Western Ridge Greenhouse Gas Emissions Inventory

Final Report
Version 2

Prepared for BHP Iron Ore

April 2021

Project Number: 1180

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Final Report

DOCUMENT CONTROL

Version	Description	Date	Author	Reviewer
0	Draft issued for client review	18.03.2021	ETA (KH)	ETA (DT)
1	Final issued for client use	21.04.2021	ETA (KH)	BHP
2	Revision of final issued for client use	30.04.2021	ETA (KH)	BHP

Approval for Release

Name	Position	File Reference
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Signature
Karla Hinkley

Executive Summary

Overview of assessment

BHP Iron Ore (BHP) propose to expand the existing mining operations at Newman through the development of the Western Ridge Project (the Project) located approximately 10 kilometres (km) south west of the Newman townsite in the Pilbara region of Western Australia.

An inventory of greenhouse gas (GHG) emissions estimated for the Project has been prepared to inform the assessment of potential environmental impacts and the proposed management measures with respect to the approval of the Project under the *Environmental Protection Act 1986* (EP Act).

Scope of work

The scope of work included:

- Undertaking a peer review of emission estimates for Scope 1 (direct emission) and Scope 2 (indirect emission) derived for the Project to confirm:
    - All significant sources of GHG emissions, inclusive of stationary energy, fugitives, and transport related emissions are included.
    - Appropriate emission estimation techniques and factors, consistent with the National Greenhouse and Energy Reporting (NGER) legislation (refer to Section 0), are applied, accounting for greenhouse gases carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulphur hexafluoride (SF_6), hydro fluorocarbons (HFCs) and perfluorocarbons (PFCs).
    - Emission estimates of the proposal are credible, based on comparison of modelled emissions intensity to Australian iron ore sectoral averages published by the Clean Energy Regulator through the NGER scheme for iron ore mining operations.
- Estimating GHG emissions associated with changes to land use (clearing of vegetation) using FullCAM (Full Carbon Accounting Model) (Richards, 2001), the model used in the Australian National Greenhouse Accounts for the land use, land use change and forestry sectors.
- Preparing a report to document the emission estimation techniques and factors, and to present the breakdown of GHG emissions by source for the alternative Western Ridge development scenarios.

Key findings

- Emissions from all key sources associated with the Project have been derived using accepted methods of emission estimation, consistent with the NGER scheme and Australian National Greenhouse Accounts.

- GHG emissions attributed to land clearing were estimated using the FullCAM model, which allows a consistent, scientifically rigorous and transparent model platform that provides for ongoing improvements in fundamental input data and model calibration.

- The peer review of emission estimates derived for the Project has confirmed that all significant sources of GHG emissions are included, and that appropriate emission estimation techniques and factors, consistent with the NGER scheme have been applied. Further, the emission estimates are credible based on comparison of emissions intensities published by the Clean Energy Regulator through the NGER scheme for the Australian iron ore sector.

- The Scope 1 (direct emission) and Scope 2 (indirect emission) estimates documented in this report are consistent with the Environmental Protection Authority (EPA, 2020) guideline for GHG emissions, to the extent covered by the scope of work.

- A summary of GHG emissions estimated for the Project for two Western Ridge development scenarios defined by BHP – Trucking ore (TO) and Conveying and trucking ore (CTO), are presented in Table ES 1 below.

Table ES 1 Summary of estimated greenhouse gas emissions (t CO_2-e per year) - Western Ridge TO and CTO scenarios

	Year	TO			CTO		
		Scope 1	Scope 2	Total	Scope 1	Scope 2	Total
Maximum	2030	374,211	76,672	450,883	284,237	88,479	372,716
Average	2022 - 2048	116,627	24,414	141,041	99,857	28,051	127,907

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1 Introduction

1.1 Background

BHP Iron Ore (BHP) propose to expand the existing mining operations at Newman through the development of the Western Ridge Project (the Project) located approximately 10 kilometres (km) south west of the Newman townsite in the Pilbara region of Western Australia.

The Project comprises open pit mining from four deposits (Eastern Syncline, Bills Hills, Mount Helen and Silver Knight) (Figure 1-1) to be progressively mined. Ore will be transported to the existing Whaleback hub for processing using a combination of truck haulage and overland conveyor. Initially truck haulage will be used to transport ore from the Eastern Syncline and Bills Hills to the Whaleback ore processing hub. Once mining at the Mount Helen and Silver Knight deposits commence, it is proposed to construct a new crusher and an overland conveyor to transport this ore to the Whaleback ore processing hub.

The proposed mining rate for the Project is 50 Million tonnes per annum (Mtpa) of ore, noting this will replenish supplies from depleting ore reserves across existing mining operations. The rate of ore processing through the Whaleback hub will therefore not increase because of the Project. The estimated life of mine is approximately 30 years.

Electricity supply for the operation of the Project is proposed to be supplied from the existing Yarnima Power Station, located in Newman. Yarnima Power Station is a combined cycle gas-fired power generation plant, operated by BHP supplying power to the Newman township and BHP's iron ore mining operations in the Pilbara region.

An inventory of GHG emissions estimated for the Project has been prepared to inform the assessment of potential environmental impacts and the proposed management measures with respect to the approval of the Project under the *Environmental Protection Act 1986* (EP Act).

