88462304.7	88462304.7	88462304.7	88462304.7
Total Annual Expense		R 78 710 785.24	R 78 710 785.24	R 78 710 785.24	R 78 710 785.24	R 78 710 785.24	R 78 710 785.24	R 78 710 785.24	R 78 710 785.24	R 78 710 785.24	R 78 710 785.24
Annual Cash Flow		R 9 751 519.46	R 9 751 519.46	R 9 751 519.46	R 9 751 519.46	R 9 751 519.46	R 9 751 519.46	R 9 751 519.46	R 9 751 519.46	R 9 751 519.46	R 9 751 519.46
Annual Depreciation and Other Tax Allowances		R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42
Amount of Tax		0	0	0	0	0	0	0	0	0	0
Total Annual Capital Expenditure	R 129 748 084.16	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -129 748 084.16	R 9 751 519.46	R 9 751 519.46	R 9 751 519.46	R 9 751 519.46	R 9 751 519.46	R 9 751 519.46	R 9 751 519.46	R 9 751 519.46	R 9 751 519.46	R 9 751 519.46
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -129 748 084.16	R 9 181 357.18	R 8 644 531.75	R 8 139 094.01	R 7 663 208.75	R 7 215 148.06	R 6 793 285.06	R 6 396 087.99	R 6 022 114.67	R 5 670 007.22	R 5 338 487.17
Net Present Value	R -129 748 084.16	R -120 566 726.98	R -111 922 195.23	R -103 783 101.21	R -96 119 892.46	R -88 904 744.40	R -82 111 459.35	R -75 715 371.36	R -69 693 256.69	R -64 023 249.47	R -58 684 762.30

Figure B.66: NPV Calculations for Acid Leach Process (68 kg/h) Throughput 7

Throughput 8: 55 kg/hr

	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		101099776.8	101099776.8	101099776.8	101099776.8	101099776.8	101099776.8	101099776.8	101099776.8	101099776.8	101099776.8
Total Annual Expense		R 83 404 207.52	R 83 404 207.52	R 83 404 207.52	R 83 404 207.52	R 83 404 207.52	R 83 404 207.52	R 83 404 207.52	R 83 404 207.52	R 83 404 207.52	R 83 404 207.52
Annual Cash Flow		R 17 695 569.28	R 17 695 569.28	R 17 695 569.28	R 17 695 569.28	R 17 695 569.28	R 17 695 569.28	R 17 695 569.28	R 17 695 569.28	R 17 695 569.28	R 17 695 569.28
Annual Depreciation and Other Tax Allowances		R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42
Amount of Tax		1321813.042	1321813.042	1321813.042	1321813.042	1321813.042	1321813.042	1321813.042	1321813.042	1321813.042	1321813.042
Total Annual Capital Expenditure	R 129 748 084.16	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -129 748 084.16	R 16 373 756.24	R 16 373 756.24	R 16 373 756.24	R 16 373 756.24	R 16 373 756.24	R 16 373 756.24	R 16 373 756.24	R 16 373 756.24	R 16 373 756.24	R 16 373 756.24
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -129 748 084.16	R 15 416 397.93	R 14 515 015.47	R 13 666 336.00	R 12 867 278.04	R 12 114 940.25	R 11 406 590.95	R 10 739 658.18	R 10 111 720.34	R 9 520 497.45	R 8 963 842.81
Net Present Value	R -129 748 084.16	R -114 331 686.23	R -99 816 670.76	R -86 150 334.76	R -73 283 056.73	R -61 168 116.48	R -49 761 525.53	R -39 021 867.36	R -28 910 147.01	R -19 389 649.56	R -10 425 806.75

Figure B.67: NPV Calculations for Acid Leach Process (68 kg/h) Throughput 8

Throughput 9: 61.875 kg/hr

	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		113737248.9	113737248.9	113737248.9	113737248.9	113737248.9	113737248.9	113737248.9	113737248.9	113737248.9	113737248.9
Total Annual Expense		R 88 097 721.29	R 88 097 721.29	R 88 097 721.29	R 88 097 721.29	R 88 097 721.29	R 88 097 721.29	R 88 097 721.29	R 88 097 721.29	R 88 097 721.29	R 88 097 721.29
Annual Cash Flow		R 25 639 527.61	R 25 639 527.61	R 25 639 527.61	R 25 639 527.61	R 25 639 527.61	R 25 639 527.61	R 25 639 527.61	R 25 639 527.61	R 25 639 527.61	R 25 639 527.61
Annual Depreciation and Other Tax Allowances		R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42
Amount of Tax		3546121.375	3546121.375	3546121.375	3546121.375	3546121.375	3546121.375	3546121.375	3546121.375	3546121.375	3546121.375
Total Annual Capital Expenditure	R 129 748 084.16	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -129 748 084.16	R 22 093 406.24	R 22 093 406.24	R 22 093 406.24	R 22 093 406.24	R 22 093 406.24	R 22 093 406.24	R 22 093 406.24	R 22 093 406.24	R 22 093 406.24	R 22 093 406.24
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -129 748 084.16	R 20 801 625.31	R 19 585 373.60	R 18 440 235.01	R 17 362 051.61	R 16 346 908.58	R 15 391 120.03	R 14 491 215.54	R 13 643 927.64	R 12 846 179.87	R 12 095 075.67
Net Present Value	R -129 748 084.16	R -108 946 458.85	R -89 361 085.24	R -70 920 850.23	R -53 558 798.63	R -37 211 890.04	R -21 820 770.02	R -7 329 554.47	R 6 314 373.17	R 19 160 553.03	R 31 255 628.70

Figure B.68: NPV Calculations for Acid Leach Process (68 kg/h) Throughput 9

Throughput 10: 68.75 kg/hr

	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		126374721	126374721	126374721	126374721	126374721	126374721	126374721	126374721	126374721	126374721
Total Annual Expense		R 92 791 326.55	R 92 791 326.55	R 92 791 326.55	R 92 791 326.55	R 92 791 326.55	R 92 791 326.55	R 92 791 326.55	R 92 791 326.55	R 92 791 326.55	R 92 791 326.55
Annual Cash Flow		R 33 583 394.45	R 33 583 394.45	R 33 583 394.45	R 33 583 394.45	R 33 583 394.45	R 33 583 394.45	R 33 583 394.45	R 33 583 394.45	R 33 583 394.45	R 33 583 394.45
Annual Depreciation and Other Tax Allowances		R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42	R 12 974 808.42
Amount of Tax		5770404.09	5770404.09	5770404.09	5770404.09	5770404.09	5770404.09	5770404.09	5770404.09	5770404.09	5770404.09
Total Annual Capital Expenditure	R 129 748 084.16	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -129 748 084.16	R 27 812 990.36	R 27 812 990.36	R 27 812 990.36	R 27 812 990.36	R 27 812 990.36	R 27 812 990.36	R 27 812 990.36	R 27 812 990.36	R 27 812 990.36	R 27 812 990.36
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -129 748 084.16	R 26 186 790.66	R 24 655 673.35	R 23 214 079.04	R 21 856 773.41	R 20 578 828.18	R 19 375 603.22	R 18 242 729.70	R 17 176 094.25	R 16 171 823.98	R 15 226 272.46
Net Present Value	R -129 748 084.16	R -103 561 293.49	R -78 905 620.15	R -55 691 541.11	R -33 834 767.70	R -13 255 939.52	R 6 119 663.70	R 24 362 393.40	R 41 538 487.65	R 57 710 311.64	R 72 936 584.10

Figure B.69: NPV Calculations for Acid Leach Process (68 kg/h) Throughput 10

B.8 NPV Calculations Coldstream Process (25 kg/h)

Throughput 1:	2.5	kg/hr									
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		4021013.85	4021013.85	4021013.85	4021013.85	4021013.85	4021013.85	4021013.85	4021013.85	4021013.85	4021013.85
Total Annual Expense		R 14 877 542.17	R 14 877 542.17	R 14 877 542.17	R 14 877 542.17	R 14 877 542.17	R 14 877 542.17	R 14 877 542.17	R 14 877 542.17	R 14 877 542.17	R 14 877 542.17
Annual Cash Flow		R -10 856 528.32	R -10 856 528.32	R -10 856 528.32	R -10 856 528.32	R -10 856 528.32	R -10 856 528.32	R -10 856 528.32	R -10 856 528.32	R -10 856 528.32	R -10 856 528.32
Annual Depreciation and Other Tax Allowances		R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40
Amount of Tax		0	0	0	0	0	0	0	0	0	0
Total Annual Capital Expenditure	R 37 181 353.98	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -37 181 353.98	R -10 856 528.32	R -10 856 528.32	R -10 856 528.32	R -10 856 528.32	R -10 856 528.32	R -10 856 528.32	R -10 856 528.32	R -10 856 528.32	R -10 856 528.32	R -10 856 528.32
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -37 181 353.98	R -10 221 757.20	R -9 624 100.55	R -9 061 388.34	R -8 531 577.38	R -8 032 743.98	R -7 563 076.90	R -7 120 870.83	R -6 704 520.13	R -6 312 513.07	R -5 943 426.29
Net Present Value	R -37 181 353.98	R -47 403 111.17	R -57 027 211.73	R -66 088 600.06	R -74 620 177.44	R -82 652 921.43	R -90 215 998.33	R -97 336 869.16	R -104 041 389.28	R -110 353 902.35	R -116 297 328.64

Figure B.70: NPV Calculations for Coldstream Process (25 kg/h) Throughput 1

Throughput 2:	5	kg/hr									
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		8042027.7	8042027.7	8042027.7	8042027.7	8042027.7	8042027.7	8042027.7	8042027.7	8042027.7	8042027.7
Total Annual Expense		R 16 116 506.14	R 16 116 506.14	R 16 116 506.14	R 16 116 506.14	R 16 116 506.14	R 16 116 506.14	R 16 116 506.14	R 16 116 506.14	R 16 116 506.14	R 16 116 506.14
Annual Cash Flow		R -8 074 478.44	R -8 074 478.44	R -8 074 478.44	R -8 074 478.44	R -8 074 478.44	R -8 074 478.44	R -8 074 478.44	R -8 074 478.44	R -8 074 478.44	R -8 074 478.44
Annual Depreciation and Other Tax Allowances		R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40
Amount of Tax		0	0	0	0	0	0	0	0	0	0
Total Annual Capital Expenditure	R 37 181 353.98	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -37 181 353.98	R -8 074 478.44	R -8 074 478.44	R -8 074 478.44	R -8 074 478.44	R -8 074 478.44	R -8 074 478.44	R -8 074 478.44	R -8 074 478.44	R -8 074 478.44	R -8 074 478.44
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -37 181 353.98	R -7 602 371.19	R -7 157 867.61	R -6 739 353.74	R -6 345 309.99	R -5 974 305.61	R -5 624 993.52	R -5 296 105.37	R -4 986 447.01	R -4 694 894.09	R -4 420 388.00
Net Present Value	R -37 181 353.98	R -44 783 725.16	R -51 941 592.78	R -58 680 946.52	R -65 026 256.51	R -71 000 562.13	R -76 625 555.64	R -81 921 661.02	R -86 908 108.03	R -91 603 002.12	R -96 023 390.12

Figure B.71: NPV Calculations for Coldstream Process (25 kg/h) Throughput 2

Throughput 3:	7.5	kg/hr									
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		12063041.55	12063041.55	12063041.55	12063041.55	12063041.55	12063041.55	12063041.55	12063041.55	12063041.55	12063041.55
Total Annual Expense		R 17 355 470.11	R 17 355 470.11	R 17 355 470.11	R 17 355 470.11	R 17 355 470.11	R 17 355 470.11	R 17 355 470.11	R 17 355 470.11	R 17 355 470.11	R 17 355 470.11
Annual Cash Flow		R -5 292 428.56	R -5 292 428.56	R -5 292 428.56	R -5 292 428.56	R -5 292 428.56	R -5 292 428.56	R -5 292 428.56	R -5 292 428.56	R -5 292 428.56	R -5 292 428.56
Annual Depreciation and Other Tax Allowances		R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40
Amount of Tax		0	0	0	0	0	0	0	0	0	0
Total Annual Capital Expenditure	R 37 181 353.98	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -37 181 353.98	R -5 292 428.56	R -5 292 428.56	R -5 292 428.56	R -5 292 428.56	R -5 292 428.56	R -5 292 428.56	R -5 292 428.56	R -5 292 428.56	R -5 292 428.56	R -5 292 428.56
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -37 181 353.98	R -4 982 985.18	R -4 691 634.67	R -4 417 319.15	R -4 159 042.60	R -3 915 867.25	R -3 686 910.13	R -3 471 339.92	R -3 268 373.90	R -3 077 275.12	R -2 897 349.70
Net Present Value	R -37 181 353.98	R -42 164 339.16	R -46 855 973.83	R -51 273 292.97	R -55 432 335.58	R -59 348 202.83	R -63 035 112.95	R -66 506 452.87	R -69 774 826.77	R -72 852 101.89	R -75 749 451.59

Figure B.72: NPV Calculations for Coldstream Process (25 kg/h) Throughput 3

Throughput 4:	10 kg/hr										
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		16084055.4	16084055.4	16084055.4	16084055.4	16084055.4	16084055.4	16084055.4	16084055.4	16084055.4	16084055.4
Total Annual Expense		R 18 594 434.08	R 18 594 434.08	R 18 594 434.08	R 18 594 434.08	R 18 594 434.08	R 18 594 434.08	R 18 594 434.08	R 18 594 434.08	R 18 594 434.08	R 18 594 434.08
Annual Cash Flow		R -2 510 378.68	R -2 510 378.68	R -2 510 378.68	R -2 510 378.68	R -2 510 378.68	R -2 510 378.68	R -2 510 378.68	R -2 510 378.68	R -2 510 378.68	R -2 510 378.68
Annual Depreciation and Other Tax Allowances		R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40
Amount of Tax		0	0	0	0	0	0	0	0	0	0
Total Annual Capital Expenditure	R 37 181 353.98	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -37 181 353.98	R -2 510 378.68	R -2 510 378.68	R -2 510 378.68	R -2 510 378.68	R -2 510 378.68	R -2 510 378.68	R -2 510 378.68	R -2 510 378.68	R -2 510 378.68	R -2 510 378.68
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -37 181 353.98	R -2 363 599.17	R -2 225 401.73	R -2 095 284.56	R -1 972 775.21	R -1 857 428.88	R -1 748 826.74	R -1 646 574.47	R -1 550 300.79	R -1 459 656.14	R -1 374 311.40
Net Present Value	R -37 181 353.98	R -39 544 953.15	R -41 770 354.87	R -43 865 639.43	R -45 838 414.64	R -47 695 843.53	R -49 444 670.27	R -51 091 244.73	R -52 641 545.52	R -54 101 201.66	R -55 475 513.06

Figure B.73: NPV Calculations for Coldstream Process (25 kg/h) Throughput 4

Throughput 5:	12.5 kg/hr										
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		20105069.25	20105069.25	20105069.25	20105069.25	20105069.25	20105069.25	20105069.25	20105069.25	20105069.25	20105069.25
Total Annual Expense		R 19 833 398.05	R 19 833 398.05	R 19 833 398.05	R 19 833 398.05	R 19 833 398.05	R 19 833 398.05	R 19 833 398.05	R 19 833 398.05	R 19 833 398.05	R 19 833 398.05
Annual Cash Flow		R 271 671.20	R 271 671.20	R 271 671.20	R 271 671.20	R 271 671.20	R 271 671.20	R 271 671.20	R 271 671.20	R 271 671.20	R 271 671.20
Annual Depreciation and Other Tax Allowances		R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40
Amount of Tax		0	0	0	0	0	0	0	0	0	0
Total Annual Capital Expenditure	R 37 181 353.98	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -37 181 353.98	R 271 671.20	R 271 671.20	R 271 671.20	R 271 671.20	R 271 671.20	R 271 671.20	R 271 671.20	R 271 671.20	R 271 671.20	R 271 671.20
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -37 181 353.98	R 255 786.83	R 240 831.22	R 226 750.04	R 213 492.17	R 201 009.49	R 189 256.65	R 178 190.99	R 167 772.33	R 157 962.83	R 148 726.89
Net Present Value	R -37 181 353.98	R -36 925 567.14	R -36 684 735.92	R -36 457 985.89	R -36 244 493.71	R -36 043 484.23	R -35 854 227.58	R -35 676 036.59	R -35 508 264.27	R -35 350 301.43	R -35 201 574.54

