POSCO

Port Hedland Green Steel Project

Decarbonisation Project

Emissions Assessment

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1 Executive Summary

The Port Hedland Green Steel (PHGS) opportunity is a joint venture between POSCO (POSCO), Marubeni Corporation (Marubeni), and China Steel Corporation (CSC) on behalf of Port Hedland Green Steel Pty Ltd (PHGS). PHGS, which is wholly owned by POSCO, is a special purpose company formed to develop a large-scale downstream iron ore processing facility at the Boodarie Strategic Industrial Area (BSIA) in Port Hedland, Western Australia (the "Project").

The Project will process magnetite concentrate from iron ore operations in the Pilbara to produce hot briquetted iron (HBI) for export to customers who will convert the HBI into a low-carbon emission steel overseas.

The Proposal is located in the BSIA approximately 8 km west of South Hedland town site and approximately 12 km south of Port Hedland town site.

The Project will be developed in stages. Stage 1 will involve the design and construction of an HBI plant, consuming approximately 3-3.5 Mt/a of iron ore. The first processing step is to produce iron ore pellets (3-3.5 Mt/a). Most of the pellets will be fed into the HBI plant to produce approximately 2 Mt/a HBI. The remainder of the pellets (~0.7 Mt/a) will be sold and exported. The exported pellet and HBI will be shipped to POSCO in South Korea, China Steel in Taiwan, and steel mills in Japan.

PHGS has requested the Wood Decarbonisation Team to assess the Scope 1, 2, and 3 emissions (in tCO_{2e}/tHBI product) that can be expected from the Port Hedland Green Steel Project on an average annual basis for Stage 1, based on the information available in June 2024. This includes emissions over the construction phase, ramp-up period, and Stage 1 of the operation phase. The life-of-asset (LOA) for Stage 1 was reported to be 99 years.

Wood has calculated a Baseline Emissions Assessment, which is representative of the scenario where no carbon abatement options are incorporated into the PHGS. The implication of carbon abatement opportunities including hydrogen (H_2) injection carbon capture and storage (CCS), electrification of vehicles and machinery, as well as a higher uptake of renewables in the electrical grid were assessed on the Project product emission intensity. These two studied cases are referred to as the Base Case and Low-carbon Case in the report.

The following results have been obtained from the Baseline and Low-carbon case emissions assessment:

- Emissions assessment over the construction years:
  - Total Scope 1 emissions over the construction period is 179,231 tCO_{2e}.
  - No grid connection is envisaged during connection years, therefore Scope 2 emissions equal to zero.
  - Total Scope 3 emissions over the construction period is 448,341 tCO_{2e}.
  - No carbon abatement opportunities have been considered for construction years.
  - The ramp-up period has been merged with the construction years when reporting emissions over the whole life time of the project., as it is only a quarter commencing right after construction in Q4-2029.
- Emissions assessment over the operation years:
  - Total Scope 1 baseline emissions over the operation period is 111,486,086 tCO_{2e}.
  - Total Scope 2 baseline emissions over the operation period is 33,093,285 tCO_{2e}.
  - Total Scope 3 baseline emissions over the operation period is 510,055,067 tCO_{2e}.

