SPECIALIST CLIMATE CHANGE ASSESSMENT OF THE PROPOSED INSTALLATION OF SULPHUR DIOXIDE (SO_2) ABATEMENT EQUIPMENT AT THE POLOKWANE SMELTER

Produced by Promethium Carbon

For WSP Parsons Brinckerhoff

On Behalf of Anglo American Platinum (Ltd)

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www.promethium.co.za | Tel : +27 11 706 8185 | Fax: +27 86 589 3466
BALLYOAKS OFFICE PARK | LACEY OAK HOUSE , 2ND FLOOR | 35 BALLYCLARE DRIVE | PO BOX 131253 | BRYANSTON 2021
PROMETHIUM CARBON (PTY) Ltd / Reg no: 2005/018622/07 / Directors / H Immink, RT Louw, HJ Swanepoel

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EXECUTIVE SUMMARY

The National Environmental Management Air Quality Act requires that the Polokwane Smelter install an SO_2 abatement system. The selected abatement technology is a wet gas sulphuric acid (WSA) plant. This specialist climate change assessment explored the potential greenhouse gas emission and climate change impact of the proposed project. This study calculated the potential direct and indirect greenhouse gas emissions from the construction and operation of the SO_2 abatement equipment. These emissions are interpreted in terms of their contribution to the national greenhouse gas inventory and the existing smelting operation. The calculated greenhouse gas emissions are compared against an alternative technology for SO_2 abatement as well as a possible mitigation option.

The proposed SO_2 abatement project for the Polokwane Smelter will account for relatively small quantities of greenhouse gas emissions that are negligible in terms of the national greenhouse gas inventory. A large proportion of the emissions (80%) will be indirect Scope 2 emissions due to the consumption of electricity. The addition of the abatement equipment will only increase the Scope 2 emissions of the Polokwane Smelter by 1.90% on the whole. Despite its very small magnitude, the greenhouse gas emissions from the proposed SO_2 abatement equipment will still contribute to global climate change. The significance of the impact is calculated to be moderate based on the extent, duration and probability of the greenhouse gas emissions. However, greenhouse gas emissions attributed to the SO_2 abatement project cannot be directly associated with any specific climatic changes or any consequent local environmental impacts.

There is an opportunity to mitigate the direct Scope 1 emissions from LPG combustion through the substitution with biodiesel and Scope 2 emissions through renewable energy deployment. Similarly, the emissions from the plant may decrease in the future as the electricity grid decarbonises. These opportunities are not available to the alternative SO_2 abatement technology considered since this process produces mostly Scope 3 emissions. Therefore, it is concluded that the selected WSA Plant is the most suitable SO_2 abatement technology based on its greenhouse gas emissions and potential to mitigate them.

While there is limited scope to save waste energy from the project's operations, it is important that the facility be included within Anglo American's ECO2MAN programme to monitor its energy use and emissions. This programme and other climate change management tools will help Anglo American control its climate change impacts and risks. This is important as the Polokwane Smelter area of operation will experience climatic changes that will increase temperatures drastically and decrease rainfall within observed variable ranges. This may impact water availability and possibly the operations of the smelter.

DECLARATION OF INDEPENDENCE

Robbie Louw, Harmke Immink and Sam Vosper as the authors of this report, do hereby declare their independence as consultants appointed by WSP Parsons Brinckerhoff to undertake a climate change assessment for of the proposed installation of sulphur dioxide (SO_2) abatement equipment at the Polokwane Smelter located south of the city of Polokwane in the Limpopo Province. Other than fair remuneration for the work performed, the specialists have no personal, financial business or other interests in the project activity. The objectivity of the specialists is not compromised by any circumstances and the views expressed within the report are their own.

Robbie Louw

Harmke Immink

Sam Vosper

DETALS OF SPECIALIST

Promethium Carbon

Promethium Carbon is a South African climate change and carbon advisory company group based in Johannesburg. With a vision to making a difference in climate change in Africa and a focus on technical expertise, our team of climate change professionals assists businesses ranging from small enterprises to multinational entities on their journey towards a low carbon economy. We also assist governments and government institutions in planning for the coming global carbon constrained environment. Through our participation on various working groups and standards boards, we have established ourselves as knowledge leaders in the climate space and act as trusted advisors to our clients.

Promethium Carbon has been active in the climate change and carbon management space since 2004. Our client base includes many of the international mining houses and industrial companies that are operating in and from South Africa. One of our clients was awarded the European Energy Risk Deal of the Year award in 2010 for a carbon credit commercial transaction that Promethium advised the client on. Promethium Carbon also received the Star Excellence Award in recognition of its outstanding contribution to Africa's Economic Growth and Development. This award was received in Abu Dhabi during the World Future Energy Summit 2014. Promethium was furthermore awarded with the Best Project Implementer award by the British High Commission in 2015.

An accurate carbon footprint forms the basis from which an organisation can plan its journey into the low carbon economy. The rules, according to which a carbon footprint is calculated, have been developed at a fast pace over a short number of years, and have reached a level of maturity. Promethium has calculated the carbon footprints and greenhouse gas inventories for numerous companies. Through these carbon footprints and strategy documents Promethium Carbon has helped companies to understand their climate change impacts as well as the associated risks.

Robbie Louw

Robbie is the founder and director of Promethium Carbon. He has over 10 years of experience in the climate change industry. His experience over a period of 28 years covers the chemical, mining, minerals process and energy fields, in which he was, involved in R&D, project, operational and management levels.

Robbie's experience in climate change includes but is not limited to:

- Carbon footprinting: He has extensive experience in carbon footprinting. The team under his leadership has performed carbon footprint calculations for major international corporations operating complex businesses in multiple jurisdictions and on multiple continents.
- Climate strategy development: He has developed carbon and climate change strategies for major international corporations.
- Climate change impact and risk assessments: He has developed climate change risk assessments for various companies and projects.
- Project development: He has extensive experience in project development in the energy, chemical and mining industries. This covers the scope from project identification, feasibility studies to project implementation. Some examples include carbon sequestration projects focussed on the restoration of impacted grasslands and mining impacted land and greenhouse gas mitigation projects in many industries including farming, mine land restoration and bio-energy production.
- Carbon trading systems: He is the lead author of numerous publications on the design of a potential carbon trading system for South Africa.

Harmke Immink

Harmke is a Director at Promethium Carbon. Her 12 years of climate change expertise is developed from environmental life cycle assessments (LCA), environmental audits and technical performance evaluation. She has a Masters degree in Environmental Measurement Techniques (Sweden), and gained experience across industry sectors through a variety of technical surveys and industry roadmaps.

