Final Report

Greenhouse Gas (GHG) Forecast for the Proposed Yeelirrie Development

MAY 2015

Prepared for

Cameco Australia Pty Ltd

42908765

URS

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Abbreviations

ACCU	Australian Carbon Credit Unit
ANE	Ammonium nitrate emulsion
ANFO	Ammonium nitrate mixed with fuel oil
BOC	Biodegradable organic carbon
CFCs	Chlorofluorocarbons
CFI	Carbon Farming Initiative
CH_4	Methane
CO_2	Carbon dioxide
CO_2-e	Carbon dioxide equivalents
CVRS	Computer Vehicle and Routing Systems
DOE	Department of Environment
FY	Financial Year
GHG	Greenhouse Gas
GWP	Global Warming Potential
ha	hectare (10^4 metres squared)
HFC's	Hydrofluorocarbons
IPCC	Intergovernmental Panel on Climate Change
J	Joule
KPI	Key Performance Indicator
L	litre
LCA	Life cycle assessment
m	metre
NGA Factors	National Greenhouse Accounts Factors
NGER Act	National Greenhouse and Energy Reporting Act 2007
NF_3	Nitrogen trifluoride
N_2O	Nitrous oxide
PFC's	Perfluorocarbons
SF_6	Sulphur hexafluoride
t	tonne (10^3 kilograms)
tpa	Tonnes per annum
TSF	Tailings Storage Facility
UNFCCC	United Nations Framework Convention on Climate Change
W	Watt
Wh	Watt-hour
WBCSD	World Business Council for Sustainable Development
WNA	World Nuclear Association

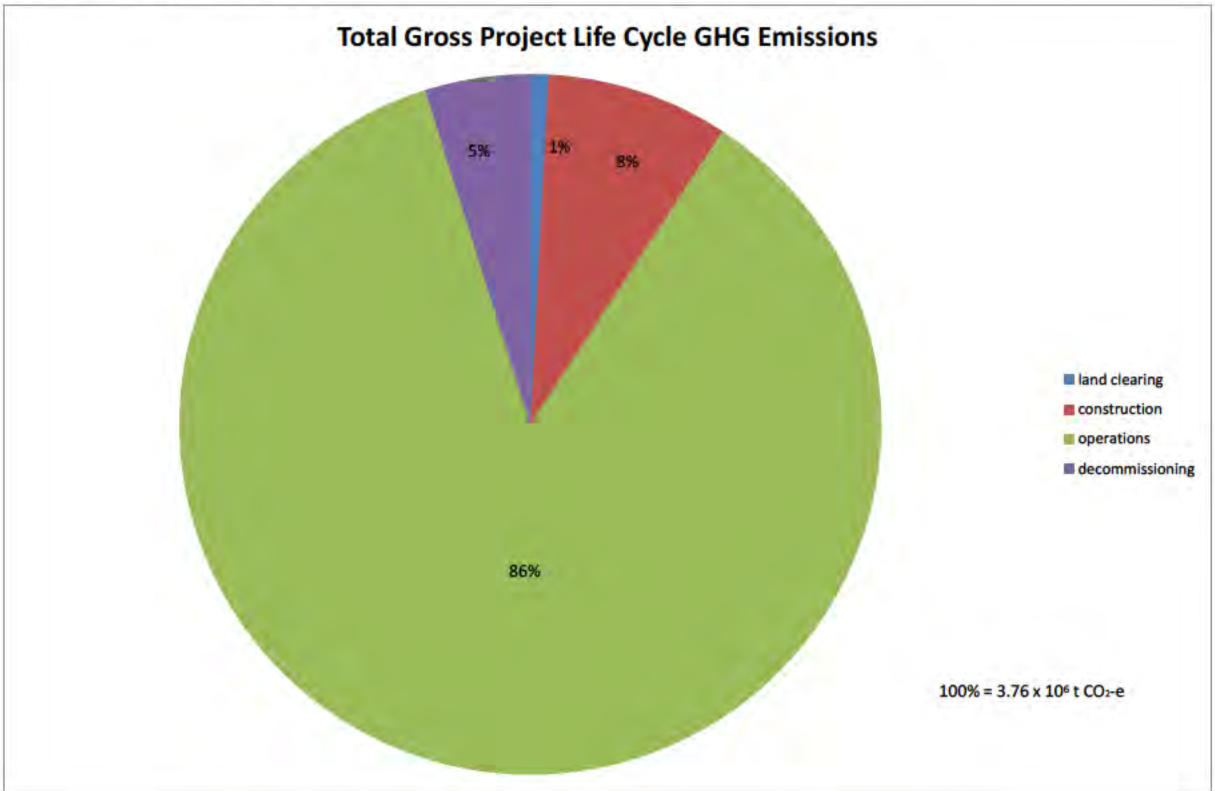
kilo (k)	10^3
Mega (M)	10^6
Giga (G)	10^9
Tera (T)	10^{12}
Peta (P)	10^{15}

Glossary

Benchmarking	Process used in management, in which organisations evaluate various aspects of their processes in relation to best practice, usually within their own sector
Global warming potential	Measure of chemical's warming potential referenced against CO_2
Greenhouse gases	A list of seven (7) gases agreed upon under the Kyoto Protocol, including: CO_2, CH_4, N_2O, HFCs, PFCs, SF_6 and NF_3
Life of Mine	Number of years that an operation is planning to mine and treat ore
kW_eh	Equivalent to 10^7 J @ 36% conversion efficiency
kWh	Equivalent to 3.6 x 10^6 J
Raised blade clearing	Method results in soil biomass and root systems being retained in soil
Soil carbon pool	Carbon contained in soil biomass and plant root systems
Tonne	Metric tonne equivalent to 10^3 kilograms or 2,200 pounds

Executive Summary

This greenhouse gas (GHG) emissions forecast is prepared for the proposed Project located in the Northern Goldfields of Western Australia. The predictive estimate calculated a total gross emission of approximately 3.76×10^6 tonnes of CO_2-e across the project life. The project life cycle includes land clearing, construction, operations and decommissioning, for a period of up to 22 years. The Project's mining is proposed at a rate of up to 14×10^6 tonnes per annum (tpa), that is estimated to produce up to 7,500 tpa of uranium oxide concentrate (UOC). Figure_ES 1 shows predicted gross GHG emissions across the project life cycle[1].



Figure_ES 1 Indicative Total Gross GHG Emissions across project life

Progressive rehabilitation is a key feature of the project, and is calculated to sequester approximately 3.01×10^4 t CO_2-e, bringing the project life net emission release to approximately 3.73×10^6 t CO_2-e. Table_ES 1 presents the tonnages of GHG emissions for the various project phases across the project life.

[1] 2 year construction phase, 17 year operations and 4 years decommissioning phase

Table_ES 1 Total Indicative GHG Emissions across the Project Life

Emission Source	Indicative Total GHG Emissions ($t\ CO_2$-e)
Land Clearing	31,380
Construction Phase	316,630
Operations Phase	3,234,040
Decommissioning Phase	182,500
Carbonation Process	-204,090
De-carbonation – from Tailings Residue	204,090
Re-vegetation	-30,100

The biggest contribution of the emissions is expected to occur during the operations phase.

