Manono Lithium and Tin Project, Democratic Republic of Congo

Greenhouse Gas Assessment

MN200-5525-ENV-EN-REP-001

20 January 2021

Project No.: 0541532

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Document details	
Document title	Manono Lithium and Tin Project, Democratic Republic of Congo
Document subtitle	Greenhouse Gas Assessment
Project No.	0541532
Date	20 January 2021
Version	5
Author	Environmental Resources Management
Client Name	Dathcom Mining SA

Document history

				ERM approval to issue		
Version	Revision	Author	Reviewed by	Name	Date	Comments
Draft	1.0	Ryan McGloin	Bethany Warren	Bethany Warren	18.11.2020	
Final	2.0	Ryan McGloin	Bethany Warren	Bethany Warren	08.12.2020	
Final	3.0	Ryan McGloin	Bethany Warren	Bethany Warren	18.12.2020	
Final	4.0	Ryan McGloin	Bethany Warren	Bethany Warren	18.01.2021	
Final	5.0	Ryan McGloin	Bethany Warren	Bethany Warren	20.01.2021	

Signature Page

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Acronyms and Abbreviations

Acronym	Meaning
ANFO	Ammonium Nitrate Fuel Oil
CH_4	Methane
CO_2	Carbon dioxide
CO_2-e	Carbon dioxide equivalent
DRC	Democratic Republic of Congo
ESIA	Environment and Social Impact Assessment
FCEV	Fuel Cell Electric Vehicles
GHG	Greenhouse gas
GWP	Global Warming Potential
H_2	Hydrogen
HEPP	Hydro Electric Power Plant
HFC	Hydrofluorocarbon
IPCC	Intergovernmental Panel on Climate Change
kWh	kilowatt-hours
LCE	Lithium Carbonate Equivalent
LULUCF	Land Use Land Use Change and Forestry
Mt CO_2-e	Mega tonnes CO_2-equivalent = 1,000,000 t CO_2-e.
MW	Megawatt
MWh	Megawatt-hours
N_2O	Nitrous oxide
NGER	National Greenhouse and Energy Reporting
OECD	Organisation for Economic Co-operation and Development
PLS	Primary Lithium Sulphate
PFC	Perfluorocarbon
Scope 1 emissions	Direct greenhouse gas emissions; defined as those emissions that occur from sources that are owned or controlled by the reporting entity.
Scope 2 emissions	A category of indirect emissions that accounts for GHG emissions from the generation of purchased energy products (principally, electricity, steam/heat and reduction materials used for smelting) by the entity.
Scope 3 emissions	Those emissions that are a consequence of the activities of an entity, but which arise from sources not owned or controlled by that entity. Examples of Scope 3 activities include extraction and production of purchased materials, transportation of purchased fuels, and use of sold products and services.
SC6	Spodumene Concentrate 6%
SF_6	Sulphur hexafluoride
t CO_2-e	tonnes of carbon dioxide equivalent
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WMO	World Meteorological Organisation

EXECUTIVE SUMMARY

AVZ Minerals Limited is the majority owner (60%, with the option to increase to 75%) of Dathcom Mining SA (Dathcom). Dathcom is seeking to convert its existing Exploration Licence PR13359, which contains the Manono-Kitotolo lithium-rich pegmatite deposits in the Democratic Republic of Congo (DRC), into a Mining Lease in order to progress with the Manono Lithium and Tin Project (herby termed the 'Project'). Dathcom will own the Mining Lease.

The Project will include an open-pit mining operation at the Roche Dure pegmatite deposit, producing lithium, tin and tantalum. The Project will also consist of construction of spodumene concentrate (SC6) and primary lithium sulphate (PLS) processing facilities. It is expected that 700,000 t/year of SC6 and 46,000 t/year of PLS will be produced annually with 153,000 t/year of the SC6 product used as feedstock in the PLS production. Once processed, products will be transported using company owned vehicles to Kabondo Dianda where it will be loaded onto trains for transport to the port

ERM have been appointed to prepare a greenhouse gas (GHG) assessment for the life of the Project (20 years). The GHGs evaluated in this study are carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4), which were estimated using a methodology consistent with the 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines. This assessment includes the estimation of GHG emissions (Scope 1 and Scope 2) associated with all operations at the mine, processing facilities and transport of the products. Key activities include land clearing, fuel consumption in mining equipment and transport vehicles, electricity production and blasting.

The GHG emissions associated with the production of PLS (i.e. **715,443 t CO_2-e/life of project**) are anticipated to be greater than the emissions associated with the production of SC6 (i.e. **552,785 t CO_2-e/ life of project**).This is due to the large amount of diesel that is expected to be combusted in the calciner plant within the PLS processing facility, which is expected to account for almost half of the total emissions associated with the life of the Project.

Mean annual emissions are expected to be **27,639 t CO_2-e/year** and **35,772 t CO_2-e/year** for SC6 and PLS production, respectively, with an annual total of **63,411 t CO_2-e/year**.

To contextualise the Project's GHG emissions, the Project's emission intensity for SC6 production (i.e. Scope 1 and Scope 2 emissions per tonne of product produced) and LCE production from PLS (including Scope 1 and Scope 2 emissions as well as Scope 3 emissions associated with transporting and refining the PLS product) were compared to published emission intensities for other facilities, as shown in **Figure E1** and **Figure E2**.

Comparison of the Project's emission intensity with other available intensities for SC6 production, suggests that the Project will use technology that will result in the emission intensity being less than half of those at other existing pegmatite facilities. The emissions intensity for LCE production from PLS is lower than the lowest existing emission intensity for mineral mines. It is noted that brine facilities typically involve less fuel intensive extraction methods, shorter transport distances to refining facilities and lower refining emissions than mineral mining.

The Project is investigating and planning substantial GHG mitigation measures. These include the establishment of a 5000 ha plantation forest, purchase of an electric mining fleet once commercially viable equipment is available and generation of Hydrogen (H_2) from excess renewable electricity to enable Fuel Cell Electric Vehicles (FCEVs). If Dathcom are able to transition to a fleet of mining and haulage vehicles that are entirely electric (i.e. no mobile combustion), this will reduce GHG emissions of the Project by an estimated **29,404, t CO_2-e/year**, as shown in the hashed bars in **Figure E1** and **Figure E2**.

Furthermore, additional carbon capture sequestration technology is being reviewed which will recover the CO_2 from the diesel fired calcining kilns and convert it to soda ash, thereby decreasing the CO_2-e/year further

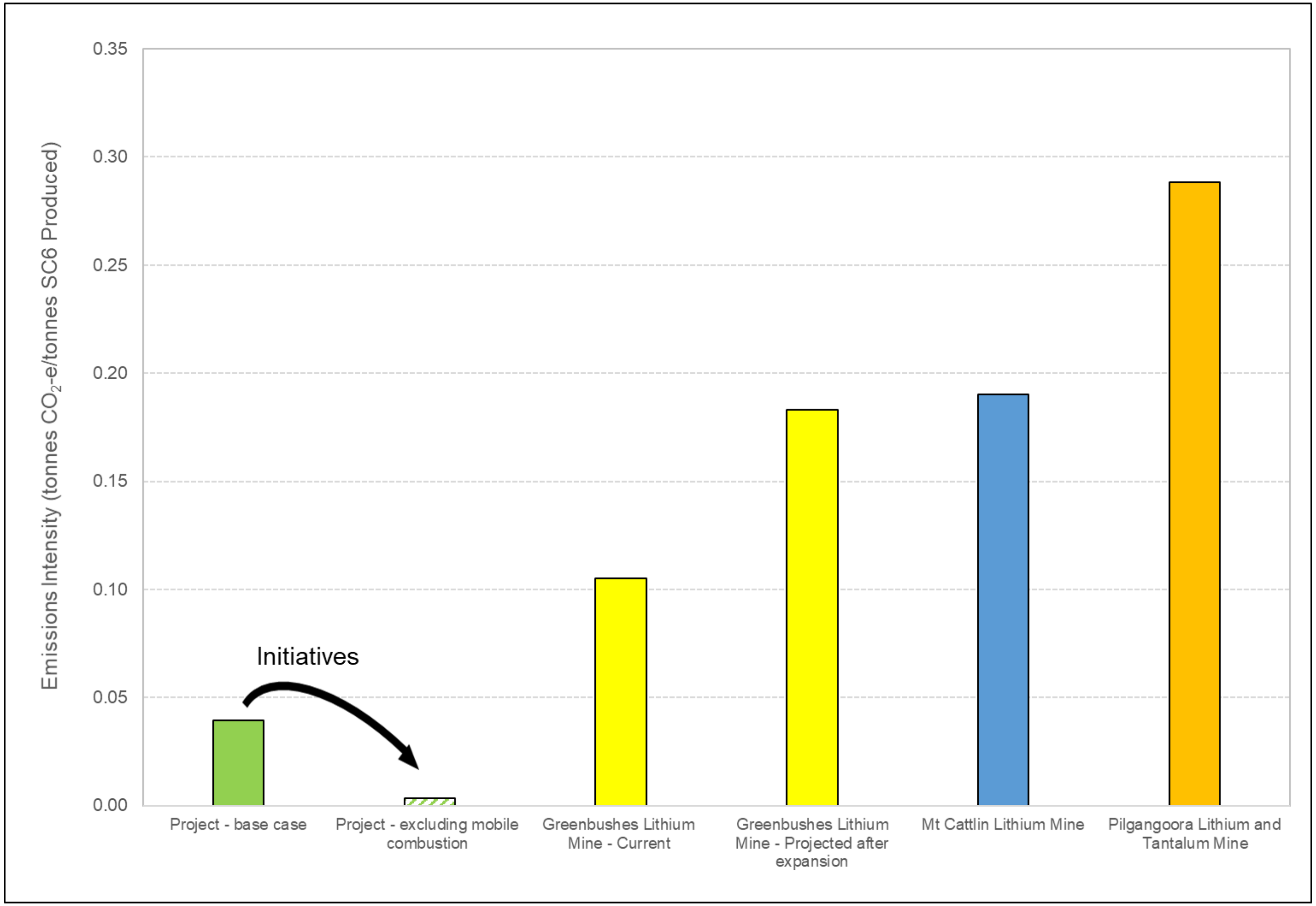

Figure E1: Project SC6 Emission Intensities Comparison (using Scope 1 and Scope 2 Emissions)

Sources: (i) (GHD, 2018) - Greenbushes Lithium Mine Expansion: Environmental Referral Additional Information, prepared by GHD Pty Ltd for Talison Lithium Australia Pty Ltd.
(ii) (Pilbara Minerals, 2019) - 2019 Annual Report. Pilbara Minerals Limited
(iii) (Galaxy Resources, 2020) - Sustainability Report for the Year Ended 31 December 2019. Galaxy Resources Limited

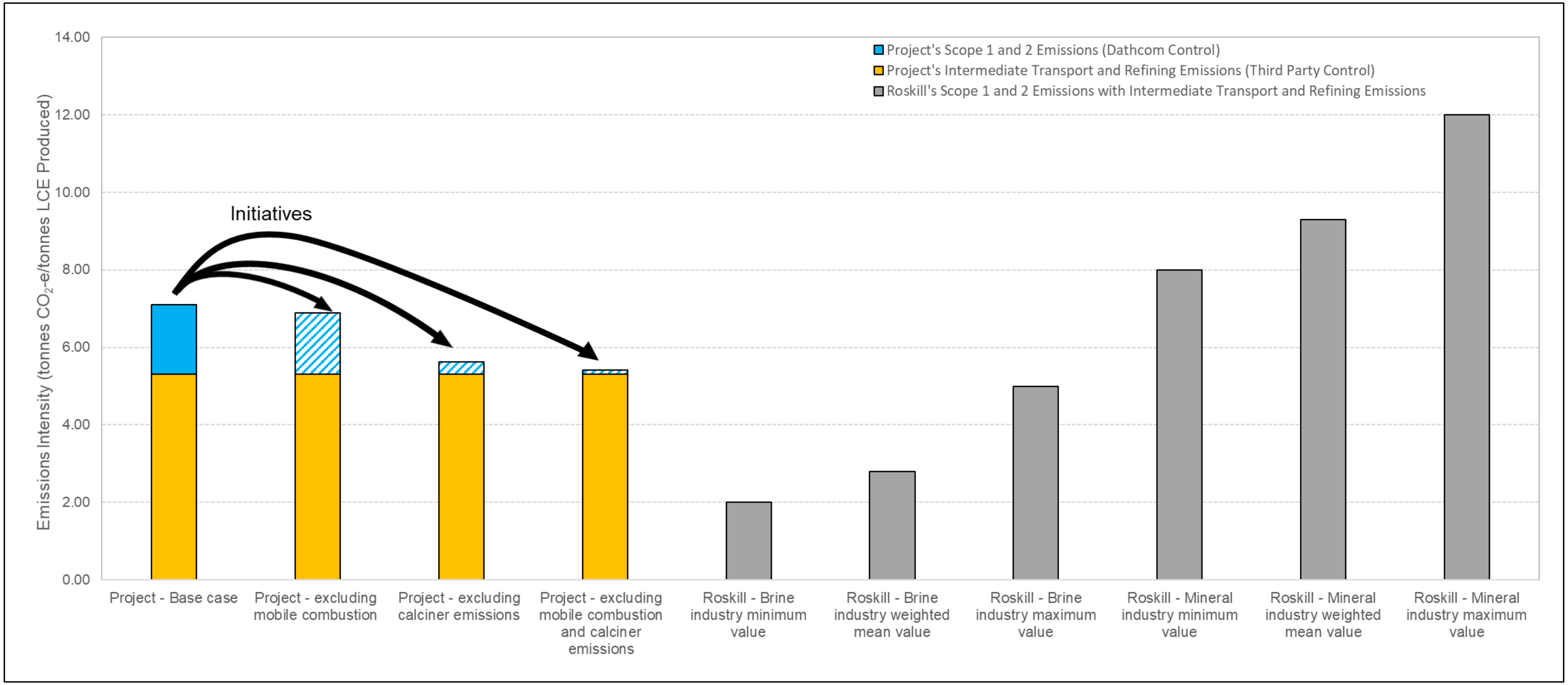

Figure E2: Project LCE Emission Intensity Comparison (using Scope 1, Scope 2 and Intermediate Transport and Refining Emissions)