  - Integration of green hydrogen, carbon capture and storage, and fleet electrification reduces the total Scope 1 emissions by 84% to 18,352,279 tCO_{2e}. This corresponds to the Scope 1 emissions intensity of 0.55 tCO_{2e}/tHBI and 0.08 tCO_{2e}/tHBI for baseline and Low-carbon case emissions assessment, respectively.
  - Higher uptake of renewable energy, as committed / agreed by power suppliers, reduces total Scope 2 emissions to 2,245,007 tCO_{2e}, corresponding to 93% emissions reduction.
  - No emissions abatement opportunity assessment has been conducted for Scope 3 emissions. Fleet electrification will decrease diesel consumption (Scope 3 – Purchased goods and services) and the use of renewable energy will lead to a lower Scope 3 – Fuel and energy, however, the impact will be marginal (<0.5% reduction).
  - The HBI baseline emissions intensity for Scope 1 and 2 is 0.70 tCO_{2e}/tHBI, which is well below the reported Safeguard Mechanism best practice benchmark emission intensity of 1.77 tCO_{2e}/unit, where the unit is tonnes of metallic iron products. The implementation of abatement opportunities reduces the HBI emissions intensity to 0.08 tCO_{2e}/tHBI (Scope 1 and 2 emissions).
  - Total emissions intensity (Scope 1, 2, and 3 emissions) for baseline and low-carbon cases are 2.57 tCO_{2e}/tHBI and 1.94 tCO_{2e}/tHBI, respectively.
- The emissions intensity of pellet product is 0.07 tCO_{2e}/tPellet for Scope 1 and 2. Inclusion of Scope 3 increases the pellet emissions intensity to 1.99 tCO_{2e}/tPellet.

The total carbon emissions over the construction years and the emissions over the operating phase (for one average year and LOA) are shown in Figure 1.1 to Figure 1.7 and in Table 1.1.