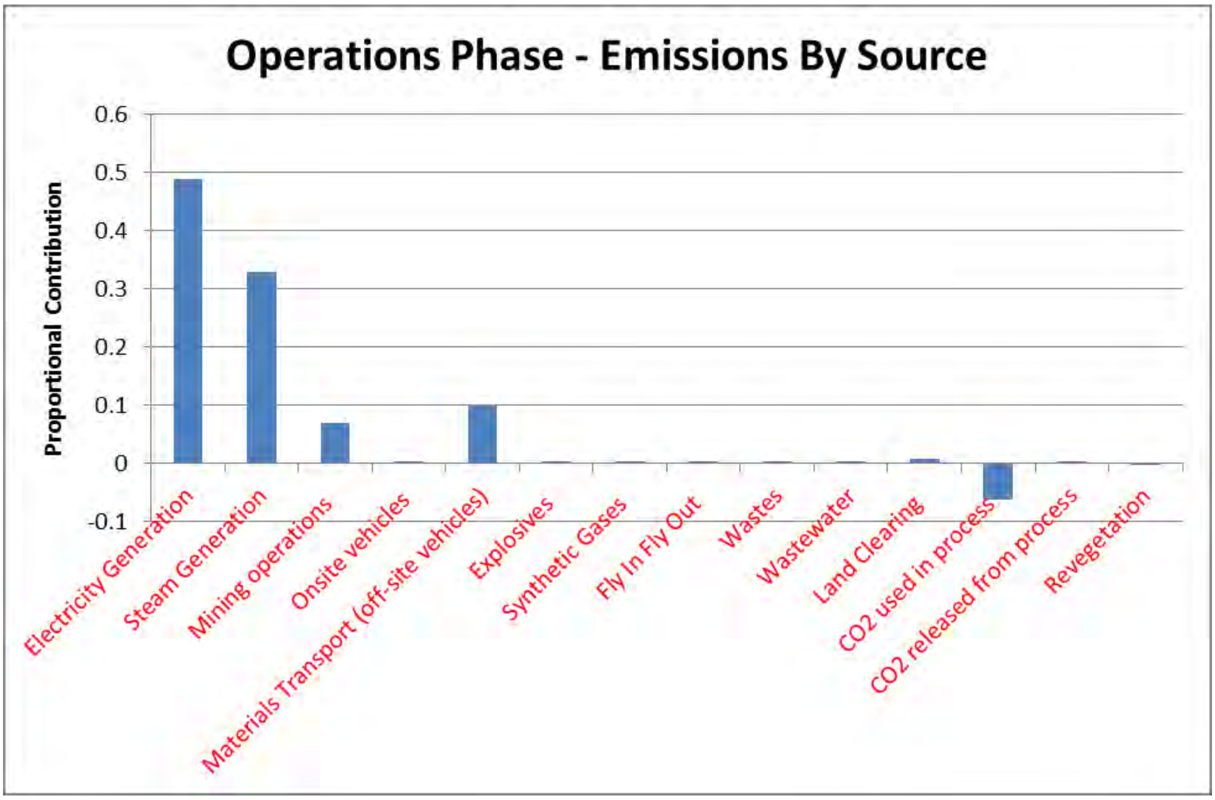
Table_ES 2 shows the annual GHG emissions by source during the operations phase.

Table_ES 2 Annual GHG Emissions during Operations Phase

Activity/source	Annual GHG emissions ($t\ CO_2$-e per annum)	
	Scope 1	Scope 3
Steam generation	70,920	Not Applicable (NA)
Electricity generation	105,330	NA
Mining	15,590	490
Carbonation process	-13,600	NA
Waste water treatment	370	NA
From Tailings Residue	13,600	NA
Explosives	10	NA
Waste	500	NA
Synthetic gases	620	NA
Materials transport	NA	21,590
Workforce transport	NA	80
CO_2 released from the process	190	NA
TOTAL	**193,530**	**22,160 (average)**

Figure_ES 2 shows the indicative total GHG emissions, by source, during the operations phase. Diesel fuel consumption for electricity generation, at approximately 49 per cent, is the single largest source of total GHG emissions during the operations phase. This is followed by diesel fuel consumption for steam generation at 33 per cent and off-site diesel fuel use at 10 per cent.

Some of the CO_2 released from the combustion of diesel for power and steam generation will be used in the process. Approximately 13,600 t CO_2 per annum will be absorbed into the metallurgical process. However, for the purpose of the GHG emissions forecast, the CO_2 emissions sequestered through the carbonation process have not been deducted in the GHG emission inventory, as a worst case scenario has been assumed to preserve conservatism in emissions accounting.



100% = 3.25 x 10^6 t CO_2-e

Figure_ES 2 GHG Emission Sources - Operations Phase

A high-level greenhouse gas emission life cycle assessment of the Project was undertaken using available literature to estimate emissions associated with uranium production, use and disposal.

Based on this analysis, 53 kilograms of CO_2-e are produced for each kilogram of recovered U_3O_8 at a concentration of 84.8 per cent uranium (99.3% U_{238}, 0.7% U_{235}).

Approximately 8.49 kg of pure U_3O_8 from Yeelirrie is required to produce 1 kg of 3% U_{235} nuclear fuel-grade UO_2, sufficient to generate approximately 304 MWh of electricity. Given that 1 kg of Yeelirrie uranium is equivalent to 1.18 kg of 100 per cent pure U_3O_8, and using the nuclear life-cycle information presented in the literature[2], it is estimated that 1 kg of pure U_3O_8 has the energy equivalence of approximately 9.3 kL of diesel that would generate 24.86 tonnes of CO_2-e. Therefore, the CO_2-e saving is 24.81 tonnes of CO_2-e per kilogram of U_3O_8 produced.

The potential greenhouse gas emission impacts of the Project has been assessed against state, national and global greenhouse gas emission projections. A comparison of these emissions with the Project's annual GHG emission forecast is presented in Table_ES 3 (excludes land use change).

The data presented in Table_ES 3 show that, as a proportion of state, national and global emissions, the contribution of the development to atmospheric greenhouse gas emission levels is very low.

[2] International Atomic Energy Agency (2009)

However, given the national and global importance of this issue, Cameco would investigate greenhouse gas emissions reduction initiatives throughout the life of the proposed Project.

Table_ES 3 Current and Projected Australian and global GHG emissions in Mtpa of CO_2-e

Source	Unit[1]	2010	2020	2030	2040
Western Australia (DEC 2008)	Total	74	81	98	102
	%	-	0.14	0.22	0.04
Australia (DEC 2008)	Total	549	638	695	752
	%	-	0.017	0.030	0.006
Global (ABARE 2007)	Total	42,300	53,800	63,600	75,800
	%	-	0.00020	0.00033	0.00005

[1]Total refers to the projected GHG emissions for the source, and % refers to the proportion of that total represented by the proposed Yeelirrie development

1 Introduction

1.1 Background

Cameco Australia Pty Ltd (hereafter Cameco) proposes to develop an open pit mine and associated processing facilities (hereafter the Project) at Yeelirrie in the Northern Goldfields region of Western Australia, approximately 500 km north of Kalgoorlie, 60 km west of Mount Keith, 70 km south-west of Wiluna and 110 km north-west of Leinster.

The Project life of mine is anticipated to be 18 years, plus four years of decommissioning and rehabilitation.

The Project's extraction rate would be up to 14 x 10^6 tonnes per annum (tpa) of mineralised ore and non-mineralised material (average of 6.7 x 10^6 tpa) from a continuous mining operation. The Project would produce up to 7,500 tpa of uranium oxide concentrate through the development and operation of an open pit mine and on-site alkali leach and direct precipitation hydrometallurgical plant.

1.1.1 Mining

The uranium mineralisation at Yeelirrie occurs as carnotite ($K_2(UO_2)_2VO_4.3H_2O$), associated with calcrete and clay sediments that occurs at shallow depth, centred at approximately 5.5m below surface, with a thickness of between three and seven metres. The deposit is believed to have a strike length of nine kilometres, an average width of one kilometre and a maximum width of 1.5 kilometres. The location and extent of the mineral resource proposed for mining warrants open cut mining using truck and excavator mining equipment, with the use of some explosives, where necessary. Site preparation activities will be conducted prior to, and concurrently with, the progressive mining activities across the project area. Areas to be disturbed are shown below in Figure 1-1.

1.2 Purpose and Scope

The purpose of this document is to provide a GHG emission forecast for the proposed Project by applying consistent international and Australian methodologies. This section explains how the proposed development would result in greenhouse gas emissions.