Harmke's experience in climate change includes but is not limited to:

- South African representative for ISO technical committee 207 on GHG standards, including eco-labelling and climate change;
- Technical assessor for SANAS accredited: ISO 14065 GHG validation and verification;
- Part of World Resource Institute technical development team for the GHG Protocol standard on accounting for goals and targets;

- Climate change related services include GHG baseline evaluations, a survey for practical sustainable development indicators for Clean Development Mechanism (CDM) projects, new or revised methodologies and successful registration of CDM projects;
- Standardised Baseline Calculations for Grid Emission Factors in Kenya and South Africa;
- Climate change adaptation projects for mining clients, focused on community vulnerabilities and strategically linking with social responsibility;
- Carbon Disclosure Projects (CDP) is a global initiative to collect and distribute high quality information that motivates investors, corporations and governments to take action in the attempt to mitigate climate change. Promethium Carbon CDP clients consistently are in both the top ten disclosure as well as the performance leadership index since 2007;
- Project leader for the Private Sector Energy Efficiency audits through the NBI; and
- Carbon capture and storage research and Carbon Offset Administration system development.

Sam Vosper

Sam holds the following degrees: Bachelor of Science (Rhodes University), Bachelor of Science (Hons) (Rhodes University), MPhil Environmental Policy (University of Cambridge). He has completed postgraduate courses in: Energy & Climate Change, Environmental Economics, Climate Change Policy, Policy Assessment & Evaluation, International Environmental Law, Ecological Modelling, Climate Change Adaptability and General Linear Models. Sam's undergraduate studies included: Environmental Science, Mathematics, Mathematical Statistics and Economics.

Sam currently works as an environmental consultant specializing in services which include:

- Carbon footprints and Water footprints;
- Researching for South Africa's Third National Communication to the UNFCCC;
- Researching and drafting a measuring, reporting and verification policy for Swaziland to apply to their nationally determined contributions; and
- Energy efficiency and energy management studies.

Sam has previously executed a research project on water supply and catchment sustainability for the town of Mussoorie in the Himalayan foothills. The project involved amalgamating and mapping data on; forest composition, climate change, infrastructural upgrades and land use.

The above listed authors have all worked on previous climate change assessments for power generation projects such as coal fired power plants and combine cycle gas turbines.

1 INTRODUCTION

The Polokwane Smelter, which is located 12km south of the city of Polokwane is one of Anglo American Platinum Limited's three existing smelting complexes. The smelter includes a metallurgical industrial furnace where sulphide concentrates are smelted. Currently, the off-gas is treated via a forced draft cooler followed by a baghouse. Pollutants in the emitted off-gas include; particulate matter (PM), sulphur dioxide (SO_2) and nitrogen oxides (NO_x).

It is required by the National Environmental Management Air Quality Act (No. 39 of 2004) (NEM:AQA) that efficient SO_2 abatement is implemented on existing metallurgical furnaces by 1st April 2015. The Polokwane Smelter has been given an extension until 1st April 2020 to comply with the emissions standards. To meet these standards, it is proposed that an SO_2 abatement system be installed at the smelter. The selected technology is a wet gas sulphuric acid (WSA) plant that will convert the SO_2 in the off-gas into commercial-grade concentrated sulphuric acid (H_2SO_4).

In accordance with the relevant regulations, an Environmental Impact Assessment process must be completed before project development can proceed. In addition to the Environmental Impact Assessment, Promethium Carbon has been appointed to undertake a specialist climate change assessment of the project. This involves assessing the project's prospective contribution to climate change through the emission of greenhouse gases (GHGs) such as carbon dioxide (CO_2).

The contribution of a metal smelting operation to global climate change is dependent on the greenhouse gas emissions that it produces. However, the greenhouse gas emissions from any individual source cannot be attributed directly or indirectly to any specific environmental impact as a consequence of climate change. Thus, this assessment focuses on exploring the additional greenhouse gas emissions that would be attributed to the selected SO_2 abatement technology as well as the alternatives and mitigation option available to the project developer. The potential climate change impacts for the area in which the smelter operates will also be assessed.

This approach is aligned with the principles of the National Environmental Management Act 1998 as it seeks to provide the project developer with the best possible information to evaluate the project's environmental sustainability. For each of the assessed technology alternatives and mitigation options the project scope considered would include the development of infrastructure related to the abatement plant, material storage facilities, effluent treatment facilities and access roads.

The broad terms of reference and scope of work for this specialist climate change assessment include the following:

1) Calculating the construction and operational carbon footprint of the project with respect to:
   - Direct emissions from fuel combustion and processes;
   - Indirect emissions from electricity consumption; and
   - Indirect emissions from the transport and production of materials.
2) Analysing the project alternatives with regards to:
   - Concentrated Mode Dual Alkali (CMDA) scrubbing process.
3) Reviewing emissions mitigation options with regards to:
   - Fuel switching;
   - Solar photovoltaic energy sources; and
   - Waste heat recovery.
4) Conducting an impact assessment of the project, its alternatives and mitigation options by:
   - Considering its contribution to the national emissions inventory and the emissions of the existing operation.
5) Exploring the potential climate change impacts faced by the Limpopo Province.
6) Assessing any GHG emission management activities for the plant's operations.

2 RECEIVING ENVIRONMENT

The Polokwane Smelter is located near the centre of the Limpopo Province, approximately 12km south of the city of Polokwane (a map of the location is provided in Annex A). The province has been (and still is) an important area for the country's mining and power generation operations. As such, the area has faced challenges with air quality due to the emission of sulphur oxides and particulate matter from these operations.

The area of operation is described as having a temperate semi-arid climate. The climate is characterised by warm summers and cool winters due in part to its 1230m altitude. The summer temperatures range between 19 – 27°C. The winters are cooler and vary between 2 – 16°C. Rainfall in the area is typically low, averaging 470 mm per annum.

As such water resources are relatively scarce in the area of operation. Any significant shortages in water yields may directly impact upon the Polokwane Smelter and its operations. However, the greenhouse gas emissions attributed to the SO_2 abatement project at the Polokwane Smelter cannot be directly associated with any specific climatic changes and cannot be directly linked to any local environmental impacts as a consequence. Despite this, it is still important to have considered the context of the receiving environment impacted by the smelter.

3 METHODOLOGY

3.1 ESTIMATING GREENHOUSE GAS EMISSIONS

The carbon footprints presented in this assessment have been guided by the ISO/SANS 14064-1 standard. This standard specifies principles and requirements at the organization level for the quantification and reporting of historical figures of greenhouse gas emissions and removals. Requirements for the design, development, management, reporting and verification of an organisation's greenhouse gas inventory are also included in the standard. The principles of this standard have, in this analysis, been applied at a project level to the calculation of the future greenhouse gas emissions of the prospective project

The basic principles of SANS 14064-1 aim to ensure that the greenhouse gas information presented within a carbon footprint is a true and fair account. These principles include:

RELEVANCE: by selecting all the greenhouse gas sources, greenhouse gas sinks, greenhouse gas reservoirs, data and methodologies that are appropriate to the needs of the intended user.