Sources: (i) All project emission intensities were calculated by ERM
(ii) ((Roskill, 2020) - Lithium's Growing CO_2 Footprint: An Analysis of Energy Consumption and Emissions Intensity from Global Lithium Supply. Roskill Information Services Ltd.

1. INTRODUCTION

AVZ Minerals Limited is the majority owner (60%, with the option to increase to 75%) of Dathcom Mining SA (Dathcom). Dathcom is seeking to convert its existing Exploration Licence PR13359, which contains the Manono-Kitotolo lithium-rich pegmatite deposits in the Democratic Republic of Congo (DRC), into a Mining Lease in order to progress with the Manono Lithium and Tin Project (herby termed the 'Project'). Dathcom will own the Mining Lease.

1.1 Project Description

The proposed Project is located within the Manono Territory of the Tanganyika Province in the DRC. The mine will cover an area of approximately 188 square kilometres. General activity and production estimates for the Project are given in **Table 1-1**.

The Project will include the Roche Dure an open-pit pegmatite mining operation producing lithium, tin and tantalum. The Project will also consist of construction of processing facilities for spodumene concentrate (SC6) and primary lithium sulphate (PLS). It is expected that 700,000 t/year of SC6 and 46,000 t/year of PLS will be produced with 153,000 t/year of the SC6 product used as feedstock in the PLS production. Once processed, products will be transported using company owned vehicles to Kabondo Dianda where it will be loaded onto trains for transport to the ports

The Project also includes the refurbishment of the abandoned Mpiana Mwanga Hydro Electric Power Plant (HEPP). The HEPP will provide all of the facility's energy requirements (excluding diesel fuel usage in mining equipment and vehicles).

Table 1-1: Project Production Estimates

Description	Value	Units
Life of project [a]	20	years
Spodumene Concentrate (SC6) production [a]	700,000	t/year
Lithium Sulphate (PLS) production [a]	46,000	t/year
SC6 used in PLS production [a]	153,000	t/year
SC6 transported from mine [a]	547,000	t/year
PLS transported from mine [a]	46,000	t/year

a. Source: Dathcom responses to RFI received on 20/11/2020 (Dathcom Mining SA, 2020)

1.2 Scope of Assessment

ERM have been appointed to prepare a greenhouse gas (GHG) assessment for the Project. This GHG assessment includes:

- An assessment of the Project's Scope 1 and Scope 2 emissions using the IPCC emission estimation methodology. Sources include: land clearing, fuel consumption in mining equipment and transport activities, electricity usage and blasting. Emission estimates have been split according to each product stream.
- Benchmarking against similar pegmatite mines and other facilities. To contextualise the Project's estimated emissions, the Project's emission intensities (t-CO_2e/t of product produced) for the two product streams were compared against publically available data from other lithium production facilities.
- A qualitative review of the Project's proposed GHG mitigation actions.

2. LEGAL FRAMEWORK AND GUIDELINES

The DRC signed the United Nations Framework Convention on Climate Change (UNFCCC) on 11 June 1992. This was subsequently ratified by the DRC government in January 1995 and came into force in April of the same year (UNFCCC, 2020a).

2.1 Intergovernmental Panel on Climate Change

The Intergovernmental Panel on Climate Change (IPCC) is a panel established in 1988 by the World Meteorological Organisation (WMO) and the United Nations Environment Programme (UNEP) to provide independent scientific advice on climate change. The panel was originally asked to prepare a report, based on available scientific information, on all aspects relevant to climate change and its impacts and to formulate realistic response strategies. This first assessment report of the IPCC served as the basis for negotiating the UNFCCC.

The IPCC also produce a variety of guidance documents and recommended methodologies for GHG emissions inventories, including (for example):

- the 2006 IPCC Guidelines for National GHG Inventories (IPCC, 2006)
- the Good Practice Guidance and Uncertainty Management in National GHG Inventories (IPCC, 2000).

Since the UNFCCC entered into force in 1994, the IPCC remains the pivotal source for scientific and technical information relevant to GHG emissions and climate change science.

2.2 United Nations Framework Convention on Climate Change

The UNFCCC sets an overall framework for intergovernmental efforts to tackle the challenge posed by climate change. It recognises that the climate system is a shared resource, the stability of which can be affected by industrial and other emissions of carbon dioxide (CO_2) and other GHGs. The convention has near-universal membership, with 172 countries (parties) having ratified the treaty, the Kyoto Protocol.

Under the UNFCCC, governments:

- Gather and share information on GHG emissions, national policies and best practices.
- Launch national strategies for addressing GHG emissions and adapting to expected impacts, including the provision of financial and technological support to developing countries.
- Cooperate in preparing for adaptation to the impacts of climate change.

2.3 Kyoto Protocol

The Kyoto Protocol entered into force on 16 February 2005. The Kyoto Protocol built upon the UNFCCC by committing to individual, legally binding targets to limit or reduce GHG emissions. The Kyoto Protocol was ratified by the DRC government in March 2005, and came into force in June of the same year. The GHGs included in the Kyoto Protocol were:

- carbon dioxide (CO_2)
- methane (CH_4)
- nitrous oxide (N_2O)
- hydrofluorocarbons (HFCs)
- perfluorocarbons (PFCs)
- sulfur hexafluoride (SF_6).

Each of the above gases has a different effect on the earth's warming and this is a function of radiative efficiency and lifetime in the atmosphere for each individual gas. To account for these variables, each gas is given a 'global warming potential' (GWP) that is normalised to CO_2. For example, CH_4 has a GWP of 28 over a 100 year lifetime (IPCC, 2014). This factor is multiplied by the total mass of gas to be released to provide a CO_2 equivalent mass, termed 'CO_2-equivalent' or CO_2-e.

Emission reduction targets were calculated based on a party's domestic GHG emission inventories (which included land use change and forestry clearing, transportation and stationary energy sectors). The Kyoto Protocol required developed countries to meet national targets for GHG emissions over a five-year period between 2008 and 2012.

To achieve their targets, Annex I Parties had to implement domestic policies and measures. The Kyoto Protocol provided an indicative list of policies and measures that might help mitigate climate change and promote sustainable development. The DRC does not comprise an Annex 1 Party.

2.4 Paris Agreement

In 2015, a historic global climate agreement was reached under the UNFCCC at the 21st Conference of the Parties (COP21) in Paris (known as the Paris Agreement). The Paris Agreement sets in place a durable and dynamic framework for all countries to take action on climate change from 2020 (that is, after the Kyoto period), building on existing efforts in the period up to 2020. Key outcomes of the Paris Agreement include:

- A global goal to hold average temperature increase to well below 2°C and pursue efforts to keep warming below 1.5°C above pre-industrial levels.
- All countries to set mitigation targets from 2020 and review targets every five years to build ambition over time, informed by a global stocktake.
- Robust transparency and accountability rules to provide confidence in countries' actions and track progress towards targets.
- Promoting action to adapt and build resilience to climate change.
- Financial, technological and capacity building support to help developing countries implement the Paris Agreement.

The DRC signed the Paris Agreement on 22 April 2016. This was ratified by the DRC government in December 2017 and came into force in January 2018.

In preparation for the Paris Agreement, DRC submitted its Intended Nationally Determined Contribution (INDC) in 2015. This document set a conditional emissions reduction target of 17% by 2030 compared to a business-as-usual (BAU) scenario. The INDC covers the energy, agriculture and forest sectors, with the DRC's intended contribution dependent on adequate support in the form of technology transfer, capacity development and financial resources.

3. EMISSIONS ESTIMATION METHODOLOGY

3.1 Introduction to Greenhouse Gases

GHGs are gases in Earth's atmosphere that play an important role in regulating the earth's temperature. The GHG emissions associated with the proposed activities are methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2). GHG emissions are all expressed as tonnes of carbon dioxide equivalents (t CO_2-e).

Global Warming Potential (GWP) is a measure of the total energy that a gas absorbs over a particular period of time (usually 100 years), compared to carbon dioxide. Carbon dioxide equivalent (CO_2-e) is a metric measure used to compare the emissions from various GHG based on their GWP (USEPA, 2017). The GWP values used for this assessment are presented in **Table 3-1** and were obtained from the IPCC Fifth Assessment Report (IPCC, 2014). These values are recommended to be used by the Greenhouse Gas Protocol (GHG Protocol, 2018) and exclude climate-carbon feedbacks.

Table 3-1: 100-Year Global Warming Potential Values

Greenhouse Gas	Global Warming Potential Values
Carbon dioxide (CO_2)	1
Methane (CH_4)	28
Nitrous oxide (N_2O)	265

Source: Table 8.7, Chapter 8 of the IPCC Fifth Assessment Report (IPCC, 2014).

GHG emissions are divided into three categories; i.e. Scope 1, Scope 2 and Scope 3. The definition of each scope, in accordance with the Greenhouse Gas Protocol (World Resources Institute, 2004), is as follows:

- Scope 1 - Direct GHG emissions occur from sources that are owned or controlled by the company, for example, emissions from combustion in owned or controlled boilers, furnaces, vehicles, etc.; emissions from chemical production in owned or controlled process equipment. This includes fugitive emissions such as gas venting or flaring.
- Scope 2 - Scope 2 accounts for GHG emissions from the generation of purchased electricity consumed by the company. Purchased electricity is defined as electricity that is purchased or otherwise brought into the organisational boundary of the company. Scope 2 emissions physically occur at the facility where electricity is generated.
- Scope 3 - Scope 3 is an optional reporting category that allows for the treatment of all other indirect emissions. Scope 3 emissions are a consequence of the activities of the company, but occur from sources not owned or controlled by the company. Some examples of scope 3 activities are extraction and production of purchased materials; transportation of purchased fuels; and use of sold products and services.

A visual representation of Scope 1, Scope 2 and Scope 3 emissions are provided in **Figure 3 1.**

Standard practice for GHG emission estimation for regulatory reporting purposes is to only include Scope 1 and Scope 2 emissions. This is because Scope 3 emissions are difficult to estimate accurately and will also include an element of 'double-counting' as the Scope 3 emissions of one entity (e.g. employee business travel) will comprise Scope 1 emissions of another entity (e.g. the airline in question) when considered on a national scale. As a result, this report mainly focusses on the Scope 1 and Scope 2 emissions associated with the Project, however, emissions from some Scope 3 sources were quantified in order to effectively compare Project emissions with similar facilities. The identified emissions sources are described in **Section 3.2**.