1.2.1 Scopes and boundaries

The World Business Council for Sustainable Development (WBCSD), in partnership with the World Resources Institute, has developed the Greenhouse Gas Protocol that defines three scopes for the estimation and assessment of greenhouse gas (GHG) emissions (WBCSD, 2004):

- Scope 1 – Direct GHG emissions. Emissions occur from sources that are owned or controlled by Cameco, such as energy consumption for electricity and steam generation and fuelling of the mine fleet.
- Scope 2 – Indirect GHG emissions. Emissions arising from the generation of purchased electricity, steam, and/or heating/cooling by third party sources.
- Scope 3 – Other indirect GHG emissions. Emissions that arise as a consequence of the upstream and downstream corporate value chain, sources used by Cameco that are owned or controlled by third parties, such as air flights and off-site transport.

The GHG assessment for the proposed Project included all identified Scope 1 emissions, no Scope 2 emissions (no purchase of off-site electricity, steam, heating/cooling is planned), and Scope 3 emissions were limited to those activities within Australia that were a consequence of the proposed Project's activities, specifically:

- diesel fuel for transport of construction materials to site;
- diesel fuel for transport of UOC to port (Adelaide and/or Darwin);
- aviation fuel (Avtur) associated with the fly-in, fly-out workforce; and
- hazardous waste transported off-site for disposal by licensed third parties.

Due to significant uncertainty regarding the boundaries associated with life cycle assessments, and to allow comparison of development emissions with state, federal and global GHG projections, emissions associated with the embedded energy of the materials used to construct the proposed Project infrastructure were not included in the assessment. A discussion regarding the life cycle emissions associated with the mining, processing and use of uranium is presented later in this report.

1.2.2 Assessment methods

The emissions generated from the following sources were used to assess the potential greenhouse gas footprint of the proposed development:

- stationary energy emissions, such as from fuel burning equipment for steam and electricity generation;
- transport fuel emissions;
- emissions associated with changes to land use, such as land clearing; and
- emissions associated with chemical reactions within the tailings storage facility.

1.2.3 Greenhouse gases

Greenhouse gases absorb and re-emit infra-red radiation (heat) that can warm the Earth's surface and enhance the natural greenhouse effect. This enhanced greenhouse effect, which is synonymous with climate change and global warming, has been defined as 'any change in climate over time, whether due to natural variability or as a result of human activity' (IPCC 2007).

The impact of greenhouse gas emissions on the atmosphere is the combined effect of the radiative properties of the gases, their ability to absorb solar and infra-red radiation, and the time that it takes for those gases to be removed from the atmosphere by natural processes. Global Warming Potentials (GWP) are used to compare the relative effects of different gases over a particular time period and are referenced in units of carbon dioxide equivalents (CO_2-e); carbon dioxide is used as the base reference, and has a GWP of 1. Table 1-1 presents the seven major groups of greenhouse gases and their GWPs, calculated over a 100-year time scale.

GWPs reflect that:

- an emission of 1 kg of methane has the same GWP as an emission of 21 kg of carbon dioxide; and that
- if 1 kg of carbon dioxide is emitted together with 1 kg of methane, the total emission would be valued at 22 kg of CO_2-e.

Table 1-1 Greenhouse gas categories and indicative global warming potentials

Greenhouse gas	GWP range
Carbon dioxide (CO_2)	1
Methane (CH_4)	21
Nitrous oxide (N_2O)	310
Hydrofluorocarbons (HFCs)	140–11,700
Perfluorocarbons (PFCs)	6,500–9,200
Sulphur hexafluoride (SF_6)	23,900
Nitrogen trifluoride (NF_3)	17,200

Source: National Greenhouse Accounts Factors 2014 (DOE 2014)

1.2.4 Emission factors

The emission factors used in this study were sourced from the National Greenhouse and Energy Reporting (Measurement) Technical Guidelines (DOE 2014) or, where NGER factors were not available, the National Greenhouse Accounts (NGA) Factors, 2014 (DOE 2014). The NGA factors were also used to determine Scope 3 (indirect) emissions, where necessary.

The emissions for the proposed development were calculated by multiplying the volume or mass of a greenhouse gas-emitting fuel or process by an emission factor, to generate a value for the likely amount of CO_2-e emitted. The CO_2-e value accounts for the various greenhouse gases emitted, taking into account their respective GWP and the amount emitted.

Land clearing emissions were predicted using the National Carbon Accounting Toolkit Full Carbon Accounting Model (FullCAM). Details regarding the inputs and assumptions associated with the use of this model are outlined in Section 3.1.1.

1.2.5 Emission sources

Greenhouse gas emissions were divided by scope as follows.

Scope 1 - Direct emission sources

Table 1-2 details the direct emission sources assessed in this study.

Scope 2 - Indirect emission sources

There are no proposed purchases of electricity, steam, heating or cooling proposed for the development. Consequently, Scope 2 emissions have been excluded from this report.

Scope 3 - Indirect emission sources

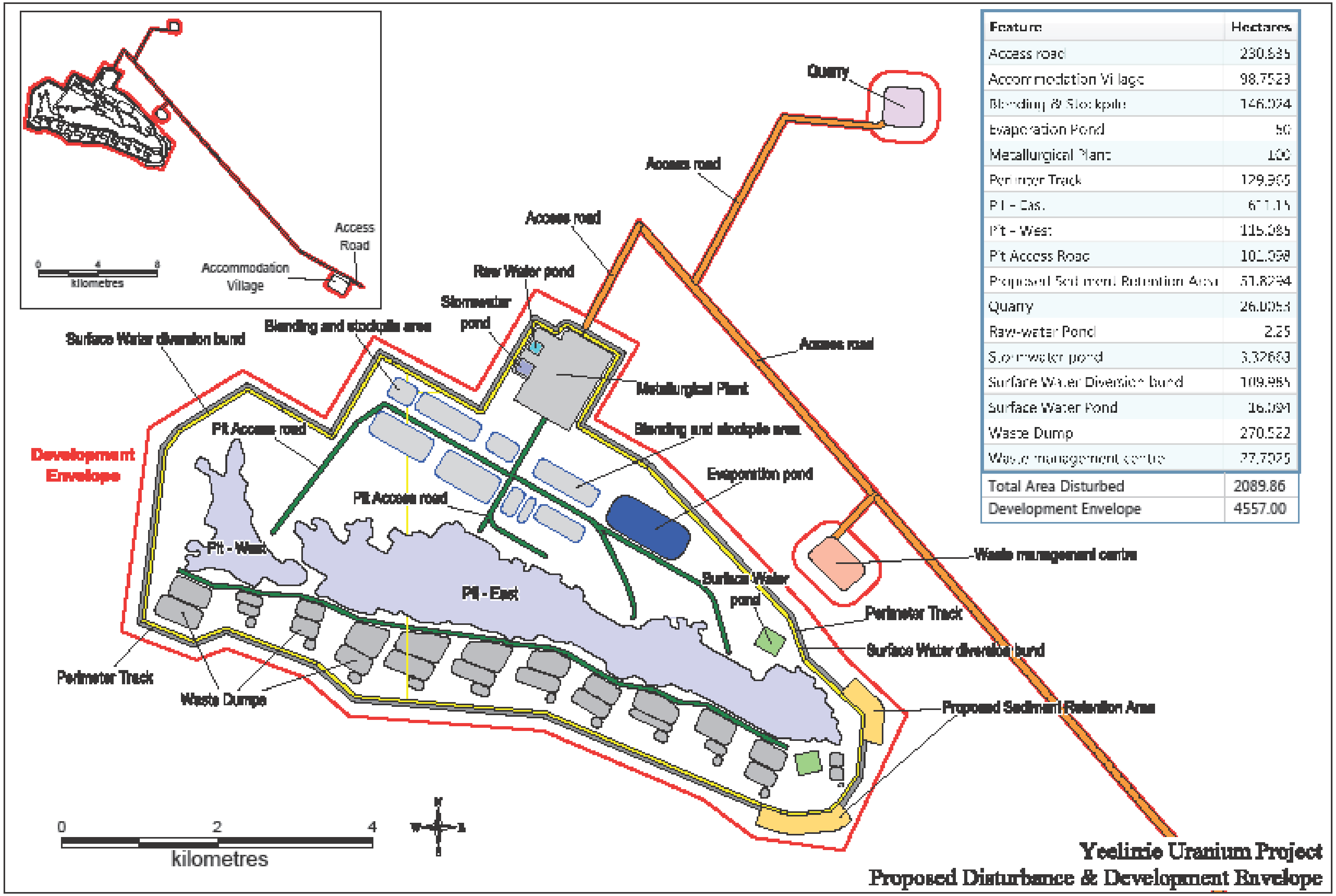
Table 1-3 details the indirect emission sources assessed in this study.