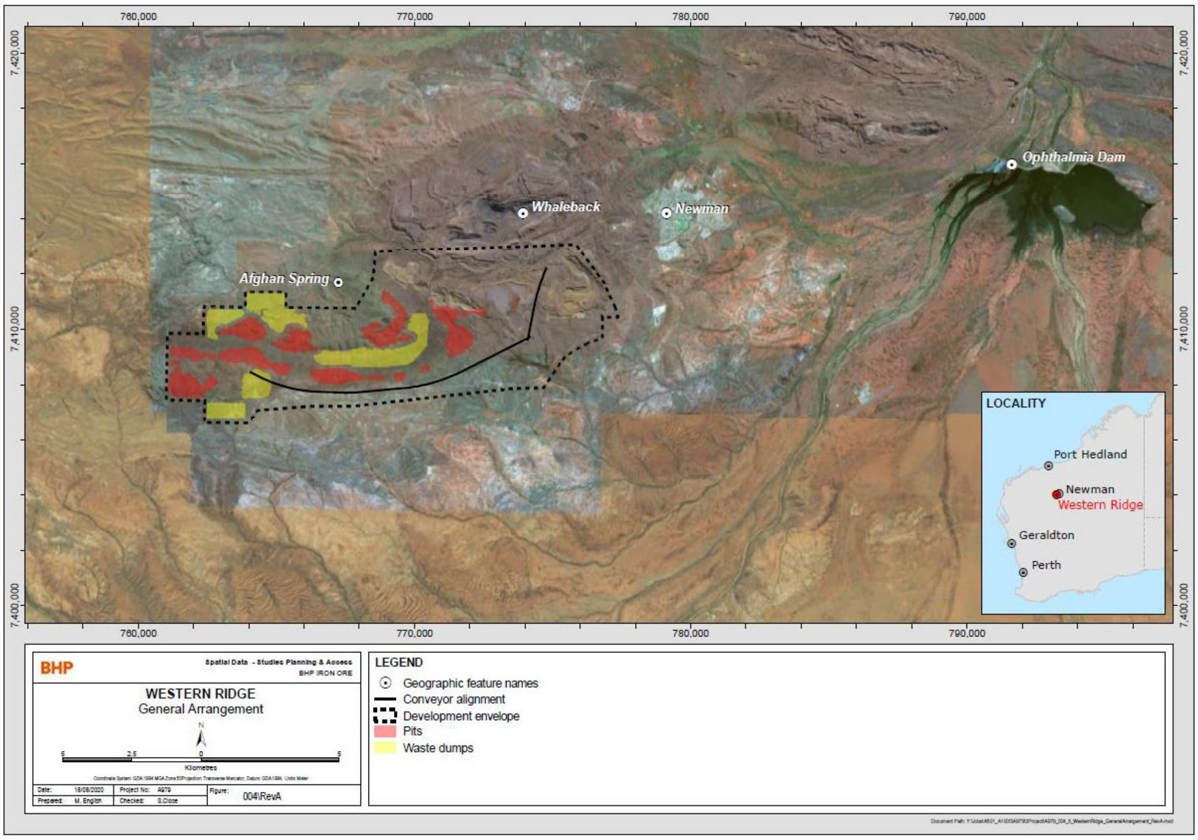

Figure 1-1: Project overview

1.2 Scope of work

Environmental Technologies & Analytics Pty Ltd (ETA) was engaged by BHP to assist in the preparation of the inventory of GHG emissions estimated for the Project. Emissions were estimated for two Western Ridge development scenarios defined by BHP, each of these varied the use of truck haulage and overland conveying as the primary method to transport ore from orebody to the existing Whaleback ore processing hub (refer to Section 3.3).

The scope of work included:

- Undertaking a peer review of emission estimates for Scope 1 (direct emission) and Scope 2 (indirect emission) derived for the Project to confirm:
  - All significant sources of GHG emissions, inclusive of stationary energy, fugitives, and transport related emissions are included.
  - Appropriate emission estimation techniques and factors, consistent with the National Greenhouse and Energy Reporting (NGER) scheme (refer to Section 0), are applied, accounting for greenhouse gases carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulphur hexafluoride (SF_6), hydro fluorocarbons (HFCs) and perfluorocarbons (PFCs).
  - Emission estimates of the proposal are credible, based on comparison of modelled emissions intensity to Australian iron ore sectoral averages published by the Clean Energy Regulator through the NGER scheme for iron ore mining operations.
- Estimating GHG emissions associated with changes to land use (clearing of vegetation) using FullCAM (Full Carbon Accounting Model) (Richards, 2001), the model used in the Australian National Greenhouse Accounts for the land use, land use change and forestry sectors.

- Preparing a report to document the emission estimation techniques and factors, and to present the breakdown of GHG emissions by source for the alternative Western Ridge development scenarios.

Scope 1 (direct emissions) and Scope 2 (indirect emissions) GHG emissions (annual and total) were estimated over the estimated life of mine. Scope 3 emissions (indirect emissions other than Scope 2 emissions) are excluded from the scope of work. Definitions of Scope 1, 2 and 3 emissions adopted for this study are set out in Section 3.2.

1.3 Structure of report

This report describes the estimation methodology, assumptions and results of the GHG emissions inventory developed for the Project. The assessment includes:

- Background information and scope of work (Section 1).
- Overview of the regulatory context (Section 2).
- Inventory framework (Section 3).
- Emissions inventory for the Project, for alternative development scenarios (Section 4).
- Conclusions (Section 4.4.1).

2 Regulatory Context

2.1 Environmental Factor Guideline: Greenhouse Gas Emissions

The inventory of GHG emissions estimated for the Project has been prepared to inform the assessment of potential environmental impacts and the proposed management measures with respect to the approval of the Project under the EP Act.

In April 2020, the Environmental Protection Authority (EPA) published the new Environmental Factor Guideline for GHG emissions (EPA, 2020) which outlines how and when GHG emissions are to be considered in the context of the State regulatory environmental impact assessment (EIA) process. Under the guideline, generally, GHG emissions from a proposal will be assessed where they exceed 100,000 tCO_2-e of Scope 1 emissions each year. This is currently the same as the threshold criteria for designation of a large facility under the Australian Government's Safeguard Mechanism.

To inform the assessment process, disclosure and documented estimates of GHG emissions may be required by the EPA, including the following information:

- credible estimate of Scope 1, 2 and 3 GHG emissions (annual and total) over the life of a proposal.
- a breakdown of GHG emissions by source inclusive of, but not limited to, stationary energy, fugitives, transport, and emissions associated with changes to land use.

The Greenhouse gas emissions estimates contained within this report intend to characterise the annual and life of mine emissions associated with the proposal, to support the EPA's determination of the significance of greenhouse gas emissions as a factor.

Indirect emissions associated with off-site electricity supplied, outside the scope of the proposal, have been included to assess the potential GHG emissions when Scope 1 and 2 emissions are evaluated holistically.

2.2 National Greenhouse and Energy Reporting

The *National Greenhouse and Energy Reporting Act 2007* (NGER Act) established a national framework for corporations to report GHG emissions and energy consumption. The NGER Act is administered by the Clean Energy Regulator, responsible more broadly for administering schemes legislated by the Australian Government for measuring, managing, reducing or offsetting Australian carbon emissions.

The *National Greenhouse and Energy Reporting (Measurement) Determination 2008* (NGER Measurement Determination) provides methods, criteria and measurement standards for calculating GHG emissions and energy data under the NGER Act. It covers Scope 1 and Scope 2 emissions, and energy production and consumption. The Measurement Determination is updated annually to reflect improvements in emission estimation methods. The categories of emission sources that are covered include:

- fuel combustion
- fugitive emissions
- industrial process emissions
- waste
- energy
- Scope 2 emissions

Estimates of GHG emissions from the Project have been derived in accordance with the methods prescribed under the NGER Act and the most recent Measurement Determination for 2019-20 (*NGER (Measurement) Determination*, 2020). It is noted that the calculation and reporting of GHG emissions associated with change in land use is not covered under the NGER Act.

3 Inventory Framework

3.1 Greenhouse gases

Guidelines applied by the EPA (2020) relate to the six categories of GHG covered by the United Nations Framework Convention on Climate Change (UNFCCC). These include carbon dioxide (CO_2) methane (CH_4), nitrous oxide (N_2O), sulphur hexafluoride (SF_6), hydro fluorocarbons (HFCs) and perfluorocarbons (PFCs).

Emissions from iron ore mining activities are largely associated with fuel (diesel) combustion emissions and as such tend to be comprised of CO_2 primarily, and the remainder as CH_4 and N_2O at very low levels in comparison. These three GHG categories (CO_2, CH_4 and N_2O) are included in the emission estimates calculated for the Project.

Emissions of SF_6, HFCs and PFCs have been considered, but not included for the purposes of this assessment. Annual GHG emissions inventory reporting required by the NGER Act for BHP's existing iron ore mining operations continue to validate these categories of GHG to be below reporting thresholds under the NGER scheme or not applicable to iron ore mining (*Pers. comm.*, BHP. 16 February 2021).

As a standard method, the potential impact of these GHGs is described in terms of their Global Warming Potential (GWP), a comparison using CO_2, the most prevalent GHG. GWP for relevant GHGs are summarised in Table 3-1 (*NGER Regulations*, 2020).

Table 3-1 Greenhouse gases and their Global Warming Potential

Greenhouse Gas	Formula	GWP
Carbon dioxide	CO_2	1
Methane	CH_4	28
Nitrous oxide	N_2O	265

Total GHG emissions are expressed in terms of CO_2 equivalents as:

$$\boldsymbol{ER_{CO2} = \sum_{i=1}^{n} ER_i * GWP_i}$$ **Equation 1**

Where: ER_{CO2-e} = total GHG emissions expressed as CO_2 equivalent (tonnes CO_2-e)
ER_i = tonnes of GHG ***i*** emissions (tonnes)
GWP_i = Global Warming Potential of GHG ***i*** (dimensionless)

3.2 Scopes of emissions

National and international GHG reporting standards define a set of distinct classes (scopes) of GHG emissions that delineate sources and associated responsibilities to account for the emissions. The definition of Scope 1, 2 and 3 GHG emissions is described below. Figure 3-1 is used to further illustrate examples of the different scopes of emissions.