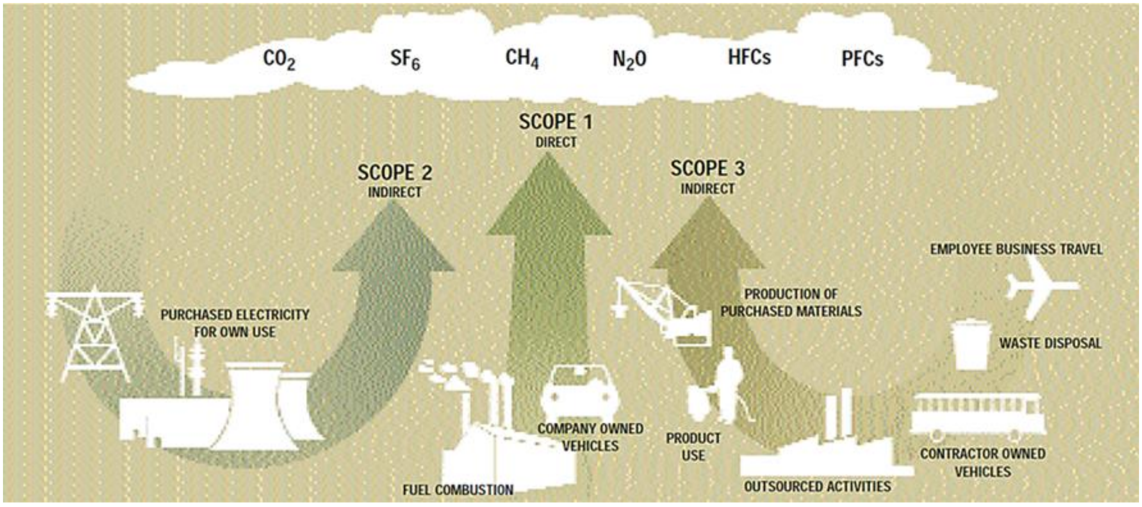

Figure 3-1: Overview of Scopes and Emissions across a Reporting Entity (WRI and WBCSD, 2004)

3.2 Emission Sources

The Scope 1 and Scope 2 sources of the GHG emissions identified for the Project are presented in **Table 3-2**, while the relevant Scope 3 emissions are identified in **Table 3-3** (it should be noted that this does not represent the full range of Scope 3 emissions associated with the Project but only those required to make effective comparisons with published values from other facilities). The emissions estimated for these sources are presented in **Section 3.4**.

Initially, diesel will be the only fuel used in on-site mobile mining equipment, stationary mining equipment and company-owned vehicles used to transport the SC6 and PLS products to the rail transports. There is the intention to convert to an electric mining fleet once commercially viable equipment is available (this is discussed further in **Section 4.2**).

All electricity will be generated on-site by AVZ Power SAU (AVZ Power), which will-own the HEPP on a 25 year lease from the DRC Government, with no electricity purchased from the grid. Therefore, emissions associated with electricity production are considered as Scope 1 emissions in this assessment.

Table 3-2: Scope 1 and 2 GHG Emission Sources Identified for the Project

Emission Source	Scope / Greenhouse Gases
Mobile combustion – fuel consumption in mobile mining equipment [a], and company owned vehicles used to transport products [b]	Scope 1 CO_2, CH_4 and N_2O
Stationary combustion – fuel consumption in stationary mining equipment [c]	Scope 1 CO_2, CH_4 and N_2O
Explosives usage	Scope 1 CO_2, CH_4 and N_2O
Land clearing	Scope 1 CO_2
Electricity production	Scope 1 CO_2

a. It has been assumed that the pit shovel and front end loaders will be electric from day one of operations, with the electrical power coming from AVZ Power's HEPP.

b. AVZ is currently investigating the use of fuel cell electric vehicles (FCEVs) for product transportation.

c. AVZ is currently researching carbon capture sequestration technology to reduce calcining kiln carbon emissions and convert them to soda ash.

Table 3-3: Scope 3 GHG Emission Sources Identified for the Project

Emission Source	Scope / Greenhouse Gases
Emissions associated with transporting the SC6 by rail from Kabondo Dianda to Dar es Salaam	Scope 3 CO_2
Emissions associated with transporting the PLS by rail from Kabondo Dianda to Lobito	Scope 3 CO_2
Emissions associated with transporting the SC6 by ship to Shanghai	Scope 3 CO_2
Emissions associated with transporting the PLS by ship to Rotterdam	Scope 3 CO_2
Emissions associated with transporting the PLS from Rotterdam to German refining facility	Scope 3 CO_2
Emissions associated with refining the PLS into Lithium Carbonate Equivalent (LCE)	Scope 3 CO_2

3.3 Overview of Emissions Estimation Methodology

Scope 1 and Scope 2 GHG emissions were estimated based on activity data provided by Dathcom and the methods outlined in the 2006 IPCC guidelines for national GHG inventories (IPCC, 2006) and the 2019 Refinement to the 2006 IPCC guidelines for national GHG inventories (IPCC, 2019).

The 2006 IPCC guidelines for national GHG inventories (2006 IPCC Guidelines) provide methodologies for estimating national inventories of anthropogenic emissions by sources and removals by sinks of greenhouse gases. The 2019 refinement to the 2006 IPCC Guidelines was published with the aim to provide an updated and sound scientific basis for supporting the preparation of national greenhouse gas inventories (IPCC, 2019). The 2019 refinement updated the 2006 IPCC Guidelines where gaps or out-of-date science were identified. It does not replace the 2006 IPCC Guidelines, but should be used in conjunction with the 2006 Guidelines (IPCC, 2019).

As the DRC signed the UNFCCC on 11 June 1992 (ratified in January 1995, and came into force in April 1995 (UNFCCC, 2020a)), the DRC follows the UNFCC reporting guidelines. The UNFCCC reporting guidelines on annual inventories for Annex I Parties (decision 24/CP.19) requires the use of the 2006 IPCC Guidelines for National GHG Inventories (UNFCCC, 2020b). These guidelines, as used for this assessment, consist of a three-tier approach to estimate emissions from fossil fuel combustion, as shown in **Table 3-4**.

The methods used to estimate Scope 3 emissions are covered in **Section 3.4.6**.

Table 3-4: Methodology Tiers for GHG Emissions Estimation from Fossil Fuel

Scope	Description	Treatment in this assessment
Tier 1 Approach	Calculates emissions by multiplying estimated fuel consumed with a default emission factor. For CO_2, emission factors mainly depend upon the carbon content of the fuel and therefore emissions can be estimated fairly accurately using this method. Emission factors for CH_4 and N_2O depend on the combustion technology and operating conditions and vary significantly. As such, large uncertainties are anticipated from this method.	Approach used for CO_2, CH_4, and N_2O.
Tier 2 Approach	The approach is the same as Tier 1 but country-specific emission factors are used in place of the Tier 1 defaults.	Not used in this assessment as no country-specific published data were found for the DRC.
Tier 3 Approach	Technology-specific emission factors.	Not used in this assessment as no technology-specific emission factors were found for the DRC.

Source: (IPCC, 2006) - Section 1.3 of Volume 2 (Energy) Chapter 1 (Introduction).

3.4 Emissions Inventory

The methodology used and resulting emissions for the emission sources presented in **Table 3-2** are presented in **Sections 3.4.1** to **3.4.5**. These sections provide an overview of the Project's activities, processes and expected GHG emissions. Key assumptions and data that were used in developing the emission inventory for each activity are also provided in the following sections.

3.4.1 Fossil Fuel Combustion – Scope 1

In accordance with Section 1.3, Volume 2, Chapter 1 of the 2006 IPCC Guidelines (IPCC, 2006), three tier approaches are available to estimate emissions from fossil fuel combustion. While most carbon is immediately emitted as CO_2 during the combustion process, some carbon is released as carbon monoxide (CO), CH_4 and non-methane volatile organic compounds (NMVOCs).

CO_2 emissions (and emission factors) are dependent on the total carbon in the fuel but are independent of combustion technology while CH_4 and N_2O emissions are strongly dependent on the combustion technology.

Equation 1 was used to estimate the emissions from fuel combustion in terms of CO_2-e for CO_2, CH_4 and N_2O. The individual gas types converted using their respective GWP, as presented in **Table 3-1,** were summed to provide the total CO_2-e for each activity (IPCC, 2006).

Equation 1: Fuel Combustion

$$\mathrm{E_j} = \frac{\mathrm{Q_i} \times \mathrm{EC}_j \times \mathrm{EF_{ijoxec}}}{1000}$$

where:

$\mathrm{E_j}$	=	Estimated emissions of gas type (j) (CO_2, CH_4 or N_2O) from fuel type (i)	(t CO_2-e/year)
$\mathrm{Q_i}$	=	Estimated quantity of fuel type (i)	(tonnes or kL/year)
$\mathrm{EC_j}$	=	Energy content factor of fuel (j)	(GJ/t or GJ/kL)
$\mathrm{EF_{ijoxec}}$	=	Emission factor for each fuel type (j)	(kg CO_2-e/GJ or tonne)

3.4.1.1 Mobile Combustion

While the long-term goal of the Project is to convert to an electric mining fleet, this assessment assumes that diesel will be consumed in ore mining and SC6 processing operations in heavy mobile equipment such as; excavators, motor graders, bulldozers, loaders, compactors and crushers. It is also assumed that diesel will also be consumed in company-owned vehicles used to transport the SC6 and PLS products to the rail transports. All on-site light vehicles, including the pit shovel and front end loaders, will be electric from day one of operations, with the electrical power coming from AVZ Power's HEPP.

Default Tier 1 emission factors for off-road sources (industry) were used to estimate CO_2, CH_4 and N_2O emissions for mobile combustion associated with the Project. The emission factors were obtained from Table 3.3.1 of Volume 2 (Energy), Chapter 3 (Mobile Combustion) of the 2006 IPCC Guidelines (IPCC, 2006). The CH_4 and N_2O default emission factors were converted to a tonne CO_2-equivalent basis using their respective GWP (shown in **Table 3-1**).

The default net calorific value for diesel was obtained from Table 1.2 of Volume 2 (Energy), Chapter 1 (Introduction) of the 2006 IPCC Guidelines (IPCC, 2006).

A summary of the emissions factors, energy content factors and relevant parameters are presented in **Table 3-5**. The estimated quantities of diesel combusted were provided by Dathcom and are presented in **Table 3-6**. Note that diesel usage has been split into combustion associated with SC6 and PLS production.

Table 3-5: Default Emissions Factors and Energy Content Factors for Diesel and Gasoline Combustion in Mobile Equipment and Vehicles

Description	Value	Units
Energy content factor for diesel	43 [a]	TJ/Gg or GJ/t
	35.9 [b]	GJ/kL
Diesel density [c]	0.836	kg/L or t/kL
Tier 1 CO_2 emission factor – diesel [d]	74.1	kg CO_2-e / GJ
Tier 1 CH_4 emission factor – diesel [d]	4.15	kg CH_4 / TJ
	0.12	kg CO_2-e / GJ
Tier 1 N_2O emission factor – diesel [d]	28.6	kg N_2O / TJ
	7.6	kg CO_2-e / GJ

a. Source: (IPCC, 2006) - Table 1.2 (default net calorific values (NCVs) and lower and upper limits of the 95% confidence intervals), page 1.18, Volume 2 (Energy), Chapter 1 (Introduction).

b. Estimated by ERM based on the fuel density.

c. Source: (DEWHA, 2012) - Table 1, page 6, National Pollutant Inventory Emission Estimation Technique Manual for Fuel and Organic Liquid Storage, Version 3.3.

d. Source: (IPCC, 2006) - Table 3.3.1 (default emission factors for off-road mobile sources and machinery), page 3.36, Volume 2 (Energy), Chapter 3 (Mobile Combustion). Emission factors were provided in kg of GHG per TJ on a net calorific basis. As such, these emission factors were converted to a CO_2-e basis using their respective GWP from **Table 3-1**.

Table 3-6: Mobile Equipment and Vehicles Fuel Consumption

Description	Value	Units
Total estimated annual diesel usage in mobile mining equipment	4,800,000 [a]	L/year
	172,550 [b]	GJ/year
Total estimated annual diesel usage in company-owned vehicles used to transport the SC6 and PLS products	5,200,000 [a]	L/year
	186,930 [b]	GJ/year
Estimated annual diesel used in mobile mining equipment in the production of SC6	134,836 [c]	GJ/year
Estimated annual diesel used in mobile mining equipment in the production of PLS	37,715 [c]	GJ/year
Estimated annual diesel used in company-owned vehicles used to transport the SC6 product	172,429 [d]	GJ/year
Estimated annual diesel used in company-owned vehicles used to transport the PLS product	14,500 [d]	GJ/year

a. Source: Dathcom responses to RFI received on 20/11/2020 (Dathcom Mining SA, 2020).

b. Estimated by ERM based on energy content factor for diesel from **Table 3-5**.

c. Estimated by ERM based on the total estimated annual diesel usage in mobile mining equipment and light vehicles, and the total SC6 production and SC6 used in PLS production from **Table 1-1**.

d. Estimated by ERM based on the total estimated annual diesel usage in company-owned vehicles used to transport the SC6 and PLS products, and the SC6 transported from mine and PLS transported from mine from **Table 1-1**.