Figure B.74: NPV Calculations for Coldstream Process (25 kg/h) Throughput 5

Throughput 6:	15 kg/hr										
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		24126083.1	24126083.1	24126083.1	24126083.1	24126083.1	24126083.1	24126083.1	24126083.1	24126083.1	24126083.1
Total Annual Expense		R 21 072 362.02	R 21 072 362.02	R 21 072 362.02	R 21 072 362.02	R 21 072 362.02	R 21 072 362.02	R 21 072 362.02	R 21 072 362.02	R 21 072 362.02	R 21 072 362.02
Annual Cash Flow		R 3 053 721.08	R 3 053 721.08	R 3 053 721.08	R 3 053 721.08	R 3 053 721.08	R 3 053 721.08	R 3 053 721.08	R 3 053 721.08	R 3 053 721.08	R 3 053 721.08
Annual Depreciation and Other Tax Allowances		R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40
Amount of Tax		0	0	0	0	0	0	0	0	0	0
Total Annual Capital Expenditure	R 37 181 353.98	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -37 181 353.98	R 3 053 721.08	R 3 053 721.08	R 3 053 721.08	R 3 053 721.08	R 3 053 721.08	R 3 053 721.08	R 3 053 721.08	R 3 053 721.08	R 3 053 721.08	R 3 053 721.08
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -37 181 353.98	R 2 875 172.84	R 2 707 064.16	R 2 548 784.63	R 2 399 759.56	R 2 259 447.85	R 2 127 340.04	R 2 002 956.44	R 1 885 845.44	R 1 775 581.81	R 1 671 765.19
Net Present Value	R -37 181 353.98	R -34 306 181.13	R -31 599 116.97	R -29 050 332.34	R -26 650 572.78	R -24 391 124.93	R -22 263 784.89	R -20 260 828.45	R -18 374 983.01	R -16 599 401.20	R -14 927 636.01

Figure B.75: NPV Calculations for Coldstream Process (25 kg/h) Throughput 6

Throughput 7:	17.5 kg/hr										
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		28147096.95	28147096.95	28147096.95	28147096.95	28147096.95	28147096.95	28147096.95	28147096.95	28147096.95	28147096.95
Total Annual Expense		R 22 311 325.99	R 22 311 325.99	R 22 311 325.99	R 22 311 325.99	R 22 311 325.99	R 22 311 325.99	R 22 311 325.99	R 22 311 325.99	R 22 311 325.99	R 22 311 325.99
Annual Cash Flow		R 5 835 770.96	R 5 835 770.96	R 5 835 770.96	R 5 835 770.96	R 5 835 770.96	R 5 835 770.96	R 5 835 770.96	R 5 835 770.96	R 5 835 770.96	R 5 835 770.96
Annual Depreciation and Other Tax Allowances		R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40
Amount of Tax		592937.9561	592937.9561	592937.9561	592937.9561	592937.9561	592937.9561	592937.9561	592937.9561	592937.9561	592937.9561
Total Annual Capital Expenditure	R 37 181 353.98	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -37 181 353.98	R 5 242 833.00	R 5 242 833.00	R 5 242 833.00	R 5 242 833.00	R 5 242 833.00	R 5 242 833.00	R 5 242 833.00	R 5 242 833.00	R 5 242 833.00	R 5 242 833.00
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -37 181 353.98	R 4 936 289.43	R 4 647 669.17	R 4 375 924.27	R 4 120 068.05	R 3 879 171.50	R 3 652 359.94	R 3 438 809.85	R 3 237 745.84	R 3 048 437.85	R 2 870 198.52
Net Present Value	R -37 181 353.98	R -32 245 064.55	R -27 597 395.38	R -23 221 471.11	R -19 101 403.06	R -15 222 231.56	R -11 569 871.62	R -8 131 061.77	R -4 893 315.93	R -1 844 878.08	R 1 025 320.44

Figure B.76: NPV Calculations for Coldstream Process (25 kg/h) Throughput 7

Throughput 8:	20 kg/hr										
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		32168110.8	32168110.8	32168110.8	32168110.8	32168110.8	32168110.8	32168110.8	32168110.8	32168110.8	32168110.8
Total Annual Expense		R 23 550 289.97	R 23 550 289.97	R 23 550 289.97	R 23 550 289.97	R 23 550 289.97	R 23 550 289.97	R 23 550 289.97	R 23 550 289.97	R 23 550 289.97	R 23 550 289.97
Annual Cash Flow		R 8 617 820.83	R 8 617 820.83	R 8 617 820.83	R 8 617 820.83	R 8 617 820.83	R 8 617 820.83	R 8 617 820.83	R 8 617 820.83	R 8 617 820.83	R 8 617 820.83
Annual Depreciation and Other Tax Allowances		R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40
Amount of Tax		1371911.922	1371911.922	1371911.922	1371911.922	1371911.922	1371911.922	1371911.922	1371911.922	1371911.922	1371911.922
Total Annual Capital Expenditure	R 37 181 353.98	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -37 181 353.98	R 7 245 908.91	R 7 245 908.91	R 7 245 908.91	R 7 245 908.91	R 7 245 908.91	R 7 245 908.91	R 7 245 908.91	R 7 245 908.91	R 7 245 908.91	R 7 245 908.91
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -37 181 353.98	R 6 822 247.35	R 6 423 356.89	R 6 047 789.18	R 5 694 180.57	R 5 361 247.12	R 5 047 779.98	R 4 752 640.98	R 4 474 758.48	R 4 213 123.51	R 3 966 786.09
Net Present Value	R -37 181 353.98	R -30 359 106.62	R -23 935 749.74	R -17 887 960.55	R -12 193 779.99	R -6 832 532.87	R -1 784 752.88	R 2 967 888.10	R 7 442 646.57	R 11 655 770.08	R 15 622 556.17

Figure B.77: NPV Calculations for Coldstream Process (25 kg/h) Throughput 8

Throughput 9:	22.5 kg/hr										
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		36189124.65	36189124.65	36189124.65	36189124.65	36189124.65	36189124.65	36189124.65	36189124.65	36189124.65	36189124.65
Total Annual Expense		R 24 789 253.94	R 24 789 253.94	R 24 789 253.94	R 24 789 253.94	R 24 789 253.94	R 24 789 253.94	R 24 789 253.94	R 24 789 253.94	R 24 789 253.94	R 24 789 253.94
Annual Cash Flow		R 11 399 870.71	R 11 399 870.71	R 11 399 870.71	R 11 399 870.71	R 11 399 870.71	R 11 399 870.71	R 11 399 870.71	R 11 399 870.71	R 11 399 870.71	R 11 399 870.71
Annual Depreciation and Other Tax Allowances		R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40
Amount of Tax		2150885.888	2150885.888	2150885.888	2150885.888	2150885.888	2150885.888	2150885.888	2150885.888	2150885.888	2150885.888
Total Annual Capital Expenditure	R 37 181 353.98	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -37 181 353.98	R 9 248 984.82	R 9 248 984.82	R 9 248 984.82	R 9 248 984.82	R 9 248 984.82	R 9 248 984.82	R 9 248 984.82	R 9 248 984.82	R 9 248 984.82	R 9 248 984.82
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -37 181 353.98	R 8 708 205.28	R 8 199 044.61	R 7 719 654.09	R 7 268 293.09	R 6 843 322.74	R 6 443 200.02	R 6 066 472.11	R 5 711 771.12	R 5 377 809.17	R 5 063 373.67
Net Present Value	R -37 181 353.98	R -28 473 148.70	R -20 274 104.09	R -12 554 450.00	R -5 286 156.92	R 1 557 165.83	R 8 000 365.85	R 14 066 837.96	R 19 778 609.08	R 25 156 418.25	R 30 219 791.91

Figure B.78: NPV Calculations for Coldstream Process (25 kg/h) Throughput 9

Throughput 10:	25 kg/hr										
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		40210138.5	40210138.5	40210138.5	40210138.5	40210138.5	40210138.5	40210138.5	40210138.5	40210138.5	40210138.5
Total Annual Expense		R 26 028 217.91	R 26 028 217.91	R 26 028 217.91	R 26 028 217.91	R 26 028 217.91	R 26 028 217.91	R 26 028 217.91	R 26 028 217.91	R 26 028 217.91	R 26 028 217.91
Annual Cash Flow		R 14 181 920.59	R 14 181 920.59	R 14 181 920.59	R 14 181 920.59	R 14 181 920.59	R 14 181 920.59	R 14 181 920.59	R 14 181 920.59	R 14 181 920.59	R 14 181 920.59
Annual Depreciation and Other Tax Allowances		R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40	R 3 718 135.40
Amount of Tax		2929859.855	2929859.855	2929859.855	2929859.855	2929859.855	2929859.855	2929859.855	2929859.855	2929859.855	2929859.855
Total Annual Capital Expenditure	R 37 181 353.98	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -37 181 353.98	R 11 252 060.74	R 11 252 060.74	R 11 252 060.74	R 11 252 060.74	R 11 252 060.74	R 11 252 060.74	R 11 252 060.74	R 11 252 060.74	R 11 252 060.74	R 11 252 060.74
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -37 181 353.98	R 10 594 163.20	R 9 974 732.33	R 9 391 519.00	R 8 842 405.61	R 8 325 398.37	R 7 838 620.06	R 7 380 303.23	R 6 948 783.76	R 6 542 494.83	R 6 159 961.24
Net Present Value	R -37 181 353.98	R -26 587 190.77	R -16 612 458.45	R -7 220 939.45	R 1 621 466.16	R 9 946 864.53	R 17 785 484.59	R 25 165 787.82	R 32 114 571.58	R 38 657 066.41	R 44 817 027.65

Figure B.79: NPV Calculations for Coldstream Process (25 kg/h) Throughput 10

B.9 NPV Calculations Coldstream Process (44.5 kg/h)

Throughput 1:	4.45 kg/h										
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		7157404.653	7157404.653	7157404.653	7157404.653	7157404.653	7157404.653	7157404.653	7157404.653	7157404.653	7157404.653
Total Annual Expense		R 19 649 892.02	R 19 649 892.02	R 19 649 892.02	R 19 649 892.02	R 19 649 892.02	R 19 649 892.02	R 19 649 892.02	R 19 649 892.02	R 19 649 892.02	R 19 649 892.02
Annual Cash Flow		R -12 492 487.36	R -12 492 487.36	R -12 492 487.36	R -12 492 487.36	R -12 492 487.36	R -12 492 487.36	R -12 492 487.36	R -12 492 487.36	R -12 492 487.36	R -12 492 487.36
Annual Depreciation and Other Tax Allowances		R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84
Amount of Tax		0	0	0	0	0	0	0	0	0	0
Total Annual Capital Expenditure	R 46 930 148.36	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -46 930 148.36	R -12 492 487.36	R -12 492 487.36	R -12 492 487.36	R -12 492 487.36	R -12 492 487.36	R -12 492 487.36	R -12 492 487.36	R -12 492 487.36	R -12 492 487.36	R -12 492 487.36
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -46 930 148.36	R -11 762 063.24	R -11 074 346.33	R -10 426 839.59	R -9 817 191.97	R -9 243 189.88	R -8 702 749.16	R -8 193 907.50	R -7 714 817.34	R -7 263 739.14	R -6 839 035.07
Net Present Value	R -46 930 148.36	R -58 692 211.59	R -69 766 557.92	R -80 193 397.52	R -90 010 589.49	R -99 253 779.37	R -107 956 528.52	R -116 150 436.02	R -123 865 253.37	R -131 128 992.51	R -137 968 027.58

Figure B.80: NPV Calculations for Coldstream Process (44.5 kg/h) Throughput 1

Throughput 2:	8.9 kg/h										
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		14314809.31	14314809.31	14314809.31	14314809.31	14314809.31	14314809.31	14314809.31	14314809.31	14314809.31	14314809.31
Total Annual Expense		R 21 845 902.72	R 21 845 902.72	R 21 845 902.72	R 21 845 902.72	R 21 845 902.72	R 21 845 902.72	R 21 845 902.72	R 21 845 902.72	R 21 845 902.72	R 21 845 902.72
Annual Cash Flow		R -7 531 093.41	R -7 531 093.41	R -7 531 093.41	R -7 531 093.41	R -7 531 093.41	R -7 531 093.41	R -7 531 093.41	R -7 531 093.41	R -7 531 093.41	R -7 531 093.41
Annual Depreciation and Other Tax Allowances		R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84
Amount of Tax		0	0	0	0	0	0	0	0	0	0
Total Annual Capital Expenditure	R 46 930 148.36	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -46 930 148.36	R -7 531 093.41	R -7 531 093.41	R -7 531 093.41	R -7 531 093.41	R -7 531 093.41	R -7 531 093.41	R -7 531 093.41	R -7 531 093.41	R -7 531 093.41	R -7 531 093.41
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -46 930 148.36	R -7 090 757.38	R -6 676 167.38	R -6 285 818.08	R -5 918 292.14	R -5 572 255.10	R -5 246 450.52	R -4 939 695.43	R -4 650 876.03	R -4 378 943.63	R -4 122 910.87
Net Present Value	R -46 930 148.36	R -54 020 905.74	R -60 697 073.12	R -66 982 891.20	R -72 901 183.34	R -78 473 438.44	R -83 719 888.96	R -88 659 584.39	R -93 310 460.43	R -97 689 404.06	R -101 812 314.93

Figure B.81: NPV Calculations for Coldstream Process (44.5 kg/h) Throughput 2

Throughput 3:	13.35	kg/h									
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		21472213.96	21472213.96	21472213.96	21472213.96	21472213.96	21472213.96	21472213.96	21472213.96	21472213.96	21472213.96
Total Annual Expense		R 24 041 913.42	R 24 041 913.42	R 24 041 913.42	R 24 041 913.42	R 24 041 913.42	R 24 041 913.42	R 24 041 913.42	R 24 041 913.42	R 24 041 913.42	R 24 041 913.42
Annual Cash Flow		R -2 569 699.46	R -2 569 699.46	R -2 569 699.46	R -2 569 699.46	R -2 569 699.46	R -2 569 699.46	R -2 569 699.46	R -2 569 699.46	R -2 569 699.46	R -2 569 699.46
Annual Depreciation and Other Tax Allowances		R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84
Amount of Tax		0	0	0	0	0	0	0	0	0	0
Total Annual Capital Expenditure	R 46 930 148.36	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -46 930 148.36	R -2 569 699.46	R -2 569 699.46	R -2 569 699.46	R -2 569 699.46	R -2 569 699.46	R -2 569 699.46	R -2 569 699.46	R -2 569 699.46	R -2 569 699.46	R -2 569 699.46
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -46 930 148.36	R -2 419 451.52	R -2 277 988.44	R -2 144 796.57	R -2 019 392.31	R -1 901 320.32	R -1 790 151.89	R -1 685 483.37	R -1 586 934.72	R -1 494 148.12	R -1 406 786.67
Net Present Value	R -46 930 148.36	R -49 349 599.88	R -51 627 588.32	R -53 772 384.89	R -55 791 777.20	R -57 693 097.51	R -59 483 249.40	R -61 168 732.77	R -62 755 667.49	R -64 249 815.61	R -65 656 602.28

Figure B.82: NPV Calculations for Coldstream Process (44.5 kg/h) Throughput 3

Throughput 4:	17.8	kg/h									
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		28629618.61	28629618.61	28629618.61	28629618.61	28629618.61	28629618.61	28629618.61	28629618.61	28629618.61	28629618.61
Total Annual Expense		R 26 237 924.12	R 26 237 924.12	R 26 237 924.12	R 26 237 924.12	R 26 237 924.12	R 26 237 924.12	R 26 237 924.12	R 26 237 924.12	R 26 237 924.12	R 26 237 924.12
Annual Cash Flow		R 2 391 694.49	R 2 391 694.49	R 2 391 694.49	R 2 391 694.49	R 2 391 694.49	R 2 391 694.49	R 2 391 694.49	R 2 391 694.49	R 2 391 694.49	R 2 391 694.49
Annual Depreciation and Other Tax Allowances		R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84
Amount of Tax		0	0	0	0	0	0	0	0	0	0
Total Annual Capital Expenditure	R 46 930 148.36	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -46 930 148.36	R 2 391 694.49	R 2 391 694.49	R 2 391 694.49	R 2 391 694.49	R 2 391 694.49	R 2 391 694.49	R 2 391 694.49	R 2 391 694.49	R 2 391 694.49	R 2 391 694.49
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -46 930 148.36	R 2 251 854.34	R 2 120 190.51	R 1 996 224.94	R 1 879 507.52	R 1 769 614.46	R 1 666 146.75	R 1 568 728.70	R 1 477 006.59	R 1 390 647.39	R 1 309 337.53
Net Present Value	R -46 930 148.36	R -44 678 294.02	R -42 558 103.51	R -40 561 878.57	R -38 682 371.05	R -36 912 756.59	R -35 246 609.84	R -33 677 881.14	R -32 200 874.55	R -30 810 227.16	R -29 500 889.63