COMPLETENESS: by including all the greenhouse gas emissions and removals relevant to the company.

CONSISTENCY: to enable meaningful comparisons to be made with other greenhouse gas related information.

ACCURACY: by reducing bias and uncertainties as far as is practical.

TRANSPARENCY: by disclosing sufficient and appropriate greenhouse gas related information to allow intended users to make decisions with reasonable confidence.

Following the SANS 14064-1, the carbon footprint of the proposed SO_2 abatement plant's direct combustion emissions was developed through the following process:

- Setting the boundaries of analysis;
- Identifying the greenhouse gas sources inside the boundary;
- Establishing the quantification method that will be applied;
- Selecting or developing greenhouse emission and removal factors; and
- Calculating the greenhouse gas emissions.

The Greenhouse Gas Protocol's Corporate Accounting and Reporting Standard was also used in addition to the SANS 14064-1 standard as a guide in the calculation of the carbon footprint presented in this study. Further details of the boundaries and emissions factors are presented in the subsequent sections of the report.

The emissions calculated in this study are reported in terms of direct emissions (Scope 1), indirect electricity emissions (Scope 2) and other indirect emissions (Scope 3).

3.2 Climate Change Impact of Greenhouse Gas Emissions

The EIA reporting requirements, listed below, set out the criteria to describe and assess an environmental impact. It is these criteria that are used to assess the climate change impacts associated with the greenhouse gas emissions from the proposed installation of sulphur dioxide (SO_2) abatement equipment at the Polokwane Smelter in terms of their contribution to the national greenhouse gas inventory.

Nature: a description of what causes the effect, what will be affected and how it will be affected.

Extent (E): an indication of whether the impact will be local (limited to the immediate area or site of development) or regional, and a value between 1 and 5 will be assigned as appropriate (with 1 being low and 5 being high):

Duration (D): an indication of the lifetime of the impact quantified on a scale from 1-5. Impacts with durations that are; very short (0–1 years) are assigned a score of 1, short (2-5 years) are assigned a score of

2, medium-term (5–15 years) are assigned a score of 3, long term (> 15 years) are assigned a score of 4 or permanent are assigned a score of 5.

Magnitude (M): an indication of the consequences of the effect quantified on a scale from 0-10. A score of 0 implies the impact is small, 2 is minor, 4 is low and will cause a slight impact, 6 is moderate, 8 is high with sizable changes, and 10 is very high resulting in drastic changes.

Probability (P): an indication of the likelihood of the impact actually occurring estimated on a scale of 1–5. A score of 1 implies that the impact is very improbable, 2 is improbable, 3 is probable, 4 is highly probable and 5 is definite with the impact occurring regardless of any prevention measures.

Significance (S): a weighting based on a synthesis of the characteristics described above and can be assessed as low (< 30 points), medium (30-60 points) or high (> 60 points). The significance points are calculated as:

$S = (E + D + M) \times P.$

The status of the impact will be described as positive, negative or neutral. Additional details will also be provided on the degree to which the impact can be reversed and the degree to which the impact may cause irreplaceable loss of resources. The extent to which the impact can be mitigated will also be highlighted.

3.3 Contextualising Impact of Project Emissions

The greenhouse gas emissions and climate change impacts of the project case are evaluated on several levels. The greenhouse gas emissions and impacts are firstly compared against the technological alternative for SO_2 abatement. Secondly, the emissions and impacts of the project case are contrasted against the possible mitigation options. The greenhouse gas emissions from the project case are also considered within the context of South Africa's national inventory and the greenhouse gas emissions of the existing smelting operation. Lastly the potential local impacts of climate change for the project area are also considered.

4 PROJECT DESCRIPTION

The Polokwane Smelter currently receives wet concentrate which it dries in flash dryers prior to smelting in an electric furnace. Platinum group metals (PGMs) and other base metals are recovered in the form of furnace matte which is then tapped, cast and crushed. The Polokwane Smelter operates a furnace with a 68 MW capacity.

SO_2 gas is emitted as a by-product of the smelting process from the Polokwane Smelter at a concentration of approximately 1 - 2 volume %. In order to meet the requirements of the National Environmental Management Air Quality Act (No. 39 of 2004) a number of different SO_2 abatement technologies were assessed in the Pre-Feasibility Study for the project. From the assessed options, the selected abatement technology is a Wet gas Sulphuric Acid (WSA) Plant, to be supplied by Haldor Topsøe. This technology, which will convert the SO_2 contained in the off-gas into commercial-grade concentrated sulphuric acid (H_2SO_4), was identified as the most suitable SO_2 abatement technology for the smelter. The implementation of this technology involves several processes and requires a number of infrastructural developments as illustrated in Figure 1.

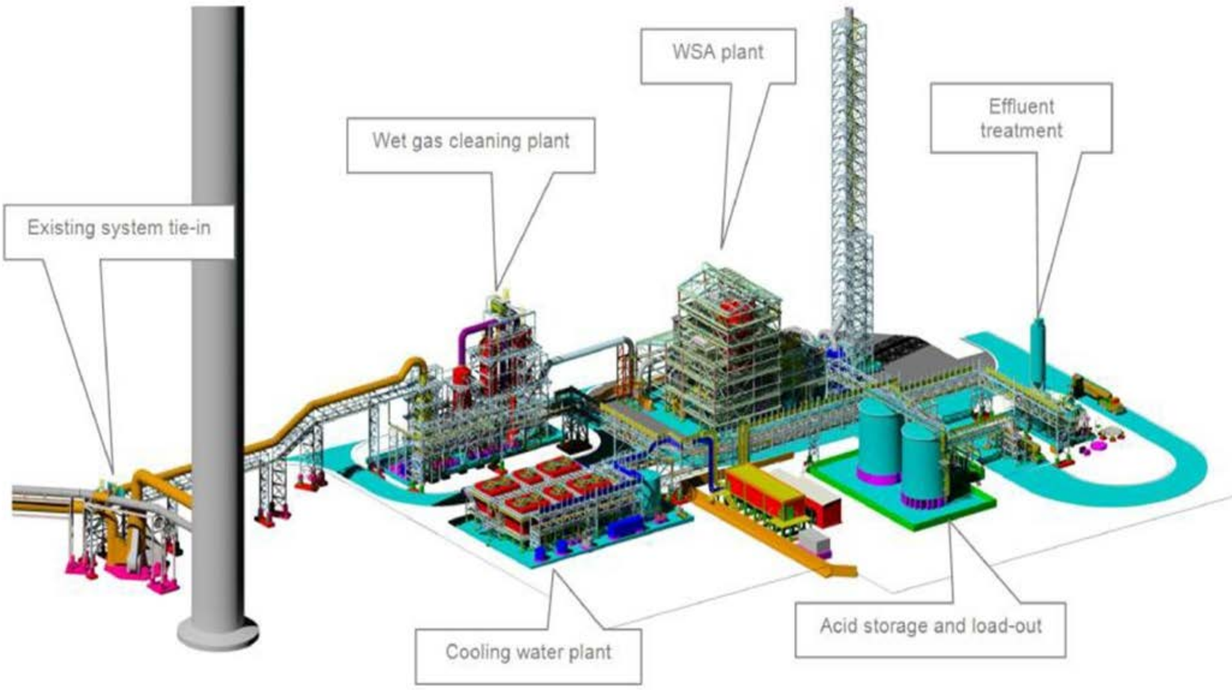

Figure1: Anticipated design of the selected SO_2 abatement technology at the Polokwane Smelter