The GHG emissions for the Project from all mobile sources were estimated using Equation 1 and are presented in **Table 3-7.** Note that emissions have been split into those associated with SC6 and PLS production.

Table 3-7: Annual GHG Emissions from Mobile Combustion

Product	Description	GHG Emissions (t CO_2-e/year)			
		CO_2	CH_4	N_2O	**Total**
SC6	Diesel used in mobile mining equipment	9,991	16	1,022	11,029
	Diesel used in company-owned vehicles used to transport the product	12,777	20	1,307	14,104
PLS	Diesel used in mobile mining equipment	2,795	4	286	3,085
	Diesel used in company-owned vehicles used to transport the product	1,074	2	110	1,186
All Product	Diesel used in mobile mining equipment	12,786	20	1,308	14,114
	Diesel used in company-owned vehicles used to transport the product	13,851	22	1,417	15,290
	Total	**26,637**	**42**	**2,724**	**29,404**

3.4.1.2 Stationary Combustion

A diesel fired rotary calcining kiln will be used for calcination and conversion within the PLS processing facility.

Default Tier 1 emission factors for stationary combustion in manufacturing industries and construction were used to estimate CO_2, CH_4 and N_2O emissions from diesel combustion in the rotary kiln in the calciner plant. These emission factors were obtained from Table 2.3 of Volume 2 (Energy), Chapter 2 (Stationary Combustion) of the 2006 IPCC Guidelines (IPCC, 2006) and were converted to a tonne CO_2-equivalent basis for CH_4 and N_2O using their respective GWP (shown in **Table 3-1**).The default net calorific value for diesel was obtained from Table 1.2 of Volume 2 (Energy), Chapter 1 (Introduction) of the 2006 IPCC Guidelines (IPCC, 2006).

A summary of the emission factors, energy content factors and relevant parameters are presented in **Table 3-8**.

The estimated quantities of diesel combusted in the calciner plant during the Project are presented in **Table 3-9**. The GHG emissions were estimated using Equation 1 and are presented in **Table 3-10**.

Table 3-8: Emission Factors and Energy Content Factors for Stationary Combustion

Description	Value	Units
Energy content factor (or net calorific value) for diesel [a]	35.9 [a]	GJ/kL
Tier 1 CO_2 emission factor – diesel [b]	74.1	kg CO_2-e/ GJ
Tier 1 CH_4 emission factor – diesel [b]	3	kg CH_4/ TJ
	0.084	kg CO_2-e/ GJ
Tier 1 N_2O emission factor – diesel [b]	0.6	kg N_2O/ TJ
	0.159	kg CO_2-e/ GJ

a. Source: See energy content factor for diesel in **Table 3-5**.

b. Source: (IPCC, 2006) - Table 2.3 (default emission factors for stationary combustion in manufacturing industries and construction), Volume 2 (Energy), Chapter 2 (Stationary Combustion). Emission factors were provided in kg of GHG per TJ on a net calorific basis. As such, these emission factors were converted to a CO_2-e basis using their respective GWP from **Table 3-1.**

Table 3-9: Fuel Consumption for Stationary Energy Purposes

Description	Value	Units
Total estimated annual diesel usage in PLS processing facility	11,000,000 [a]	L/year
	395,428 [b]	GJ/year

a. Source: Source: Dathcom responses to RFI received on 20/11/2020 (Dathcom Mining SA, 2020).

b. Estimated by ERM based on energy content factor for diesel from **Table 3-5.**

Table 3-10: Annual GHG Emissions from Stationary Combustion

Product	Description	GHG Emissions (t CO_2-e/year)			
		CO_2	CH_4	N_2O	**Total**
PLS	Diesel usage in PLS processing facility	29,301	33	63	**29,397**

3.4.2 Land Clearing – Scope 1

Land clearing needs to be considered in terms of the carbon sink lost with the removal of plant life, both above ground and below ground.

Emissions of CO_2 from land clearing were calculated using the methodology provided in Chapter 9 (Other Land) of Volume 4 (Agriculture, Forestry and Other Land Use) of the 2006 IPCC Guidelines (IPCC 2006), where ‘Other land’ includes bare soil and rock. The biomass carbon stocks of the land cleared were estimated using the below equation, as per equation 2.16 from Chapter 2 of Volume 4 (Agriculture, Forestry and Other Land Use) of the 2006 IPCC Guidelines (IPCC 2006):

Equation 2: Change in Biomass Carbon Stocks on Land Converted to Other Land Category

$$\Delta C_{Conversion} = A_{Conversion} \times (B_{After} - B_{Before}) \times CF$$

where:

$\Delta C_{Conversion}$	=	Change in biomass carbon stocks on land converted to another land category,	(t C/year)
$A_{Conversion}$	=	Area of land converted to 'other land' from initial land use	(tonnes or GJ/year)
B_{After}	=	Amount of living biomass immediately after conversion to 'other land'	(tonnes of dry matter/ha)
B_{Before}	=	Amount of living biomass immediately before conversion to 'other land'	(tonnes of dry matter/ha)
CF		Carbon fraction of dry matter	(tonnes C/tonnes d.m.)

Based on a plot plan of the mine site provided by Dathcom and analysis in ArcMap, it was estimated that the total amount of land to be cleared for the life of the Project is 251 ha (Dathcom Mining SA, 2020).

According to Chapter 9 of Volume 4 (Agriculture, Forestry and Other Land Use) of the 2006 IPCC Guidelines, conversion of land to 'Other Land' will result in the removal of all biomass stocks (i.e. $B_{After} = 0$). Based on the available data for the types of vegetation and climate at the Project site and the data presented in Table 4.7 in Chapter 4 (Forest Land) of Volume 4 (Agriculture, Forestry and Other Land Use) of the 2019 Refinement to the 2006 IPCC Guidelines, the type of existing vegetation that will be cleared for the Project was assumed to be African tropical shrub land. It is assumed that the area after land clearing will be bare soil or rock.

According to Chapter 9 of Volume 4 (Agriculture, Forestry and Other Land Use) of the 2006 IPCC Guidelines, conversion of land to 'Other Land' will result in a release of organic carbon previously held in soil if the conversion is to impervious surfaces such as bare rock, with the mineral soil carbon stocks assumed to be zero at the end of a 20 year transition period (IPCC, 2006). Based on the data presented in Table 2.3 in Chapter 2 of Volume 4 (Agriculture, Forestry and Other Land Use) of the 2019 Refinement to the 2006 IPCC Guidelines, the type of existing soil that will be cleared for the Project was assumed to be tropical low activity clay (LAC) minerals that are dominated by clay minerals and amorphous iron and aluminium oxides.

The carbon stocks of dead organic matter for the existing land use at the proposed mine site are assumed to be negligible as carbon stocks in litter and dead wood pools in all non-forest land categories are assumed to be zero (IPCC, 2006).

The carbon stocks before and after land conversion are summarised in **Table 3-11**.

The total cumulative GHG emissions associated with land disturbance for the Project are presented in **Table 3-12**. Note that emissions for land clearing are presented as cumulative totals over the entire life of the Project and not on a per year basis.

Table 3-11: Carbon Stocks Before and After Land Conversion

Description	Value	Unit
Above-ground biomass before conversion	48.4 [a]	tonnes of dry matter/ha
Ratio of below-ground biomass to above-ground biomass	0.23 [b]	N/A
Below-ground biomass before conversion	11.2 [c]	tonnes of dry matter/ha
Total biomass before conversion (B_{Before})	59.6 [c]	tonnes of dry matter/ha
Total biomass after conversion (B_{After})	0 [d]	tonnes of dry matter/ha
CF (Carbon fraction) for biomass	0.47 [e]	N/A
Mineral soil carbon stocks before conversion	52.0 [f]	tonnes of C/ha
Mineral soil carbon stocks after conversion	0[d]	tonnes of C/ha

a. Source: Table 4.7 in Chapter 4 (Forest Land) of Volume 4 (Agriculture, Forestry and Other Land Use) of the 2019 Refinement to the 2006 IPCC Guidelines (IPCC, 2019).

b. Source: Table 4.4 in Chapter 4 (Forest Land) of Volume 4 (Agriculture, Forestry and Other Land Use) of the 2019 Refinement to the 2006 IPCC Guidelines (IPCC, 2019).

c. Estimated by ERM.

d. Source: Chapter 9 (Other Land) of Volume 4 (Agriculture, Forestry and Other Land Use) of the 2006 IPCC Guidelines (IPCC, 2006).

e. .Source: Table 4.3 in Chapter 4 (Forest Land) of Volume 4 (Agriculture, Forestry and Other Land Use) of the 2006 IPCC Guidelines (IPCC, 2019).

f. Source: Table 2.3 in Chapter 2 (Generic Methodologies Applicable to Multiple Land-Use Categories) of Volume 4 (Agriculture, Forestry and Other Land Use) of the 2019 Refinement to the 2006 IPCC Guidelines (IPCC, 2019).

Table 3-12: Life of Project GHG Emissions from Land Clearing

Description	GHG Emissions (t CO_2-e) [a]	
	CO_2	**Total**
Emissions associated with removal of biomass	25,777 [a]	25,777 [a]
Emissions associated with removal of soil	47,828 [a]	47,828 [a]
Total	**73,606 [a]**	**73,606 [a]**

a. Tonnes C/year were converted to tonnes CO_2-e/year using the ratio of the molecular weights for C (12 g/mol) and CO_2 (44 g/mol).

3.4.3 Explosives Usage – Scope 1

Blasting activities will occur as part of mining operations during the Project. It is estimated that 55,509 t of Ammonium Nitrate Fuel Oil (ANFO) based explosives are expected to be used during the lifetime of the Project. While there is no current IPCC methodology for estimating GHG emissions from explosives, emissions can be estimated by calculating the emissions associated with the combustion of the fuel oil component contained in the explosives.

A summary of the emissions factors, energy content factors and relevant parameters are presented in **Table 3-13**. The estimated quantities of explosives used are presented in **Table 3-14**, both as the total and the split associated with SC6 and PLS production. The GHG emissions are presented in **Table 3-15**.

Table 3-13: Emission Factors and Energy Content Factors for Fuel Oil Combustion in Explosives

Description	Value	Units
Energy content factor (or net calorific value) for fuel oil [a]	40.4[a]	GJ/kL
Density of Fuel oil [b]	0.836	kg/L or t/kL
Tier 1 CO_2 emission factor – fuel oil [c]	77.4	kg CO_2-e/ GJ
Tier 1 CH_4 emission factor – fuel oil [c]	3	kg CH_4/ TJ
	0.084	kg CO_2-e/ GJ
Tier 1 N_2O emission factor – fuel oil [c]	0.6	kg N_2O/ TJ
	0.159	kg CO_2-e/ GJ
Typical ANFO fuel oil fraction [d]	0.06	N/A
Calculated CO_2 emission factor – ANFO Explosives [e]	0.224	t CO_2-e/ tonne explosives
Calculated CH_4 emission factor – ANFO Explosives [e]	0.000224	t CO_2-e/ tonne explosives
Calculated N_2O emission factor – ANFO Explosives [e]	0.000461	t CO_2-e/ tonne explosives

a. Source: (IPCC, 2006) - Table 1.2 (default net calorific values (NCVs) and lower and upper limits of the 95% confidence intervals), page 1.18, Volume 2 (Energy), Chapter 1 (Introduction).

b. Source: (DEWHA, 2012) - Table 1, page 6, National Pollutant Inventory Emission Estimation Technique Manual for Fuel and Organic Liquid Storage, Version 3.3.

c. Source: (IPCC, 2006) - Table 2.3 (default emission factors for stationary combustion in manufacturing industries and construction), page 2.18, Volume 2 (Energy), Chapter 2 (Stationary Combustion). Emission factors were provided in kg of GHG per TJ on a net calorific basis. As such, these emission factors were converted to a CO_2-e basis using their respective GWP from **Table 3-1**.

d. Source: (NPI, 2016) - Table 8, page 21, Appendix C of National Pollutant Inventory Emission Estimation Technique Manual for Explosives Detonation and Firing Ranges Version 3.1.

e. Calculated by ERM using the assumed fuel oil content of 6%.