Figure B.83: NPV Calculations for Coldstream Process (44.5 kg/h) Throughput 4

Throughput 5:	22.25	kg/h									
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		35787023.27	35787023.27	35787023.27	35787023.27	35787023.27	35787023.27	35787023.27	35787023.27	35787023.27	35787023.27
Total Annual Expense		R 28 433 934.82	R 28 433 934.82	R 28 433 934.82	R 28 433 934.82	R 28 433 934.82	R 28 433 934.82	R 28 433 934.82	R 28 433 934.82	R 28 433 934.82	R 28 433 934.82
Annual Cash Flow		R 7 353 088.45	R 7 353 088.45	R 7 353 088.45	R 7 353 088.45	R 7 353 088.45	R 7 353 088.45	R 7 353 088.45	R 7 353 088.45	R 7 353 088.45	R 7 353 088.45
Annual Depreciation and Other Tax Allowances		R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84
Amount of Tax		744820.6107	744820.6107	744820.6107	744820.6107	744820.6107	744820.6107	744820.6107	744820.6107	744820.6107	744820.6107
Total Annual Capital Expenditure	R 46 930 148.36	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -46 930 148.36	R 6 608 267.83	R 6 608 267.83	R 6 608 267.83	R 6 608 267.83	R 6 608 267.83	R 6 608 267.83	R 6 608 267.83	R 6 608 267.83	R 6 608 267.83	R 6 608 267.83
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -46 930 148.36	R 6 221 888.56	R 5 858 100.51	R 5 515 582.82	R 5 193 091.82	R 4 889 456.57	R 4 603 574.58	R 4 334 407.86	R 4 080 979.06	R 3 842 368.00	R 3 617 708.32
Net Present Value	R -46 930 148.36	R -40 708 259.80	R -34 850 159.29	R -29 334 576.47	R -24 141 484.65	R -19 252 028.08	R -14 648 453.50	R -10 314 045.64	R -6 233 066.59	R -2 390 698.58	R 1 227 009.73

Figure B.84: NPV Calculations for Coldstream Process (44.5 kg/h) Throughput 5

Throughput 6:	26.7	kg/h									
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		R 42 944 427.92	42944427.92	42944427.92	42944427.92	42944427.92	42944427.92	42944427.92	42944427.92	42944427.92	42944427.92
Total Annual Expense		R 30 629 945.52	R 30 629 945.52	R 30 629 945.52	R 30 629 945.52	R 30 629 945.52	R 30 629 945.52	R 30 629 945.52	R 30 629 945.52	R 30 629 945.52	R 30 629 945.52
Annual Cash Flow		R 12 314 482.40	R 12 314 482.40	R 12 314 482.40	R 12 314 482.40	R 12 314 482.40	R 12 314 482.40	R 12 314 482.40	R 12 314 482.40	R 12 314 482.40	R 12 314 482.40
Annual Depreciation and Other Tax Allowances		R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84
Amount of Tax		2134010.917	2134010.917	2134010.917	2134010.917	2134010.917	2134010.917	2134010.917	2134010.917	2134010.917	2134010.917
Total Annual Capital Expenditure	R 46 930 148.36	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -46 930 148.36	R 10 180 471.48	R 10 180 471.48	R 10 180 471.48	R 10 180 471.48	R 10 180 471.48	R 10 180 471.48	R 10 180 471.48	R 10 180 471.48	R 10 180 471.48	R 10 180 471.48
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -46 930 148.36	R 9 585 228.77	R 9 024 789.35	R 8 497 118.31	R 8 000 299.70	R 7 532 529.61	R 7 092 109.60	R 6 677 440.54	R 6 287 016.80	R 5 919 420.77	R 5 573 317.74
Net Present Value	R -46 930 148.36	R -37 344 919.58	R -28 320 130.23	R -19 823 011.92	R -11 822 712.22	R -4 290 182.62	R 2 801 926.99	R 9 479 367.53	R 15 766 384.33	R 21 685 805.10	R 27 259 122.84

Figure B.85: NPV Calculations for Coldstream Process (44.5 kg/h) Throughput 6

Throughput 7:	31.5	kg/h									
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		50101832.57	50101832.57	50101832.57	50101832.57	50101832.57	50101832.57	50101832.57	50101832.57	50101832.57	50101832.57
Total Annual Expense		R 32 825 956.22	R 32 825 956.22	R 32 825 956.22	R 32 825 956.22	R 32 825 956.22	R 32 825 956.22	R 32 825 956.22	R 32 825 956.22	R 32 825 956.22	R 32 825 956.22
Annual Cash Flow		R 17 275 876.35	R 17 275 876.35	R 17 275 876.35	R 17 275 876.35	R 17 275 876.35	R 17 275 876.35	R 17 275 876.35	R 17 275 876.35	R 17 275 876.35	R 17 275 876.35
Annual Depreciation and Other Tax Allowances		R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84
Amount of Tax		3523201.224	3523201.224	3523201.224	3523201.224	3523201.224	3523201.224	3523201.224	3523201.224	3523201.224	3523201.224
Total Annual Capital Expenditure	R 46 930 148.36	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -46 930 148.36	R 13 752 675.13	R 13 752 675.13	R 13 752 675.13	R 13 752 675.13	R 13 752 675.13	R 13 752 675.13	R 13 752 675.13	R 13 752 675.13	R 13 752 675.13	R 13 752 675.13
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -46 930 148.36	R 12 948 568.99	R 12 191 478.20	R 11 478 653.80	R 10 807 507.57	R 10 175 602.65	R 9 580 644.62	R 9 020 473.23	R 8 493 054.54	R 7 996 473.54	R 7 528 927.16
Net Present Value	R -46 930 148.36	R -33 981 579.36	R -21 790 101.17	R -10 311 447.37	R 496 060.20	R 10 671 662.85	R 20 252 307.47	R 29 272 780.70	R 37 765 835.25	R 45 762 308.78	R 53 291 235.95

Figure B.86: NPV Calculations for Coldstream Process (44.5 kg/h) Throughput 7

Throughput 8:	35.6	kg/h									
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		57259237.22	57259237.22	57259237.22	57259237.22	57259237.22	57259237.22	57259237.22	57259237.22	57259237.22	57259237.22
Total Annual Expense		R 35 021 966.92	R 35 021 966.92	R 35 021 966.92	R 35 021 966.92	R 35 021 966.92	R 35 021 966.92	R 35 021 966.92	R 35 021 966.92	R 35 021 966.92	R 35 021 966.92
Annual Cash Flow		R 22 237 270.30	R 22 237 270.30	R 22 237 270.30	R 22 237 270.30	R 22 237 270.30	R 22 237 270.30	R 22 237 270.30	R 22 237 270.30	R 22 237 270.30	R 22 237 270.30
Annual Depreciation and Other Tax Allowances		R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84
Amount of Tax		4912391.531	4912391.531	4912391.531	4912391.531	4912391.531	4912391.531	4912391.531	4912391.531	4912391.531	4912391.531
Total Annual Capital Expenditure	R 46 930 148.36	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -46 930 148.36	R 17 324 878.77	R 17 324 878.77	R 17 324 878.77	R 17 324 878.77	R 17 324 878.77	R 17 324 878.77	R 17 324 878.77	R 17 324 878.77	R 17 324 878.77	R 17 324 878.77
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -46 930 148.36	R 16 311 909.21	R 15 358 167.04	R 14 460 189.28	R 13 614 715.45	R 12 818 675.69	R 12 069 179.64	R 11 363 505.92	R 10 699 092.29	R 10 073 526.30	R 9 484 536.58
Net Present Value	R -46 930 148.36	R -30 618 239.15	R -15 260 072.11	R -799 882.83	R 12 814 832.63	R 25 633 508.32	R 37 702 687.96	R 49 066 193.88	R 59 765 286.16	R 69 838 812.47	R 79 323 349.05

Figure B.87: NPV Calculations for Coldstream Process (44.5 kg/h) Throughput 8

Throughput 9:	40.05 kg/h										
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		64416641.88	64416641.88	64416641.88	64416641.88	64416641.88	64416641.88	64416641.88	64416641.88	64416641.88	64416641.88
Total Annual Expense		R 37 217 977.62	R 37 217 977.62	R 37 217 977.62	R 37 217 977.62	R 37 217 977.62	R 37 217 977.62	R 37 217 977.62	R 37 217 977.62	R 37 217 977.62	R 37 217 977.62
Annual Cash Flow		R 27 198 664.26	R 27 198 664.26	R 27 198 664.26	R 27 198 664.26	R 27 198 664.26	R 27 198 664.26	R 27 198 664.26	R 27 198 664.26	R 27 198 664.26	R 27 198 664.26
Annual Depreciation and Other Tax Allowances		R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84
Amount of Tax		6301581.838	6301581.838	6301581.838	6301581.838	6301581.838	6301581.838	6301581.838	6301581.838	6301581.838	6301581.838
Total Annual Capital Expenditure	R 46 930 148.36	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -46 930 148.36	R 20 897 082.42	R 20 897 082.42	R 20 897 082.42	R 20 897 082.42	R 20 897 082.42	R 20 897 082.42	R 20 897 082.42	R 20 897 082.42	R 20 897 082.42	R 20 897 082.42
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -46 930 148.36	R 19 675 249.43	R 18 524 855.88	R 17 441 724.77	R 16 421 923.33	R 15 461 748.73	R 14 557 714.65	R 13 706 538.61	R 12 905 130.03	R 12 150 579.07	R 11 440 146.00
Net Present Value	R -46 930 148.36	R -27 254 898.93	R -8 730 043.05	R 8 711 681.72	R 25 133 605.05	R 40 595 353.79	R 55 153 068.44	R 68 859 607.05	R 81 764 737.08	R 93 915 316.15	R 105 355 462.16

Figure B.88: NPV Calculations for Coldstream Process (44.5 kg/h) Throughput 9

Throughput 10:	44.5 kg/h										
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		71574046.53	71574046.53	71574046.53	71574046.53	71574046.53	71574046.53	71574046.53	71574046.53	71574046.53	71574046.53
Total Annual Expense		R 39 413 988.32	R 39 413 988.32	R 39 413 988.32	R 39 413 988.32	R 39 413 988.32	R 39 413 988.32	R 39 413 988.32	R 39 413 988.32	R 39 413 988.32	R 39 413 988.32
Annual Cash Flow		R 32 160 058.21	R 32 160 058.21	R 32 160 058.21	R 32 160 058.21	R 32 160 058.21	R 32 160 058.21	R 32 160 058.21	R 32 160 058.21	R 32 160 058.21	R 32 160 058.21
Annual Depreciation and Other Tax Allowances		R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84	R 4 693 014.84
Amount of Tax		7690772.144	7690772.144	7690772.144	7690772.144	7690772.144	7690772.144	7690772.144	7690772.144	7690772.144	7690772.144
Total Annual Capital Expenditure	R 46 930 148.36	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -46 930 148.36	R 24 469 286.06	R 24 469 286.06	R 24 469 286.06	R 24 469 286.06	R 24 469 286.06	R 24 469 286.06	R 24 469 286.06	R 24 469 286.06	R 24 469 286.06	R 24 469 286.06
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -46 930 148.36	R 23 038 589.65	R 21 691 544.72	R 20 423 260.26	R 19 229 131.21	R 18 104 821.78	R 17 046 249.67	R 16 049 571.30	R 15 111 167.78	R 14 227 631.84	R 13 395 755.43
Net Present Value	R -46 930 148.36	R -23 891 558.71	R -2 200 013.99	R 18 223 246.27	R 37 452 377.48	R 55 557 199.25	R 72 603 448.93	R 88 653 020.22	R 103 764 188.00	R 117 991 819.84	R 131 387 575.26

Figure B.89: NPV Calculations for Coldstream Process (44.5 kg/h) Throughput 10

B.10 NPV Calculations Coldstream Process (75 kg/h)

Throughput 1:	7.5 kg/h										
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		12063041.55	12063041.55	12063041.55	12063041.55	12063041.55	12063041.55	12063041.55	12063041.55	12063041.55	12063041.55
Total Annual Expense		R 34 806 743.03	R 34 806 743.03	R 34 806 743.03	R 34 806 743.03	R 34 806 743.03	R 34 806 743.03	R 34 806 743.03	R 34 806 743.03	R 34 806 743.03	R 34 806 743.03
Annual Cash Flow		R -22 743 701.48	R -22 743 701.48	R -22 743 701.48	R -22 743 701.48	R -22 743 701.48	R -22 743 701.48	R -22 743 701.48	R -22 743 701.48	R -22 743 701.48	R -22 743 701.48
Annual Depreciation and Other Tax Allowances		R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37
Amount of Tax		0	0	0	0	0	0	0	0	0	0
Total Annual Capital Expenditure	R 84 152 443.74	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -84 152 443.74	R -22 743 701.48	R -22 743 701.48	R -22 743 701.48	R -22 743 701.48	R -22 743 701.48	R -22 743 701.48	R -22 743 701.48	R -22 743 701.48	R -22 743 701.48	R -22 743 701.48
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -84 152 443.74	R -21 413 898.39	R -20 161 847.65	R -18 983 003.16	R -17 873 084.60	R -16 828 061.96	R -15 844 140.81	R -14 917 748.62	R -14 045 521.72	R -13 224 293.12	R -12 451 080.99
Net Present Value	R -84 152 443.74	R -105 566 342.13	R -125 728 189.79	R -144 711 192.94	R -162 584 277.55	R -179 412 339.50	R -195 256 480.31	R -210 174 228.93	R -224 219 750.66	R -237 444 043.78	R -249 895 124.77

Figure B.90: NPV Calculations for Coldstream Process (75 kg/h) Throughput 1

Throughput 2:	15 kg/h									
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		24126083.1	24126083.1	24126083.1	24126083.1	24126083.1	24126083.1	24126083.1	24126083.1	24126083.1	24126083.1
Total Annual Expense		R 38 507 096.37	R 38 507 096.37	R 38 507 096.37	R 38 507 096.37	R 38 507 096.37	R 38 507 096.37	R 38 507 096.37	R 38 507 096.37	R 38 507 096.37	R 38 507 096.37
Annual Cash Flow		R -14 381 013.27	R -14 381 013.27	R -14 381 013.27	R -14 381 013.27	R -14 381 013.27	R -14 381 013.27	R -14 381 013.27	R -14 381 013.27	R -14 381 013.27	R -14 381 013.27
Annual Depreciation and Other Tax Allowances		R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37
Amount of Tax		0	0	0	0	0	0	0	0	0	0
Total Annual Capital Expenditure	R 84 152 443.74	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -84 152 443.74	R -14 381 013.27	R -14 381 013.27	R -14 381 013.27	R -14 381 013.27	R -14 381 013.27	R -14 381 013.27	R -14 381 013.27	R -14 381 013.27	R -14 381 013.27	R -14 381 013.27
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -84 152 443.74	R -13 540 168.78	R -12 748 487.70	R -12 003 095.47	R -11 301 285.63	R -10 640 509.96	R -10 018 369.23	R -9 432 604.49	R -8 881 088.87	R -8 361 819.86	R -7 872 912.02
Net Present Value	R -84 152 443.74	R -97 692 612.52	R -110 441 100.22	R -122 444 195.69	R -133 745 481.32	R -144 385 991.28	R -154 404 360.52	R -163 836 965.01	R -172 718 053.89	R -181 079 873.75	R -188 952 785.77