The processes involved in the SO_2 abatement equipment include the following:

<u>Gas cleaning</u>

Currently the plant cools and de-dusts its off-gas via a forced draft cooler and baghouse before being emitted into the atmosphere. This system does present challenges with air ingress and will be upgraded to a spray cooler and electrostatic precipitator (ESP) to perform the primary off-gas de-dusting. To reduce the particulate matter in the off-gas to the levels required by the WSA Plant (less than 1 mg/Nm^3) additional secondary gas cleaning is also required.

This would involve the addition of:

- A scrubber – which will saturate and cool the off-gas with water to capture the remaining dust. This will produce a weak acid waste stream that will be transported to the effluent treatment plant for neutralisation.
- A gas cooling tower – which will cool the off-gas to the desired WSA inlet temperature of 30 to 40°C.
- A wet electrostatic precipitator (WESP) – which will reduce the particulate matter concentration in the off-gas entering the WSA plant to less than 1 mg/Nm^3 and the acid mist to below 20 mg/Nm^3.

Acid production

The off-gas from the WESP will enter the WSA acid plant where the gas is pre-heated to the required catalytic reaction temperature (~400°C) by hot air from the acid condenser. The gas is further heated by direct heat exchange and a support heater using LPG when necessary. The off-gas then enters the SO_2 converter, where the SO_2 in the off-gas is converted to SO_3. The SO_3 gas is then reacted with water vapour in the off-gas to form H_2SO_4 vapour. The off-gas containing H_2SO_4 is cooled in a condenser producing liquid sulphuric acid with a concentration of between 95-98 wt% (weight percentage). The acid is further cooled before it is sent to the acid storage tank.

The stripped off-gas is filtered to remove any acid mist carried over from the condenser before finally being emitted to the atmosphere via the acid plant stack. The weak acid produced by the mist filter is fed to the effluent treatment plant for neutralisation.

Effluent treatment

An effluent treatment plant will treat all streams of waste water produced by the SO_2 abatement equipment, including: weak acid effluent, acid mist condensate, storm water runoff, cooling tower bleed off and, blow-down from the steam system. The effluent treatment plant will have a daily design throughput capacity of approximately $700m^3$.The effluent containing weak sulphuric acid will be neutralised by a lime slurry to produce gypsum. The gypsum will be fed back to the furnace at the Polokwane Smelter. The neutralising process uses hydrated lime in the following reaction:

$$H_2SO_4 + Ca(OH)_2 \rightarrow CaSO_4.2H_2O$$

The production of hydrated lime does however produce carbon dioxide (CO_2).

Storage and handling dangerous goods

Prior to transportation, the acid produced will be stored on site in two storage tanks of ~1 000 m^3. LPG used in the heating of the off-gas will also potentially be stored onsite.

Water usage and storage

Cooling water will be prepared by evaporative cooling towers and recirculated in the system. The water will be chemically treated with flocculants, and sand filters to remove any particulate matter with the blow down discharged to the effluent treatment plant. The development will require 450 m^3/day of potable water during normal operation with possible peak demands up to 3000 m^3/day. It is envisaged that the water will be obtained from the existing allocation of 2 700 m^3/day. The Polokwane Smelter currently utilises 800 Nm^3/day water (on average). Buffer storage will be required to cater for intermittent peak demands.

4.1 Setting the Boundaries of Climate Change Impact Analysis

While the ISO/SANS 14064-1 standard sets the boundary of analysis for a company based on an equity share or operational control approach the emissions calculations for the proposed installation of sulphur dioxide (SO_2) abatement equipment at the Polokwane Smelter construction and operation are applied based on a project boundary. The project boundary is set based on a "cradle to gate" approach whereby all the contributing emissions up until the point where the 'product' leaves the facility "gate" are considered. In the case of the Polokwane Smelter this would include upstream emissions related to input materials and energy sources as well as on site emissions but not the downstream transport and use of end products.

4.2 Emissions Factors

It is important that the emissions factors used in carbon footprint calculations are appropriate for the local context and relevant to the technology being assessed. Local emissions factors, such as the grid emission factor, have been sourced from the reports of local entities such as Eskom as it is the main electricity generator within the country. Recognised emissions factors have also been sourced from the South Africa's Draft Technical Guidelines for Monitoring, Reporting and Verification of Greenhouse Gas Emission by Industry which is based on the Intergovernmental Panel on Climate Change's 2006 reporting guidance document.

Emissions factors not provided in the Technical Guidelines have been sourced from a number of other appropriate entities, including the UK's Department for Environment, Food and Rural Affairs (DEFRA). Annual updates are published by DEFRA to assist with company level reporting on greenhouse gas emissions. This assessment makes use of the DEFRA emission factors published in 2016. It is assumed that these emission factors are representative of the activity data supplied for the project.

A detailed list of the emission factors and other factors used in the calculation of the carbon footprints is summarised in Table 1. These factors are quoted in tonnes of carbon dioxide equivalent (tCO_2e) as they account for all greenhouse gases produced from a given source.

Table 1: Summary of the emissions factors used in the carbon footprint calculations

Emissions Source	Value	Source
Scope 1		
LPG	2.94 tCO_2e/tonne	DEFRA (2016)
Biodiesel	0.02 tCO_2e/tonne	DEFRA (2016)
Scope 2		
Grid electricity	0.96 tCO_2e/MWh	Eskom (2016)
Scope 3		
Water	0.34 $kgCO_2e/m^3$	DEFRA (2016)
LPG well to tank	0.37 tCO_2e/tonne	DEFRA (2016)
Grid electricity transmission and distribution losses	0.14 tCO_2e/MWh	Eskom (2016)
Transport	0.11 $kgCO_2e$/tonne.km	DEFRA (2016)
Concrete production	0.13 tCO_2e/tonne	Technical Guidelines (2016) & DEFRA (2016)
Steel production	1.06 tCO_2e/tonne	Technical Guidelines (2016)
Hydrated lime production	0.59 tCO_2e/tonne	Molar mass equation

5 TECHNOLOGICAL PROJECT ALTERNATIVES AND MITIGATION OPTIONS

The pre-feasibility study assessed two broad technological options as alternatives to the selected WSA plant. One was the Cansolv amine scrubbing process which is another regenerative technology for the capturing of SO_2 into a saleable product. This process was not selected to be taken forward as it would require significantly greater quantities of water and energy to operate. Due to the higher energy and water demands the potential greenhouse gas emissions from this process will not be assessed here as it can be inferred that it will be higher than the selected WSA plant.