Table 3-14: Life of Project Explosives Usage

Description	Value	Units
Total explosives used	55,509 [a]	t
Estimated explosives used in the production of SC6	43,376 [b]	t
Estimated explosives used in the production of PLS	12,133 [b]	t

a. Source: Source: Dathcom responses to RFI received on 20/11/2020 (Dathcom Mining SA, 2020).

b. .Estimated by ERM based on the total explosives used, and the total SC6 production and SC6 used in PLS production from **Table 1-1.**

Table 3-15: Life of Project GHG Emissions from Explosives Usage

Product	Description	GHG Emissions (t CO_2-e/life of project)			
		CO_2	CH_4	N_2O	**Total**
SC6	Explosives used in the production of SC6	9,735	11	20	9,765
PLS	Explosives used in the production of PLS	2,723	3	6	2,731
All Product	**Total**	**12,457**	**14**	**26**	**12,497**

3.4.4 Electricity Production – Scope 1

AVZ Power are planning the refurbishment of the abandoned Mpiana Mwanga HEPP, which is located 87 km southeast of Manono. Once operational, this HEPP will provide all of the Project's energy requirements (excluding diesel fuel usage in mining equipment and vehicles). The HEPP will be owned by AVZ Power and GHG emissions from the facility will be considered as Scope 1 rather than Scope 2 emissions.

As there is no IPCC methodology for estimating GHG emissions from hydropower stations, emission intensities of existing stations were reviewed to identify an appropriate value to apply to the Project.

In Chapter 5 of the IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation (IPCC, 2011), the lifecycle GHG emission intensity estimates for several hydropower stations are given. The majority of emission intensities fall between 0.004 and 0.014 t CO_2-e/MWh of electricity generated. There are some outliers with much larger GHG emissions. These outliers stem from hydropower stations that had particularly high emissions of biogenic CH_4 that resulted from the degradation of organic carbon in the reservoirs. This is not applicable to AVZP as it is a run of river fed HEPP and is not fed from an upstream reservoir.

Scope 1 and Scope 2 GHG emissions for Australian hydropower stations were downloaded from the National Greenhouse and Energy Reporting (NGER) inventory via the Clean Energy Regulator's website (cleanenergyregulator.gov.au). This data showed an average emissions intensity of 0.0015 t CO_2-e/MWh for Australian hydropower stations in FY19. The emissions associated with the degradation of organic carbon are not included in the NGER emissions.

Since the HEPP is run of river fed, there will be no reservoir no decomposition of organic material. Based on this, the Australian hydropower emission intensities are most applicable to the AVZ Power HEPP. The emission intensity of 0.0015 t CO_2-e/MWh emission intensity was selected to evaluate the Projects emissions from power generation.

The total electricity requirements for the Project are presented in **Table 3-16**. The total Scope 1 GHG emissions from electricity generation are presented in **Table 3-17**. Note that emissions have been split into those associated with SC6 and PLS production.

Table 3-16: Estimated Power Demand for the Project

Description	Value	Units
Expected power usage for SC6 production	116,508[a]	MWh/year
Expected power usage for PLS production	83,220[b]	MWh/year
Total	199,728	MWh/year

a. Calculated by ERM using a power requirement of 14 MW and operational hours of 8,322 hours per year as stated in Dathcom's responses to RFI received on 20/11/2020 (Dathcom Mining SA, 2020)

b. Calculated by ERM using a power requirement of 10 MW and operational hours of 8,322 hours per year as stated in Dathcom's responses to RFI received on 20/11/2020 (Dathcom Mining SA, 2020)

Table 3-17: Annual GHG Emissions from Electricity Production - Scope 1 Emissions

Description	Scope 1 Emissions (t CO_2-e/year)
Power usage for SC6 production	178
Power usage for PLS production	127
Total	**305**

3.4.5 Summary of Scope 1 and Scope 2 Emissions

A summary of the estimated GHG emissions for the 20 year life of the Project is provided in **Table 3-18**. The breakdown of the emission sources for the SC6 and PLS production variables, as well as for all production, are presented in **Figure 3-2, Figure 3-3**, and **Figure 3-4,** respectively. The overall split in the emissions for the two production variables is shown in **Figure 3-5**. The emissions associated with land clearing have been divided evenly between the SC6 and PLS production variables.

As shown in **Figure 3 5**, the Scope 1 emissions associated with the production of PLS (i.e. **715,443 t CO_2-e/life of project**) are anticipated to be greater than the emissions associated with the production of SC6 (i.e. **552,785 t CO_2-e/ life of project**).This is due to the large amount of diesel that is expected to be combusted in the calciner plant within the PLS processing facility, approximately 75% of emission associated with the PCL product (**Figure 3-3**). **Figure 3-2** shows that the majority of the emissions associated with the production of SC6 are associated with the combustion of fuel in mobile equipment and vehicles, accounting for approximately 83% of the SC6 emissions. Mobile combustion is expected to be the source of the majority of the emissions associated with the production of SC6, with approximately 40% attributed to diesel consumption in mobile mining equipment and 51% attributed to transport vehicles, respectively.

Overall, emissions associated with the generation of electricity at the HEPP and with the use of explosives are predicted to be a minor source of GHG emissions for the Project (see **Figure 3-4)**. The GHG emissions associated with land clearing are expected to contribute approximately 6% of the total GHG emissions for the Project.

Mean annual emissions are expected to be **27,639 t CO_2-e/year** and **35,772 t CO_2-e/year** for SC6 and PLS production, respectively, with an annual total of **63,411 t CO_2-e/year**.