- **Scope 1** - emissions released to the atmosphere as a direct result of an activity or series of activities (including ancillary activities) at a facility level. Scope 1 emissions are sometimes referred to as direct emissions.

- **Scope 2** - emissions released to the atmosphere from the indirect consumption of an energy commodity (i.e. electricity, heating, cooling or steam) that is consumed by the facility but that do not form part of the facility. For example, 'indirect emissions' come from the use of electricity produced by the combustion of fuel at another facility (power station). The emissions are then attributed to the power station as Scope 1 emissions and attributed to the facility consuming the electricity as Scope 2 emissions, so as to avoid any double accounting.
- **Scope 3** - indirect emissions other than Scope 2 emissions that are generated in the wider economy. They occur as a consequence of the activities of a facility, but from sources not owned or controlled by that facility's business. Examples of activities that emit greenhouse gases under Scope 3 include commercial airline business travel, extraction and production of purchased materials, and use of sold products and services.

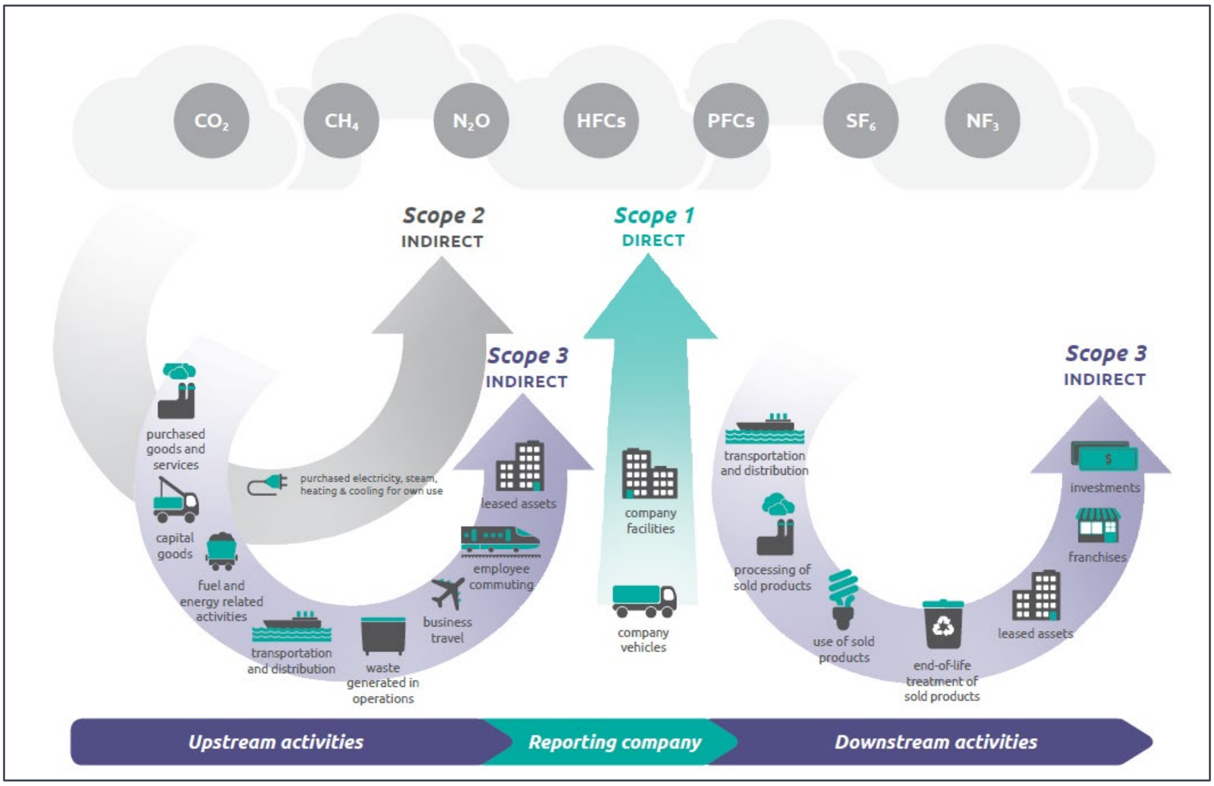

Figure 3-1: Illustration of Scope 1, 2 and 3 emissions (WRI et al, 2013)

Scope 1 and Scope 2 emissions are required to be reported under the NGER legislation (refer to Section 0), whereas Scope 3 emissions are not reported under the NGER scheme. The emissions associated with the electricity to be supplied to the Project from the Yarnima Power Station falls into the Scope 2 emissions category. Scope 3 emissions are excluded from the scope of work.

3.3 Project scenarios

GHG emissions were estimated for the two alternative Western Ridge development scenarios defined by BHP involving a combination of truck haulage and overland conveying to transport ore to the existing Whaleback ore processing hub. The scenarios are:

- **Trucking ore (TO)** – assumes that ore is transported by truck from all four Western Ridge deposits to the Whaleback hub.
- **Conveying and trucking ore (CTO)** – assumes that an overland conveyor is used to transport ore from Mount Helen and Silver Knight while trucks are used to transport ore from Eastern Syncline and Bills Hill to the Whaleback hub.

4 Greenhouse Gas Emissions

4.1 Emissions Sources

GHG emissions from the Project will be generated directly (Scope 1) from the use of earth moving equipment and heavy vehicles for open pit mining and associated activities, as listed below. Indirect (Scope 2) emissions associated with the electricity to be supplied to the Project from the Yarnima Power Station are also included in the inventory:

- Fuel (diesel) combustion
  - haul trucks
  - ancillary equipment[1]
  - explosives
  - de-watering
- Oils and grease
- Land clearing

4.1.1 Exclusions

There are various incidental sources of emissions that are not included in the Project inventory, as they are expected to be insignificant and have not been considered further. Table 4-1 identifies these incidental sources and reasons for their exclusion.

Table 4-1 Incidental source exclusions

Emission Source	Description	Reason for Exclusion
Solid waste disposal	Fugitive emissions from solid waste disposal at the Project site.	It is not proposed to dispose of putrescible waste at the Project site.
Domestic wastewater	Fugitive emissions from handling of domestic wastewater at the Project site.	Reporting under the NGER scheme is applicable to Water Supply, Sewerage and drainage services (ANZSIC code 281), not to iron ore mining.

[1] Ancillary equipment includes heavy equipment used to support mining activities such as excavators, loaders and drills, and small (passenger) vehicles.

4.2 Estimation Methods

4.2.1 Overview

Emissions from all key sources associated with the Project have been derived using accepted methods of emission estimation. Specifically:

- The emission estimation methods adopted for fuel (diesel) combustion and electricity consumption are consistent with the most recent NGERS Measurement Determination for 2019-20 (*NGER (Measurement) Determination*, 2020).
- Emissions associated with clearing of vegetation (change in the land use) have been estimated using the Full Carbon Accounting Model (FullCAM) (Richards, 2001).

Use of these accepted methods of emission estimation promotes consistency between inventories at company or facility level and the emission estimates presented in the State and Territory Greenhouse Gas Inventories (DISER, 2021a & 2021b).

Mine production and consumption forecasts for the Project were developed by BHP for the life of mine and have been used as the basis for the emission estimates (refer to Section 4.3). The scope of work included to confirm emission estimates for the proposal as credible, based on comparison of modelled emissions intensity to Australian iron ore sectoral averages published by the Clean Energy Regulator through the NGER scheme for iron ore mining operations (refer to Section 4.4.1). The accuracy and completeness of mine production and consumption forecasts developed by BHP has not been verified as part of the scope of work. However, benchmarking the proposal to relevant industry averages indicate the emissions are credible.