Figure B.91: NPV Calculations for Coldstream Process (75 kg/h) Throughput 2

Throughput 3:	22.5 kg/h									
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		36189124.65	36189124.65	36189124.65	36189124.65	36189124.65	36189124.65	36189124.65	36189124.65	36189124.65	36189124.65
Total Annual Expense		R 42 207 449.70	R 42 207 449.70	R 42 207 449.70	R 42 207 449.70	R 42 207 449.70	R 42 207 449.70	R 42 207 449.70	R 42 207 449.70	R 42 207 449.70	R 42 207 449.70
Annual Cash Flow		R -6 018 325.05	R -6 018 325.05	R -6 018 325.05	R -6 018 325.05	R -6 018 325.05	R -6 018 325.05	R -6 018 325.05	R -6 018 325.05	R -6 018 325.05	R -6 018 325.05
Annual Depreciation and Other Tax Allowances		R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37
Amount of Tax		0	0	0	0	0	0	0	0	0	0
Total Annual Capital Expenditure	R 84 152 443.74	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -84 152 443.74	R -6 018 325.05	R -6 018 325.05	R -6 018 325.05	R -6 018 325.05	R -6 018 325.05	R -6 018 325.05	R -6 018 325.05	R -6 018 325.05	R -6 018 325.05	R -6 018 325.05
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -84 152 443.74	R -5 666 439.18	R -5 335 127.74	R -5 023 187.78	R -4 729 486.66	R -4 452 957.97	R -4 192 597.66	R -3 947 460.37	R -3 716 656.03	R -3 499 346.60	R -3 294 743.06
Net Present Value	R -84 152 443.74	R -89 818 882.92	R -95 154 010.66	R -100 177 198.44	R -104 906 685.10	R -109 359 643.07	R -113 552 240.72	R -117 499 701.09	R -121 216 357.12	R -124 715 703.72	R -128 010 446.78

Figure B.92: NPV Calculations for Coldstream Process (75 kg/h) Throughput 3

Throughput 4:	30 kg/h									
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		48252166.2	48252166.2	48252166.2	48252166.2	48252166.2	48252166.2	48252166.2	48252166.2	48252166.2	48252166.2
Total Annual Expense		R 45 907 803.03	R 45 907 803.03	R 45 907 803.03	R 45 907 803.03	R 45 907 803.03	R 45 907 803.03	R 45 907 803.03	R 45 907 803.03	R 45 907 803.03	R 45 907 803.03
Annual Cash Flow		R 2 344 363.17	R 2 344 363.17	R 2 344 363.17	R 2 344 363.17	R 2 344 363.17	R 2 344 363.17	R 2 344 363.17	R 2 344 363.17	R 2 344 363.17	R 2 344 363.17
Annual Depreciation and Other Tax Allowances		R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37
Amount of Tax		0	0	0	0	0	0	0	0	0	0
Total Annual Capital Expenditure	R 84 152 443.74	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -84 152 443.74	R 2 344 363.17	R 2 344 363.17	R 2 344 363.17	R 2 344 363.17	R 2 344 363.17	R 2 344 363.17	R 2 344 363.17	R 2 344 363.17	R 2 344 363.17	R 2 344 363.17
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -84 152 443.74	R 2 207 290.43	R 2 078 232.21	R 1 956 719.91	R 1 842 312.31	R 1 734 594.02	R 1 633 173.92	R 1 537 683.76	R 1 447 776.82	R 1 363 126.66	R 1 283 425.91
Net Present Value	R -84 152 443.74	R -81 945 153.31	R -79 866 921.09	R -77 910 201.19	R -76 067 888.88	R -74 333 294.85	R -72 700 120.93	R -71 162 437.17	R -69 714 660.35	R -68 351 533.69	R -67 068 107.79

Figure B.93: NPV Calculations for Coldstream Process (75 kg/h) Throughput 4

Throughput 5:	37.5	kg/h									
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		60315207.75	60315207.75	60315207.75	60315207.75	60315207.75	60315207.75	60315207.75	60315207.75	60315207.75	60315207.75
Total Annual Expense		R 49 608 156.36	R 49 608 156.36	R 49 608 156.36	R 49 608 156.36	R 49 608 156.36	R 49 608 156.36	R 49 608 156.36	R 49 608 156.36	R 49 608 156.36	R 49 608 156.36
Annual Cash Flow		R 10 707 051.39	R 10 707 051.39	R 10 707 051.39	R 10 707 051.39	R 10 707 051.39	R 10 707 051.39	R 10 707 051.39	R 10 707 051.39	R 10 707 051.39	R 10 707 051.39
Annual Depreciation and Other Tax Allowances		R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37
Amount of Tax		641705.9635	641705.9635	641705.9635	641705.9635	641705.9635	641705.9635	641705.9635	641705.9635	641705.9635	641705.9635
Total Annual Capital Expenditure	R 84 152 443.74	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -84 152 443.74	R 10 065 345.42	R 10 065 345.42	R 10 065 345.42	R 10 065 345.42	R 10 065 345.42	R 10 065 345.42	R 10 065 345.42	R 10 065 345.42	R 10 065 345.42	R 10 065 345.42
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -84 152 443.74	R 9 476 834.03	R 8 922 732.35	R 8 401 028.48	R 7 909 828.15	R 7 447 347.85	R 7 011 908.34	R 6 601 928.58	R 6 215 919.95	R 5 852 480.89	R 5 510 291.77
Net Present Value	R -84 152 443.74	R -74 675 609.71	R -65 752 877.36	R -57 351 848.88	R -49 442 020.72	R -41 994 672.87	R -34 982 764.53	R -28 380 835.95	R -22 164 916.00	R -16 312 435.11	R -10 802 143.34

Figure B.94: NPV Calculations for Coldstream Process (75 kg/h) Throughput 5

Throughput 6:	45	kg/h									
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		72378249.3	72378249.3	72378249.3	72378249.3	72378249.3	72378249.3	72378249.3	72378249.3	72378249.3	72378249.3
Total Annual Expense		R 53 308 509.70	R 53 308 509.70	R 53 308 509.70	R 53 308 509.70	R 53 308 509.70	R 53 308 509.70	R 53 308 509.70	R 53 308 509.70	R 53 308 509.70	R 53 308 509.70
Annual Cash Flow		R 19 069 739.60	R 19 069 739.60	R 19 069 739.60	R 19 069 739.60	R 19 069 739.60	R 19 069 739.60	R 19 069 739.60	R 19 069 739.60	R 19 069 739.60	R 19 069 739.60
Annual Depreciation and Other Tax Allowances		R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37
Amount of Tax		2983258.664	2983258.664	2983258.664	2983258.664	2983258.664	2983258.664	2983258.664	2983258.664	2983258.664	2983258.664
Total Annual Capital Expenditure	R 84 152 443.74	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -84 152 443.74	R 16 086 480.94	R 16 086 480.94	R 16 086 480.94	R 16 086 480.94	R 16 086 480.94	R 16 086 480.94	R 16 086 480.94	R 16 086 480.94	R 16 086 480.94	R 16 086 480.94
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -84 152 443.74	R 15 145 919.35	R 14 260 351.52	R 13 426 562.02	R 12 641 523.41	R 11 902 385.29	R 11 206 463.88	R 10 551 232.35	R 9 934 311.60	R 9 353 461.63	R 8 806 573.42
Net Present Value	R -84 152 443.74	R -69 006 524.39	R -54 746 172.87	R -41 319 610.86	R -28 678 087.44	R -16 775 702.16	R -5 569 238.28	R 4 981 994.08	R 14 916 305.68	R 24 269 767.31	R 33 076 340.73

Figure B.95: NPV Calculations for Coldstream Process (75 kg/h) Throughput 6

Throughput 7:	52.5	kg/h									
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		84441290.85	84441290.85	84441290.85	84441290.85	84441290.85	84441290.85	84441290.85	84441290.85	84441290.85	84441290.85
Total Annual Expense		R 57 008 863.03	R 57 008 863.03	R 57 008 863.03	R 57 008 863.03	R 57 008 863.03	R 57 008 863.03	R 57 008 863.03	R 57 008 863.03	R 57 008 863.03	R 57 008 863.03
Annual Cash Flow		R 27 432 427.82	R 27 432 427.82	R 27 432 427.82	R 27 432 427.82	R 27 432 427.82	R 27 432 427.82	R 27 432 427.82	R 27 432 427.82	R 27 432 427.82	R 27 432 427.82
Annual Depreciation and Other Tax Allowances		R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37
Amount of Tax		5324811.365	5324811.365	5324811.365	5324811.365	5324811.365	5324811.365	5324811.365	5324811.365	5324811.365	5324811.365
Total Annual Capital Expenditure	R 84 152 443.74	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -84 152 443.74	R 22 107 616.46	R 22 107 616.46	R 22 107 616.46	R 22 107 616.46	R 22 107 616.46	R 22 107 616.46	R 22 107 616.46	R 22 107 616.46	R 22 107 616.46	R 22 107 616.46
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -84 152 443.74	R 20 815 004.67	R 19 597 970.69	R 18 452 095.55	R 17 373 218.67	R 16 357 422.72	R 15 401 019.42	R 14 500 536.12	R 13 652 703.25	R 12 854 442.38	R 12 102 855.08
Net Present Value	R -84 152 443.74	R -63 337 439.07	R -43 739 468.39	R -25 287 372.84	R -7 914 154.16	R 8 443 268.56	R 23 844 287.98	R 38 344 824.10	R 51 997 527.35	R 64 851 969.73	R 76 954 824.81

Figure B.96: NPV Calculations for Coldstream Process (75 kg/h) Throughput 7

Throughput 8:	60	kg/h									
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		96504332.4	96504332.4	96504332.4	96504332.4	96504332.4	96504332.4	96504332.4	96504332.4	96504332.4	96504332.4
Total Annual Expense		R 60 709 216.36	R 60 709 216.36	R 60 709 216.36	R 60 709 216.36	R 60 709 216.36	R 60 709 216.36	R 60 709 216.36	R 60 709 216.36	R 60 709 216.36	R 60 709 216.36
Annual Cash Flow		R 35 795 116.04	R 35 795 116.04	R 35 795 116.04	R 35 795 116.04	R 35 795 116.04	R 35 795 116.04	R 35 795 116.04	R 35 795 116.04	R 35 795 116.04	R 35 795 116.04
Annual Depreciation and Other Tax Allowances		R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37
Amount of Tax		7666364.066	7666364.066	7666364.066	7666364.066	7666364.066	7666364.066	7666364.066	7666364.066	7666364.066	7666364.066
Total Annual Capital Expenditure	R 84 152 443.74	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -84 152 443.74	R 28 128 751.97	R 28 128 751.97	R 28 128 751.97	R 28 128 751.97	R 28 128 751.97	R 28 128 751.97	R 28 128 751.97	R 28 128 751.97	R 28 128 751.97	R 28 128 751.97
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -84 152 443.74	R 26 484 089.98	R 24 935 589.85	R 23 477 629.09	R 22 104 913.93	R 20 812 460.16	R 19 595 574.95	R 18 449 839.89	R 17 371 094.90	R 16 355 423.13	R 15 399 136.73
Net Present Value	R -84 152 443.74	R -57 668 353.76	R -32 732 763.90	R -9 255 134.81	R 12 849 779.12	R 33 662 239.28	R 53 257 814.23	R 71 707 654.12	R 89 078 749.02	R 105 434 172.15	R 120 833 308.88

Figure B.97: NPV Calculations for Coldstream Process (75 kg/h) Throughput 8

Throughput 9:	67.5	kg/h									
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		108567374	108567374	108567374	108567374	108567374	108567374	108567374	108567374	108567374	108567374
Total Annual Expense		R 64 409 569.69	R 64 409 569.69	R 64 409 569.69	R 64 409 569.69	R 64 409 569.69	R 64 409 569.69	R 64 409 569.69	R 64 409 569.69	R 64 409 569.69	R 64 409 569.69
Annual Cash Flow		R 44 157 804.26	R 44 157 804.26	R 44 157 804.26	R 44 157 804.26	R 44 157 804.26	R 44 157 804.26	R 44 157 804.26	R 44 157 804.26	R 44 157 804.26	R 44 157 804.26
Annual Depreciation and Other Tax Allowances		R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37
Amount of Tax		10007916.77	10007916.77	10007916.77	10007916.77	10007916.77	10007916.77	10007916.77	10007916.77	10007916.77	10007916.77
Total Annual Capital Expenditure	R 84 152 443.74	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -84 152 443.74	R 34 149 887.49	R 34 149 887.49	R 34 149 887.49	R 34 149 887.49	R 34 149 887.49	R 34 149 887.49	R 34 149 887.49	R 34 149 887.49	R 34 149 887.49	R 34 149 887.49
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -84 152 443.74	R 32 153 175.30	R 30 273 209.02	R 28 503 162.62	R 26 836 609.19	R 25 267 497.59	R 23 790 130.49	R 22 399 143.67	R 21 089 486.55	R 19 856 403.87	R 18 695 418.39
Net Present Value	R -84 152 443.74	R -51 999 268.44	R -21 726 059.42	R 6 777 103.21	R 33 613 712.40	R 58 881 209.99	R 82 671 340.48	R 105 070 484.15	R 126 159 970.70	R 146 016 374.57	R 164 711 792.96

Figure B.98: NPV Calculations for Coldstream Process (75 kg/h) Throughput 9

Throughput 10:	75	kg/h									
	0	1	2	3	4	5	6	7	8	9	10
Revenue from Annual Sales		120630415.5	120630415.5	120630415.5	120630415.5	120630415.5	120630415.5	120630415.5	120630415.5	120630415.5	120630415.5
Total Annual Expense		R 68 109 923.03	R 68 109 923.03	R 68 109 923.03	R 68 109 923.03	R 68 109 923.03	R 68 109 923.03	R 68 109 923.03	R 68 109 923.03	R 68 109 923.03	R 68 109 923.03
Annual Cash Flow		R 52 520 492.47	R 52 520 492.47	R 52 520 492.47	R 52 520 492.47	R 52 520 492.47	R 52 520 492.47	R 52 520 492.47	R 52 520 492.47	R 52 520 492.47	R 52 520 492.47
Annual Depreciation and Other Tax Allowances		R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37	R 8 415 244.37
Amount of Tax		12349469.47	12349469.47	12349469.47	12349469.47	12349469.47	12349469.47	12349469.47	12349469.47	12349469.47	12349469.47
Total Annual Capital Expenditure	R 84 152 443.74	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Net Annual Cash Flow	R -84 152 443.74	R 40 171 023.01	R 40 171 023.01	R 40 171 023.01	R 40 171 023.01	R 40 171 023.01	R 40 171 023.01	R 40 171 023.01	R 40 171 023.01	R 40 171 023.01	R 40 171 023.01
Discount Factor	1.00	0.94	0.89	0.83	0.79	0.74	0.70	0.66	0.62	0.58	0.55
Net Annual Discounted Cash Flow	R -84 152 443.74	R 37 822 260.62	R 35 610 828.19	R 33 528 696.16	R 31 568 304.45	R 29 722 535.03	R 27 984 686.02	R 26 348 447.44	R 24 807 878.20	R 23 357 384.62	R 21 991 700.04
Net Present Value	R -84 152 443.74	R -46 330 183.12	R -10 719 354.93	R 22 809 341.23	R 54 377 645.68	R 84 100 180.71	R 112 084 866.73	R 138 433 314.17	R 163 241 192.37	R 186 598 576.99	R 208 590 277.04

Figure B.99: NPV Calculations for Coldstream Process (75 kg/h) Throughput 10

Appendix C

Zinc Recycling Process Raw Data

25.15.18 Cost Center Activity
Pilot Tools (Pty) Ltd

Date: 09/03/18
Time: 09:14:53

Pilot Tools (Pty) Ltd   Reporting Currency: ZAR
Exchange Rate:

CC	Description	Account	Description	Period Activity 01/03/17 - 28/02/18	CC Total
212	PRZ	20102	Plant & Equipment	51,524.38	
		20102-W3600	Plant & Equipment	0.00	
		21300	Prepay Creditors ZAR	0.00	
		21300-W3600	Prepay Creditors ZAR	0.00	
		21444	Prepay-Brightmail	0.00	
		31310	VAT Input - Capital Good	0.00	
		71200	W/O & Recovery of Item	0.00	
		71404-W1115	Labour Usage & Rate Var	0.00	
		71404-W1155	Labour Usage & Rate Var	0.00	
		71404-W1170	Labour Usage & Rate Var	0.00	
		71404-W2950	Labour Usage & Rate Var	0.00	
		71404-W3600	Labour Usage & Rate Var	0.00	
		71406-W1115	Non Productive Lab Var	0.00	
		71406-W1155	Non Productive Lab Var	0.00	
		71406-W1170	Non Productive Lab Var	0.00	
		71406-W2950	Non Productive Lab Var	0.00	
		71406-W3600	Non Productive Lab Var	0.00	
		71408-W1115	Burden Usage & Rate Var	0.00	
		71408-W1155	Burden Usage & Rate Var	0.00	
		71408-W1170	Burden Usage & Rate Var	0.00	
		71408-W2950	Burden Usage & Rate Var	0.00	
		71408-W3600	Burden Usage & Rate Var	0.00	
		71500-W1115	Applied Labour	2,239.20cr	
		71500-W1155	Applied Labour	911.45cr	
		71500-W1170	Applied Labour	0.00	
		71500-W2950	Applied Labour	1,680.00cr	
		71500-W3600	Applied Labour	11,848.79cr	
		71502-W1115	Applied Burden	7,169.70cr	
		71502-W1155	Applied Burden	0.00	
		71502-W1170	Applied Burden	0.00	

25.15.18 Cost Center Activity
Pilot Tools (Pty) Ltd

Date: 09/03/18
Time: 09:14:53

Pilot Tools (Pty) Ltd

Reporting Currency: ZAR
Exchange Rate:

CC	Description	Account	Description	Period Activity 01/03/17 - 28/02/18	CC Total
212	PRZ (Cont.)	71502-W2950	Applied Burden	1,148.49cr	
		71502-W3600	Applied Burden	62,774.34cr	
		80100	Material Tests	0.00	
		80100-w3030	Material Tests	0.00	
		80100-w3600	Material Tests	0.00	
		80100-W8110	Material Tests	0.00	
		80310	Wages- Payroll	117,819.04	
		80311	Wages- Non Payroll	0.00	
		80340	Food and Beverages	0.00	
		80361	Clothing and Gear	0.00	
		80361-W3600	Clothing and Gear	0.00	
		80416	Security Services	0.00	
		80416-w3600	Security Services	0.00	
		80418	Production Service	2,088.00	
		80499-w3600	Other- Consulting Servic	0.00	
		80600	Vehicle-Running Costs	0.00	
		80640	Buildings- Write Off	9,000.00	
		80641	Plant&Equip- Write Off	17,787.29	
		80641-W3600	Plant&Equip- Write Off	0.00	
		80642	Furn&Equip- Write Off	0.00	
		80646	Jigs,Fixture & PressTool	0.00	
		80648	Hand & Small Tools	576.88	
		80648-W3300	Hand & Small Tools	427.93	
		80648-W3600	Hand & Small Tools	473.75	
		80700	Repairs&Maint-Buildings	7,528.94	
		80700-W3600	Repairs&Maint-Buildings	0.00	
		80720	Repairs&Maint-Plant&Equi	222,453.93	
		80720-w1100	Repairs&Maint-Plant&Equi	3,210.00	
		80720-w1115	Repairs&Maint-Plant&Equi	785.27	
		80720-w1120	Repairs&Maint-Plant&Equi	10,618.74	

25.15.18 Cost Center Activity
Pilot Tools (Pty) Ltd

Date: 09/03/18
Time: 09:14:53

Pilot Tools (Pty) Ltd   Reporting Currency: ZAR
Exchange Rate:

CC	Description	Account	Description	Period Activity 01/03/17 - 28/02/18	CC Total
212	PRZ (Cont.)	80720-W1155	Repairs&Maint-Plant&Equi	0.00	
		80720-w1400	Repairs&Maint-Plant&Equi	0.00	
		80720-W1410	Repairs&Maint-Plant&Equi	0.00	
		80720-W2630	Repairs&Maint-Plant&Equi	0.00	
		80720-W2950	Repairs&Maint-Plant&Equi	0.00	
		80720-w3600	Repairs&Maint-Plant&Equi	9,306.80	
		80800	Gas	1,560.26	
		80800-w1120	Gas	0.00	
		80800-W3600	Gas	0.00	
		80806	Lubricants & Coolants	5,564.24	
		80806-W3600	Lubricants & Coolants	2,541.92	
		80810	Wheels	67.54	
		80814	Zinc	477,861.95	
		80814-w3600	Zinc	132,547.60	
		80820	Cleaning Production Cons	3,160.39	
		80820-W3600	Cleaning Production Cons	0.00	
		80822-W3600	Cutting Tools	153.45	
		80838	Insulation	15,269.03	
		80838-w2600	Insulation	743.30	
		80838-W3600	Insulation	743.30	
		80899	Other consumables	0.00	
		80899-w1100	Other consumables	0.00	
		80899-W1115	Other consumables	0.00	
		80899-W2020	Other consumables	0.00	
		80899-w2950	Other consumables	0.00	
		80899-w3000	Other consumables	0.00	
		80899-W3100	Other consumables	0.00	
		80899-W3240	Other consumables	0.00	
		80899-W3600	Other consumables	0.00	
		81100	Electricity	652,602.14	

25.15.18 Cost Center Activity
Pilot Tools (Pty) Ltd

Date: 09/03/18
Time: 09:14:53

Pilot Tools (Pty) Ltd

Reporting Currency: ZAR
Exchange Rate:

CC	Description	Account	Description	Period Activity 01/03/17 - 28/02/18	CC Total
212	PRZ (Cont.)	81100-w3600	Electricity	0.00	
		81102	Water and Refuse	24,690.49	
		81104	Rates	8,613.64	
		81108	Generator Running Costs	0.00	
		81300	Telephones	921.45	
		81500	Interest Paid	13.62	
					1,692,883.35
					1,692,883.35

End of Report

25.15.18 Cost Center Activity
Pilot Tools (Pty) Ltd

Report Criteria:

Report Submitted By: marpre

Entity:	A	To: A
Description:	Pilot Tools (Pty) Ltd	
Cost Center:	212	To: 212
Account:		To:
Sub-Account:		To:
Effective Date:	01/03/17	To: 28/02/18
Suppress Zeroes:	No	
Round to Nearest Whole Unit:	No	
Reporting Currency:	ZAR	

Output: 13
Batch ID:

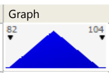
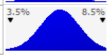
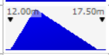
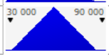
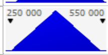
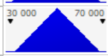
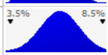
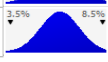
Appendix D

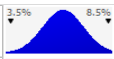
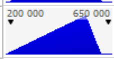
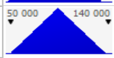
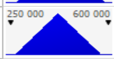
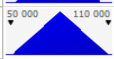
Monte-Carlo Simulation Model Inputs

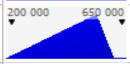
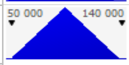
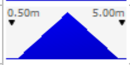
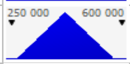
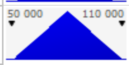
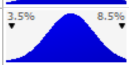
D.1 Simulation Inputs

@RISK Model Inputs

Performed By: De Wet du Toit
Date: 30 June 2018 18:20:50

Name	Worksheet	Cell	Graph	Function	Min	Mean	Max
WC Powder PRICE	Global Variables	D6		RiskTriang(E31,G31,F31,RiskStatic(G31),RiskName("WC Powder PRICE "))	82.8	92.59	102.48
Rand per USD	Global Variables	J4		RiskNormal(13.0464,1.3232,RiskStatic(12.47),RiskName("Rand per USD"))	-∞	R13.05	+∞
Rand per Euro	Global Variables	J5		RiskNormal(15.3038,1.6356,RiskStatic(14.6),RiskName("Rand per Euro"))	-∞	R15.30	+∞
Income Tax Rates	Global Variables	J9		RiskTriang(I13,K13,J13,RiskStatic(K13),RiskName("Income Tax Rates"))	0.266	0.289333	0.322
ZincRepo2019	ZincRISK(45kghr)	D79		RiskNormal(0.0619735,0.0094991,RiskStatic(0.0621),RiskName("ZincRepo2019"))	-∞	0.061974	+∞
ZincRepo2020	ZincRISK(45kghr)	E79		RiskNormal(0.0619735,0.0094991,RiskStatic(0.0621),RiskName("ZincRepo2020"))	-∞	0.061974	+∞
Zinc_EquipmentCost	ZincRISK(45kghr)	F3		RiskTriang(G3,I3,H3,RiskStatic(I3),RiskName("Zinc_EquipmentCost"))	R12 268 490.00	R14 313 240.00	R17 039 570.00
Zinc_Annual Interest Rate	ZincRISK(45kghr)	F22		RiskTriang(G22,I22,H22,RiskStatic(I22),RiskName("Zinc_Annual Interest Rate"))	0.05125	0.1025	0.15375
Zinc_Raw Materials	ZincRISK(45kghr)	F39		RiskTriang(G39,I39,H39,RiskStatic(I39),RiskName("Zinc_Raw Materials"))	R20 151 590.00	R29 107 850.00	R40 303 180.00
Zinc_Operating Labour	ZincRISK(45kghr)	F40		RiskTriang(G40,I40,H40,RiskName("Zinc_Operating Labour"))	R203 184.00	R336 648.00	R603 576.00
Zinc_Clerical and Supervisory Labour	ZincRISK(45kghr)	F43		RiskTriang(G43,I43,H43,RiskStatic(I43),RiskName("Zinc_Clerical and Supervisory Labour"))	R33 664.80	R58 913.40	R84 162.00
Zinc_Maintenance	ZincRISK(45kghr)	F44		RiskTriang(G44,I44,H44,RiskStatic(I44),RiskName("Zinc_Maintenance "))	R888 160.90	R2 664 483.00	R4 440 805.00
Zinc_Operating Supplies	ZincRISK(45kghr)	F45		RiskTriang(G45,I45,H45,RiskStatic(I45),RiskName("Zinc_Operating Supplies"))	R266 448.30	R399 672.40	R532 896.50
Zinc_Laboratory Charges	ZincRISK(45kghr)	F46		RiskTriang(G46,I46,H46,RiskStatic(I46),RiskName("Zinc_Laboratory Charges "))	R33 664.80	R50 497.20	R67 329.60
Zinc_Patents & Royalties	ZincRISK(45kghr)	F47		RiskTriang(G47,I47,H47,RiskStatic(I47),RiskName("Zinc_Patents & Royalties"))	R0.00	R1 406 233.00	R2 812 466.00
Zinc_Local Taxes	ZincRISK(45kghr)	F51		RiskTriang(G51,I51,H51,RiskStatic(I51),RiskName("Zinc_Local Taxes"))	R621 712.60	R1 421 057.00	R2 220 402.00
Zinc_Overhead Costs	ZincRISK(45kghr)	F52		RiskTriang(G52,I52,H52,RiskStatic(I52),RiskName("Zinc_Overhead Costs"))	R1 361 698.00	R1 634 038.00	R1 906 377.00
Zinc_Zinc_Distribution	ZincRISK(45kghr)	F56		RiskTriang(G56,I56,H56,RiskStatic(I56),RiskName("Zinc_Zinc_Distribution"))	R937 488.50	R5 156 187.00	R9 374 885.00
Zinc_Zinc_Efficiency	ZincRISK(45kghr)	F63		RiskTriang(G63,I63,H63,RiskStatic(I63),RiskName("Zinc_Zinc_Efficiency"))	R68 357 230.00	R72 110 180.00	R78 007 670.00
ZincRepo2021	ZincRISK(45kghr)	F79		RiskNormal(0.0619735,0.0094991,RiskStatic(0.0621),RiskName("ZincRepo2021"))	-∞	0.061974	+∞
ZincRepo2022	ZincRISK(45kghr)	G79		RiskNormal(0.0619735,0.0094991,RiskStatic(0.0621),RiskName("ZincRepo2022"))	-∞	0.061974	+∞
ZincRepo2023	ZincRISK(45kghr)	H79		RiskNormal(0.0619735,0.0094991,RiskStatic(0.0621),RiskName("ZincRepo2023"))	-∞	0.061974	+∞
ZincRepo2024	ZincRISK(45kghr)	I79		RiskNormal(0.0619735,0.0094991,RiskStatic(0.0621),RiskName("ZincRepo2024"))	-∞	0.061974	+∞
ZincRepo2025	ZincRISK(45kghr)	J79		RiskNormal(0.0619735,0.0094991,RiskStatic(0.0621),RiskName("ZincRepo2025"))	-∞	0.061974	+∞
ZincRepo2026	ZincRISK(45kghr)	K79		RiskNormal(0.0619735,0.0094991,RiskStatic(0.0621),RiskName("ZincRepo2026"))	-∞	0.061974	+∞

ZincRepo2027	ZincRISK(45kghr)	L79		RiskNormal(0.0619735,0.0094991,RiskStatic(0.0621),RiskName("ZincRepo2027"))	-∞	0.061974	+∞
ZincRepo2028	ZincRISK(45kghr)	M79		RiskNormal(0.0619735,0.0094991,RiskStatic(0.0621),RiskName("ZincRepo2028"))	-∞	0.061974	+∞
Zinc_electricity_per_kg	ZincRISK(45kghr)	O41		RiskNormal(5.99379,0.44081,RiskStatic('Global Variables'!M34),RiskName("Zinc_electricity_per_kg"))	-∞	R5.99	+∞
ColdRepo2019	ColdstreamRISK(44kghr)	D79		RiskNormal(0.0619735,0.0094991,RiskStatic(0.0621),RiskName("ColdRepo2019"))	-∞	0.061974	+∞
ColdRepo2020	ColdstreamRISK(44kghr)	E79		RiskNormal(0.0619735,0.0094991,RiskStatic(0.0621),RiskName("ColdRepo2020"))	-∞	0.061974	+∞
Coldstream_Equipment Cost	ColdstreamRISK(44kghr)	F3		RiskTriang(G3,I3,H3,RiskStatic(I3),RiskName("Coldstream_Equipment Cost"))	R12 958 080.00	R15 117 760.00	R17 997 340.00
Coldstream_AnnualInterestRate	ColdstreamRISK(44kghr)	F22		RiskTriang(G22,I22,H22,RiskStatic(I22),RiskName("Coldstream_AnnualInterestRate"))	0.05125	0.1025	0.15375
Coldstream_RawMaterials	ColdstreamRISK(44kghr)	F39		RiskTriang(G39,I39,H39,RiskStatic(I39),RiskName("Coldstream_RawMaterials"))	R10 455 220.00	R15 101 980.00	R20 910 440.00
Coldstream_Operating Labour	ColdstreamRISK(44kghr)	F40		RiskTriang(G40,I40,H40,RiskStatic(I40),RiskName("Coldstream_Operating Labour"))	R203 184.00	R448 200.00	R603 576.00
Coldstream_Clerical and Supervisory Labour	ColdstreamRISK(44kghr)	F43		RiskTriang(G43,I43,H43,RiskStatic(I43),RiskName("Coldstream_Clerical and Supervisory Labour"))	R53 784.00	R94 122.00	R134 460.00
Coldstream_Maintenance	ColdstreamRISK(44kghr)	F44		RiskTriang(G44,I44,H44,RiskStatic(I44),RiskName("Coldstream_Maintenance "))	R938 082.90	R2 814 249.00	R4 690 415.00
Coldstream_Operating Supplies	ColdstreamRISK(44kghr)	F45		RiskTriang(G45,I45,H45,RiskStatic(I45),RiskName("Coldstream_Operating Supplies"))	R281 424.80	R422 137.30	R562 849.70
Coldstream_Laboratory Charges	ColdstreamRISK(44kghr)	F46		RiskTriang(G46,I46,H46,RiskStatic(I46),RiskName("Coldstream_Laboratory Charges"))	R53 784.00	R80 676.00	R107 568.00
Coldstream_Patents & Royalties	ColdstreamRISK(44kghr)	F47		RiskTriang(G47,I47,H47,RiskStatic(I47),RiskName("Coldstream_Patents & Royalties"))	R0.00	R956 736.10	R1 913 472.00
Coldstream_Local Taxes	ColdstreamRISK(44kghr)	F51		RiskTriang(G51,I51,H51,RiskStatic(I51),RiskName("Coldstream_Local Taxes "))	R656 658.00	R1 500 933.00	R2 345 207.00
Coldstream_Overhead Costs	ColdstreamRISK(44kghr)	F52		RiskTriang(G52,I52,H52,RiskStatic(I52),RiskName("Coldstream_Overhead Costs"))	R1 454 185.00	R1 745 022.00	R2 035 859.00
Coldstream_Distribution	ColdstreamRISK(44kghr)	F56		RiskTriang(G56,I56,H56,RiskStatic(I56),RiskName("Coldstream_Distribution"))	R637 824.10	R3 508 032.00	R6 378 241.00
Coldstream_Efficiency	ColdstreamRISK(44kghr)	F63		RiskTriang(G63,I63,H63,RiskStatic(I63),RiskName("Coldstream_Efficiency"))	R48 252 170.00	R52 273 180.00	R56 294 190.00
ColdRepo2021	ColdstreamRISK(44kghr)	F79		RiskNormal(0.0619735,0.0094991,RiskStatic(0.0621),RiskName("ColdRepo2021"))	-∞	0.061974	+∞
ColdRepo2022	ColdstreamRISK(44kghr)	G79		RiskNormal(0.0619735,0.0094991,RiskStatic(0.0621),RiskName("ColdRepo2022"))	-∞	0.061974	+∞
ColdRepo2023	ColdstreamRISK(44kghr)	H79		RiskNormal(0.0619735,0.0094991,RiskStatic(0.0621),RiskName("ColdRepo2023"))	-∞	0.061974	+∞
ColdRepo2024	ColdstreamRISK(44kghr)	I79		RiskNormal(0.0619735,0.0094991,RiskStatic(0.0621),RiskName("ColdRepo2024"))	-∞	0.061974	+∞
ColdRepo2025	ColdstreamRISK(44kghr)	J79		RiskNormal(0.0619735,0.0094991,RiskStatic(0.0621),RiskName("ColdRepo2025"))	-∞	0.061974	+∞
ColdRepo2026	ColdstreamRISK(44kghr)	K79		RiskNormal(0.0619735,0.0094991,RiskStatic(0.0621),RiskName("ColdRepo2026"))	-∞	0.061974	+∞
ColdRepo2027	ColdstreamRISK(44kghr)	L79		RiskNormal(0.0619735,0.0094991,RiskStatic(0.0621),RiskName("ColdRepo2027"))	-∞	0.061974	+∞
ColdRepo2028	ColdstreamRISK(44kghr)	M79		RiskNormal(0.0619735,0.0094991,RiskStatic(0.0621),RiskName("ColdRepo2028"))	-∞	0.061974	+∞
Coldstream_Electricity_per_kg	ColdstreamRISK(44kghr)	O41		RiskNormal(1.40641,0.10343,RiskStatic('Global Variables'!M35),RiskName("Coldstream_Electricity_per_kg"))	-∞	R1.41	+∞