The second alternative technology considered for SO_2 abatement was the Concentrated Mode Dual Alkali (CMDA) scrubbing process. This is a non-regenerative wet scrubbing process which produces gypsum. This option was not favoured as it was indicated that the Polokwane Smelter operation does not wish to produce gypsum in large quantities. However, this process has significantly lower energy requirements than the regenerative processes. As such this process will be explored to determine whether it may offer a lower emissions option to the project developer.

5.1 Technological Project Alternatives

5.1.1 Concentrated Mode Dual Alkali (CMDA) Scrubbing Process

At the CMDA scrubber the off-gas it is contacted with scrubbing liquor. The SO_2 in the off-gas reacts with the active sodium in the scrubbing liquor to form Na_2SO_3 (and some $NaHSO_3$). The scrubbed gas is then passed through a wet electrostatic precipitator to remove solids and acid mist, before it is released into the atmosphere.

Hydrated lime is used to regenerate the scrubbing solution in a series of reactors. The reactions produce a mix of calcium sulphite solids containing a small amount of co-precipitated calcium sulphate. This slurry that is formed is dewatered via thickening and filtration to remove the waste solids and recover the regenerated scrubbing liquor.

The scrubbing liquor is recirculated to the scrubber while the waste products require additional oxidation to produce gypsum. This gypsum would then be disposed or sold.

5.2 Mitigation Options

The mitigation options presented here are not listed within the scoping design documents for the project. However, they are mitigation options that could be considered for future inclusion within the facility.

5.2.1 Fuel Switching

In the event that an operation runs on fossil based fuels there is always the opportunity to reduce carbon emissions by switching to less emissions intensive sources. Typically biofuels can serve as near zero emissions substitutes due to the sustainable nature of their production where biomass is purposely grown and harvested for fuel.

Biofuels that may present mitigation option to the SO_2 abatement plant at the Polokwane smelter would be biodiesel to replace LPG. As a supplementary energy source LPG can be combusted in-line with the cleaned off gas. However, the use of biodiesel would need to be done via indirect heating to avoid the production of soot and other combustion products that may foul downstream catalysts.

5.2.2 Solar Photovoltaic Energy Sources

As with fossil fuel switching, an operation which consumes grid electricity may also have the opportunity to substitute with renewable sources of electricity. In the case of relatively small electricity capacity requirements (less than 1 MW), solar photovoltaic (PV) electricity generation can be a viable option.

In the case of the Polokwane Smelter the required additional electricity capacity is 1.3 MW. Installing a solar PV unit of the same capacity would effectively displace up to 20% of the grid electricity demand, under conservative generation assumptions. This would therefore reduce the emissions from grid electricity by 20%. Each MW of PV capacity requires roughly 1 hectare of land area to develop upon.

5.2.3 Waste Heat Recovery

For the Polokwane Smelter potential energy saving opportunities, waste heat recovery was explored. Water from the wet gas cleaning plant is heated by the hot furnace gases to 40°C and is cooled in the cooling towers back to 30°C for recirculation. The volumetric flow rate of this water under normal operations is 341 m^3/h and this relates to an energy capacity of 4.0 MW. Heat from the condenser of the WSA plant is already recycled in the system but some hot air is rejected. Under normal operation 40 707 kg/h of air at 118°C is rejected. This is equivalent to an energy capacity of 1.1 MW (relative to 25°C).

However, it is unlikely that either of these heat sources could be used to supplement the process energy in the WSA plant. This is especially the case considering that LPG is only used to preheat the off-gas from 314°C to 410°C during the worst operating case. Thus this mitigation option is not discussed further.

6 PROJECT IMPACTS

A smelter's greenhouse gas emissions inherently determine its contribution to the onset of global climate change. As such a carbon footprint of the project can help to inform the consequent climate change impact of the project and its comparability to other technologies or baselines.

6.1 Carbon Footprint of SO_2 Abatement Equipment

The carbon footprint of the project is calculated for both the construction phase and operational phase of the project. As mentioned previously the greenhouse gas emission have been quantified (where possible) for both the indirect upstream and direct sources.

The breakdown of the emissions between the calculated construction and operational emissions is summarised in Table 2. It is shown that the calculated construction emissions are less than a quarter that of the operational emissions of the plant for one year.

Table 2: Summary of the construction and operational greenhouse gas emissions of the proposed project.

Source	Carbon emissions	
Construction	2 788.93	tCO_2e
Operation	13 273.95	tCO_2e per annum

The construction emissions were calculated based on the available information for the development. Estimates of the fuel and electricity use on site were not available. However, it is assumed that the calculated sources will make up a material portion of the greenhouse gas emissions of the construction of the project. Furthermore, even if the construction emission are understated they will account for a very small proportion of the lifetime emissions from the plant.

Table 3: Summary of the calculated construction greenhouse gas emissions for the proposed project

Source	Carbon emissions		Category
Production - Steel	784.40	tCO_2e	Scope 3
Production - Concrete	1 509.82	tCO_2e	Scope 3
Transport - Steel	33.83	tCO_2e	Scope 3
Transport - Concrete	460.88	tCO_2e	Scope 3
Sum	**2 788.93**	**tCO_2e**	

The calculated greenhouse gas emissions for the operation of the proposed project are broken down per source in Table 4. While the number of calculated emissions sources for the indirect Scope 3 category is the greatest, the category still accounts for the smallest proportion of the calculated emissions. The combustion of LPG onsite accounts for the majority of the Scope 1 emissions and the well to tank emissions account for the majority of the Scope 3 emissions.

Table 4: The calculated annual greenhouse gas emissions for the operation of the proposed project

Source	Carbon emissions		Category
LPG	1 468.89	tCO_2e per annum	Scope 1
	1 468.89	**tCO_2e per annum**	
Grid electricity	10 865.32	tCO_2e per annum	Scope 2
	10 865.32	**tCO_2e per annum**	
Water	89.78	tCO_2e per annum	Scope 3
LPG well to tank	184.60	tCO_2e per annum	Scope 3
Production of hydrated lime	801.31	tCO_2e per annum	Scope 3
Transport upstream (hydrated lime)	51.35	tCO_2e per annum	Scope 3
Grid electricity transmission and distribution losses	39.02	tCO_2e per annum	Scope 3
	1 166.05	**tCO_2e per annum**	
Sum	**13 500.25**	**tCO_2e per annum**	

It can be seen that the Scope 2 emissions from electricity consumption account for the vast majority (80%) of the calculated annual operational emissions across scopes. This is further illustrated in Figure 2.