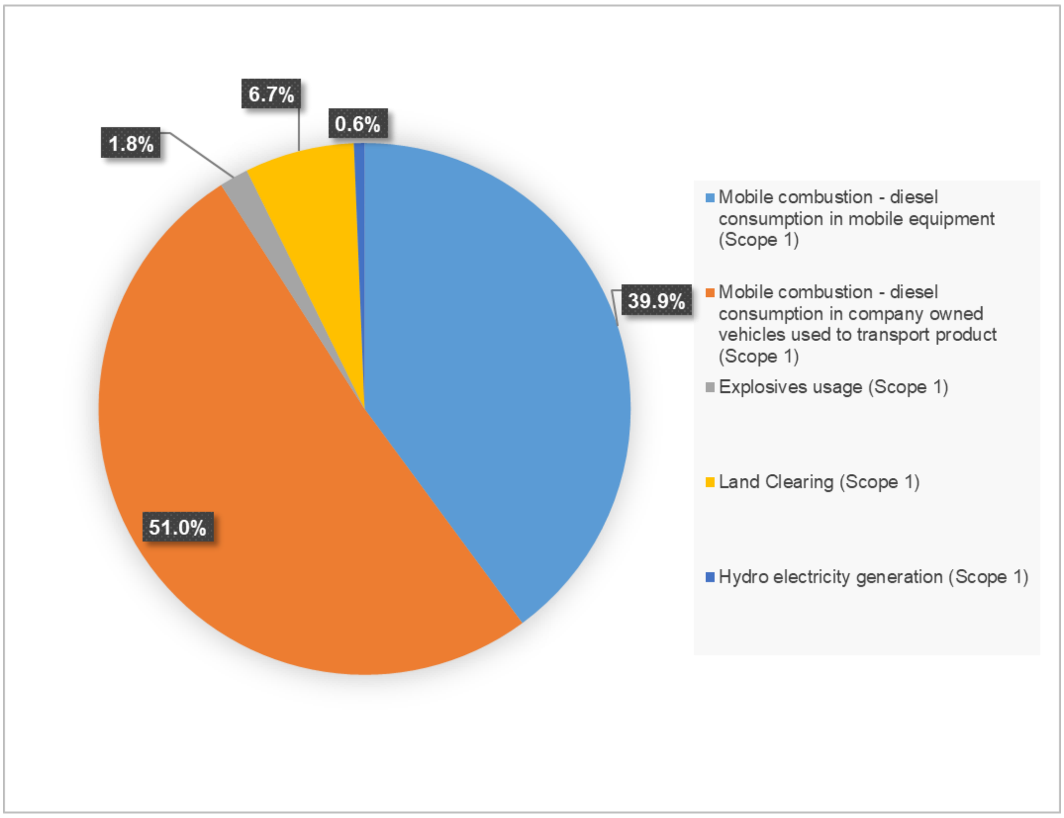

Figure 3-2: Breakdown in Life of Project GHG Emissions for SC6 Production

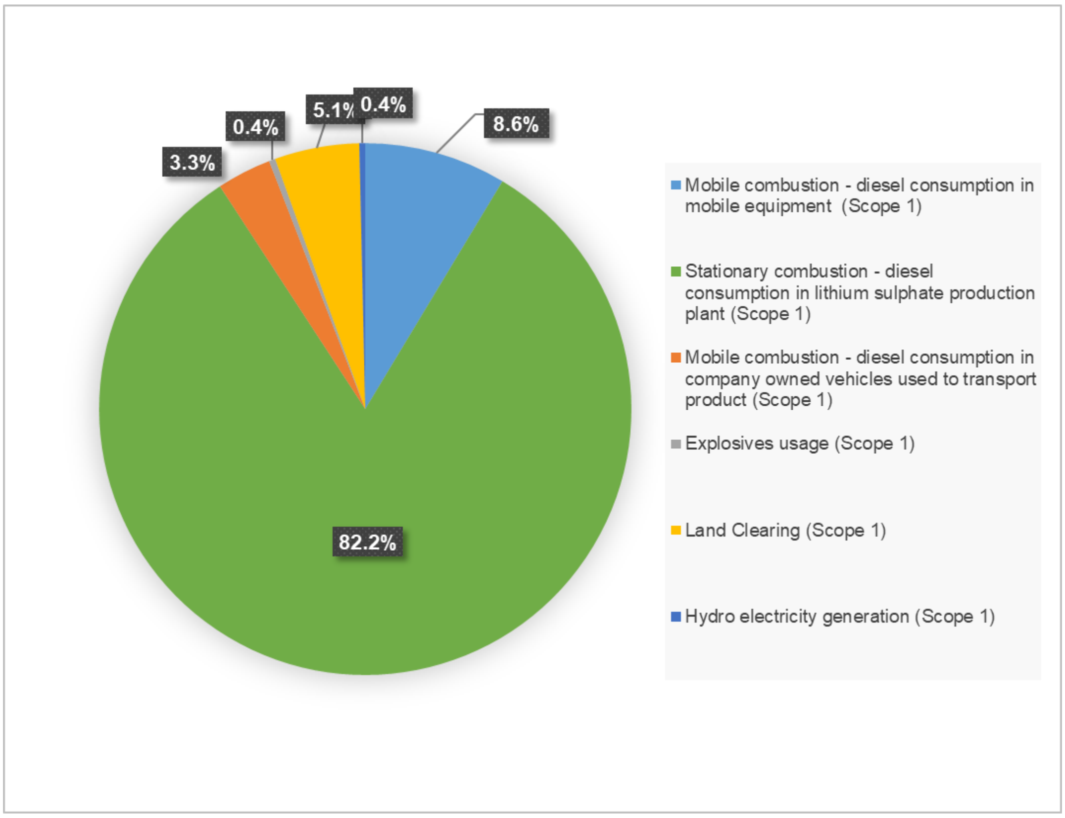

Figure 3-3: Breakdown in Life of Project GHG Emissions for PLS Production

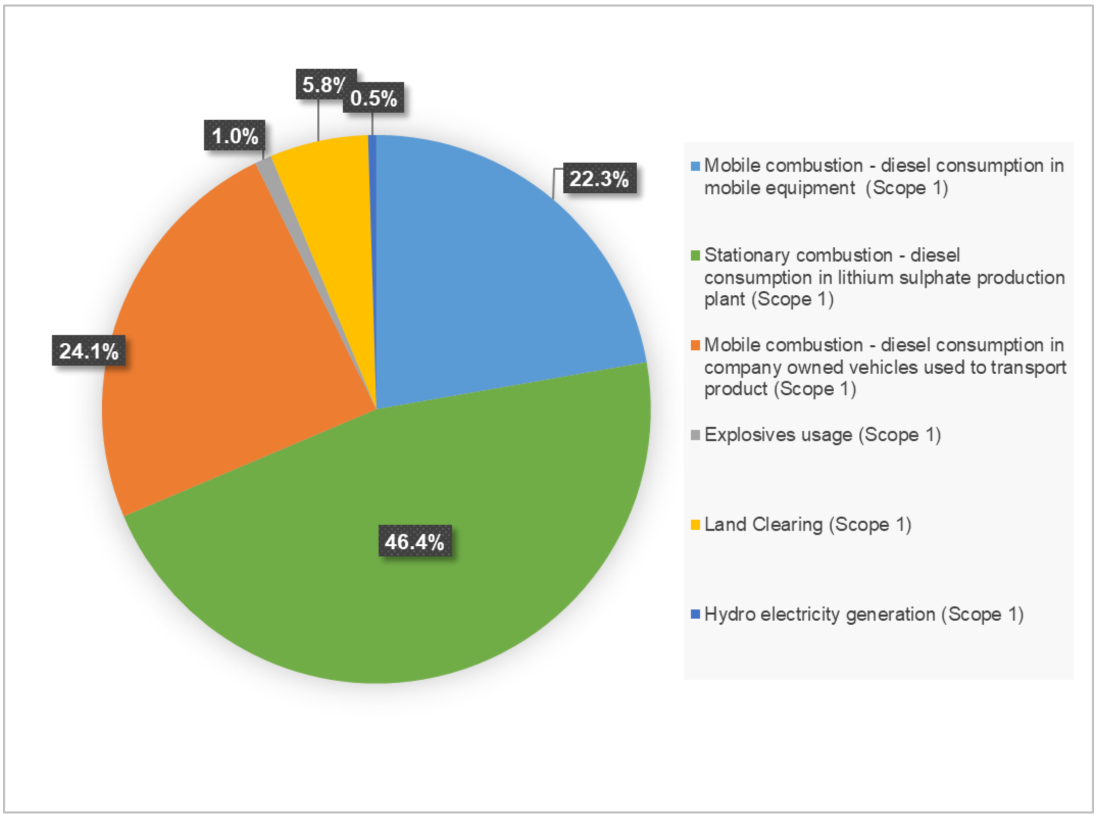

Figure 3-4: Breakdown in Life of Project GHG Emissions for All Production

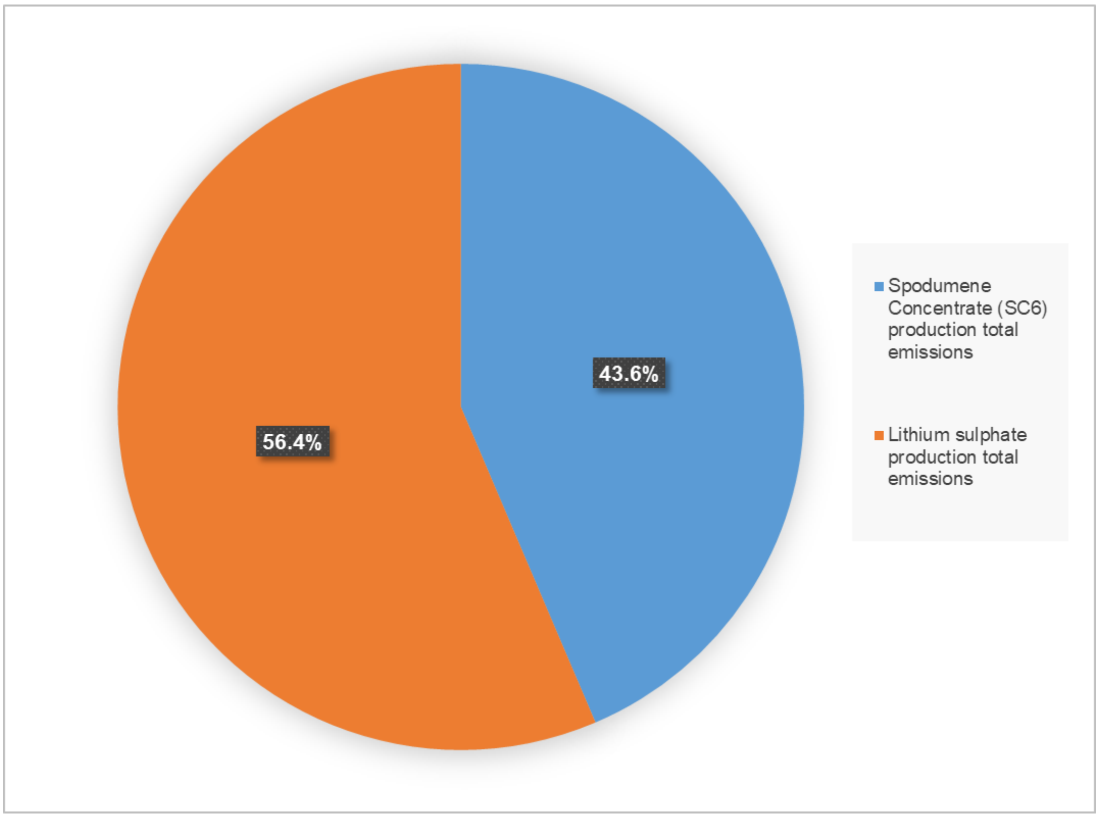

Figure 3-5: Split in Life of Project GHG Emissions for SC6 and PLS Production

Table 3-18: Estimated Total Greenhouse Emissions for the Life of the Project

Project Phase	Description	Emissions (t CO_2-e)			
		CO_2	CH_4	N_2O	Total
SC6 Production	Mobile combustion - diesel consumption in mobile equipment (Scope 1)	199,827	313	20,438	220,578
	Mobile combustion - diesel consumption in company owned vehicles used to transport product (Scope 1)	255,540	401	26,137	282,078
	Explosives usage (Scope 1)	9,735	11	20	9,765
	Land Clearing (Scope 1)	36,803	0	0	36,803
	Hydro electricity generation (Scope 1)	3,561	0	0	3,561
	Total Scope 1 Emissions	**505,465**	**725**	**46,595**	**552,785**
PLS Production	Mobile combustion - diesel consumption in mobile equipment (Scope 1)	55,893	88	5,717	61,697
	Stationary combustion - diesel consumption in PLS production plant (Scope 1)	586,024	664	1,257	587,946
	Mobile combustion - diesel consumption in company owned vehicles used to transport product (Scope 1)	21,490	34	2,198	23,721
	Explosives usage (Scope 1)	2,723	3	6	2,731
	Land Clearing (Scope 1)	36,803	0	0	36,803
	Hydro electricity generation (Scope 1)	2,544	0	0	2,544
	Total Scope 1 Emissions	**705,476**	**789**	**9,178**	**715,443**
All Production	Mobile combustion - diesel consumption in mobile equipment (Scope 1)	255,720	401	26,155	282,276
	Stationary combustion - diesel consumption in PLS production plant (Scope 1)	586,024	664	1,257	587,946
	Mobile combustion - diesel consumption in company owned vehicles used to transport product (Scope 1)	277,030	434	28,335	305,799
	Explosives usage (Scope 1)	12,457	14	26	12,497
	Land Clearing (Scope 1)	73,606	0	0	73,606
	Hydro electricity generation (Scope 1)	6,104	0	0	6,104
	Total Scope 1 Emissions	**1,210,941**	**1,513**	**55,773**	**1,268,227**

3.4.6 Scope 3 Emissions

Emissions associated with the rail and shipping transportation of Project products have been estimated based on emission factors for freight trains and bulk carrier cargo ships from the UK Government (2020) '*Greenhouse gas reporting: conversion factors 2020'*. The average value for bulk carrier cargo ships was applied. An average emission factor of 8.06 t CO_2-e/t LCE was estimated for LCE refinery facilities in China using information from the Roskill (2020) white paper. An emission factor for the refining of PLS into LCE was then estimated using this number and information from Dathcom Mining SA. Dathcom Mining SA (P Allen, 2020, personal communication, 11 December) suggested reducing the 8.06 t CO_2-e/t LCE emission factor by two-fifths due to the refinement of PLS into LCE being less energy intensive than the refinement of SC6 into LCE (as in the Roskill (2020) white paper). It is estimated that two-fifths of the energy required to perform the LCE refining has already been accounted for via the processing of SC6 into PLS. This estimation is only intended as an estimate of what the emissions associated with refining the PLS into LCE might be, there is no existing emission factor available for PLS refining.

The emission factors for Scope 3 sources are shown in **Table 3-19**. **Table 3-20** shows the activity data used to estimate the Scope 3 emissions. In order to be conservative, the Scope 3 emissions associated with the transport legs have been estimated by multiplying the one-way trip distances by 2 in order to represent the return journey. The GHG emissions associated with the Scope 3 emission sources are presented in **Table 3-21**.

Table 3-19: Emission Factors for Scope 3 Sources

Description	Value	Units
Freight train transport [a]	0.0256	kg CO_2-e/tonne/km
Bulk carrier cargo ship transport [a]	0.00354	kg CO_2-e/tonne/km
SC6 to LCE Refining [b]	8.06	t CO_2-e/t LCE
PLS to LCE Refining [c]	4.84	t CO_2-e/t LCE

a. Source: (UK Government, 2020) – 'Freighting goods' tab of 'Greenhouse gas reporting: conversion factors 2020'.

b. Estimated by ERM using (Roskill, 2020) – 'Lithium's Growing CO_2 Footprint'.

c. Estimated by ERM using the following sources: (Roskill, 2020) – 'Lithium's Growing CO_2 Footprint' and (Dathcom Mining SA, 2020) - P Allen, 2020, personal communication, 11 December.

Table 3-20: Activity Data for Estimating Scope 3 Emissions

Description	Value	Units
Freight train transport one way distance: Kabondo Dianda to Lobito	2,146 [a]	km
Freight train transport one way distance: Kabondo Dianda to Dar es Salaam	2,797 [a]	km
Freight train transport one way distance: Rotterdam to German refining facility	600 [b]	km
Cargo ship transport one way distance: Lobito to Rotterdam	9,350 [c]	km
Cargo ship transport one way distance: Dar es Salaam to Shanghai	12,971 [c]	km
SC6 transported to Shanghai	547,000 [d]	Tonnes/year
PLS transported to refining facilities	46,000 [d]	Tonnes/year
LCE refined in Germany	20,000 [e]	Tonnes/year

a. Source: (Dathcom Mining SA, 2020) - M Hughes, 2020, personal communication, 8 December.

b. Estimated by ERM using Google Earth

c. Estimated by ERM using the SeaRates tool (https://www.searates.com/services/distances-time/)

d. Source: Dathcom responses to RFI received on 20/11/2020 (Dathcom Mining SA, 2020)

e. Source: (AVZ Minerals, 2020) - 'Definitive Feasibility Study Manono Lithium and Tin Project'.

The GHG emissions associated with the Scope 3 emission sources are presented in **Table 3-21**. Inclusion of the emissions associated with transporting the SC6 product to China (via Dar es Salaam) increases the estimated annual emissions for the Project's SC6 production from **27,639 t CO_2-e/year** to **156,194 t CO_2-e/year**, while including the emissions associated with transporting the PLS to Rotterdam (via Lobito) increases the estimated annual emissions associated with the Project's PLS production from **35,772 t CO_2-e/year** to **43,870 t CO_2-e/year**. Including the emissions associated with both the transport of the PLS to Germany and refining of PLS into LCE further increases the estimated emissions associated with the PLS product by **98,181 t CO_2-e/year**.

Table 3-21: Annual GHG Emissions from Scope 3 Sources

Description	GHG Emissions (t CO_2-e/year)
Emissions associated with transporting the SC6 by rail from Kabondo Dianda to Dar es Salaam	78,334
Emissions associated with transporting the PLS by rail from Kabondo Dianda to Lobito	5,054
Emissions associated with transporting the SC6 by ship from Dar es Salaam to Shanghai	50,221
Emissions associated with transporting the PLS by ship from Lobito to Rotterdam	3,044
Emissions associated with transporting the PLS by rail from Rotterdam to the German refining facility	1,413
Emissions associated with refining the PLS into Lithium Carbonate Equivalent (LCE)	96,768

4. BENCHMARKING, MITIGATION AND MANAGEMENT

4.1 Benchmarking Against Similar Facilities

To contextualise the Project's estimated GHG emissions, the Project's emission intensity (i.e. total emissions per tonne of product produced) for both SC6 and PLS were compared to published emission intensities for other lithium production facilities.

Published data relating to GHG emissions associated with lithium mining is scarce due the low number of mines globally. Lithium extraction is typically carried out from two broad deposit types, mineral and brine. Most mineral mining occurs in Western Australia, where SC6 product is produced and then typically shipped to plants in China for conversion and refining into Lithium Carbonate Equivalent (LCE). Lithium brine production is mainly located in the high Andes in Chile, Argentina and Bolivia in areas with high amounts of solar radiation and limited rainfall. Unlike with mineral mines, for brine operations, the extraction of the lithium at the brine ponds and the LCE refining typically occur within the same country (often the two facilities are in close proximity to one another (Roskill, 2020)).

Emission intensities for several Australian lithium mines producing SC6 were found in annual and environmental reports published by the operating companies. The intensities were calculated by dividing the facilities total Scope 1 and Scope 2 GHG emissions (as downloaded from the Clean Energy Regulator's website) by the total SC6 produced at the facility and are shown in **Table 4-1** and **Figure 4-1**. The Project's emission intensity (i.e. **0.039 t CO_2-e/t SC6**) is lower than the intensity at each of the other facilities, with the next closest facility releasing over twice as much CO_2 per tonne of SC6 produced. The Projects lower emission intensity is likely due to the use of the HEPP as the main power source.