ZincRepo2027	ZincRISK(45kghr)	L79		RiskNormal(0.0619735,0.0094991,RiskStatic(0.0621),RiskName("ZincRepo2027"))	-∞	0.061974	+∞
ZincRepo2028	ZincRISK(45kghr)	M79		RiskNormal(0.0619735,0.0094991,RiskStatic(0.0621),RiskName("ZincRepo2028"))	-∞	0.061974	+∞
Zinc_electricity_per_kg	ZincRISK(45kghr)	O41		RiskNormal(5.99379,0.44081,RiskStatic('Global Variables'!M34),RiskName("Zinc_electricity_per_kg"))	-∞	R5.99	+∞
ColdRepo2019	ColdstreamRISK(44kghr)	D79		RiskNormal(0.0619735,0.0094991,RiskStatic(0.0621),RiskName("ColdRepo2019"))	-∞	0.061974	+∞
ColdRepo2020	ColdstreamRISK(44kghr)	E79		RiskNormal(0.0619735,0.0094991,RiskStatic(0.0621),RiskName("ColdRepo2020"))	-∞	0.061974	+∞
Coldstream_Equipment Cost	ColdstreamRISK(44kghr)	F3		RiskTriang(G3,I3,H3,RiskStatic(I3),RiskName("Coldstream_Equipment Cost"))	R12 958 080.00	R15 117 760.00	R17 997 340.00
Coldstream_AnnualInterestRate	ColdstreamRISK(44kghr)	F22		RiskTriang(G22,I22,H22,RiskStatic(I22),RiskName("Coldstream_AnnualInterestRate"))	0.05125	0.1025	0.15375
Coldstream_RawMaterials	ColdstreamRISK(44kghr)	F39		RiskTriang(G39,I39,H39,RiskStatic(I39),RiskName("Coldstream_RawMaterials"))	R10 455 220.00	R15 101 980.00	R20 910 440.00
Coldstream_Operating Labour	ColdstreamRISK(44kghr)	F40		RiskTriang(G40,I40,H40,RiskStatic(I40),RiskName("Coldstream_Operating Labour"))	R203 184.00	R448 200.00	R603 576.00
Coldstream_Clerical and Supervisory Labour	ColdstreamRISK(44kghr)	F43		RiskTriang(G43,I43,H43,RiskStatic(I43),RiskName("Coldstream_Clerical and Supervisory Labour"))	R53 784.00	R94 122.00	R134 460.00
Coldstream_Maintenance	ColdstreamRISK(44kghr)	F44		RiskTriang(G44,I44,H44,RiskStatic(I44),RiskName("Coldstream_Maintenance "))	R938 082.90	R2 814 249.00	R4 690 415.00
Coldstream_Operating Supplies	ColdstreamRISK(44kghr)	F45		RiskTriang(G45,I45,H45,RiskStatic(I45),RiskName("Coldstream_Operating Supplies"))	R281 424.80	R422 137.30	R562 849.70
Coldstream_Laboratory Charges	ColdstreamRISK(44kghr)	F46		RiskTriang(G46,I46,H46,RiskStatic(I46),RiskName("Coldstream_Laboratory Charges"))	R53 784.00	R80 676.00	R107 568.00
Coldstream_Patents & Royalties	ColdstreamRISK(44kghr)	F47		RiskTriang(G47,I47,H47,RiskStatic(I47),RiskName("Coldstream_Patents & Royalties"))	R0.00	R956 736.10	R1 913 472.00
Coldstream_Local Taxes	ColdstreamRISK(44kghr)	F51		RiskTriang(G51,I51,H51,RiskStatic(I51),RiskName("Coldstream_Local Taxes "))	R656 658.00	R1 500 933.00	R2 345 207.00
Coldstream_Overhead Costs	ColdstreamRISK(44kghr)	F52		RiskTriang(G52,I52,H52,RiskStatic(I52),RiskName("Coldstream_Overhead Costs"))	R1 454 185.00	R1 745 022.00	R2 035 859.00
Coldstream_Distribution	ColdstreamRISK(44kghr)	F56		RiskTriang(G56,I56,H56,RiskStatic(I56),RiskName("Coldstream_Distribution"))	R637 824.10	R3 508 032.00	R6 378 241.00
Coldstream_Efficiency	ColdstreamRISK(44kghr)	F63		RiskTriang(G63,I63,H63,RiskStatic(I63),RiskName("Coldstream_Efficiency"))	R48 252 170.00	R52 273 180.00	R56 294 190.00
ColdRepo2021	ColdstreamRISK(44kghr)	F79		RiskNormal(0.0619735,0.0094991,RiskStatic(0.0621),RiskName("ColdRepo2021"))	-∞	0.061974	+∞
ColdRepo2022	ColdstreamRISK(44kghr)	G79		RiskNormal(0.0619735,0.0094991,RiskStatic(0.0621),RiskName("ColdRepo2022"))	-∞	0.061974	+∞
ColdRepo2023	ColdstreamRISK(44kghr)	H79		RiskNormal(0.0619735,0.0094991,RiskStatic(0.0621),RiskName("ColdRepo2023"))	-∞	0.061974	+∞
ColdRepo2024	ColdstreamRISK(44kghr)	I79		RiskNormal(0.0619735,0.0094991,RiskStatic(0.0621),RiskName("ColdRepo2024"))	-∞	0.061974	+∞
ColdRepo2025	ColdstreamRISK(44kghr)	J79		RiskNormal(0.0619735,0.0094991,RiskStatic(0.0621),RiskName("ColdRepo2025"))	-∞	0.061974	+∞
ColdRepo2026	ColdstreamRISK(44kghr)	K79		RiskNormal(0.0619735,0.0094991,RiskStatic(0.0621),RiskName("ColdRepo2026"))	-∞	0.061974	+∞
ColdRepo2027	ColdstreamRISK(44kghr)	L79		RiskNormal(0.0619735,0.0094991,RiskStatic(0.0621),RiskName("ColdRepo2027"))	-∞	0.061974	+∞
ColdRepo2028	ColdstreamRISK(44kghr)	M79		RiskNormal(0.0619735,0.0094991,RiskStatic(0.0621),RiskName("ColdRepo2028"))	-∞	0.061974	+∞
Coldstream_Electricity_per_kg	ColdstreamRISK(44kghr)	O41		RiskNormal(1.40641,0.10343,RiskStatic('Global Variables'!M35),RiskName("Coldstream_Electricity_per_kg"))	-∞	R1.41	+∞