Figure 1.1: Total Emissions ($ktCO_{2e}$)– Construction and Ramp-up Phases

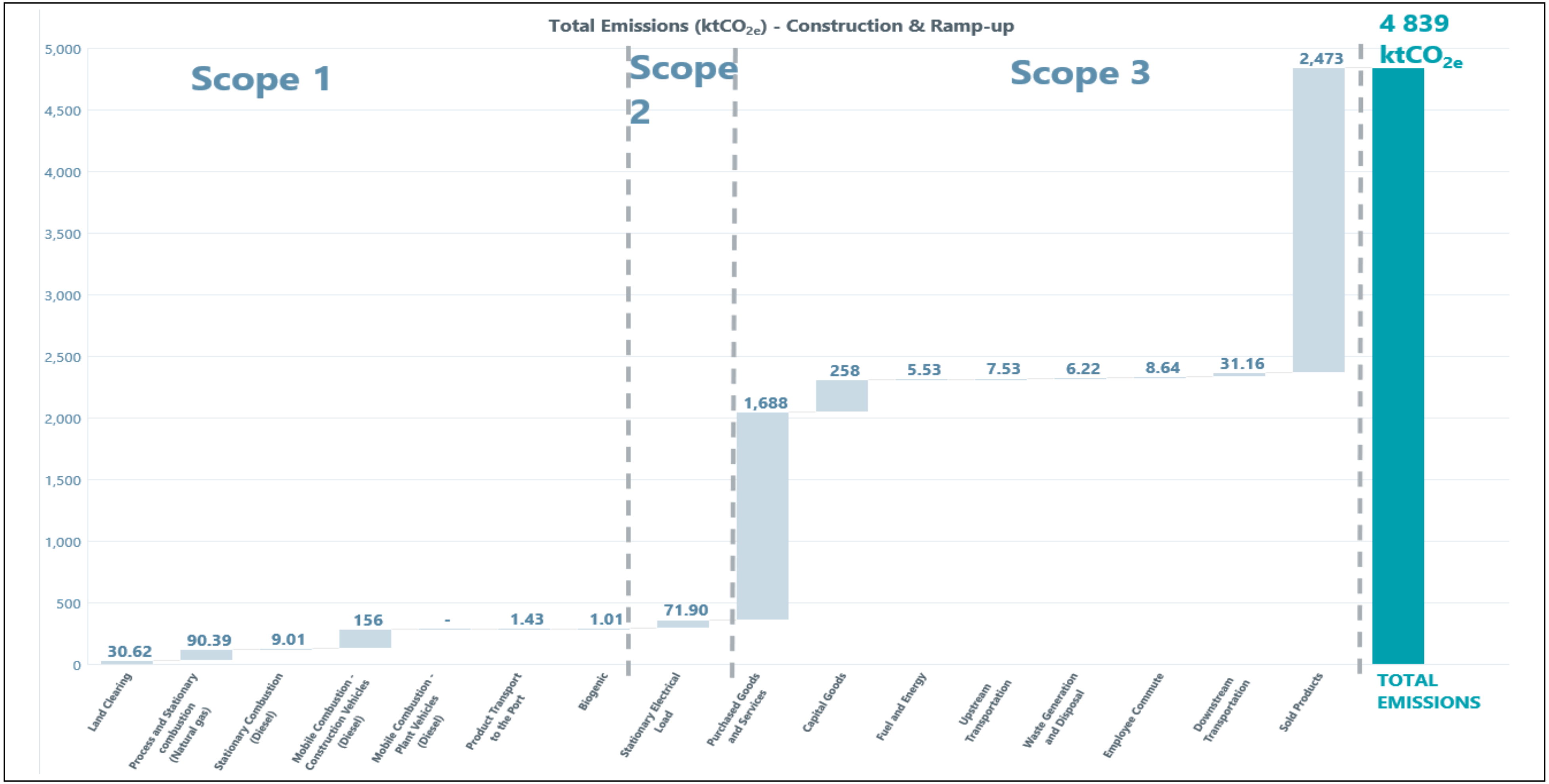


Figure 1.2: Average Annual Emissions ($ktCO_{2e}/a$)– Operating Phase (Base Case)