Table 1-2 Inventory of direct (Scope 1) GHG emissions sources

Activity	Source	Annual Consumption (except where noted)
Land use change	Land clearing	Open pit - 726 ha over the life of the project, with progressive rehabilitation from Year 12
		Infrastructure – 1,364 ha
Mining / light vehicle fleet	Diesel fuel	6,190 kL
Explosives	ANFO/ANE	70 tonnes
Steam generation	Diesel fuel	26,440 kL
Electricity generation	Diesel fuel	39,260 kL
Process emissions	Absorption	CO_2-e generated from steam and electricity generation absorbed in process
Tailings Storage Facility (TSF)	Desorption	Absorbed CO_2-e is assumed, as a worst case, to be liberated from the TSF
Liquid waste	Anaerobic	24,400 kL (wastewater)
Putrescible solid waste	BOC	500 tonnes of mixed solid wastes
Synthetic gases	Leakage	20% of capacity for mobile equipment, 35% of capacity for stationary equipment

Table 1-3 Inventory of indirect (Scope 3) GHG emissions sources

Activity	Source	Annual Consumption (except where noted)
Materials transport	Diesel fuel	8,000 kL
Workforce transport	Avtur fuel	2040 kg of Avtur per one way trip. 100 round trips per annum (412 tonnes Avtur per annum)
On-site hydrocarbon scope 3 component	Grease/Lubricants	On-site oil/grease consumption at 28 tonnes



Feature	Hectares
Access road	230.635
Accommodation Village	98.7523
Blending & Stockpile	146.094
Evaporation Pond	50
Metallurgical Plant	100
Perimeter Track	129.365
Pit - East	611.15
Pit - West	115.085
Pit Access Road	101.098
Proposed Sediment Retention Area	51.8294
Quarry	26.0053
Raw-water Pond	2.25
Stormwater pond	3.32683
Surface Water Diversion bund	109.965
Surface Water Pond	16.094
Waste Dump	270.522
Waste management centre	27.7025
Total Area Disturbed	2089.86
Development Envelope	4557.00

Figure 1-1 Site Layout and project footprint (area of disturbance)

2

Climate Change and Legislation

2.1 Climate Change Predictions for Australia

Australia and the globe are experiencing rapid climate change. Since the middle of the 20th century, Australian temperatures have, on average, increased by about 1°C, with an increase in the frequency of heatwaves and a decrease in the numbers of frosts and cold days. Rainfall patterns have also changed. Whilst the northwest has experienced an increase in rainfall over the last 50 years, much of eastern Australia and the far southwest have experienced a decline (Chambers 2006 and DEC 2009).

2.1.1 Climate Change and Rainfall

Indian Ocean Climate Initiative (IOCI) research indicates that by 2030 rainfall may decline by as much as 20 per cent relative to the 1960-1990 level (IPCC 1990, IPCC 1995). This means that the number of winter rain days may decrease by up to 17 per cent. Conversely parts of the northwest of Western Australia have become wetter over recent decades (DEC 2009).

2.1.2 Implications for the Project

The physical impacts of climate change on the Project are highly uncertain. However, some of the potential impacts of climate change that may affect the Project include:

- Predicted increase in temperatures, associated with climate change, may cause increased electricity demand.
- Security of mine water supply, potentially affecting ore processing efficiency.
- Damage to mine and associated transport infrastructure from flooding, cyclones and other extreme storm events.
- Delays and/or disruptions in construction of mine infrastructure or in production and shipping of product.
- Human health threats for mine staff from changes in working conditions or disease prevalence.
- Climate-related social dislocation and security concerns in communities around mining operations.
- Changes in surface water and groundwater interactions, with implications for mine drainage or movement of contaminants.

2.2 Climate Change Regulation and Policy

The regulation of greenhouse gases and associated policy can be broadly divided into five areas:

- International
- National
- State
- Cameco Corporate
- Project specific

This section discusses each of these elements of the policies surrounding the production and management of greenhouse gas emissions.

2.3 International Regulation

Australia ratified the Kyoto Protocol in December 2007 and the binding international agreement came into effect in March 2008.

2.3.1 Implications for Australia by ratifying the Kyoto Protocol

The Government is committed to reducing Australia's emissions to meet its target of five per cent below 2000 levels by 2020. To achieve emissions reductions the Government will implement positive and direct action domestically.

The Government will review its position, considering further action and targets in 2015 as part of negotiations on a new global climate change agreement. This review will focus on the extent to which other nations, including the major economies and Australia's major trading partners, are taking real and comparable actions to reduce emissions.

2.4 National Regulation

2.4.1 National Greenhouse and Energy Reporting Act

The *National Greenhouse and Energy Reporting Act 2007* (NGER Act 2007) established a national framework for corporations to report greenhouse gas emissions and energy consumption and production from 1 July 2008. The Act makes registration and reporting mandatory for corporations whose energy production, energy use or greenhouse gas emissions meet specified thresholds listed below (DOE 2014):

- Corporate Level – 50 kt CO_2-e emitted or 200 TJ energy consumed.
- Facility Level – 25 kt CO_2-e emitted or 100 TJ energy consumed.

The NGER Act has been designed to provide robust emissions and energy consumption data. The annual NGER report is due by 31 October.

2.4.2 Carbon Credits (Carbon Farming Initiative) Act

The Carbon Farming Initiative (CFI) is a voluntary carbon offsets scheme that provides economic rewards to farmers and landholders who take steps to reduce greenhouse gas emissions. Under the CFI, they may be able to earn carbon credits from activities such as:

- enhancing carbon in agricultural soil; and
- storing carbon through revegetation and reforestation.

Carbon farming activities that reduce greenhouse gas emissions are referred to as abatement activities, for which they receive a tradeable carbon credit. There are different credits for different activities. Carbon credits earned under the CFI are called Australian Carbon Credit Units (ACCUs).

Some abatement activities count towards Australia's national target under the Kyoto Protocol. These include reforestation and avoided deforestation. Credits earned from these activities are known as Kyoto ACCUs. Credits from these activities will be able to be sold into the voluntary carbon market.

Abatement activities must deliver lasting benefits. The CFI permanence rules underpin the market value of credits. These rules give buyers confidence that carbon credits represent genuine and lasting reductions in greenhouse gases.

An independent regulator, the Clean Energy Regulator, administers the Carbon Farming Initiative.

2.5 State Regulation

2.5.1 Greenhouse Strategy

The Western Australian Greenhouse Strategy (2004) defines several objectives for its strategic response to global climate change:

- The Western Australian Government will work to minimise its own contribution to climate change by demonstrating emission reductions which will impact on the supply chain of businesses to the government.
- Creation of a Greenhouse Abatement Fund to hold and deal with organic sequestration rights and credits generated by Government institutions.
- Western Australia is committed to reduce greenhouse gas emissions by at least 60% by 2050.

2.5.2 Environmental Protection Authority (EPA) Guidance Notes

WA EPA Guidance Statement No.12, "Minimising Greenhouse Gas Emissions", (EPA 2002) addresses the minimisation of GHG emissions from significant, new or expanding operations and requires proponents to clearly indicate, in their environmental review documentation, the following:

- GHG emissions inventory and benchmarking;
- measures to minimise annual GHG emissions and over the life of the project;
- carbon sequestration opportunities, such as bio-sequestration, geo-sequestration, chemical, soil uptake and reuse; and
- benefits of reduced GHG emissions on a National or Global scale.