Suitable proxy emission estimation methods were applied for use of explosives and oils and greases consumption, due to withdrawal of published emission factors for explosives[2] and reasonable limitations in consumption forecasts available for the Project.

4.2.2 Fuel (Diesel) combustion

GHG emissions from combustion of diesel were estimated using a Method 1 (known as the default method) approach, in accordance with Division 2.4.2 of the NGER Measurement Determination (*NGER (Measurement) Determination*,2020).

The greenhouse gas emission factors for diesel combustion for stationary energy are detailed in Table 4-2. The material source of diesel consumption is associated with stationary diesel combustion. Emissions associated with transport include road registered vehicles. As both stationary and transport diesel emission factors are very similar, and transport diesel represents a fraction of the proposal's total emissions, stationary energy emission factors have been applied.

These factors were used to estimate emissions from:

- heavy haulage

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[2] There is a historic emission factor for explosives (ANFO) use of 0.17 tCO_2-e/t product (AGO, 2006), but this has not been included as a National Greenhouse Accounts Factors for some time.

- ancillary equipment
- explosives
- dewatering pumps

Table 4-2 Energy content factor and emission factor for diesel combustion

Description		Units	Stationary
Energy content factor		GJ/kL	38.6
Emission Factor	CO_2	kg CO_2-e/GJ	69.9
	CH_4	kg CO_2-e/GJ	0.1
	N_2O	kg CO_2-e/GJ	0.2
	CO_2-e	kg CO_2-e/GJ	70.2

Greenhouse gas emissions from liquid fuel combustion are estimated based on the following equation:

$$E_{i,j} = \frac{Q_i \times EC_i \times EF_{ijoxec}}{1000} \quad \textbf{Equation 2}$$

Where: $E_{i,j}$ = emissions of gas type (j), being CO_2, CH_4 or N_2O, released from the combustion of fuel type (i) from the operation of the facility during the year measured in CO_2-e tonnes.
Q_i = quantity of fuel type (i) measured in kL
EC_i = energy content factor of fuel type (i) expressed as GJ/kL
EF_{ijoxec} = emission factor for each gas type (i) measured in kg CO2-e/GJ (Table 4-2) of fuel type (i)

4.2.3 Oils and greases

GHG emissions from the consumption of oils and greases are estimated to be 0.3% of the combined GHG emissions from haul trucks and ancillary equipment. A high-level approach was used to estimate emissions from this incidental emission source, based on analysis of the relative contribution of this source to emissions estimated for other BHP iron ore mining operations[3].

4.2.4 Electricity consumption

Power for the Project is proposed to be supplied from the existing Yarnima Power Station. This is a natural gas-fired power generation plant that supplies power to BHP's iron ore mining operations in the Pilbara region.

GHG emissions for electricity consumption (Scope 2) was estimated using a Method 1 approach, in accordance with Division 7.3 of the NGER Measurement Determination (*NGER (Measurement) Determination*, 2020). The emissions were derived based on an assumed heat rate for the Yarnima Power Station (9.1 GJ/MWh) and the emission factors for combustion of natural gas, presented in Table 4-3.

[3] Petroleum based oils and greases accounted for 0.3% of the Yandi mine emissions in FY2019, and 0.24% of the Newman Operations emissions in FY2020 (*Pers. comm*. James Flux, BHP. 16 February 2021).

Table 4-3 Emission factor for natural gas

Description		Units	Stationary
Emission Factor	CO_2	kg CO_2-e/GJ	51.4
	CH_4	kg CO_2-e/GJ	0.1
	N_2O	kg CO_2-e/GJ	0.03
	CO_2-e	kg CO_2-e/GJ	51.53

Greenhouse gas emissions from electricity consumption are estimated based on the following equations:

$$Y = \frac{Q \times EF}{1000}$$ **Equation 3**

$$EF = \frac{EF_{ij} \times HR}{1000}$$ **Equation 4**

Where: Y = Scope 2 emissions from electricity consumption in CO_2-e tonnes.

Q = quantity of electricity in kWh purchased from the electricity grid during the year and consumed during operations

EF = Emission factor for the Yarnima Power Station in kg CO_2-e/kWh

EF_{ij} = Emission factor for natural gas (Table 4-3) in kg CO_2-e/GJ

HR = heat rate for Yarnima Power Station, defined as 9.1 GJ/MWh

4.2.5 Land clearing

GHG emissions attributed to land clearing were estimated using the FullCAM model (Richards, 2001).

Greenhouse gas emissions for each year of mine operations were estimated for two scenarios. The 'baseline' scenario refers to a scenario wherein no anthropogenic clearing was assumed within the development footprint. The 'progressive clearing' scenario refers to a scenario that follows the Project's proposed clearing schedule. Clearing for the Project is expected to occur in stages (refer to Section 4.3.3).

FullCAM was developed as part of the National Carbon Accounting System (NCAS). It provides fully integrated estimates of carbon pools in forest and agricultural systems. It also accounts for anthropogenic contributions that lead to changes in emissions due to the release of sequestered carbon into the atmosphere.

Parameters used in estimating the amount of carbon stored by vegetation and then released due to land clearing are summarised in Table 4-4. Data on climate, vegetation, and soil parameters were downloaded from the FullCAM database. Default values were used consistent with the recommendations in FullCAM guidelines (DISER, 2020a), except for initial soil carbon as detailed below. Monthly climate and weather profiles were based on monthly average values from 1970 to 2018, included in the FullCAM database.

The initial soil carbon conditions were modified upon advice of the Department of Industry, Science, Energy and Resources (DISER) to address a known limitation of the FullCAM model's soil carbon calibration for more remote areas of Australia where limited data is available (*Pers. comm*. DISER. 25 March 2021).

Table 4-4 Input data used in FullCAM configuration

Parameter		Units	Value
Location		latitude longitude	-23.400434° 119.643367°
		Area	Newman, WA
Spatial data averaged over		ha	2,500
Total Area [1]		ha	3,800
Simulation period		Start	1 January 2021
		End	1 January 2059
Life of mine		year	2022 - 2048
Vegetation type		-	*Acacia Shrublands*
Maximum aboveground biomass [1]		tdm/ha	6.18544
Clay content in soil [1]		%	14.8057
Climate (site) Monthly profile basis	rainfall [1]	-	average (1970 – 2018)
	open-pan evaporation [1]		
	temperature [1]		
	forest productivity [1]		

Notes:
1. Simulation based on area to be cleared, rather than total area within Project footprint.
2. Sourced from FullCAM database.

Acacia Shrublands and *Hummock Grassland* are the dominant vegetation types. However, *Hummock Grassland* is not included in the FullCAM database, so all vegetation has been classified as *Acacia Shrublands*.

Greenhouse gas emissions for each year of mine operations were estimated for two scenarios. The 'baseline' scenario refers to a scenario wherein no anthropogenic clearing was assumed within the development footprint. The 'progressive clearing' scenario refers to a scenario that follows the Project's proposed clearing schedule. Greenhouse gas due to loss in carbon sink and net gain in emissions were estimated by comparison of these two simulated cases (no clearing case and progressive clearing case).

Sequestration from revegetation associated with mine rehabilitation is not included, as this is conservative (over-estimate of emissions) and consistent with the approach used for other EIAs.

Technical details of the FullCAM configuration and model results are reported separately (ETA, 2021).

4.3 Forecast activity data

Mine production and consumption forecasts for the Project were developed by BHP for the life of mine and have been used as the basis for the emission estimates. ETA has not verified the accuracy or completeness of this information.