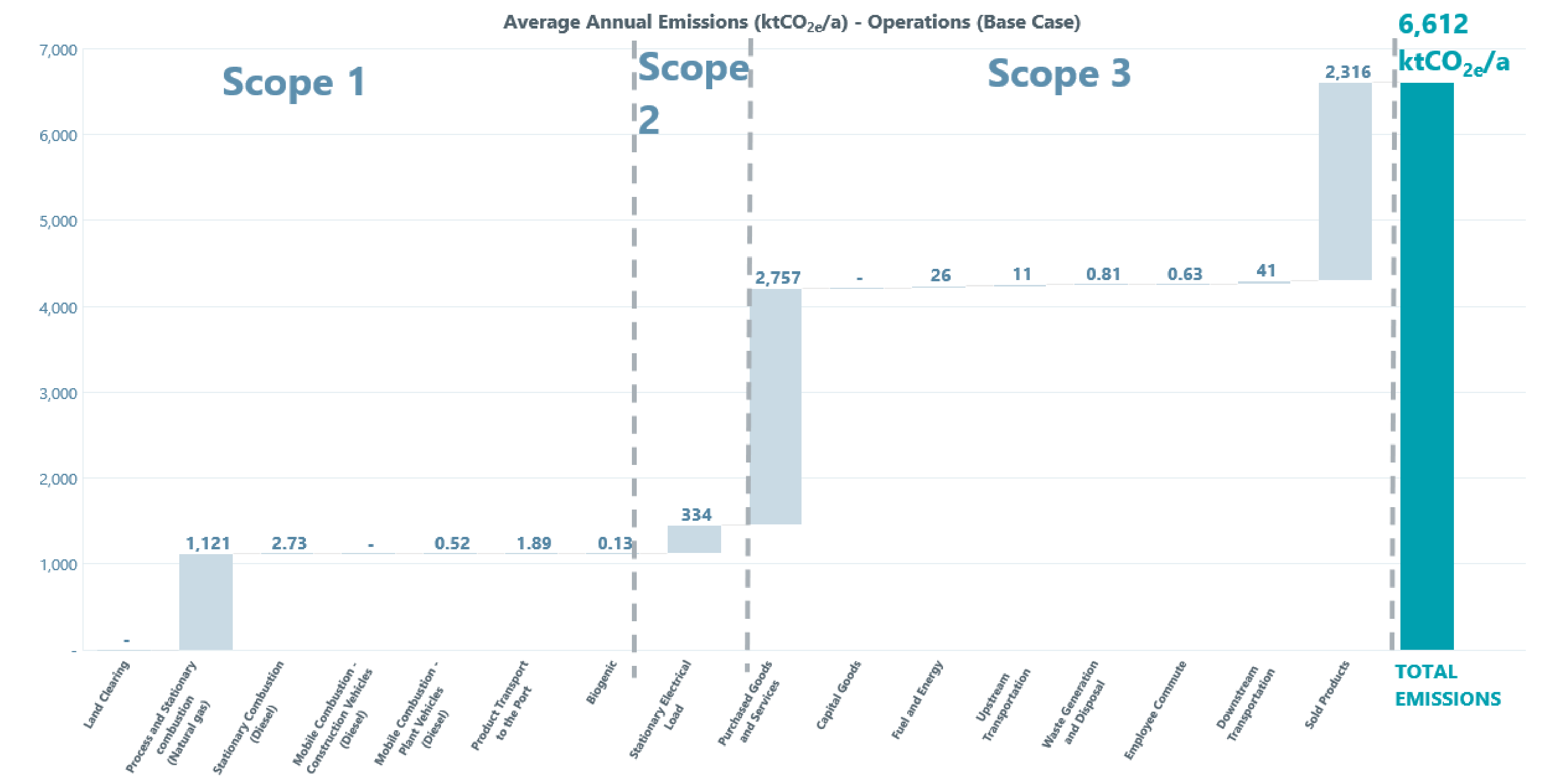


Figure 1.3: Decarbonisation over LOA ($ktCO_{2e}$)– Low Carbon Case Operations (Scope 1 and 2 Emissions)