The Roskill (2020) white paper: '*Lithium's Growing CO_2 Footprint*' provides emission intensities for both the mineral and brine lithium extraction industries, where the emissions intensity calculations include the emissions required to produce one tonne of refined LCE product. This calculation includes all CO_2 emissions grouped under Scope 1 and 2 categories as well as the CO_2 emitted in transporting feed material to any refining facilities. For direct comparison with the emission intensities in the Roskill (2020) white paper, an LCE emissions intensity for LCE production in Germany using the Project's PLS product was estimated by summing the Scope 1 and 2 emissions associated with PLS production and the Scope 3 emissions associated with the PLS transport and refining discussed in **Section 3.4.6**. This was then divided by the estimated annual production of LCE (20,000 tonnes).

The LCE emission intensities for the Project and the minimum, average and maximum values for the mineral and brine industries from the Roskill (2020) white paper are shown in **Table 4-2** and **Figure 4-2**. The Project's emission intensity (i.e. **7.1 t CO_2-e/t LCE**) is lower than the minimum intensity for the mineral industry in the Roskill (2020) white paper. There are several factors that likely contribute to this, including the low emissions associated with mining the SC6 product used to produce the PLS, the lower tonnage of product shipped overseas due to the processing of SC6 into PLS prior to shipment and the lower energy required to refine the PLS into LCE when compared to refining SC6. The emission intensities of brine facilities are lower than mineral mines, due to less active methods of extraction (requiring less fuel combustion), initial processing being aided by solar evaporation, shorter transport distances to refining facilities and because refining emissions are lower (Roskill, 2020).

Table 4-1: Project's SC6 Emissions Intensity: Benchmarking against Lithium Mines in Australia

Description	Location	Year	Emission Intensity ($t\ CO_2$-e/ t SC6)
Manono Lithium and Tin Project	DRC	NA	0.039 [a]
Greenbushes Lithium Mine – Current	Australia	FY18	0.11 [b]
Greenbushes Lithium Mine - Projected after expansion	Australia	FY29	0.18 [b]
Pilgangoora Lithium and Tantalum Mine	Australia	FY19	0.29 [c]
Mt Cattlin Lithium Mine	Australia	FY19	0.19 [d]

a. calculated by ERM

b. Source: (GHD, 2018) - Greenbushes Lithium Mine Expansion: Environmental Referral - Additional Information

c. Source: (Pilbara Minerals, 2019) - 2019 Annual Report

d. Source: (Galaxy Resources, 2020) - Sustainability Report for the Year Ended 31 December 2019

Table 4-2: Project's LCE Emissions Intensity: Benchmarking against Values from the Roskill (2020) White Paper

Description	Emission Intensity ($t\ CO_2$-e/ t LEC)
Manono Lithium and Tin Project	7.1 [a]
Roskill White Paper: Mineral industry minimum value	8.0 [b]
Roskill White Paper: Mineral industry weighted mean value	9.3 [b]
Roskill White Paper: Mineral industry maximum value	12.0 [b]
Roskill White Paper: Brine industry minimum value	2.0 [b]
Roskill White Paper: Brine industry weighted mean value	2.8 [b]
Roskill White Paper: Brine industry maximum value	5.0 [b]

a. calculated by ERM

b. Source: (Roskill, 2020) - Lithium's Growing CO_2 Footprint. Note: Roskill's emissions intensity relates to the CO_2 emissions (from all fuel sources, on and off-site) required to produce one tonne of refined lithium carbonate and/or lithium hydroxide, stoichiometrically normalised to a lithium carbonate product (lithium carbonate equivalent LCE). This calculation includes all CO_2 emissions grouped under Scope 1 and 2 categories as set out by the Greenhouse Gas Protocol. In addition, where applicable, it accounts for the CO_2 emitted in transporting feed material to any refining facilities involved in the production of refined lithium carbonate or lithium hydroxide.

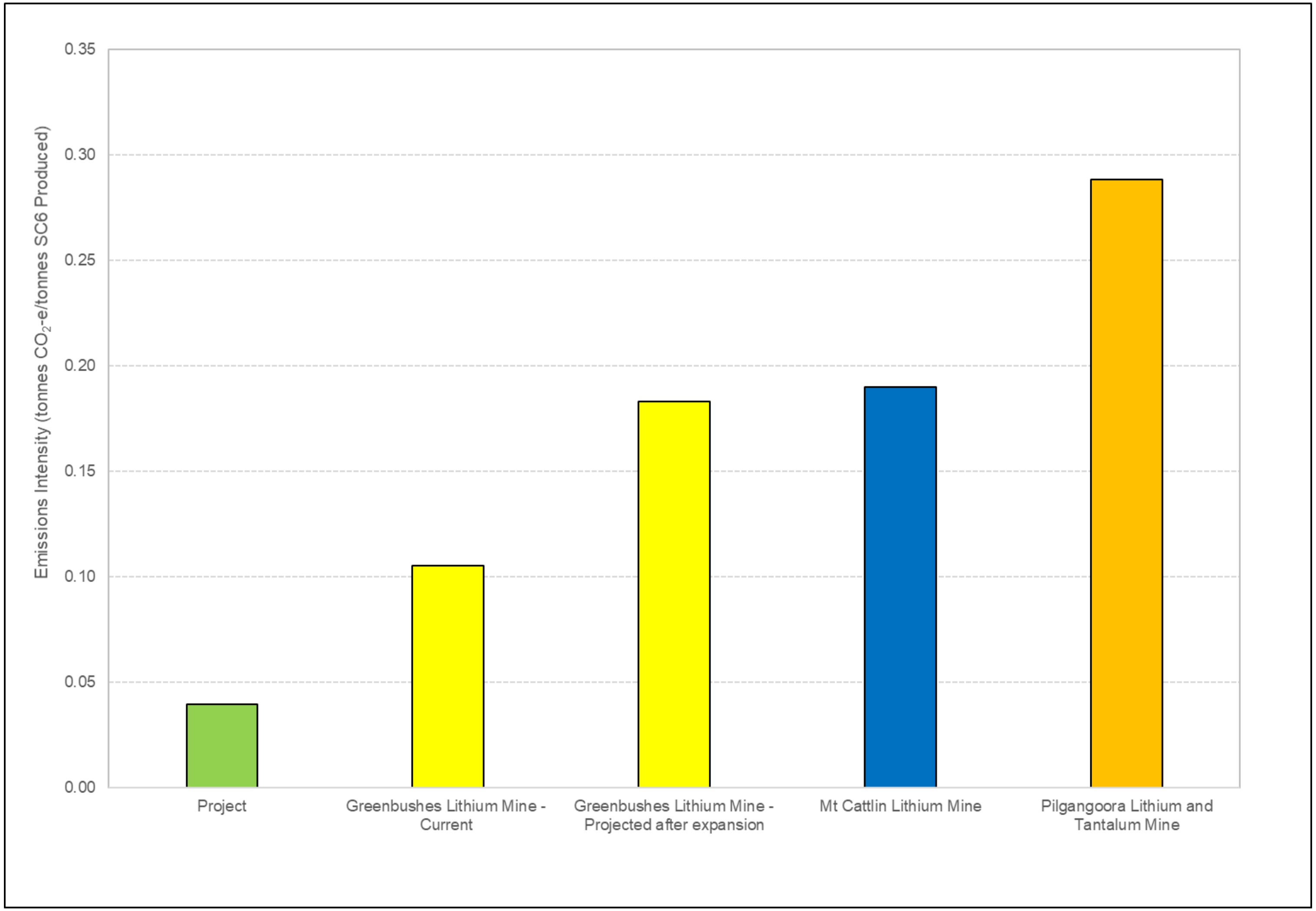

Figure 4-1: Project's SC6 Emissions Intensity (using Scope 1 and Scope 2 Emissions) and Comparison with Lithium Mines in Australia (Sources: GHD (2018), Pilbara Minerals (2019) and Galaxy Resources (2020))

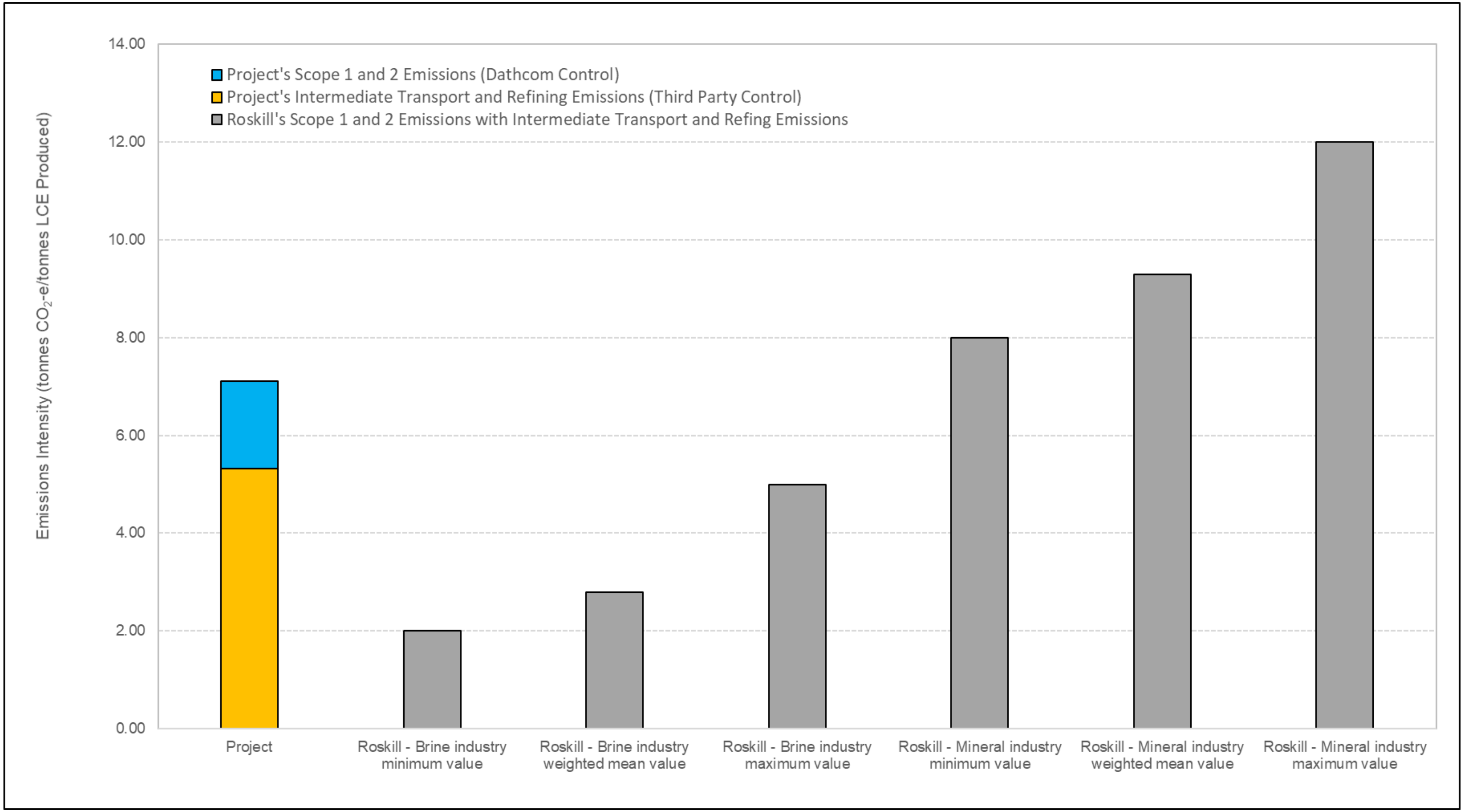

Figure 4-2: Project's LCE Emissions Intensity (using Scope 1, Scope 2 and Intermediate Transport and Refining Emissions) and Comparison with Values from the Roskill White Paper (Source: Project Emission Intensities Calculated by ERM all Other Intensities from Roskill (2020))

4.2 Greenhouse Gas Mitigation and Management

The opportunity exists to continue to optimise energy consumption and reduce GHG emissions throughout the Project design and management.

Management, monitoring and auditing provisions should be incorporated in the Environmental Management Plan (EMP) for the Project. Management shall include quantification and recording of:

- energy use
- greenhouse gas emissions
- transport activities
- other relevant GHG generating activities (such as land clearance)

Several major mitigation measures are being planned for the Project.