The forecast activity data are subject to a degree of uncertainty as it is based on conceptual design information that is currently available for the Project and will be subject to refinement as the Project proceeds.

4.3.1 Fuel consumption

Diesel fuel consumption has been projected over the life of mine for two Western Ridge development scenarios, based on records available for the existing Whaleback and Eastern Ridge mining operations. The largest source of diesel fuel consumption projected for the TO scenario is haul trucks, and for the CTO scenario is ancillary equipment.

The key assumptions underlying the fuel consumption projections are summarised below.

Haul trucks:	• Diesel consumption estimates for haul trucks derived from haul truck usage and fuel consumption records for Whaleback and Eastern Ridge for FY 2021.
Ancillary equipment:	• Diesel consumption estimates for ancillary equipment derived from equipment usage and fuel consumption records for Whaleback and Eastern Ridge for FY 2021.
De-watering:	• Diesel required for the operation of de-watering pumps is estimated from fuel consumption records for de-watering of Eastern Newman operations, adjusted on a pro-rata basis according to ore production.
Explosives:	• Diesel used with explosives for blasting is estimated based on ore production according to Equation 5.

$$Diesel_{explosives} = \frac{OreProd \times PowderFactor \times FuelOilMass}{DieselDensity} \div 1000 \quad \textbf{Equation 5}$$

Where:

$Diesel_{explosives}$ = estimated diesel consumption for explosives in kL
$OreProd$ = projected ore production for Western Ridge in tonnes
$PowderFactor$ = powder factor equivalent to 0.27 kg/tonne
$FuelOilMass$ = diesel fuel oil mass equivalent to 0.06 % of total
$DieselDensity$ = diesel density equivalent to 0.85 kg/L

4.3.2 Electricity consumption

The load forecast (kWh/ t iron ore) and electricity consumption (MWh) are projected over the life of mine for two Western Ridge development scenarios (TO and CTO). The load forecast is based on the Whaleback and Western Ridge combined operations, with electricity consumption estimates based on the projected ore production for the Western Ridge Project.

4.3.3 Clearing rates

The Western Ridge Project has a footprint of 8,080 ha, and 3,800 ha is expected to be cleared during the life of the mine. Clearing is expected to occur in stages. The indicative clearing schedule provided by BHP indicates that half of the clearing will occur during the first three years of operation, from 2022 to 2024. The rest of the clearing is estimated to occur during the course of mine operations (2025 to 2048). The indicative clearing schedule is summarised in Table 4-5.

Table 4-5 Indicative clearing schedule

Year of Operation	Units	Value
2022 - 2024	%	50%
	ha	1,900
	ha/yr	633.33
2025 - 2047	%	50%
	ha	1,900
	ha/yr	79.17

4.4 Emissions Inventory

The inventory of GHG emissions estimated for the two Western Ridge development scenarios is summarised in Table 4-6. These are also graphically represented for the TO scenario (Figure 4-1) and the CTO scenario (Figure 4-2). Percentage contribution of sources to Scope 1 GHG emissions for the TO and CTO scenarios are shown in Figure 4-3.

Detailed GHG emissions for the Scope 1 and Scope 2 sources are shown in Table 4-7 and Table 4-8 for the TO and CTO operational scenarios, respectively.

Analysis of the Project emissions inventory shows that:

- Scope 1 emissions comprise a significant portion of the total GHG emissions, contributing 72% to 89% of total GHG emissions for the TO scenario, and 65% to 87% of the CTO scenario.
- GHG emissions from diesel combustion comprise a significant portion of Scope 1 emissions, contributing 83% to 99% for the both the TO and CTO scenarios.
- Annual GHG emissions for the CTO scenario are consistently lower than the TO scenario. Total GHG emissions for the CTO scenario is approximately 9% lower than the TO scenario.
    - TO scenario generally has higher Scope 1 emissions.
    - CTO scenario is shown to have equivalent or higher Scope 2 emissions.
- GHG emissions are estimated to reduce in 2035 to 2036 due to iron ore production being substituted from existing deposits at Newman Hub. Sequencing of iron ore production rates may vary in future iteration of the proposal's mining plan.

Table 4-6 Scope 1 and Scope 2 greenhouse gas emissions (t CO_2-e) for Western Ridge TO and CTO scenarios

Year	TO			CTO		
	Scope 1	Scope 2	Total	Scope 1	Scope 2	Total
2022	31,153	9,429	40,581	27,453	9,429	36,882
2023	22,775	4,688	27,463	21,567	4,688	26,255
2024	34,718	5,760	40,478	35,724	5,760	41,484
2025	76,636	13,632	90,268	74,287	13,632	87,919
2026	192,763	31,920	224,683	157,605	34,533	192,137
2027	381,233	51,943	433,176	262,473	63,064	325,537
2028	283,171	55,667	338,838	223,905	65,189	289,094
2029	187,996	42,464	230,460	150,894	49,056	199,950
2030	374,211	76,672	450,883	284,237	88,479	372,716
2031	148,974	45,413	194,387	144,026	52,406	196,432
2032	129,649	34,291	163,940	109,954	39,572	149,526
2033	123,186	31,323	154,509	85,752	36,147	121,898
2034	133,898	25,165	159,063	79,760	29,040	108,800
2035	29,606	7,973	37,579	17,177	9,201	26,378
2036	23,563	6,812	30,375	14,861	7,862	22,722
2037	109,970	19,034	129,004	145,356	21,966	167,321
2038	99,606	38,387	137,992	123,599	44,298	167,897
2039	174,873	26,214	201,086	141,031	30,251	171,282
2040	169,196	36,117	205,313	162,477	41,680	204,157
2041	119,110	30,929	150,038	140,273	35,692	175,964
2042	60,314	15,727	76,041	73,428	18,148	91,576
2043	35,132	13,017	48,149	49,973	15,022	64,994
2044	37,424	13,663	51,086	34,406	15,767	50,173
2045	31,801	4,707	36,508	29,359	5,432	34,791
2046	75,554	9,065	84,619	55,543	10,462	66,005
2047	39,576	5,825	45,400	32,638	6,722	39,359
2048	22,837	3,353	26,191	18,378	3,870	22,248
Total	**3,148,921**	**659,191**	**3,808,112**	**2,696,133**	**757,365**	**3,453,499**
Average	**116,627**	**24,414**	**141,041**	**99,857**	**28,051**	**127,907**