D.2 Simulation Results

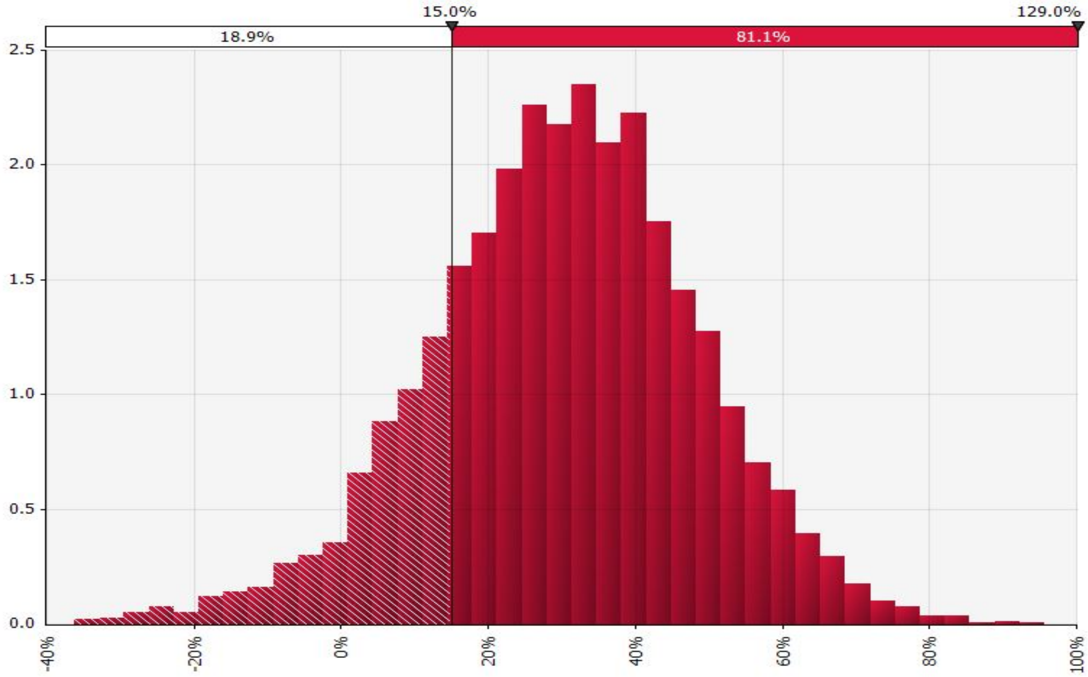


Figure D.1: Zinc Process IRR Probability Density Function

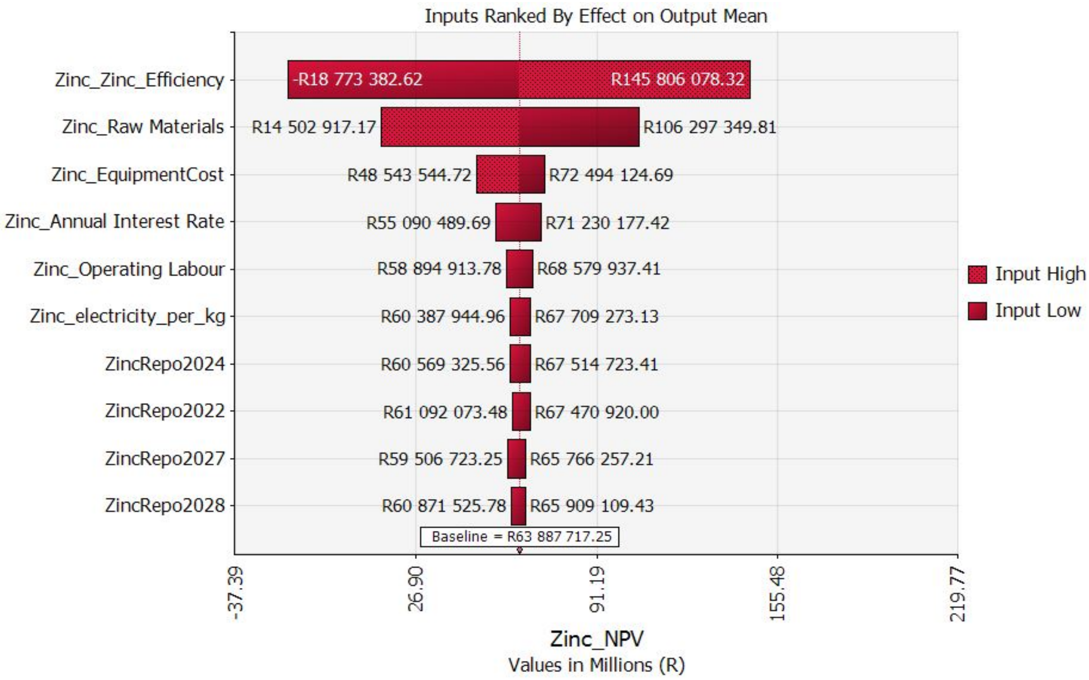


Figure D.2: Zinc Process NPV Tornado Graph

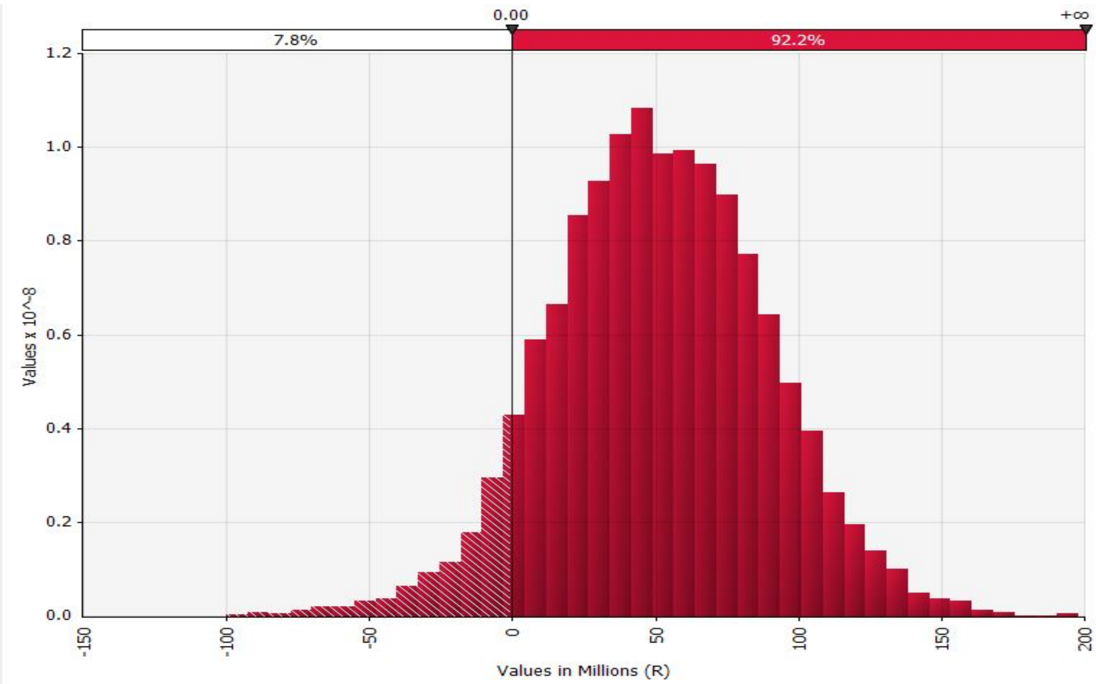


Figure D.3: Coldstream Process NPV Probability Density Function

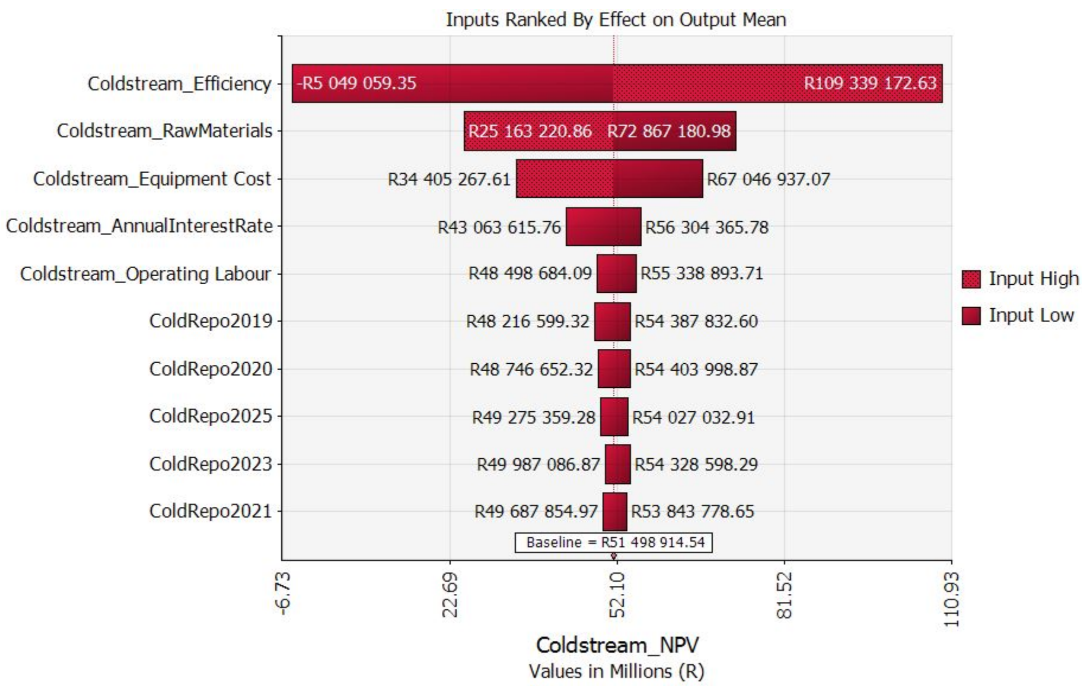


Figure D.4: Coldstream Process NPV Tornado Graph

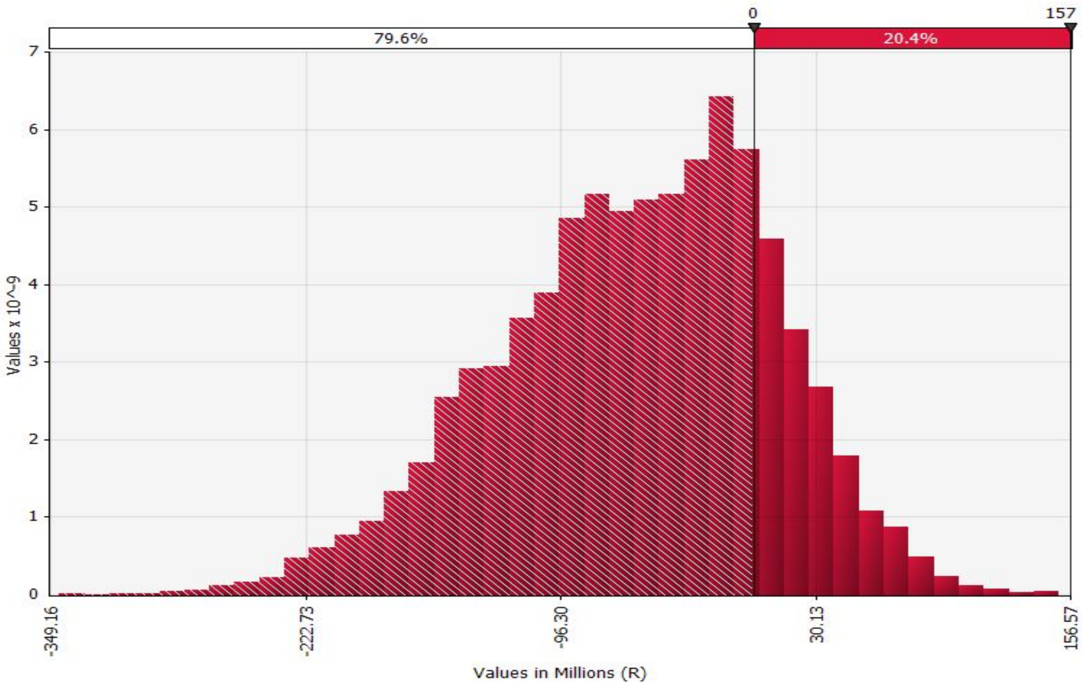


Figure D.5: Acid Leach Process NPV Probability Density Function

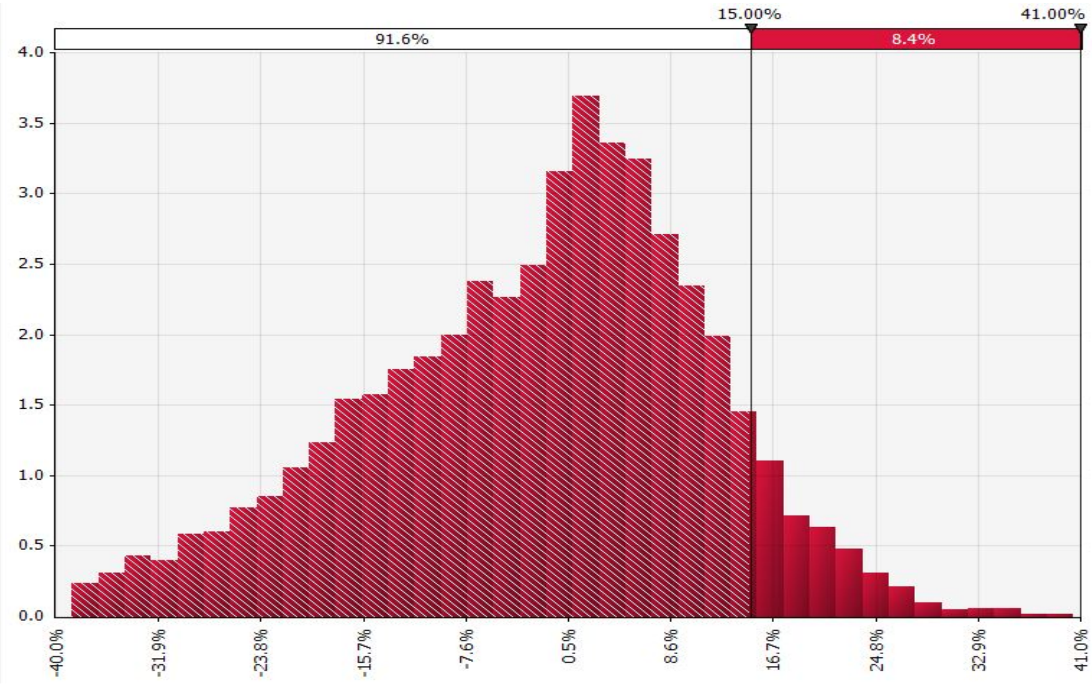


Figure D.6: Acid Leach Process IRR Probability Density Function

Appendix E

QUOTATIONS

E.1 Ball Mill Quote and Technical Data

DOVE INSTRUMENTS

BALL MILL

Major Manufacturer / Supplier of Instruments, Tools & Accessories for Mining, Minerals Processing, Minerals Exploration, Identification and Treatment.

Ball Mill is a major product, professional technology support and all around service can be offered to you. We can also make according to your special requirements.

APPLICATION:

Ball Mill is generally used to grind material 1/4 inch and finer, down to particle size of 20 to 75 microns. To achieve a reasonable efficiency with ball mills, they must be operated in a closed system, with oversize material continuously being circulated back into the mill to be reduced. Various classifiers, such as screens, spiral classifiers, cyclones and air classifiers are used for classifying the discharge from ball mills. Ball Mill is an efficient tool for grinding material into fine powder. It is also used to grind any kinds of mine and other materials. It is widely used in building material, chemical industry, etc. There are two ways of grinding: the dry process and wet process. It can be divided into tabular type and flowing type according to different forms of discharging material.

UNIQUE FEATURES:

- The longer the Ball Mill runs, the finer the powder will be.
- Ultimate particle size depends entirely on how hard the material you're grinding is, and how long the time the Ball Mill runs.

DOVE INSTRUMENTS
(Subsidiary of Dove Equipment & Machinery Co., Ltd.)
216 RAMA-III ROAD , BANGKHOLAEM, BANGKOK 10120, THAILAND
TEL : (+662) 689 - 3750 - 4
FAX : (+662) 689 - 3850 - 1
EMAIL : CORPORATE@DOVEINSTRUMENTS.COM
WWW.DOVEINSTRUMENTS.COM

BALL MILL

- Our Ball Mills have been used to grind glass, powder food products, create custom varnishes, make ceramic glaze, powder of various chemicals.

TECHNICAL SPECIFICATIONS	
Model:	**DI-BM0918**
Drum Size:	0.9 x 1.8 m
Speed:	38.8 r/min
Ball Weight:	2 tons
Feed Size:	0 – 20 mm
Output Size:	0.074 – 0.6 mm
Capacity:	0.4 – 2.14 t/h
Power:	18 kW
Total Weight:	5.34 ton
Dimension size:	3800x1500x1700mm

DOVE

DOVE INSTRUMENTS
A DIVISION OF
(DOVE EQUIPMENT & MACHINERY CO., LTD.)
216 RAMA III ROAD, BANGKHOLAEM, BANGKOK 10120, THAILAND
TEL : (662) 689-3750/54 FAX : (662) 689-3850 E-MAIL : SALES@DOVEINSTRUMENTS.COM WEBSITE : WWW.DOVEINSTRUMENTS.COM

MAJOR MANUFACTURER / SUPPLIER OF INSTRUMENTS, TOOLS & ACCESSORIES FOR MINING AND EXPLORATION

PROFORMA INVOICE

CUSTOMER

Name :	**Mr. De Wet Du Toit**
Company :	**Stellenbosch University**
Address :	15 Joubert Street, Stellenbosch 7600 South Africa
Tel/E-mail	Mobile: +27609972173
Payment :	100% Telegraphic Transfer
Term:	

No. :	**PSST180417**
Date :	**17 Apr 18**
Pages :	**1**
Validity :	**2 weeks**
Delivery :	**1-7 days**
(Ex-Work) :	**Thailand**

NO	CODE	DESCRIPTION	QTY	UNIT	UNIT PRICE (USD)	TOTAL PRICE (USD)
1.0	DI-BM0918	**WET BALL MILL**	1	SET	26,972.00	**26,972.00**
		CAPACITY: 0.4-2.14 TPH				
		FEEDING SIZE: 0-20 MM				
		OUTPUT SIZE: 0.074-0.6 MM				
		DRUM SIZE: 0.9X1.8 M				
		SPEED: 38.8 R/MIN				
		POWER:18 KW				
		WEIGHT: 5.34 TON				
		DIMENSION: 3800X1500X1700 MM				
1.1		**CHROMED FORGED CARBON STEEL BALLS**	1	SET	6,120.00	**6,120.00**
		WEIGHT OF BALL: 2 TONS				
		** WARRANTY: 1 YEAR MANUFACTURING WARRANTY.*				
		** ALL SALES ARE FINAL, IN CASE OF MANUFACTURING DEFECT PLEASE CONTACT **DO®VE** INSTRUMENTS AT **INFO@DOVEINSTRUMENTS.COM**. ANY CLAIMS OR RETURNS MUST BE MADE WITHIN 5 DAYS UPON THE PRODUCT DELIVERY TO THE FINAL DESTINATION.*				
		**** THIS QUOTATION IS PROPERTY OF DO®VE Equipment & Machinery Co., Ltd. ITS CONTENTS ARE CONFIDENTIAL AND IS SOLELY FOR THE INFORMATION AND USE OF THE QUOTATION DESCRIBED HEREIN. SUCH PROPRIETARY INFOMRATION MAY NOT BE USED, REPRODUCED OR DISCLOSED TO ANY PARTIES OR USED INDIRECTLY FOR ANY OTHER PURPOSE THAN AS EXPRESSLY DETERMINED IN WRITING BY DO®VE Equipment & Machinery Co., Ltd.***				
		TOTAL AMOUNT EX-WORKS, THAILAND				**33,092.00**

PREPARED BY:	MANAGER:	APPROVED BY:	CUSTOMER APPROVED:	DATE:

E.2 Furnace Quote and Technical Data

Heinrich-Hertz-Platz 1
92275 Eschenfelden / Germany
Phone: +49 9665 9140-0
Fax: +49 9665 1720
info@linn.de
www.linn.de

Stellenbosch University
44 Witzenberglaan
6835 Ceres
South Africa

2018-04-03
Yu / Zi

QUOTATION NO: 115677
****

Dear Sirs,

We thank you for your inquiry. Subject to our attached General Terms of Sale and Delivery green/white which are an essential part of this quotation and contain the right of property we will quote as follows:

1 pc. Rotary tubular furnace type FDHK-3-250/1000/1000

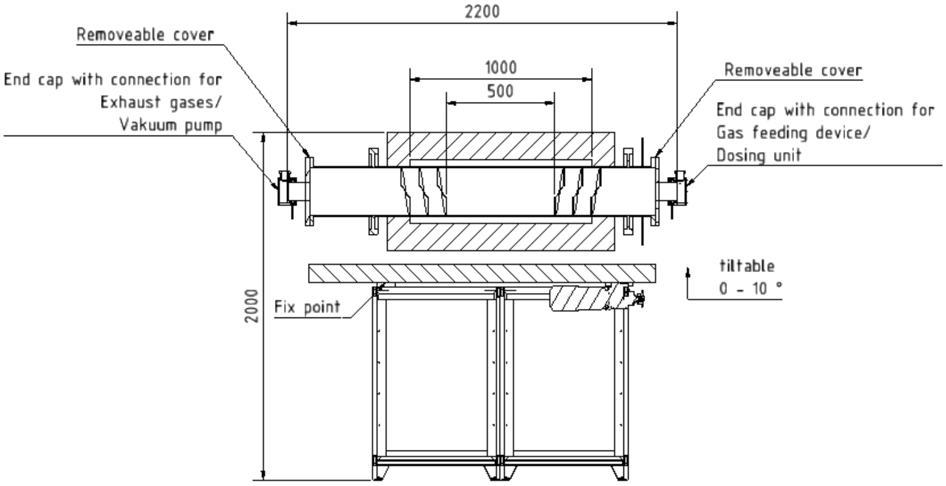
Electrical heated, 3-zoned fibre insulated rotary tubular furnace with rotating insert tube and adjustable sloping position up to 10°.

Technical specifications:

inner diameter furnace	appr. 350 mm
max. outer tube diameter	appr. 275 mm
heated length	appr. 1000 mm (250/500/250 mm)
temperature constant zone	appr. 500 mm
continuous operating temperature	appr. 1000 °C
max. temperatur short time	appr. 1050 °C
temperature uniformity	appr. ± 10 °C and better in the middle of the furnace. This depends on insert load, control unit and tightly closed ends.

heating up time to 1000 °C	appr. 35 minutes at empty furnace without insert tube at closed ends.
heating	FeCrAl-Alloy wire
outside dimensions of furnace with underframe and insert tube	appr. 2800x800x1800 mm (WxDxH)
power density:	app. 195 W/dm³
heating power:	app. 18 kW (5,0/8,8/5,0 kW)
mains input:	app. 25 kVA
Voltage:	390 V / 50 Hz / 3 Ph / PE / N
weight	app. 1300 kg

Short Description



Furnace housing with rotary and tilting device

The furnace housing consists of a stainless steel construction and is equipped on a tilting frame. Low outside wall temperatures are achieved by a circulating air layer between the insulation and the sheet-metal case.