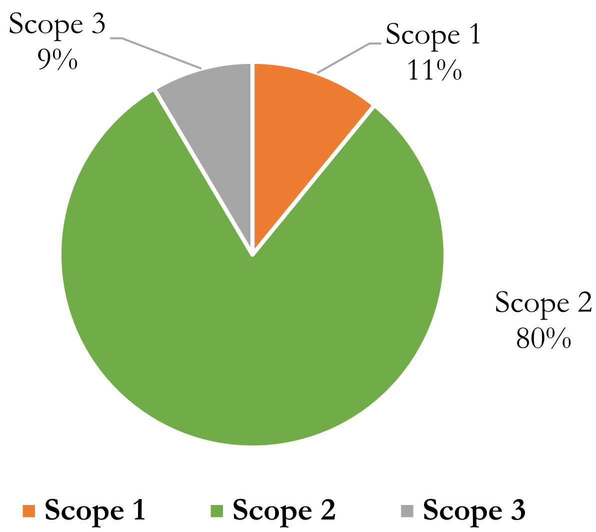

Figure 2: Summary of the proportion of calculated greenhouse gas emissions from the various scopes for the operation of the proposed project.

Beyond changing the project's consumption of electricity these indirect Scope 2 emissions are largely dependent on the grid emissions factor for electricity. Assuming that the selected SO_2 abatement equipment will be developed as efficiently as possible, there is likely to be little scope to reduce electricity consumption and thus the greenhouse gas emissions from this source. However, as the South African electricity grid decarbonises, the emissions from this source will decline at the same rate.

As the Scope 3 emissions sources only account for a small proportion (9%) of the calculated emissions, any emissions reductions in this scope will have a mild impact on the operation emissions of the project. Furthermore, in many cases the project implementers will not exact much control over their Scope 3 emissions and will have limited opportunity to effect reductions. The remaining direct emissions calculated for Scope 1 do, however, present an opportunity for emissions reductions. The emissions also account for a small portion (11%) of those calculated with the emissions coming from the combustion of LPG on site. Switching to fuels which produce fewer emissions per unit of energy would enable the project implementer to reduce the emissions from this source. A possible fuel substitute for LPG is biodiesel.

6.2 Impact of Mitigation

The impact of substituting LPG for biodiesel in the proposed project case has been assessed in terms of its potential emissions savings. Biodiesel has a lower calorific value than LPG so greater quantities would be required to run the operation. However, if sustainably produced biodiesel has a very low emissions factor as it is assumed that the carbon emitted is re-sequestered in the growth of the fuel. A parameter comparison between the use of LPG and biodiesel is presented in Table 5.

Table 5: Comparison of the emissions parameters of combustion of LPG and biodiesel

Parameter	LPG		Biodiesel	
Emissions factor	2.94	tCO_2e/tonne	0.02	tCO_2e/tonne
Calorific Value	45.96	GJ/tonne	37.20	GJ/tonne
Quantity Required	57.00	kg/hour	70.43	kg/hour
Annual Emissions	1 468.89	tCO_2e/annum	13.74	tCO_2e/annum
	Difference:		**1 455.15**	**tCO_2e/annum**

Switching fuels from LPG to a biodiesel could potentially save the operation 1 455.15 tCO_2e per annum in its Scope 1 emissions. Considering the heat transfer efficiency losses from indirect heating this figure would be reduced slightly. However, even a heat transfer efficiency of 50% would still reduce emissions by 1 441.41 tCO_2e. Across all scopes this would reduce the emissions of the operation by 10.67 %. In the event that this was undertaken the direct Scope 1 emissions would account for as little as 0.2% of the calculated operational emissions.

This would mean that almost all of the emissions associated with the operation would happen upstream of the project operation and be for the most part beyond the control of the operation.

In the event that the project is able to develop a 1.3 MW solar PV plant it could expect to reduce its consumption of grid electricity by up to 20%. This would translate into a comparable 20% decrease in Scope 2 emissions (2 173.06 tCO_2e/annum). This would reduce the calculated emissions of the operation by 16.10% overall.

6.3 Impact of Project Alternative

The identified alternative technology for SO_2 abatement, Concentrated Mode Dual Alkali (CMDA) scrubbing process, is assessed in terms of its emissions compared to the proposed project case. While detailed project information is not available for the CMDA scrubbing process, as it was not assessed beyond the scoping phase, some values could be calculated for the major emissions sources of the process. This was done under the assumption of SO_2 capture quantities under normal operations.

It is expected that approximately 50.04 tonnes of hydrated lime would be required per day for the scrubbing process. There would be emissions associated with both the production and transportation of this input. The emissions calculated for both these sources are summarised in Table 6.

Table 6: Summary of the calculated annual emissions for the operation of the alternative CMDA scrubbing process

Source	Carbon emissions	Category
Production – Hydrated Lime $Ca(OH)_2$	10 848.97 tCO_2e per annum	Scope 3
Transport - Hydrated Lime $Ca(OH)_2$	695.19 tCO_2e per annum	Scope 3
Sum	**11 544.16 tCO_2e per annum**	

The CMDA scrubbing process will produce a significant amount of upstream Scope 3 emissions (11 544.16 tCO_2e per annum). The vast majority of these emissions are in the production of hydrated lime which is a process which releases CO_2 into the atmosphere. This technology option will also require significant quantities of electricity for the slurry pumping, filtering and thickening processes. Although, it is not possible at this stage to determine how much exactly.

Therefore, the CMDA scrubbing process will essentially displace emissions into the Scope 2 and Scope 3 category. While some other direct and indirect energy emissions may be reduced in the CMDA scrubbing process these reduction are unlikely to offset the emissions sources described above. Furthermore, by implementing this alternative technology, the project will essentially reduce its control over a larger portion of its emissions by displacing them upstream. This may make it more challenging to effect significant emissions mitigation actions such as fuel switching or energy efficiency projects.

The CMDA scrubbing process will also produce significant tonnages of gypsum annually which will have to be disposed.

6.4 Impact of Project Emissions for National Inventory and Climate Change

In terms of the national inventory the proposed SO_2 abatement equipment for the Polokwane Smelter as a whole would account for an extremely small portion even if it includes its indirect emissions. The most recently published GHG inventory for South Africa is for the year of 2010 and the national emissions are calculated to be 544 million tonnes for the year. The annual operational CO_2e emissions for the proposed project case are over 13 000 tonnes (0.002% of the national emissions). While this is an extremely small fraction it is still important to account for as each tCO_2e of greenhouse gas contributes to the national inventory and global climate change in the same way.