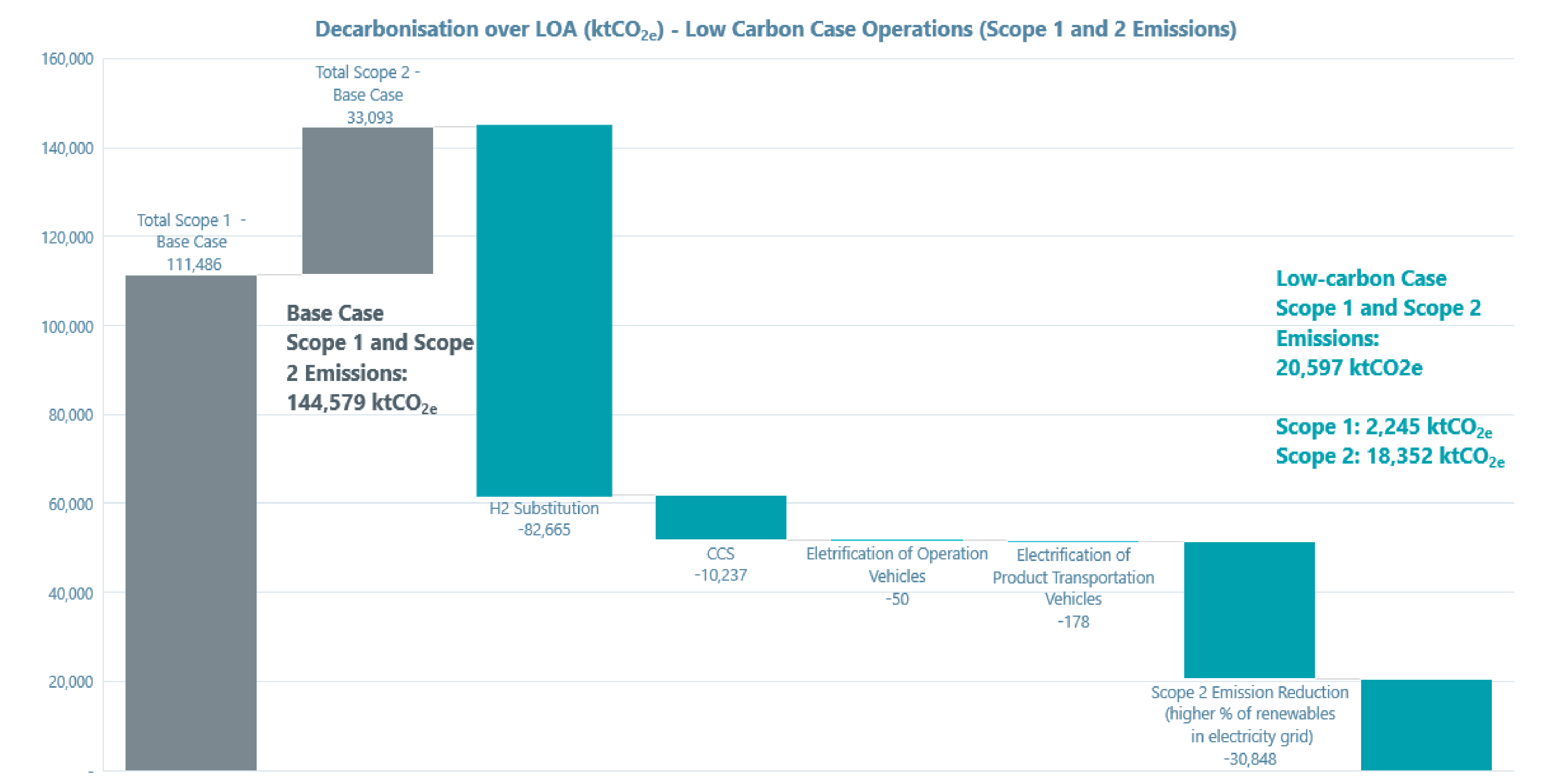


Figure 1.4: Average Annual Carbon Intensity $tCO_{2e}/tHBI$ (Scope 1 and 2)