The furnace is designed for batch operation. The Furnace is mounted on a tilting frame which is fixed on a sub-frame. The tilting frame can be manually adjusted for a furnace inclination of 0° up to 10° by a lifting tackle. The rotating tube drive is fixed on the tilting frame and drives the rotating tube via a chain wheel. Via the engine with frequency converter, which is variably adjustable up to 10 U/min, the rotation speed and direction can be adjusted infinitely variable. The longitudinal extension of the insert tube is in direction of the furnace product exit.

Furthermore the furnace is easy to handle.

Insulation

The insulation consists exclusively of ceramic fibre material. Mainly alumina fibre boards are used. Due to the thin walled low accumulating materials fast heating up and cooling down cycles are possible.

Heating

The furnace is heated with FeCrAl-Alloy heating coils which are embedded on the inner diameter of the boards in a ceramic fibre module and 3-zoned switched. The rotating tubular furnace is equipped with power reserves so that the requested temperature- and controlling accuracy could be achieved.

Rotary insert tube

The tubes are offered in different materials as an option.

Thermocouples

In the middle of each heating zone, a NiCr-Ni double thermocouple type K is installed. One of these thermocouples is lead to the appropriate temperature controller, another one to the safety controller, which act as over temperature protection. The thermocouples are fitted between two spirals of the heating elements and protrude into the useable chamber till approx. to the outer wall of the rotary tube. For measurement the temperature of the product in the outlet box, another NiCr-Ni-thermocouple type K is installed.

Controlling unit

The controlling unit is equipped together with the power part in a separate controlling part and is connected via a flexible connection with the furnace. The furnace is also equipped with the following components:

- 3 Temperature controller G800
    - 2- or 3 set point controller with PID behaviour
    - Logic- or continuous output
    - max. 4 programs with max. 16 segments/steps each (max. 8 steps per program) may be programmed
    - display of actual & set value
    - self optimization prevents overshooting (pre-adjustment or automatic self-adjustment)
    - separation of operation- and configuration level (prevents undesired changes)
    - 4 selectable parameter sets
    - failure alarm in case of thermocouple fracture
    - serial interface RS 485 as option (not possible to install afterwards)

- 3 electronic load relays
- 1 electronic engine controlling unit of the rotating tube speed
- 3 safety controller
- 1 operating time counter

as well as all other operating parts like contactor unit, fuses etc., which are necessary for the function of the control unit.

The furnace is designed according to machine guidelines, to low voltage guidelines and if there is a pressure or vacuum vessel also according to pressure vessel guidelines. Our product standard is EN-746. The furnace is designed ready for connection and contains a connection cable to mains.

price for the furnace as described **€ 59.760,--**
==========

The machine will be produced with the following provisions:

EC-guide line for machines 2006/42/EC/ and following, annex I
EC-guide line for EMC 2004/180/EC and following

Following harmonised standards are used particularly:

EN 746 – industrial thermo processing units, part 1, part 3
EN 60 204-1 * EN 60 519-1
ISO 12100-1 * ISO 12100-2
EN 55 011 * EN 61 000-6-2

Options

Depending on the option larger control housing might be necessary. This will be discussed with you in case of order.

Rotary tube made of 1.4841

The both ends of the tube are equipped with flanges of material 1.4301. On each flange is connected a cover (material 1.4301) with a tube in the middle. This tube is mechanically prepared for the end caps/seals. Inside of the tube are installed two screws. One is from inlet and second is from outlet and reaches up to heating zone. Depends on the rotation direction the product stay in the heating zone or will be discharged in cooling section.

Outer diameter:	approx. 273 mm
Inner diameter:	approx. 260 mm
Length:	approx. 2200 mm

Price for 1 tube **€ 10.810,--**
=========

Rotary tube made of 2.4851 (Inconel 601)

The both ends of the tube are equipped with flanges of material 1.4301. On each flange is connected a cover (material 1.4301) with a tube in the middle. This tube is mechanically prepared for the end caps/seals. Inside of the tube are installed two screws. One is from inlet and second is from outlet and reaches up to heating zone. Depends on the rotation direction the product stay in the heating zone or will be discharged in cooling section.

Outer diameter:	approx. 273 mm
Inner diameter:	approx. 260 mm
Length:	approx. 2200 mm

Price for 1 tube **€ 16.475,--**
=========

End cap

The end cap DN100 is made of stainless steel (1.4301) and is mounted on the tilting frame. The rotary tube reaches into the end cap. Seal between rotary tube and fixed cap is done by 2 shaft seal, which are hold by corresponding flanges on the end caps and lay on the mechanical prepared surface of the drum end. The housing for the seal has connections for water cooling and for purge gas between both shaft seals. The seal is a wear part and has to be replaced from time to time.

The front side of the end cap is equipped with a flange for connection of a dosing unit or gas feeding device or vacuum pump.

Able for low vacuum.

Price/pc **€ 1.740,--**
=========

Gas installation

This option can only be supplied with the option gas-tight version (with end caps). It is mounted in the under frame of the furnace and firmly connected to the furnace. Following components are installed:

2 shaft seal as purge gas Ar
- 1 x shut-off valve,
- 1 x flow meter with needle valve max. 3 Nm³/h,
- 1 x throttle valve for keeping gas pressure at 10 – 15 mbar

1 drum as purge gas Ar
- 1 x shut-off valve,
- 1 x flow meter with needle valve max. 6 Nm³/h,
- 1 x throttle valve for keeping gas pressure at 5 – 7 mbar

1 drum as process gas Ar
- 1 x shut-off valve,
- 1 x flow meter with needle valve max. 6 Nm³/h,

All pipes are made of copper or PVC hoses. Bottles and pressure reducing valves with pressure gauge for a max. The outlet pressure of 200 mbar must be provided by the customer. When using flammable, toxic and explosive shielding gases this option is not sufficient for plant and personal safety. Please contact us.

Price/pc. **€ 9.840,--**
=========

<u>Multi functional unit SE 702 (109772)</u>

Universal compact automation device for heat treatment systems with touch operation

Hardware:

• dimensions	210 x 144 x 55 mm (B x H x D)
• Front plate	Glass, kapacitive touch, IP65
• Display	color TFT 7 "(17.8 cm), 800 x 480 pixels
• Power supply	24 V DC
• Interfaces	1 x Ethernet, 2 x USB, CAN master Profibus DP slave (option), RS485 / 422 Modbus master (option)
• I/O systems	STANGE SIOS or CAN (via CAN bus) Up to 16 actual values, 16 analog outputs, 64 digital inputs, 64 digital outputs
• Memory	2 GB micro SD card for firmware 2 GB SD card for customer data

Software: up to:
• Programmers with 8 setpoints, 32 digital tracks, 99 programs
• 8 control zones with 8 PID parameter sets
• 64 alarms
• 8 formulas
• 16 tolerance bands, 16 limit values
• PLC with 1600 instructions, 64 timers, programmable in STL
• User administration with LogIn levels
• Visualization, animated customer images (option)
• Data logger for up to 16 values (option)

surcharge to 3 x G800 *(incl. basic programming)* **€ 6.995,--**
==========

Process Guiding Software ECS-2000 for SE 702 (104152)

- Online operation of the system with visualization and recorder function, load data storage, load date administration and load data evaluation, with overview of process data in tabulated form or tree structure, graphical evaluation with
- comparison of process curves
- operation screen design for process visualization with symbol library
- configuration program ECS-KONF
- OPC server for JBUS

However, the furnace and the corresponding application process have to be established via a graphic editor by the user or through us against payment. The data and values to be recorded can be placed by drag and drop. All data can be printed out. One program controller (with RS 232) or up to three suitable program controllers (with RS 422) can be connected to a ECS-2000 system.
The language is selectable in German and English
Process data in batch head can be defined for each batch.
Minimum system Requirements: Pentium 3/850, 512 MB RAM, 200 HDD free, one free USB connection, one free RS 232 connection, Windows NT. 4,0 service pack 6a, Win2000 SP 2, Win XP SP 1, IE 5.5 and screen resolution 800x600 HiColor (1024x768 recommended).

Price **€ 1.990,--**
==========

Interface Converter (104226)

RS 232 to RS 422

Price **€ 345,--**
==========

PC for ECS 2000

Price **€ 1.450,--**
==========

Vacuum pump stand

Price **on request**
==========

THIS OFFER IS SUBJECT TO TECHNICAL CHANGES!

Please note that this calculation is subject to latest, up-to-the minute material prices. We reserve us the right to demand at time of contract conclusion a new determination of contract price due to possible price increases in commodities, freights, taxes, duties, dues or in any other charges.

If you inquire a Preliminary- or Final Acceptance on our premises please let us know your requested test sequence so that we can give you a detailed quote.

Price base	unpacked, ex works
Validity of offer	until 30.06.2018.
Delivery time	approx. 14 - 16 weeks after receipt of firm order, receipt of 35 % down payment and receipt of clean, valid and acceptable L/C plus clarification of all technical and commercial details (indicated delivery time does not include delivery to customer)
Payment	35% down payment in advance 65% against irrevocable and confirmed letter of credit through Sparkasse Nürnberg: bank code 760 501 01 account-n°: 190 002 501 SWIFT: SSKNDE 77 L/C conditions: 65% against presentation of shipping documents. All L/C charges inside and outside of our country are for buyer's account.
Warranty	1 year, except wear parts (i.e. rotary tubes, heaters, insulation etc.)
Not included in Price	- installation, commissioning, training - transport - supply of all necessary media like electric power, purge gases - product feed and discharge

Export control

We reserve the right to examine the quotation, if at time of order following is missing or doubtful

- end user certificate
- confirmation of non-military and non-nuclear application

Please note that all contracts are subject to our general terms of sale and delivery and that other conditions will not be accepted.

Looking forward to receiving your valued comments with great interest, we remain

Yours faithfully,

Jennifer Ziegler
Sales – and Export Department

Viktor Yukhno
Engineering

Linn High Therm GmbH
President: Horst Linn
HRB 3262 Local Court Amberg

E.3 Jet Mill Quote and Technical Data

Our budget quotation:

to: **Universität Stellenbosch**
Mr. De Wet du Toit
Privatebag X1
Matieland
7602 Stellenbosch
SOUTH AFRICA

project: Jet milling of Tungsten Carbide

quotation: No. M1-250877-01 dated 08 May 2018

ALPINE 100 AFG closed loop system

Figure: ALPINE MULTI- PROCESSING SYSTEM.
The image differs eventually from the here quoted.

This quotation is a budget quotation and needs to be confirmed or adjusted. After clarification of all technical and commercial details we would be delighted to submit a contractual quotation.

Your contact person:

Michael Schmid
Tel: +49 821 5906 535
michael.schmid@alpine.hosokawa.com

2. Terms of supply and sale

Delivery	CIF South Africa Seaport according to Incoterms 2010
Delivery time	ex-factory approx. 9 months upon receipt of L/C subject to issue of export license
Shipment	via sea freight
Packing	included
Transport insurance	included
Price validity	non binding budget quotation only - no order placement is possible on base of this information.
Payment	100 % by means of an irrevocable L/C, free of charge on our favour, confirmed by a German bank. This L/C must be available at order placement. Transhipment and partial shipment has to be allowed. Out of this L/C: • 30 % payable against down payment invoice and advanced payment guarantee covering 30% of the order value. • 70 % payable against shipping documents (incl. B/L, insurance certificate, packing list, etc.) and commercial invoice.
Liability	our liability is limited to 60 % of the net order value, however maximum 500.000 EUR.

HOSOKAWA ALPINE Aktiengesellschaft

Unless otherwise agreed, our sales conditions 366 E apply.

3. Composition of prices

pos.	quantity, unit	article	option (EUR)	price (EUR)
1	1	ALPINE Multi-processing system 100 AFG		
1.1	1	Twin Screw Feeder		
1.2	1	Basic modul: ALPINE Multi-processing system		
1.3	1	ALPINE Turboplex Classifier head 50 ATP		
1.4	1	Alpine Fluidised Bed Opposed Jet Mill 100 AFG		
1.5	1	Cyclone kit		
1.6	1	Safety filter		
1.7	1	Oxygen monitoring system		
1.8	1	Accessories for close loop operation with N2 gas		
1.9	1	Process automation for ALPINE Multi-processing system		
1.10	1	On-site supply by customer		by customer
2	1	Services		
2.1	1	Freight and packing		
2.2	1	Mechanical commissioning		
2.3	1	Electrical commissioning		
3	1	Engineering		
3.1		Engineering: mechanical process		
3.2		Engineering: process automation		

quotation price complete: **215,000.-**

Assuming delivery in Germany, all prices featured in this quotation are net prices; the statutory VAT must be added.

4. Specification

Product specification:

Feed material:	Tungsten Carbide
Silica content:	< 0,1 %
Feed size:	< 1 mm
Moisture of the feed material:	< 0,5 % H_2O
End fineness:	d97 < 5 to 50 µm
Feed capacity:	max. 20 kg/h
Fines measurement:	Malvern Mastersizer

The above-mentioned data are purely informative and based on our experience with similar requirements. For confirming these data and for issuing a performance warranty, tests with the original feed material need to be done in our application testing centre.

E.4 Rotating Drum and Chemical Bath Quote and Technical Data

GREEFA MED AUTOMATION
"Think Globally, Act Locally"

30 Donkervliet Street, Daljosaphat,
Paarl, 7646
South Africa
P.O. Box 3014, Paarl, 7620

VAT No : 4680211275 Reg. No:

To: De Wet du Toit
Date: 5/5/2018

Att: De Wet du Toit
Doc. No: E2018-019-01 DDT

Re.: Thank you for the opportunity to submit this quote based on the current layout. We look forward to further discussions

Chemical Tank and Friction Chemical Rotating Drum

Item No.	Description	Qty	Total ZAR Section Cost
1	<u>Rotating Drum</u>	1	
	Stainless Steel Sideplate and construction		
	0.25KW Transtechno motor		
	Stainless Steel Insert Bearings		
	Variable Speed Controlled Drive Unit		
	Effective drum size - 1m L x 0.5m D (Footprint: 1.5m L x 1.8m W x 1.8m H		
	<u>TOTAL FOR THIS SECTION</u>		R 225 000.00
2	<u>Chemical Bath ST/ST 4800 Litre</u>	1	
	LDX2101 Stainless Steel Plate		
	Piping Included, but excluding drainage piping		
	4" Drain Nipple - excluding Valve and drain pipes		
	Water Level/ burner safety control - excluded since water heating not included		
	MED Heat Exchanger + Gas Burner - excluded, but prepared for upgrade - blanked off		
	Effective bath size - 4m L x 1.5m W x 0.8m H		
	<u>TOTAL FOR THIS SECTION</u>		R 39 240.00
10	<u>Mechanical Installation Incl Lodging/meals and travel</u>	2	R 23 000.00
	Installation of quoted items		
11	<u>Electrical Installation</u>	excl	-
	TOTALS		287 240.00

Notes:

All prices are accurate at time of writing.
All prices exclusive of VAT
All South African Components ex works Paarl
All imported items CIF closest harbour
E&OE

E.4 Rotating Drum and Chemical Bath Quote and Technical Data

Transport:
MED Automation manufactured equipment – transport and insurance excluded

Installation:
The machine (parts) offered will be installed by our service engineers.
The cost of installation - included in this quotation

To be provided by the buyer:
- During the period of installation, the buyer must see to it that at least one skilled operator is placed at the disposal for explanation and instruction, in order to be able to run and maintain the line independently after installation.
- The client shall provide tools and equipment needed for uploading and installing the materials (such as forklift, tower wagon, as needed).

Terms of delivery and payment:
Delivery time:
To be agreed upon at a later stage.

Prices:
The prices concern the parts as mentioned in the quotation. Equipment and labour not mentioned in the quotation are not included in the price and will be invoiced at our current rates.

Validity:

This quotation is valid for 14 days after date of quotation. Unextected fluctuation from suppliers due to the current market conditions will be implemented on a proven cost basis over and above the costs in this quote
The complete quotation consists of this accompanying document, the technical item list and the plan.

Payment:
40% on order placement
50% before delivery ex-works
10% hand over and commissioning