It is useful to consider the contribution of the SO_2 abatement equipment in terms of its addition to the emissions for the Polokwane Smelter as a whole. As shown in Figure 2 the Scope 2 emissions from electricity use account for the largest portion of the operational emissions. These emissions can be compared against the electricity emissions of the whole smelting facility. Relative to the 68 MW furnace, the additional energy requirement of the abatement equipment would increase the Scope 2 emissions of the smelter by 1.90%. The emissions from the abatement equipment are therefore very small compared to the smelter as a whole..

As discussed in the carbon footprint assessment the emissions from the Scope 2 category are determined by the grid emissions factor. Since the majority of the technology's emissions is associated with electrical energy requirements, the emissions may decrease as the grid emission factor decreases over time. There is already evidence of the gradual decarbonisation of the electricity sector in South Africa. As such the operational emissions of the plant may be even smaller in the future.

As a single source, the proposed SO_2 abatement equipment will make a relatively small contribution to national emissions and thus its magnitude is classified as, small. Despite its very small magnitude the emissions from the proposed SO_2 abatement equipment will still contribute to the national greenhouse gas inventory. As such the extent of the project's greenhouse emissions are considered to be national and thus very large. The duration of the impact of the greenhouse gas emissions is considered to be effectively permanent as the greenhouse gas emissions produced are assumed to remain in the atmosphere for 100 years. The combustion of LPG and consumption of electricity will definitely produce carbon emissions and it is certain that these emissions will contribute to the onset of global climate change. From these parameters the significance score for the project is calculated to be moderate (50). As the emitted greenhouse gases are assumed to remain in the atmosphere for such long durations the impact is effectively irreversible with the effects of climate change often resulting in the irreversible loss of resources.

Table 7: Summary of the climate change impacts of the estimated greenhouse gas emissions from the proposed installation of sulphur dioxide (SO_2) abatement equipment at the Polokwane Smelter.

Nature: The various sources of greenhouse gas emissions attributed to the SO_2 abatement equipment at the Polokwane Smelter will contribute to the global phenomenon of anthropogenic climate change. Climate change is projected to effect many environmental changes across the globe. However, none of the environmental impacts can be linked directly or indirectly on any particular sources of greenhouse gas emissions.			
	Equipment Emissions Without Mitigation	**Equipment Emissions With Mitigation**	**Alternative SO_2 Abatement Equipment Emissions**
Extent	National (4)	National (4)	National (4)
Duration	Permanent (5)	Permanent (5)	Permanent (5)
Magnitude	Small (1)	Small (1)	Small (1)
Probability	Definite (5)	Definite (5)	Definite (5)
Significance	**Moderate (50)**	**Moderate (50)**	**Moderate (50)**
Status	Negative	Negative	Positive
Reversibility	None	None	None
Irreplaceable loss of resources?	Yes	Yes	Yes
Can impacts be mitigated?	Yes	Yes	No
Mitigation: The project can only mitigate its contribution to the national emissions and climate change by reducing its greenhouse gas emissions from sources over which it has control. This would involve substituting towards combusting sustainable biofuels.			
Cumulative impacts: In terms of the national inventory, the emissions from the project are cumulative with the emissions from all other sources. Similarly the onset of climate change is induced by greenhouse gas emissions accumulated in the atmosphere from all sources over time. The onset of climate change is likely to be accelerated and sustained as emissions accumulate in the atmosphere.			
Residual risks: Even if the proposed project is able to reduce its greenhouse emissions and mitigate its contribution to global climate change the risks associated with the onset of climate change will still be prevalent. This is due the vast number of other sources of greenhouse gas emissions around the world.			

It was shown that the mitigation options for the project through fuel switching are very small in terms of the emissions reductions achievable. As such the magnitude of the impact of the emissions is still considered as small. As the extent, duration and probability of the impact are unaltered the significance of the mitigated project is the same as the proposed project case.

Similarly the alternative technology option of SO_2 abatement was estimated to have a comparable level of emissions. Thus, this option is also calculated to have an impact of moderate significance. However, the alternative SO_2 abatement technology has far more limited opportunities to mitigate its emissions due to the displacement of emissions into the indirect Scope 3 category.

Based on the impact scoring and the nature of greenhouse gas emissions being, national in extent, permanent in duration and definite in probability, even very small sources of emissions will be classified as moderate in significance. This suggests that while climate change is clearly a significant environmental concern, the assessment of sources emitting greenhouse gases should be considered within the national inventory and against their existing operations for the most balanced assessment of their impact.

7 LOCAL CLIMATE CHANGE IMPACTS

As already discussed, the greenhouse gas emissions of the proposed project (mitigated or not) would not directly result in any specific climatic changes or any local environmental impacts as a consequences of climate change. Despite this it is still relevant to consider the potential local impacts of climate change for the Polokwane Smelter and its surrounding area.

The Polokwane Smelter is located near the centre of the Limpopo Province, which is classified as having a temperate semi-arid climate. The climate is characterised by warm summers and cool winters. The summer temperatures range between 19 – 27°C. The winters are cooler and vary between 2 – 16°C. Rainfall in the area is typically low, averaging 470 mm per annum.

South Africa's Long Term Adaptation Scenarios identify six hydrological zones for the country, each with their own climate change projections. The Polokwane Smelter operations fall into the Limpopo/Olifants and Inkomati Hydrological Zone. It is projected by the Department of Environmental Affairs that the Limpopo/Olifants and Inkomati Hydrological Zone will experience drastic temperature increases never observed before in the recorded climate of the region. The zone will also experience rainfall decreases although these are projected to fall within the range of present-day climate variability.

These changes are likely to impact on the natural systems in the region as well as human activities. Any significant shortages in water yields may even directly impact upon the Polokwane Smelter and it operations. The proposed development will require 450m^3/day of water during normal operation (intermittent peaks of 3 00 m^3/day may be required). It is envisaged that the water will be obtained from the existing allocation of 2 700 m^3/day. The Polokwane Smelter currently utilises 800 m^3/day water. It has been predicted by the

Water Research Council's Mine Water Atlas that the Polokwane operations fall within a high risk area for climate related water risk.

8 OPERATIONAL EMISSIONS MANAGEMENT

Once the SO_2 abatement equipment is installed there will be limited scope to alter the emissions profile of the plant beyond the incorporation of mitigation measures, such as biofuels. As such, the emissions of the plant will be, for a large part, locked into the technology. Despite this, it is important that the operation is managed in such a way that the SO_2 abatement plant does not produce more greenhouse gas emissions than necessary.