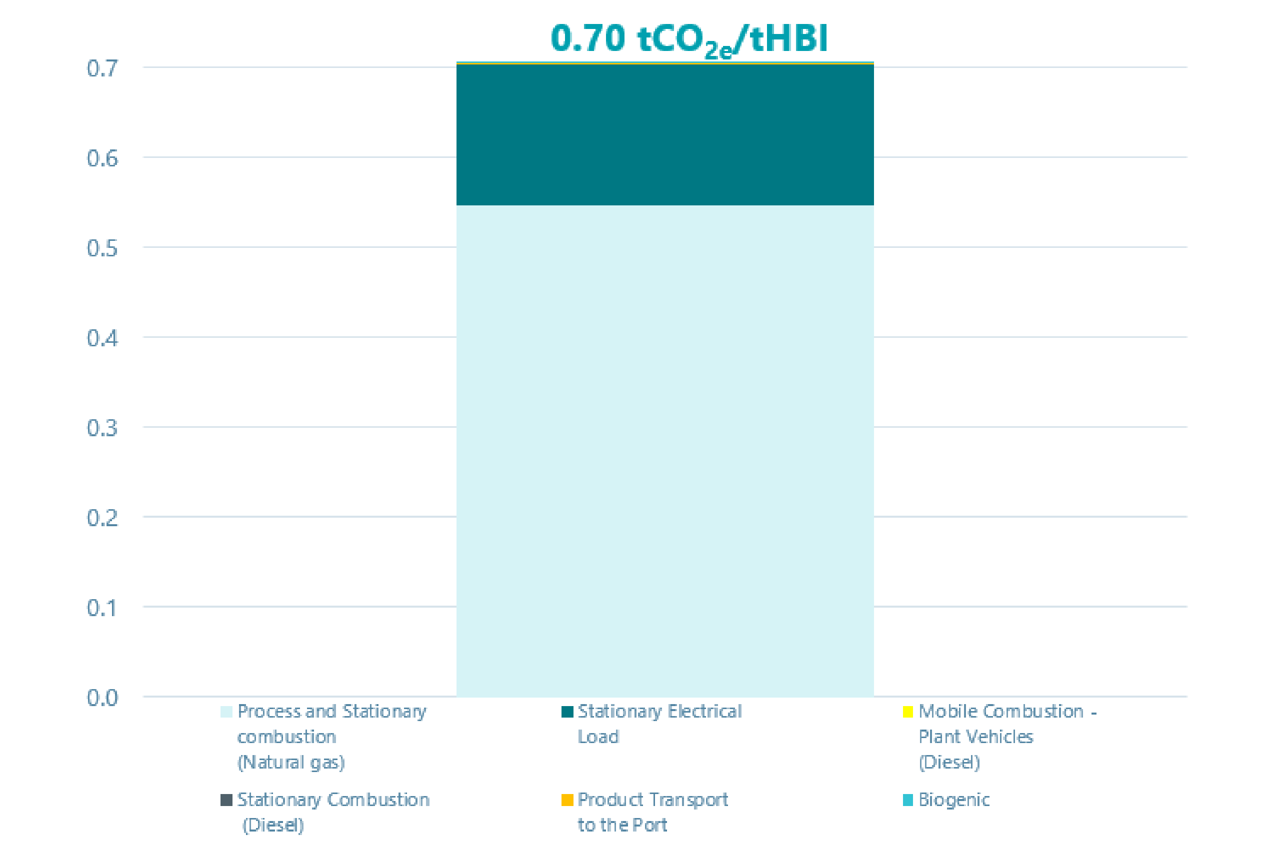


Figure 1.5: Average Annual Carbon Intensity tCO_{2e}/pellet (Scope 1 and 2)