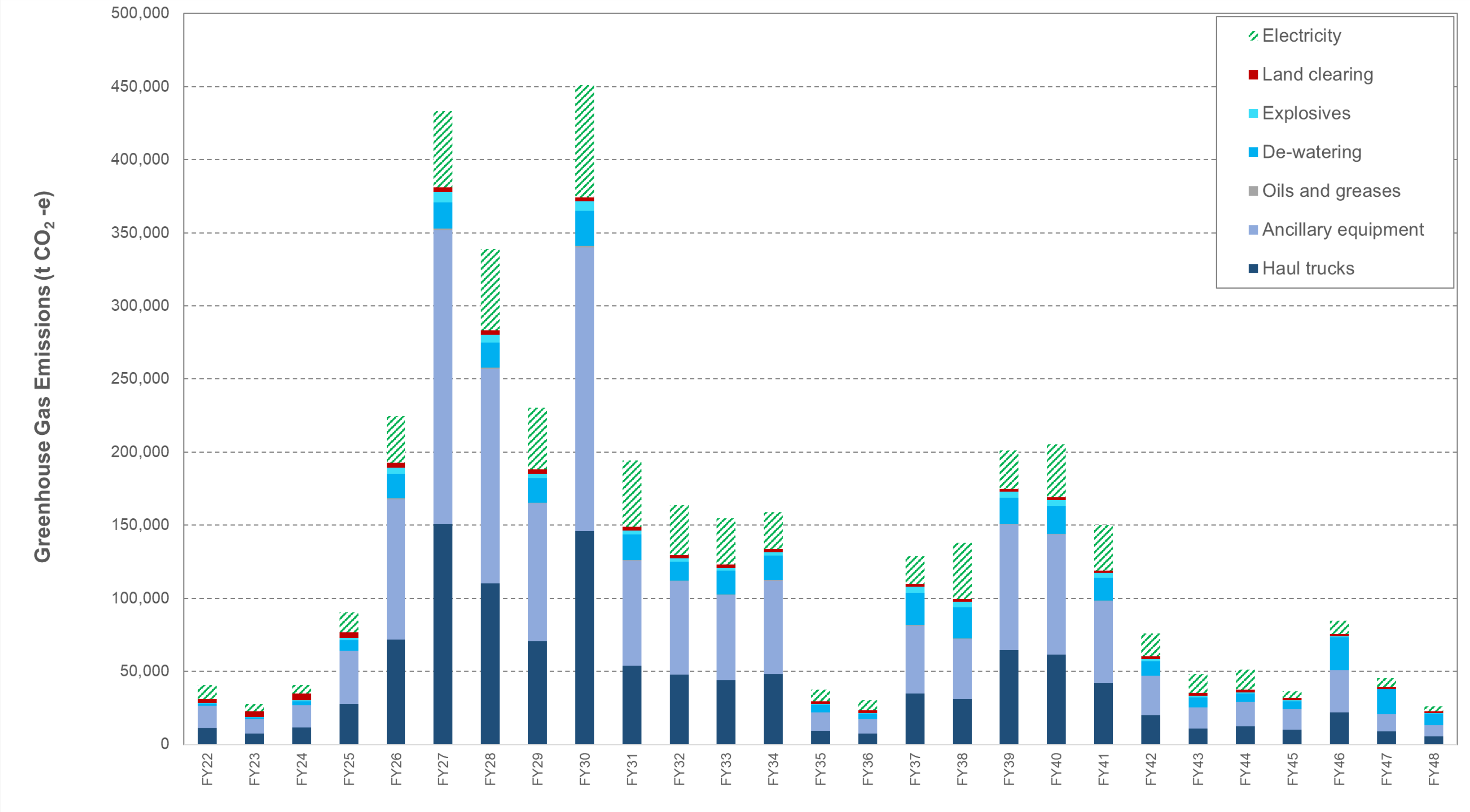
Greenhouse Gas Emissions (t CO_2 -e)
500,000
450,000
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
FY22
FY23
FY24
FY25
FY26
FY27
FY28
FY29
FY30
FY31
FY32
FY33
FY34
FY35
FY36
FY37
FY38
FY39
FY40
FY41
FY42
FY43
FY44
FY45
FY46
FY47
FY48
Electricity
Land clearing
Explosives
De-watering
Oils and greases
Ancillary equipment
Haul trucks

Figure 4-1: Estimated greenhouse gas emissions (t CO_2-e) for Western Ridge operations – Trucking ore (TO)

Table 4-7 Estimated greenhouse gas emissions (t CO_2-e) for Western Ridge TO operations

Year	Scope 1							Scope 2	Total
	Fuel combustion					Land clearing	Subtotal	Electricity consumption	
	Haul trucks	Ancillary equipment	Oils and greases	De-watering	Explosives				
2022	11,350	15,127	79	1,253	621	2,722	31,153	9,429	40,581
2023	7,390	9,850	52	1,243	471	3,769	32,655	4,688	27,463
2024	11,447	15,256	80	2,659	781	4,494	50,019	5,760	40,478
2025	27,430	36,559	192	7,106	1,774	3,575	113,304	13,632	90,268
2026	71,916	95,849	503	16,968	4,181	3,347	288,900	31,920	224,683
2027	150,755	200,926	1,055	18,159	7,191	3,147	582,761	51,943	433,176
2028	110,223	146,905	771	17,029	5,270	2,973	430,517	55,667	338,838
2029	70,671	94,190	495	16,663	3,161	2,816	282,468	42,464	230,460
2030	145,775	194,289	1,020	23,843	6,606	2,678	569,083	76,672	450,883
2031	53,840	71,758	377	17,736	2,709	2,555	220,947	45,413	194,387
2032	47,861	63,789	335	13,134	2,086	2,442	193,629	34,291	163,940
2033	43,857	58,453	307	16,392	1,834	2,343	181,815	31,323	154,509
2034	47,994	63,966	336	16,906	2,443	2,253	198,056	25,165	159,063
2035	9,360	12,475	66	5,165	371	2,170	42,118	7,973	37,579
2036	7,397	9,858	52	3,839	327	2,090	33,451	6,812	30,375

Year	Scope 1							Scope 2	Total
	Fuel combustion					Land clearing	Subtotal	Electricity consumption	
	Haul trucks	Ancillary equipment	Oils and greases	De-watering	Explosives				
2037	34,914	46,534	244	22,192	4,063	2,023	156,643	19,034	129,004
2038	30,983	41,294	217	21,399	3,756	1,958	141,023	38,387	137,992
2039	64,470	85,925	451	18,067	4,063	1,897	261,055	26,214	201,086
2040	61,541	82,022	431	18,955	4,411	1,835	251,464	36,117	205,313
2041	42,017	56,000	294	15,510	3,501	1,787	175,278	30,929	150,038
2042	20,119	26,815	141	9,781	1,721	1,737	87,210	15,727	76,041
2043	10,823	14,425	76	7,031	1,087	1,690	49,600	13,017	48,149
2044	12,511	16,674	88	5,713	799	1,639	54,148	13,663	51,086
2045	10,295	13,721	72	5,579	532	1,603	45,562	4,707	36,508
2046	21,759	29,000	152	22,283	796	1,563	104,641	9,065	84,619
2047	8,867	11,817	62	16,972	333	1,524	51,429	5,825	45,400
2048	5,661	7,544	40	7,925	188	1,480	30,404	3,353	26,191
Total	**1,141,224**	**1,521,022**	**7,987**	**349,502**	**65,076**	**64,110**	**3,148,921**	**659,191**	**3,808,112**
Average	**42,268**	**56,334**	**296**	**12,945**	**2,410**	**2,374**	**116,627**	**24,414**	**141,041**