4.2.1 Revegetation

Land clearing/disturbance will be minimised to the greatest extent possible, with the actual amount of land cleared potentially less than value used in this assessment. Revegetation of cleared areas is expected to occur once Project operations have commenced. As part of a carbon sequestration program, Dathcom are planning to plant a 5,000 ha plantation forest in the DCR. Using an estimate of above-ground biomass growth for a young (< 20 years) African deciduous plantation from Chapter 4 of the 2019 Refinement to the 2006 IPCC Guidelines (IPCC, 2019), it is estimated that the Dathcom plantation could sequester **2,092,900 t CO_2-e** after the 20 year life of the Project. This is substantially more than the estimated emissions of the Project (if Scope 3 emissions are excluded). This is assuming that there is no existing biomass on the land that the plantation will be planted on. Note that this is only meant as an estimate of the potential carbon sequestration of a 5000 ha plantation in DRC, the carbon sequestration of particular forests is highly dependent on the tree species, as well as the local climate, soil type and management practices.

It should also be noted that it is expected that development of the Project infrastructure will reduce the use of fires for drying of tin that are currently widespread in the area. This should reduce emissions associated with inefficient combustion from wood and reduce felling of trees for fuel.

4.2.2 Electric Vehicles

Once commercially viable equipment is available, an electric mining fleet will be purchased to reduce diesel combustion. This fleet will be powered using electricity from the HEPP. The Project is also well advanced in investigating the generation of Hydrogen (H_2) from excess electricity from the Hydro Power Station, which will enable Fuel Cell Electric Vehicles (FCEVs) to be used for transportation of product to the rail access point in Kabondo Dianda. This initiative is for 10MW of clean renewable electricity to be converted to 1,400 t/year of H_2. If Dathcom are able to transition to a fleet of mining and haulage vehicles that are entirely electric (i.e. no mobile combustion), this will reduce GHG emissions of the Project by an estimated **29,404, t CO_2-e/year** (see **Table 3-7**) to **34,007 t CO_2-e/year** (excluding Scope 3 emissions). The emission intensity associated with the H_2 production has been assumed to be negligible compared to the HEPP power generation emission intensity.

4.2.3 Alternate Fuel Sources and Carbon Capture in the PLS Processing Facility

Use of plasma burners in the PLS kiln is being investigated to reduce diesel usage. Furthermore, additional carbon capture sequestration technology is being reviewed which will recover the CO_2 from the diesel fired calcining kilns and convert it to soda ash, thereby decreasing the CO_2-e/year further.

As mentioned in **Section 3.4.5,** diesel usage in the PLS processing facility is expected to be the largest contributor of GHG emissions from the Project (excluding Scope 3 emissions), with almost

50% of total Project emissions attributed to this source. Therefore, substantial reductions in the diesel combusted at the PLS calciner plant will have a big impact on the Projects total emissions. If the carbon capture technology is able to capture all CO_2 emissions associated with the PLS kiln, then this will reduce the GHG emissions of the Project by an estimated **29,397, t CO_2-e/year** (see **Table 3-10**). **Figure 4-3** and **Figure 4-4** show the comparisons of emission intensities from **Section 4.1**, but this time with the inclusion of scenarios of Project emissions without mobile combustion emissions, without PLS calciner emissions and without both mobile combustion and PLS calciner emissions.

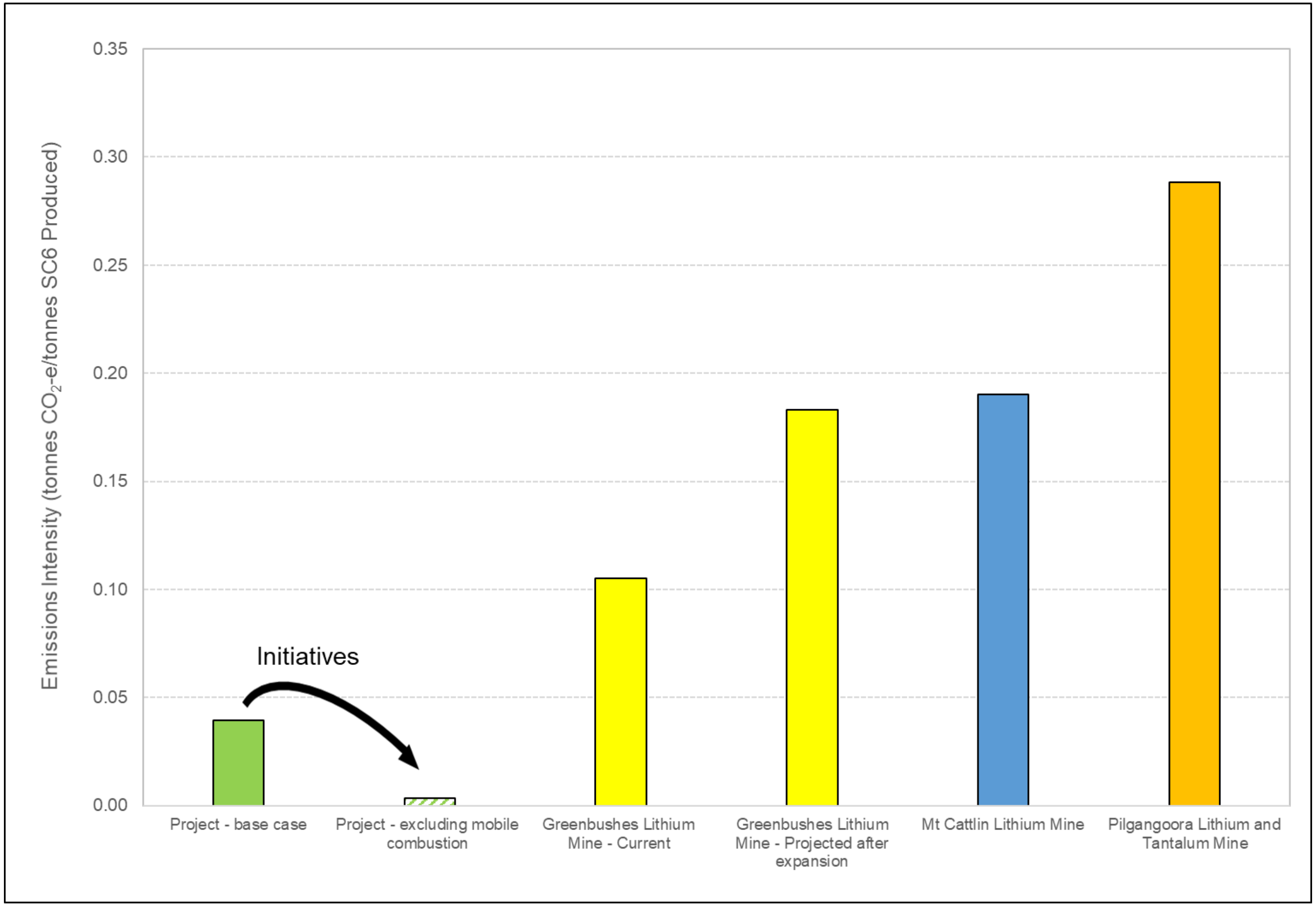

Figure 4-3: Project SC6 Emission Intensities (using Scope 1 and Scope 2 Emissions) for Different Scenarios and Comparison with Lithium Mines in Australia (Sources: GHD (2018), Pilbara Minerals (2019) and Galaxy Resources (2020))

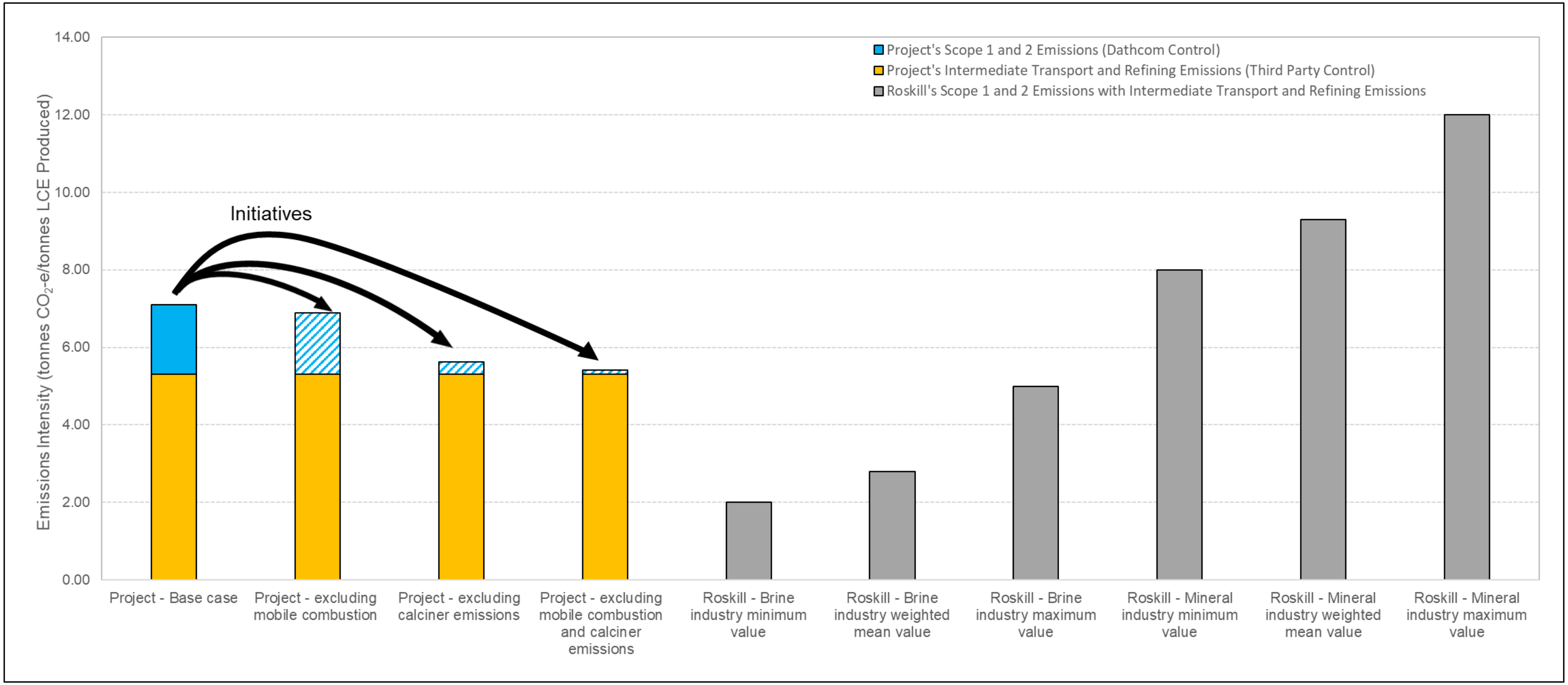

Figure 4-4: Project LCE Emission Intensities (using Scope 1, Scope 2 and Intermediate Transport and Refining Emissions) for Different Scenarios and Comparison with Values from the Roskill White Paper (Project Emission Intensities Calculated by ERM all Other Intensities from Roskill (2020))

5. CONCLUSIONS

This GHG assessment investigated the sources of the GHG emissions associated with the operation of the Project, an open-pit mining operation producing lithium, tin and tantalum, with SC6 and PLS processing facilities and a HEPP.

The GHGs evaluated in this study were calculated based on a methodology consistent with the 2006 IPCC Guidelines. Emissions were estimated over the life of the Project (approximately 20 years).

The GHG emissions associated with the production of PLS (i.e. **715,443 t CO_2-e/life of project**) are anticipated to be greater than the emissions associated with the production of SC6 (i.e. **552,785 t CO_2-e/ life of project**).This is due to the large amount of diesel that is expected to be combusted in the calciner plant within the PLS processing facility, which is expected to account for almost half of the total emissions associated with the life of the Project. Mean annual emissions are expected to be **27,639 t CO_2-e/year** and **35,772 t CO_2-e/year** for SC6 and PLS production, respectively, with an annual total of **63,411 t CO_2-e/year**.

To contextualise the Project's GHG emissions, the Project's emission intensity (i.e. total emissions per tonne of product produced) for both SC6 and PLS production were compared to published emission intensities for other lithium production facilities. Comparison of the Project's emission intensity with other available intensities for SC6 production, suggests that the Project will use technology that will result in a substantially less emission-intensive production than other existing facilities in Western Australia. The Project's emissions intensity for LCE production is lower that the emission intensities for other mineral mines.

6. LIMITATIONS

- This report is based on publically available data at the time of preparation. The report does not, and cannot, take into account changes in law, factual circumstances, applicable regulatory instruments or any other future matter.
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