Energy saving and emissions management is a core feature of Anglo American's group operations. Anglo American has a dedicated energy and CO_2 management programme ECO2MAN, which it introduced in 2010. The ECO2MAN programme identifies where energy is being used and helps pinpoint the best opportunities for improving practices. Successful implementation of this program involves:

- Electing energy managers and champions at each site to drive awareness of energy consumption and encourage improved processes;
- Introducing electricity metering to identify the equipment consuming the largest amounts of energy; and
- Establishing a fuel monitoring system at its sites to better monitor and record fuel usage.

It is recommended that the operations of the SO_2 abatement equipment at the Polokwane Smelter are incorporated within the ECO2MAN programme and that a greenhouse gas management hand book is developed for the smelting facility.

9 RECOMMENDATIONS FOR INCLUSION IN THE EMP

It is recommended that the operations of the SO2 abatement equipment at the Polokwane Smelter are incorporated within the ECO2MAN programme and that a greenhouse gas management hand book is developed for the smelting facility.

10 OPINION ON PROJECT

It has been shown that the proposed SO_2 abatement project for the Polokwane Smelter will account for relatively small quantities of greenhouse gas emissions. A large proportion of the emissions (80%) will be indirect Scope 2 emissions due to the consumption of electricity. In terms of the national greenhouse gas inventory these emissions will be negligible. The addition of the SO_2 abatement equipment will only increase the Scope 2 emissions of the Polokwane Smelter by 1.90%.

Despite its very small magnitude the emissions from the proposed SO_2 abatement equipment will still contribute to the national greenhouse gas inventory and global climate change. As such, the significance of the impact of the emissions is calculated to be moderate based on the extent, duration and probability of the emissions. Due to the nature of climate change the significance of this impact would be the same even for very small emitting sources or sources with mitigation.

Although the significance of the environmental impact will be unchanged, there is an opportunity to mitigate the direct Scope 1 emissions from LPG combustion in the proposed SO_2 abatement equipment. Replacing LPG with biodiesel will help the project reduce its calculated emissions by over 10%. Developing a 1.3 MW solar PV plant to substitute grid electricity can also reduce the calculated emissions by over 16%. Furthermore the majority of the plant's emissions from the consumption of electricity are dependent on the grid emission factor. As such the emissions from the plant may decrease in the future as the electricity grid decarbonises.

It is likely that the alternative CMDA scrubbing process would increase the emissions associated with abating the SO_2 from the Polokwane Smelter. However, it would displace these emissions into the Scope 2 and Scope 3 categories where they will be harder to manage. This may reduce the viability for emission reduction options such as fuel switching. It will also produce a waste product that may present other environmental concerns.

Therefore, it is concluded that the selected WSA Plant technology is the most suitable SO_2 abatement technology based on its greenhouse gas emissions and potential to mitigate them. While there is limited scope to save waste energy from the abatement equipment it is important that the facility be included within Anglo American's ECO2MAN programme to track and assess its energy and emissions intensity over time. This programme and any additional greenhouse gas management tools will help to ensure that the plant operates efficiently and is responsible for as few emissions as possible.

Any greenhouse gas emissions attributed to the SO_2 abatement project at the Polokwane Smelter cannot be directly associated with any specific climatic changes and cannot be directly linked to any local environmental impacts as a consequence. Despite this, it is still important to have identified that the location of the operation is projected to experience drastic temperature increases never observed before in the recorded climate of the region as well as experience rainfall decreases within the range of present-day climate variability. This may exacerbate stresses on water resources for the area and could possibly impact on the smelting operation.

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ANNEX A

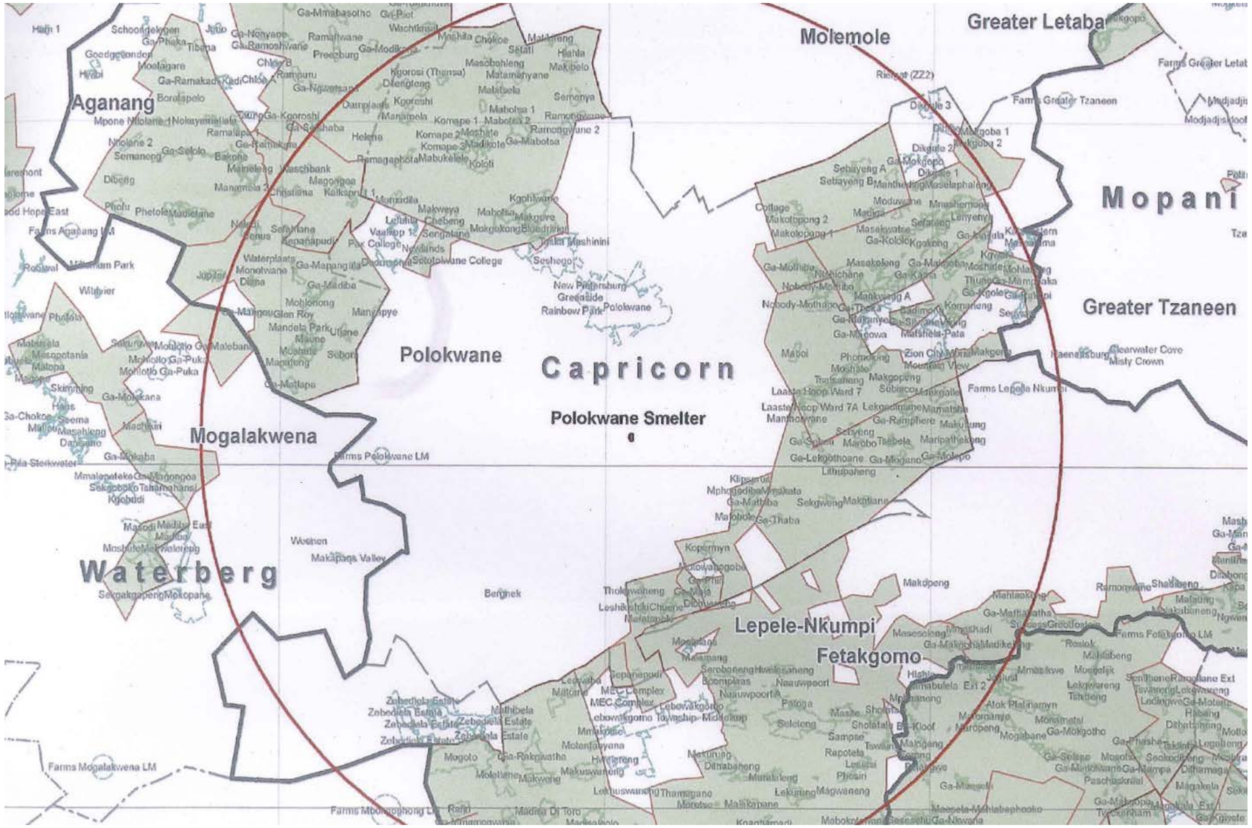

Figure 3: Map highlighting the where the Polokwane Smelter is located