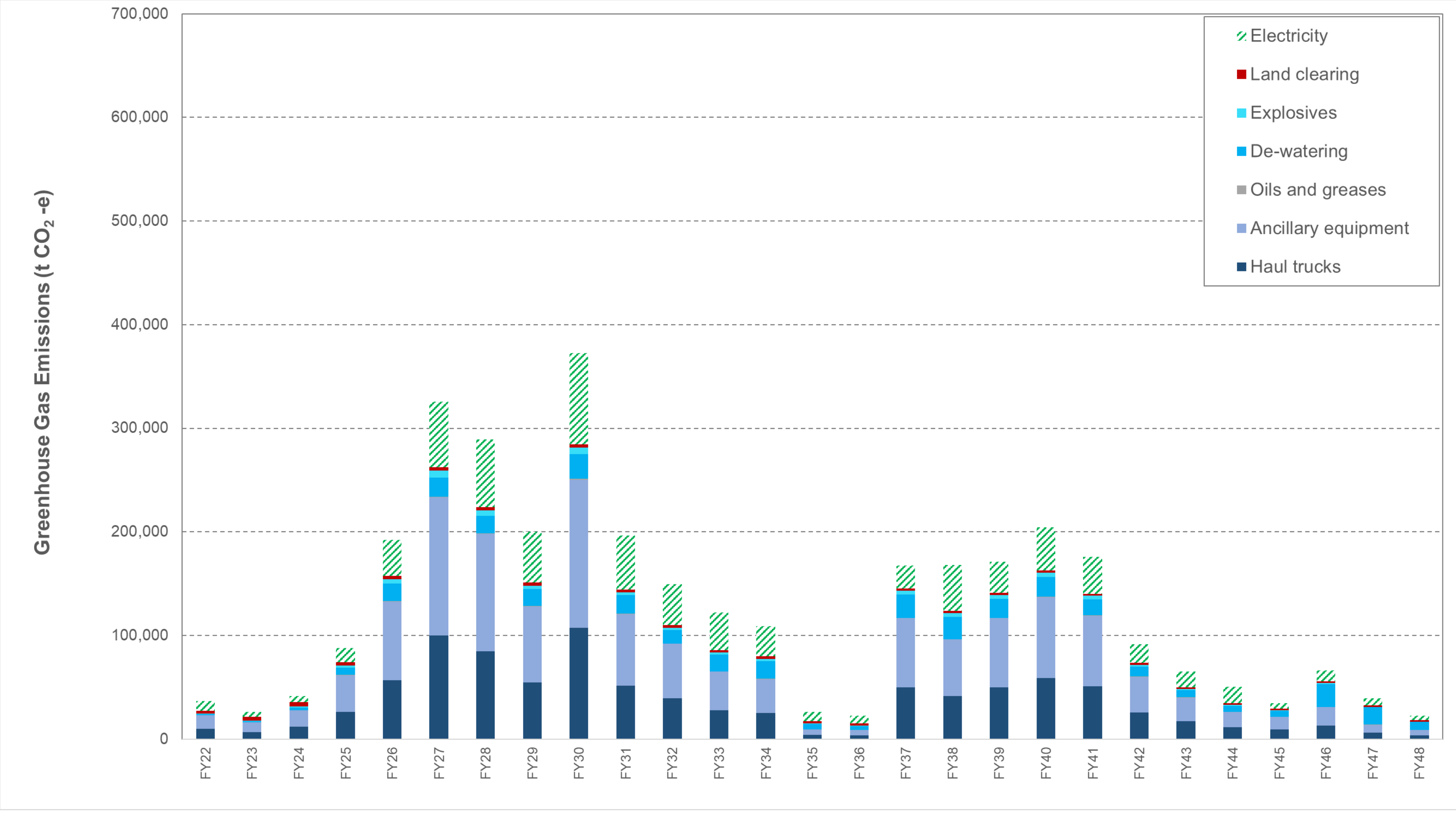

Figure 4-2: Estimated greenhouse gas emissions (t CO_2-e) for Western Ridge operations – Conveying and trucking ore (CTO)

Table 4-8 Estimated greenhouse gas emissions (t CO_2-e) for Western Ridge CTO operations

Year	Scope 1							Scope 2	Total
	Fuel combustion					Land clearing	Subtotal	Electricity consumption	
	Haul trucks	Ancillary equipment	Oils and greases	De-watering	Explosives				
2022	9,769	13,020	68	1,253	621	2,722	27,453	9,429	36,882
2023	6,874	9,162	48	1,243	471	3,769	21,567	4,688	26,255
2024	11,877	15,830	83	2,659	781	4,494	35,724	5,760	41,484
2025	26,426	35,221	185	7,106	1,774	3,575	74,287	13,632	87,919
2026	56,889	75,822	398	16,968	4,181	3,347	157,605	34,533	192,137
2027	99,998	133,277	700	18,159	7,191	3,147	262,473	63,064	325,537
2028	84,893	113,146	594	17,029	5,270	2,973	223,905	65,189	289,094
2029	54,814	73,056	384	16,663	3,161	2,816	150,894	49,056	199,950
2030	107,321	143,038	751	23,843	6,606	2,678	284,237	88,479	372,716
2031	51,725	68,939	362	17,736	2,709	2,555	144,026	52,406	196,432
2032	39,444	52,571	276	13,134	2,086	2,442	109,954	39,572	149,526
2033	27,858	37,129	195	16,392	1,834	2,343	85,752	36,147	121,898
2034	24,856	33,128	174	16,906	2,443	2,253	79,760	29,040	108,800
2035	4,048	5,395	28	5,165	371	2,170	17,177	9,201	26,378
2036	3,678	4,902	26	3,839	327	2,090	14,861	7,862	22,722
2037	50,038	66,690	350	22,192	4,063	2,023	145,356	21,966	167,321

Year	Scope 1							Scope 2	Total
	Fuel combustion					Land clearing	Subtotal	Electricity consumption	
	Haul trucks	Ancillary equipment	Oils and greases	De-watering	Explosives				
2038	41,237	54,961	289	21,399	3,756	1,958	123,599	44,298	167,897
2039	50,006	66,648	350	18,067	4,063	1,897	141,031	30,251	171,282
2040	58,670	78,195	411	18,955	4,411	1,835	162,477	41,680	204,157
2041	51,062	68,055	357	15,510	3,501	1,787	140,273	35,692	175,964
2042	25,724	34,285	180	9,781	1,721	1,737	73,428	18,148	91,576
2043	17,166	22,878	120	7,031	1,087	1,690	49,973	15,022	64,994
2044	11,221	14,955	79	5,713	799	1,639	34,406	15,767	50,173
2045	9,251	12,330	65	5,579	532	1,603	29,359	5,432	34,791
2046	13,207	17,602	92	22,283	796	1,563	55,543	10,462	66,005
2047	5,901	7,865	41	16,972	333	1,524	32,638	6,722	39,359
2048	3,755	5,004	26	7,925	188	1,480	18,378	3,870	22,248
Total	**947,708**	**1,263,104**	**6,632**	**349,502**	**65,076**	**64,110**	**2,696,133**	**757,365**	**3,453,499**
Average	**35,100**	**46,782**	**246**	**12,945**	**2,410**	**2,374**	**99,857**	**28,051**	**127,907**