The Guidance Statement also suggests that proponents address/commit to:

- applying best practice to maximise energy efficiency and minimise GHG emissions;
- undertaking comprehensive analysis to identify and implement appropriate offsets; and
- undertaking on-going programmes to monitor and report emissions and periodically assess opportunities to further reduce GHG emissions over time.

2.6 Project Position

2.6.1 Sustainability in Design

Cameco has used sustainability design criteria to screen and identify opportunities where sustainability performance might be improved during the detailed design phase. The process of screening was collaborative, the engineering design team provided innovative design solutions to combat GHG emissions and other environmental issues. In undertaking the review of the design criteria, Cameco focused on the following four sustainability goals:

- Minimise wastes, emissions and discharges to protect the quality of the surrounding environment during construction, operations and closure.
- Use resources (economic, raw materials, etc.) efficiently in the design, construction and operation of the project.
- Use water efficiently; maintain the quality of available water and protect the beneficial use of water during mining and post closure.
- Optimise the reduction in the greenhouse footprint of the mining, processing and transport operations through energy efficiency measures and the use of renewable energy.

GHG Emissions Forecast

3.1 GHG Emissions

3.1.1 Emission Sources

Emission sources and activity data description that underpin the GHG inventory are given in Table 3-1. Table 3-1 has been derived from Table 1-2 and Table 1-3 in Section 1.2.5 through regular consultation with the Project Design Engineers.

Table 3-1 Emission Sources and Data Description

Emission Activity	Description and Remarks
Land use change	Total land disturbance area for the Project is estimated at 2100 ha (refer Figure 1-1)
Power generation	Annual electricity consumption (during Operations) is estimated at 150,000 MWh, estimated diesel consumption of 39,260 kL
Steam generation	Estimated 120 kg of steam consumed per tonne of ore processed, estimated annual diesel consumption of 26,440 kL
Fleet fuel consumption	Annual diesel fuel consumption in the mining/light vehicle fleet is estimated at 6,190 kL
Emissions from chemical processes	▪ Waste water treatment; ▪ Oxidation reactions within the metallurgical process; and ▪ TSF - there is a risk that some or all of the 'sequestered' CO_2 may be released over time, if the pH of the tailings residue decreases to ≤ 5, or if the soluble carbonates and bicarbonates disintegrate to form more stable salts and carbon dioxide
Synthetic Gases	▪ Refrigerant gases used in air-conditioning both for buildings and mobile equipment. Assumptions made: - R 134a is the refrigerant gas used in both mobile equipment and buildings; - Operating emission factor (% of capacity/year) is 20% for mobile equipment and 35% for medium and large commercial refrigeration units (IPCC 2006). ▪ Mobile equipment numbers taken from Copy of Yeelirrie trip planning & commodity estimates. ▪ Only low and medium voltage switchgears to be used. Consequently, SF_6 emissions have not been included in the GHG emissions inventory.

Emission Activity	Description and Remarks
Fly In Fly Out	▪ 100 round trips per year. Aircraft consumes approximately 2040 kg of Avtur per one way trip, and 100 round trips per annum (412 tonnes per annum). Flying time to Yeelirrie is assumed to be 2 hours per leg.
Explosives	▪ 70 tpa of ANFO/ANE to be used as explosives
CO_2 used in process	▪ Based on the mass balance provided, approximately 5.6 t/hour of CO_2 will be consumed in the process.
Waste	▪ Inert, recyclable and putrescible waste generated as a result of operations.
Revegetation	▪ Progressive revegetation from year 6 of operations

The major features of the proposed open pit are summarised in Table 3-2.

Table 3-2 Features of the Open Pit development

Features	Project
Nominal mine life	18 years
Mining rate	Up to 14 x 10^6 tpa

3.1.2 GHG Emissions from Land Use Change

Two major Beard vegetation associations were identified[3] for the Project site:

- 18. Low woodland - Mulga (Acacia aneura); and
- 389. Succulent steppe with open low woodland – Mulga over saltbush.

Full Carbon Accounting Modelling (FullCAM) is a model developed by the National Carbon Accounting System, Commonwealth Department of Climate Change. The FullCAM provides an indication of carbon stocks within the soil as an integration of biomass, decomposition, soil carbon models and accounting tools to provide a single model capable of carbon accounting in transitional (e.g. afforestation, reforestation and deforestation) and mixed (e.g. agro forestry) systems. When calculating emissions from land use change in the proposed Project, the FullCAM model was run using the default vegetation type "*Acacia* Forest and Woodland" for vegetation association type 18 and the default vegetation type "*Chenopod* Shrub, *Samphire* Shrub and Forbland" for vegetation association type 389. The values in Table 3-3 and Table 3-4 give an indication of carbon stocks and the emissions released when the vegetation is cleared. The carbon stocks at this site are relatively low due to the generally low net primary productivity of the environment.

The following technical criteria were used in deriving the GHG emissions from land use change.

[3] DMP Clearing Permit Application 2965/1

1. The carbon dioxide equivalent is the GHG emissions caused if vegetation was cleared and allowed to decay or burn. This is derived by multiplying the amount of carbon estimated by the FullCAM model by 3.67 (conversion of carbon to CO_2).
2. Soil carbon is the largest component as the site has been assessed to be predominantly shrub land or grassland.
3. The soil carbon pool will be removed over approximately 89 per cent of the cleared area. The soil carbon component should be considered as an emission.
4. Raised blade clearing methods are to be used for access tracks and drill lines. These represent approximately 11 per cent of the cleared area. The soil carbon pool would not be altered significantly by clearing vegetation for access tracks and drill lines.

The FullCAM plot for the Project includes both above and below-ground vegetative biomass and has included the carbon mass of above and below ground tree components with the expectation that roots are removed during clearing the below ground component.

There are some limitations associated with this site and the FullCAM model that have been taken into consideration whilst estimating GHG emissions due to vegetative clearing:

- FullCAM is inherently conservative in estimating carbon pools for most vegetation types (i.e. it tends to underestimate carbon stocks, anecdotally in some cases up to 30 per cent).
- FullCAM has been designed to model forested areas; it is less accurate for modelling of grasslands, savannahs, agricultural land.
- The definition of 'forest' for the purpose of the model is vegetation at least 2 metres high and with at least 20 per cent canopy cover. The photos of the Project site (provided in the botanical report) suggest that much of the area does not meet this definition.
- The modelling assumes that the default vegetation types are both the *Acacia* Forest and Woodland and the *Chenopod* Shrub, *Samphire* Shrub and Forbland.

Simulation for Mulga

The default vegetation type *Acacia* Forest and Woodland was used to run this simulation. Note that for this simulation, "tree components" refers to this vegetation type.

Table 3-3 FullCAM estimate of GHG emissions due to clearing

Carbon pool	Carbon mass (t C/ha)	Emissions (t CO_2-e/ha)
Soil	9.3	34.1
Debris	0.1	0.4
Above ground tree components	4.2	15.4
Below ground tree components	1.3	4.8
Total	**14.9**	**54.7**

Simulation for Mulga over saltbush

The default vegetation type *Chenopod* Shrub, *Samphire* Shrub and Forbland was used to run this simulation. Note that for this simulation, "tree components" refers to this vegetation type.