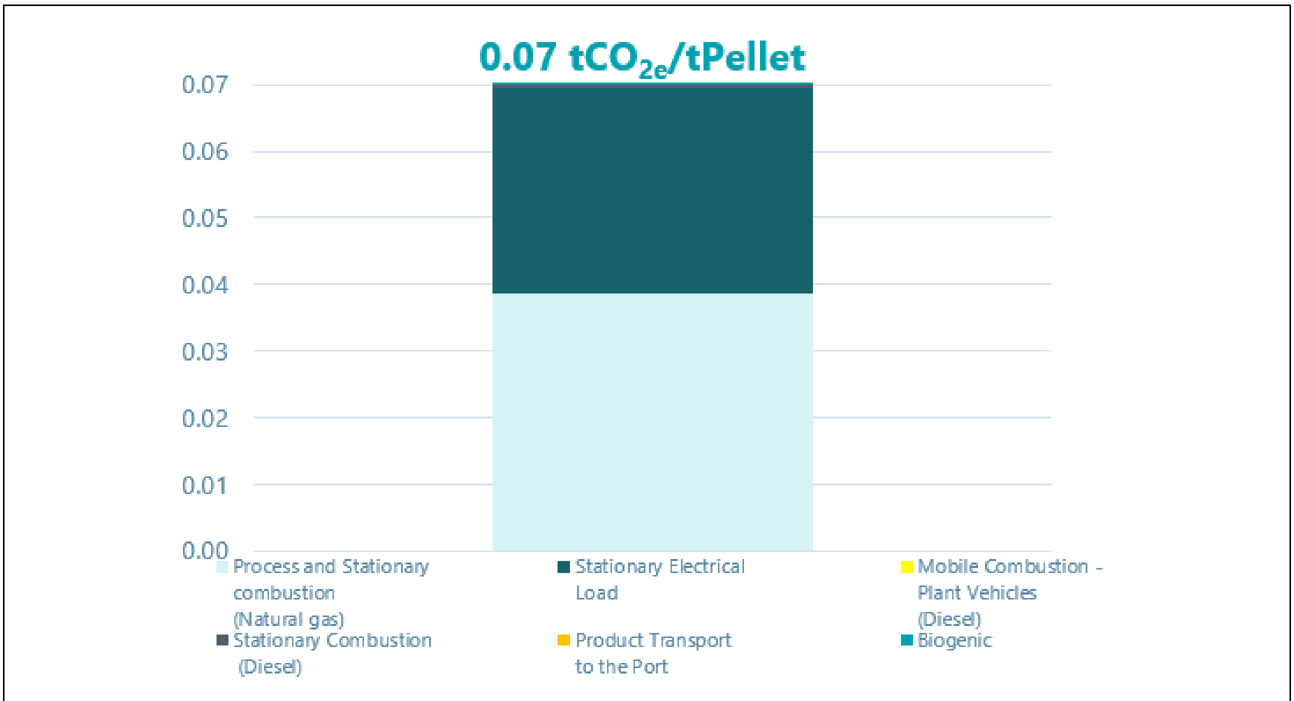


Figure 1.6: Average Annual Carbon Intensity ($tCO_{2e}/tHBI$) (Scope 1, 2, and 3)

Figure 1.7: Average Annual Carbon Intensity (tCO_{2e}/tPellet) (Scope 1, 2, and 3)