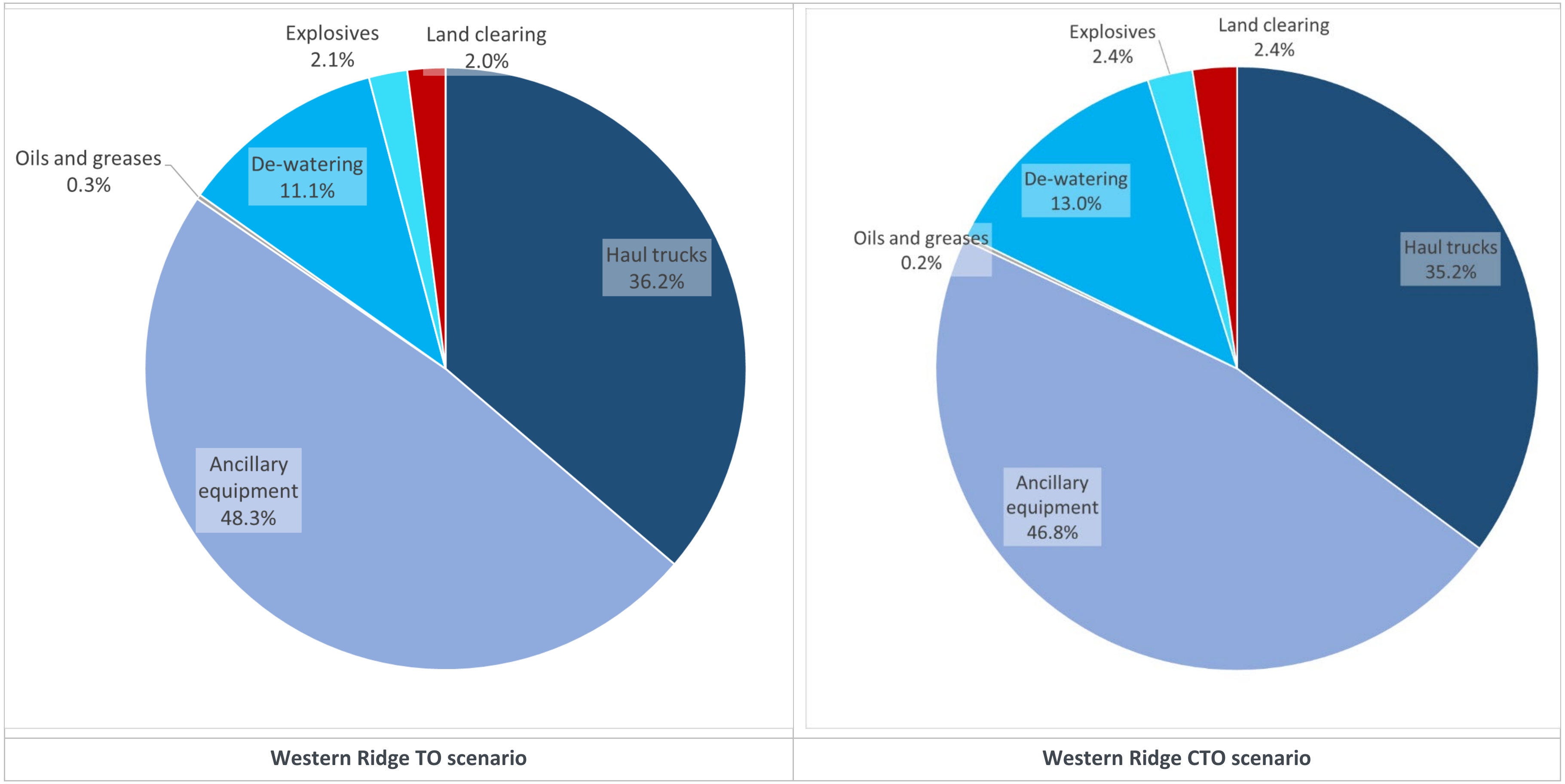

Figure 4-3: Percentage contribution of Scope 1 greenhouse gas emissions (t CO_2-e) for Western Ridge development scenarios

4.4.1 Emissions intensity

GHG emissions intensity is often used to benchmark projects against other facilities or relevant industry standards. GHG intensity represents the quantity of GHG emitted per unit of production. For the iron ore mining sector this is calculated as tCO_2-e/t of iron ore, on a wet basis, that is produced and is of a saleable quality.

Default emissions intensity values are set by the Commonwealth Government and published in the Safeguard Mechanism Rule (*NGER Regulations (Safeguard Mechanism) Rule*, 2020). They represent the industry average emissions intensity of production over five years. The default emissions intensity derived for iron ore mining for 2020-21 and later years is 0.00476 tCO_2-e/t of iron ore. This is inclusive of all Scope 1 NGER-reported facility emissions, except on-site electricity generation and processes that do not occur within the facility.

The corresponding estimates of GHG intensity for the Project, averaged over the life of mine (2022 – 2048), for alternative Western Ridge development scenarios is presented in Table 4-9.

Table 4-9: Estimated greenhouse gas emissions intensity

Parameter	Units	TO	CTO
Production	t iron ore (wet)	461,596,787	
Emissions | Scope 1	t CO_2-e	3,148,921	2,696,133
Emissions intensity	tCO_2-e/t iron ore	0.0068	0.0058

The purpose of benchmarking this Project's emissions to the default emissions intensity for iron ore mining published in the Safeguard Mechanism Rule is to confirm the emission estimates for the proposal are credible. The emissions intensity estimated for the TO and CTO development scenario are similar to the iron ore mining default, with the emissions intensity estimated to be approximately 1.4 and 1.2 times higher than the iron ore mining default, respectively. As emissions for both scenarios are expected to be broadly consistent with the Australian iron ore sector average, the benchmarking analysis indicates the emissions estimates are credible.

5 Conclusions

BHP propose to expand the existing mining operations at Newman through the development of the Western Ridge Project. GHG emissions has been identified as a potential key environmental factor for the Project. An inventory of GHG emissions estimated for the Project has been prepared to inform the assessment of potential environmental impacts and the proposed management measures with respect to the approval of the Project under the EP Act.

The key findings are outlined below:

- Emissions from all key sources associated with the Project have been derived using accepted methods of emission estimation, consistent with the NGER scheme and Australian National Greenhouse Accounts.
- GHG emissions associated with land clearing were estimated using the FullCAM model, which allows a consistent, scientifically rigorous and transparent modelling. The platform is utilised in National and State GHG Inventory reporting and provides for ongoing improvements in fundamental input data and model calibration.
- The peer review of emission estimates derived for the Project has confirmed that:
    - All significant sources of GHG emissions, inclusive of stationary energy, fugitives, and transport related emissions have been considered. A number of incidental emission sources have been excluded from emission estimates, the basis for excluding these sources which are expected to be insignificant has been noted (refer to Section 4.1.1).
    - Appropriate emission estimation techniques and factors, consistent with the NGER scheme have been applied.
    - The emission estimates are credible based on comparison of emissions intensities published by the Clean Energy Regulator through the NGER scheme for the Australian iron ore sector.
- The Scope 1 (direct emission) and Scope 2 (indirect emission) estimates documented in this report are consistent with the EPA (2020) guideline for GHG emissions in that:
    - credible estimate of Scope 1 and 2 GHG emissions (annual and total) are provided over the life of a proposal.
    - a breakdown of GHG emissions by source inclusive of stationary energy, transport, and emissions associated with changes to land use is presented.
- A summary of GHG emissions estimated for the Project for two Western Ridge Development scenarios defined by BHP – Trucking ore (TO) and Conveying and trucking ore (CTO) are presented in Table 5-1.

Table 5-1 Summary of estimated greenhouse gas emissions (t CO_2-e per year) - Western Ridge TO and CTO scenarios

	Year	TO			CTO		
		Scope 1	Scope 2	Total	Scope 1	Scope 2	Total
Maximum	2030	374,211	76,672	450,883	284,237	88,479	372,716
Average	2022 - 2048	116,627	24,414	141,041	99,857	28,051	127,907

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7 Glossary

Acronym	Meaning
ANFO	Ammonium nitrate fuel oil
ANZSIC	Australian and New Zealand Standard Industrial Classification
CH_4	Methane
CO_2	Carbon dioxide
CO_2-e	Carbon dioxide equivalent
CTO	Conveyor and Trucking Ore (scenario)
DISER	Department of Industry, Science, Energy and Resources
EPA	Environmental Protection Authority
ETA	Environmental Technologies & Analytics Pty Ltd
GHG	Greenhouse gas
GJ	Gigajoules
GJ/MWh	Gigajoules per mega watt hour (Heat rate)
HFCs	hydrofluorocarbons
kg	kilogram
kg/L	kilogram per litre
km	kilometre
kWh	Kilowatt hour
kL	kilolitre
m	Metre
Mt	Million tonnes
Mtpa	Million tonnes per annum
MWh	Mega watt hour
N_2O	nitrous oxide
NCAS	National Carbon Accounting System
NGER	National Greenhouse and Energy Reporting
SF_6	sulphur hexafluoride
tdm	Tonnes dry mass
TO	Trucking Ore (scenario)
tpa	tonnes per annum
UNFCC	United Nations Framework Convention on Climate Change
WAIO	Western Australia Iron Ore