Table 3-4 FullCAM estimate of GHG emissions due to clearing

Carbon pool	Carbon mass (t C/ha)	Emissions (t CO_2-e/ha)
Soil	9.1	33.4
Debris	1.9	7.0
Above ground tree components	3.8	13.9
Below ground tree components	3.6	13.2
Total	**18.4**	**67.5**

The following assumptions were made relating to the modelling in FullCAM and environmental conditions of the site. Terms used in the FullCAM model are in *italics*:

- Site location (which determines default environmental conditions) is Latitude: 27.288706°S and Longitude: 120.10454°E.
- Used the default values for soil, rainfall, temperature and tree growth parameters.
- The model did not have any specific *soil data* for this location (this is often the case for regions where forestry is not a common land use). Therefore a (unspecified) default soil type was used.
- Used the Plot Type; Multilayer mixed (forest and agricultural) system.
- Simulated conditions under Agriculture plantation weed species prior to 'planting' (this reflects conditions under a grassland environment similar to that at the Project site).
- 'Planted' a Mixed Species Environmental Planting of Acacia Forest and Woodland
- Simulated growth for 600 years (including an 18 year run-in). This was the point at which carbon pools were deemed to have 'stabilised' and best represents a native ecosystem in a natural (undisturbed) state.
- FullCAM output is on a per-hectare basis, values have been provided for 1 hectare.
- 60 per cent of the Project site area is covered by Acacia Forest and Woodland, as defined in FullCAM.
- 40 per cent of the Project site area is covered by Chenopod Shrub, Samphire Shrub and Forbland, as defined in FullCAM.

3.2 GHG Emissions from Project

GHG emissions for the Project have taken into account the project life emissions during the following phases:

- Construction Phase – construction and pre-stripping;
- Operations Phase - mining and processing; and
- Decommissioning Phase.

Assumptions

The following assumptions were made in estimating the annual and life of Project GHG emissions:

- Indicative figures for the consumption of energy and generation of waste, transportation, etc. taken from Project Description (Cameco, 2014).
- Metallurgical plant throughput averages 2.4 x 10^6 tpa.
- Life of the mine is 18 years, including three years of pre-strip.

- The life of the hydrometallurgical plant is 15 years, commencing three years after mining commences.
- Total land clearing is assumed to be 2100 ha (refer Figure 1-1).
- Diesel fuel consumption as per the project trip planning study estimates (Yeelirrie_Trip Planning & Commodity Estimates_Base Case_v6.0_17Mar 10.xls).
- Construction phase has been assumed to last for two (2) years.
- HFCs will be used in the heating, ventilation and air conditioning systems.
- SF_6 is not likely to be used as a dielectric in the electrical switch gear.
- Mine dewatering has the capacity to impact flora in and around the project site. It is assumed that Cameco will take measures to reduce vegetation loss in surrounding areas.
- Progressive revegetation has been assumed to begin in year 6 of operations.
- 70 tonnes per annum of ANFO/ANE will be used as explosives.
- Embedded energy and GHG emissions for materials used have not been taken into consideration in the emissions inventory.
- Raised blade clearing methods will be used for access tracks and drill lines, allowing retention of soil biomass and root systems.

3.2.2 Total Project Life Gross Project GHG Emissions

Figure 3-1 shows the total indicative GHG emissions across the project life. Total gross (excluding GHG emissions sequestered through revegetation) project GHG emissions are approximately 3.76×10^6 t CO_2-e, of which approximately 86 per cent is accounted for in the operations phase. Land clearing contributes 3.14×10^4 t CO_2-e to the emissions total.

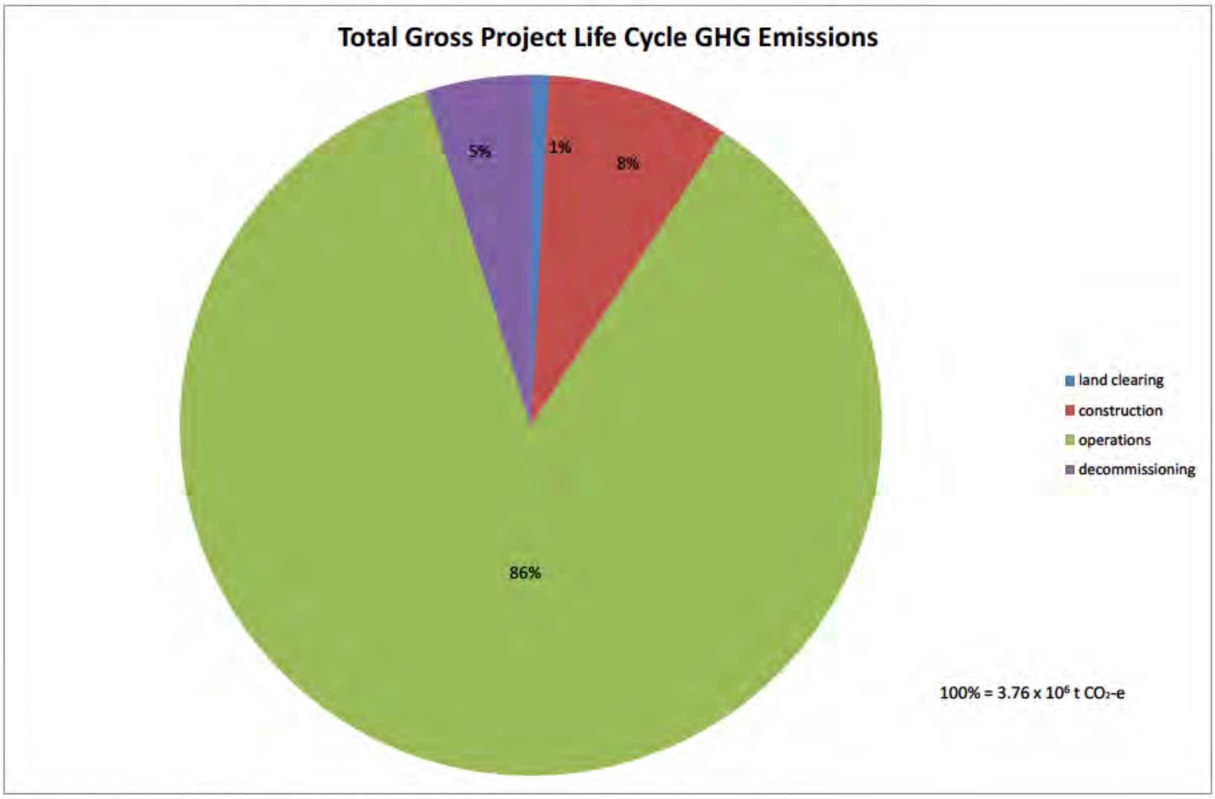


Figure 3-1 Indicative Total Gross GHG Emissions across Project life

Continuous Mining

Table 3-5 shows the total indicative gross GHG emissions across the Project life. Total Project GHG emissions are approximately 3.75 x 10^6 t CO_2-e.

Table 3-5 Indicative Gross GHG Emissions across the life of Project

Emission Source	Indicative Total GHG Emissions (t CO_2-e)
Land Clearing	31,380
Construction Phase	316,630
Operations Phase	3,234,040
Decommissioning Phase	182,500

The progressive rehabilitation of the site is estimated to result in sequestering approximately 3.01 x 10^4 t CO_2-e. Hence, the net GHG emissions released during the project life are estimated to be approximately 3.73 x 10^6 t CO_2-e[4].

3.2.3 GHG Emissions by Source during Operations Phase

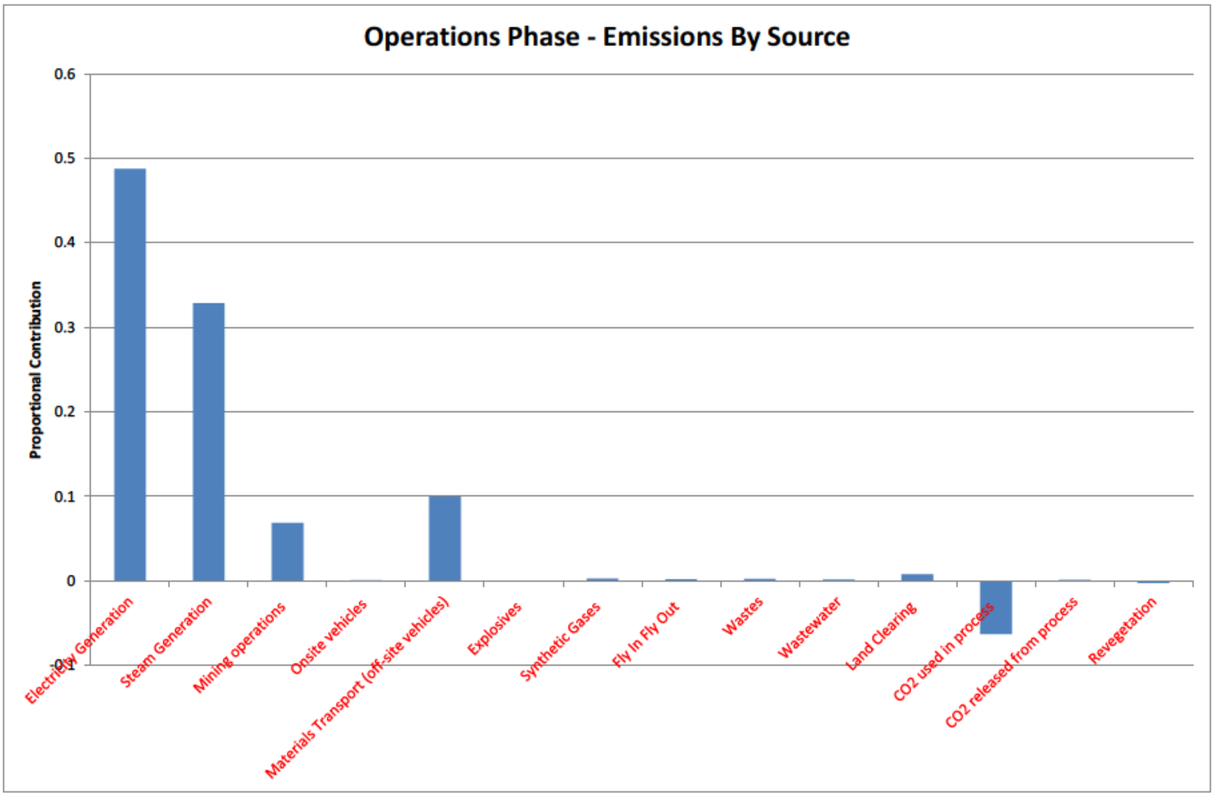
Table 3-6 shows predicted annual GHG emissions, by source, during the operations phase.

Table 3-6 Predicted Annual GHG Emissions during Operations Phase

Activity/source	GHG emissions (t CO_2-e per annum)	
	Scope 1	Scope 3
Steam generation	70,920	Not Applicable (NA)
Electricity generation	105,330	NA
Mining and light vehicle fleet	15,590	490
CO_2 absorption into liquor	-13,600	NA
Waste water treatment	370	NA
Tailings Storage Facility (TSF)	13,600	NA
Explosives	10	NA
Waste	500	NA
Synthetic gases	620	NA
Materials transport	NA	21,590
Workforce transport	NA	80
CO_2 desorption from TSF	190	NA
TOTAL	**193,530**	**22,160 (average)**

[4] CO_2 sequestered in the carbonation process has not been included in the net emissions.

Figure 3-2 shows indicative total GHG emissions by source during the operations phase. At approximately 49 per cent, diesel fuel consumption for electricity generation is the single largest source of total GHG emissions during the operations phase, followed by diesel fuel consumption for steam generation at 33 per cent. This is followed by diesel fuel use in off-site vehicles at 10 per cent.



100% Annual Average = 3.25 x 10^6 t CO_2-e

Figure 3-2 Indicative GHG Emission Sources - Operations Phase

Figure 3-3 shows indicative total annual GHG emissions versus the cumulative GHG emissions across the Project life. Net cumulative GHG emissions for the entire Project life are estimated at approximately 3.73 x 10^6 t CO_2-e, including the CO_2 sequestered due to progressive rehabilitation of the site, but not including the CO_2 that is re-used in the process. Reasons for this are described in Section 3.3.

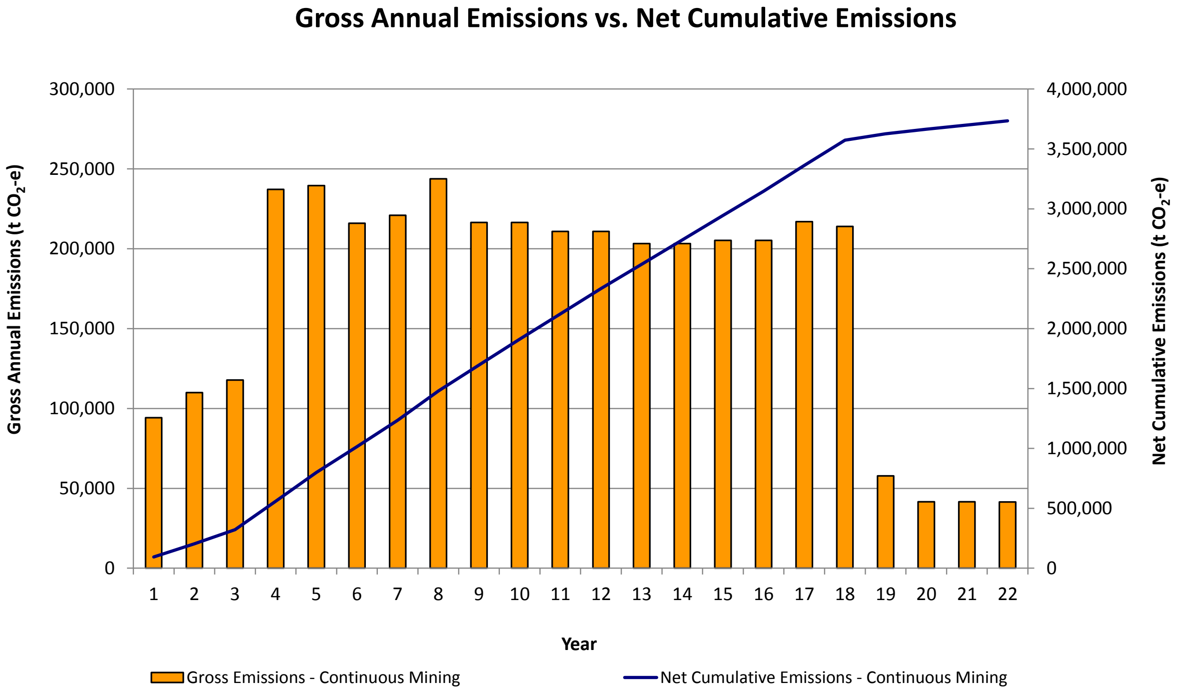


Figure 3-3 Indicative Annual GHG Emissions vs. Cumulative Emissions across the Project Life

3.3 GHG emissions from tailings residue storage

Approximately 13,600 tonnes CO_2 per annum have been estimated to be accumulated and stored in the TSF as sodium carbonates and sodium bicarbonates. The carbonate mass results from the reuse of exhaust CO_2 emissions from the electricity and steam generation facilities in the metallurgical plant. For the whole of Project life, it is estimated that approximately 2.04×10^5 tonnes of CO_2 may potentially be discharged to the TSF. A conservative approach, as has been taken in this report, assumes that this total mass will be released to the atmosphere over a time period of 100 years.

3.4 Life Cycle Greenhouse Gas Emissions

The extraction of uranium by Cameco at the Project site is the first step in a long and complex process to provide nuclear generated energy. The end-product of uranium mining may be CO_2-free nuclear power but the extraction and conversion of the ore consist of activities that generate and emit CO_2 to the atmosphere.

3.4.1 Potential Life Cycle Emission Benefits

All manufactured products cause environmental degradation in some way, whether from their manufacturing, use or disposal. Life Cycle Assessment (LCA) is a method to analyse resource issues across the life cycle of a product and can systematically identify key areas to improve environmental and economic performance.

Studies of the nuclear fuel cycle GHG emissions have shown that the generation of nuclear electricity produces about 66 grams of CO_2-e per kWh (g CO_2-e/kWh) of electricity generation (Sovacool 2008; Lenzen 2008). This emissions intensity is about 10 to 15 times less than that of other fossil fuel electricity generation and at the higher end of the range of renewable electricity generation emission intensities.

An extensive analysis of the life cycle GHG of electricity generating technologies has been undertaken (Sovacool 2008; Lenzen 2008). These studies highlighted the various aspects of the nuclear fuel cycle that have the greatest influence on life cycle GHG emissions. Specifically these are:

- the grade of the uranium ore mined;
- the method of enrichment;
- the conversion rate of the nuclear fuel cycle (i.e. the amount of fuel recycling);
- the source (fossil, renewable or nuclear) of electricity used for the enrichment phase; and
- the overall GHG intensity of the electricity mix in the countries where fuel cycle activities are undertaken.

Sovacool (2008) undertook a literature review of 19 previous nuclear life cycle emission analyses from more than 60 nuclear power stations. The results of this study are presented in Table 3-7.

Table 3-7 Emissions intensity of the nuclear fuel cycle (Sovacool 2008)

Emissions	Emissions intensity (g CO_2-e per kWh of generated electricity)					
	Front-end[1]	Construction[2]	Operation[3]	Back-end[4]	Decommissioning[5]	Total
Minimum	0.58	0.27	0.1	0.4	0.01	1.36
Maximum	118	35	40	40.75	54.5	288.25
Mean	25.09	8.2	11.58	9.2	12.01	66.08

[1] Front-end – Mining, milling, conversion, enrichment, fuel fabrication, and transport.
[2] Construction – All materials and energy inputs for building the power station.
[3] Operation – All energy needs for maintenance, cooling and fuel cycles and back-up generators.
[4] Back-end – Fuel processing, conditioning, reprocessing, interim and permanent storage.
[5] Decommissioning – Deconstruction of the facility and land reclamation.

Sovacool analysed more than one hundred lifecycle studies of nuclear plants around the world. Sovacool found that estimates of total lifecycle carbon emissions ranged from 1.4 g CO_2-e/kWh of electricity produced, up to 288 g CO_2-e/kWh. Sovacool believes the mean of 66 g CO_2-e/kWh to be a reasonable approximation.

According to Sovacool's analysis, nuclear power, at 66 g CO_2-e/kWh emissions (Sovacool 2008), is well below scrubbed coal-fired plants, which nominally emit 960 g CO_2-e/kWh, and natural gas-fired plants, that nominally emit 443 g CO_2-e/kWh.

A similar study undertaken by Lenzen (2008), on behalf of the Australian Government, concluded that the GHG intensity of nuclear power was around 60 g CO_2-e/kWh of generated electricity (ranging between 10–130 g CO_2-e/kWh) for light water reactors, and around 66 g CO_2-e/kWh (ranging between 10–120 g CO_2-e/kWh) for heavy water reactors. The GHG intensity of nuclear power is lower than any current fossil-fuelled power technology.

The results of the above-mentioned nuclear fuel life cycle emissions analysis are compared to other forms of electricity-generation technologies in Table 3-8, that shows both international GHG intensities and those in an Australian context (study ranges within brackets).

Table 3-8 Greenhouse gas emissions intensity of electricity generation technologies

Electricity technology	GHG intensity (g CO_2-e/kWh)	
	International	Australian
Off-shore wind[1]	9	-
On-shore wind[1]	10	21 (13−40)
Biogas[1]	11	-
Hydroelectric (run-of-river)[1]	13	15 (6.5−44)
Solar thermal[1]	13	-
Biomass[1]	28	-
Solar PV[2]	32	106 (53−217)
Geothermal[1]	38	-
Nuclear[3]	66	65 (10−130)
Natural gas (combined cycle)[4]	443	577 (491−655)
Natural gas (open cycle)	-	751 (627−891)
Fuel cell[4]	664	-
Diesel[4]	778	-
Heavy oil[4]	778	-
Black coal (supercritical)[4]	-	863 (774−1046)
Black coal (new subcritical)[4]	-	941 (843−1,171)
Black coal (scrubbed)[4]	960	-
Black coal (unscrubbed)[4]	1,050	-
Brown coal (new subcritical)[4]	-	1,175 (1,011−1,506)

[1] Sourced from Pehnt 2006.
[2] Sourced from Fthenakis and Kim 2008.
[3] Sourced from Sovacool 2008.
[4] Sourced from Gagnon et al 2002.

It can be seen from the data in Table 3-8 that the nuclear fuel cycle emits less GHG than any fossil fuel technology, and emissions are similar to, though at the upper range of, the renewable electricity generation technologies.

A high-level GHG emission life cycle assessment of the Project was undertaken using available literature to estimate emissions associated with uranium production, use and disposal.

Based on this analysis, 53 kilograms of CO_2-e are produced for each kilogram of recovered U_3O_8 at a concentration of 84.8 per cent uranium (99.3% U_{238}, 0.7% U_{235}).

Approximately 8.49 kg of pure U_3O_8 from Yeelirrie is required to produce 1 kg of 3% U_{235} nuclear fuel-grade UO_2, sufficient to generate approximately 304 MWh of electricity. Given that 1 kg of Yeelirrie uranium is equivalent to 1.18 kg of 100 per cent pure U_3O_8, and using the nuclear life-cycle information presented in the literature[5], it is estimated that 1 kg of pure U_3O_8 has the energy equivalence of approximately 9.3 kL of diesel that would generate 24.86 tonnes of CO_2-e. Therefore, the CO_2-e saving is 24.81 tonnes of CO_2-e per kilogram of U_3O_8 produced.

[5] International Atomic Energy Agency (2009)

Comparison with Global, National and State GHG Emissions

A comparison of the annual GHG emission forecast from the Project against the current and projected future state, national and international annual GHG emissions is discussed below.

4.1 Current and Projected GHG Emissions

Over the 23 year life of the proposed Project, Western Australian, Australian and global greenhouse gas emissions are predicted to rise from the current levels described in Table 4-1 (ABARE 2007, DEC 2008). The annual greenhouse gas emissions from the proposed Project (217,340 tpa of CO_2-e) were compared against the projected future state, national and global emissions.

Table 4-1 Current and Projected Australian and global greenhouse gas emissions in Mtpa of CO2-e (excluding land use change)

Source	Unit1	2010	2020	2030	2040
Western Australia (DEC 2008)	Total	74	81	98	102
	%	-	0.14	0.22	0.04
Australia (DEC 2008)	Total	549	638	695	752
	%	-	0.017	0.030	0.006
Global (ABARE 2007)	Total	42,300	53,800	63,600	75,800
	%	-	0.00020	0.00033	0.00005

[1]Total refers to the projected GHG emissions for the source, and % refers to the proportion of that total represented by the proposed Project

The data presented in Table 4-1 show that, as a proportion of state, national and global emissions, the contribution of the development to atmospheric GHG emission levels is very low. However, given the national and global importance of this issue, Cameco could investigate GHG emissions reduction initiatives throughout the life of the proposed Project.

4.2 Conclusions

This assessment has identified and quantified the characteristics of likely GHG sources and assessed them in the context of state, national and global greenhouse gas emission projections. The assessment has followed accepted practice for undertaking such GHG forecast and the findings are presented as estimates due to the inherent uncertainties associated with undertaking such predictive assessments.

The predictive estimate calculated a total gross emission of approximately 3.76×10^6 t CO_2-e across the Project life. The Project life includes land clearing, construction, operations and decommissioning, for a period of up to 22 years. When including into the calculated emissions, sequestration due to rehabilitation of the site, the net GHG emissions are estimated to be 3.73×10^6 t CO_2-e.

Whilst these emissions are very low on a state, national and global scale, Cameco could investigate GHG emission abatement projects throughout the life of the proposed development as technologies improve. These projects could broadly be categorised into those that reduce energy demand, and those that provide a cleaner energy supply. The on-going monitoring, implementation, and reporting of these abatement projects would be managed through a site based Greenhouse Gas and Energy Management Plan.

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The methodology adopted and sources of information used by URS are outlined in this report. URS has made no independent verification of this information beyond the agreed scope of works and URS assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to URS was false.

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