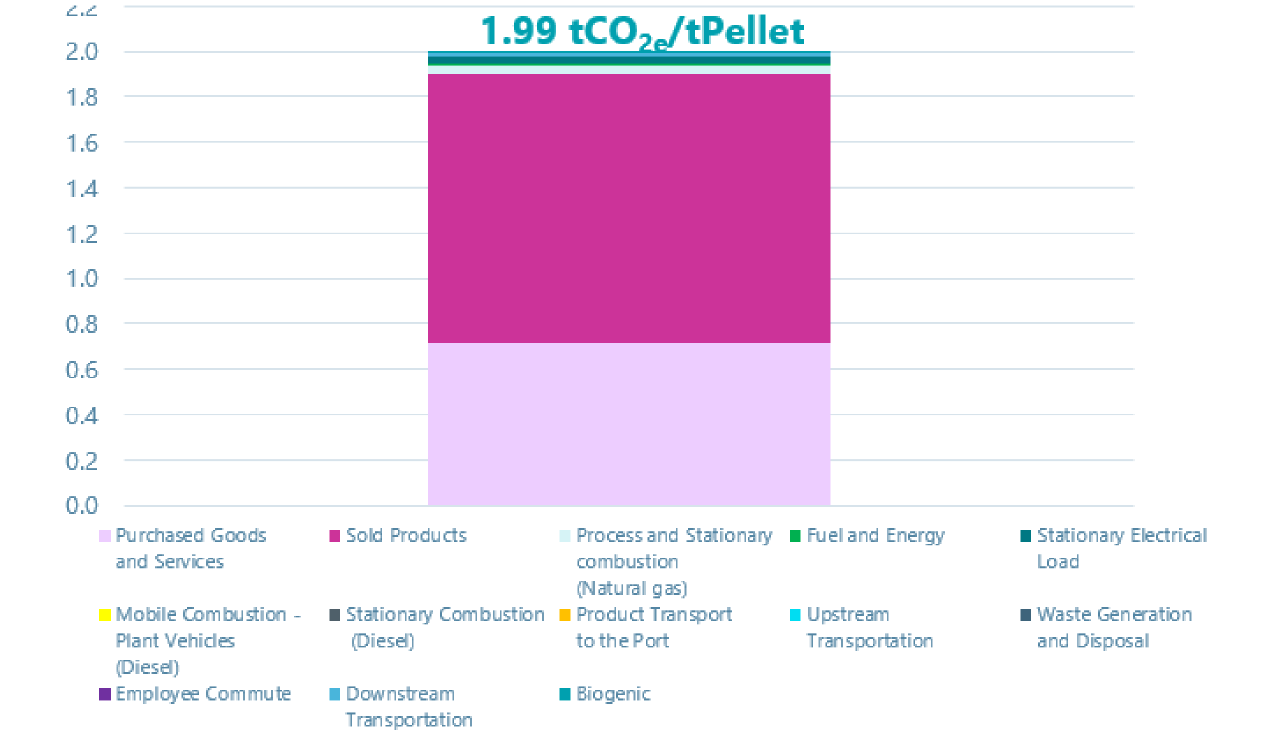


Table 1.1: Emission Summary – Base Case

Emission Category	Emission Source	Total Emissions Construction – (tCO_{2e})	Average Annual Emissions – Operations (tCO_{2e}/a)	Emission Intensity (tCO_{2e}/tHBI)[1]	Emission Intensity (tCO_{2e}/tPellet)[1]
Scope 1	Land Clearing	30 623	–	–	–
	Process and Stationary combustion (Natural gas)	90 394[2]	1 120 851	0.55	0.04
	Stationary Combustion (Diesel)	9 013	2 734	0.0012	0.0004
	Mobile Combustion – Construction Vehicles (Diesel)	155 650	–	–	–
	Mobile Combustion – Plant Vehicles (Diesel)	–	520	0.0002	0.0001
	Product Transport to Port	1 432[2]	1 886	0.001	0.0001
	Biogenic	1 009	131	0.0001	0.00002
Scope 2	Stationary Electrical Load	71 899	334 276	0.16	0.03
Scope 3	Purchased Goods and Services	1 688 109	2 756 561	1.12	0.71
	Capital Goods	258 456	–	–	–
	Fuel and Energy	5 531	25 714	0.01	0.00
	Upstream Transportation	7 531	11 353	0.004	0.003

Table 1.1: Emission Summary – Base Case					
Emission Category	**Emission Source**	**Total Emissions Construction – (tCO_{2e})**	**Average Annual Emissions – Operations (tCO_{2e}/a)**	**Emission Intensity ($tCO_{2e}/tHBI$)[1]**	**Emission Intensity ($tCO_{2e}/tPellet$)[1]**
	Waste Generation and Disposal	6 216	809	0.0004	0.0001
	Employee Commute	8 642	635	0.0003	0.0001
	Downstream Transportation	31 158[2]	41 022	0.01	0.01
	Sold Products	2 473 118[2]	2 315 979	0.72	1.19
	TOTAL (Scope 1)	**288 121**	**1 126 122**	**0.55**	**0.04**
	TOTAL (Scope 2)	**71 899**	**334 276**	**0.16**	**0.03**
	TOTAL (Scope 1 + 2)	**360 019**	**1 460 398**	**0.70**	**0.07**
	TOTAL (Scope 1 +2 +3)	**4 838 779**	**6 612 469**	**2.57**	**1.99**

[1] Operation emissions only – excludes emissions from the construction and ramp-up phases

[2] Emissions during construction phase are from the pellet production which starts during the last year of the construction phase in CY29

Abbreviations

Acronym	Term
4WD	Four-wheel Drive
BF	Blast Furnace
BOF	Basic oxygen furnace
BSIA	Boodarie Strategic Industrial Area
CCS	Carbon Capture and Storage
CCU	Carbon Capture and Utilisation
CH_4	Methane
CO_2	Carbon Dioxide
CO_{2e}	Carbon Dioxide Equivalent
COD	Chemical Oxygen Demand
CY	Calendar Year
CY27 1H	First Half of 2027
CY27 2H	Second Half of 2027
DCCEEW	Department of Climate Change, Energy, the Environment and Water
DRI	Direct Reduced Iron
EAF	Electric Arc Furnace
EF	Emission Factor
EPA	Environmental Protection Authority
ESG	Environmental, Social, and Governance
FullCAM	Full Carbon Accounting Model
g	Gram
gCO_{2e}	Grams of CO_2 equivalent
GHG	Greenhouse gas
GJ/t	Gigajoules Per Tonne
Gt	Gigatonne
GW	Gigawatts
GWP	Global Warming Potential
H_2	Hydrogen
ha	Hectares
HBI	Hot Briquetted Iron
HFC	Hydrofluorocarbon
IPCC	Intergovernmental Panel on Climate Change
JSIS	Jindal Shadeed Iron & Steel
JV	Joint Venture

Acronym	Term
kg	Kilogram
KRW	Korean Republic Won
$ktCO_2/a$	Kilotonnes of CO_2 Per Annum
$ktCO_{2e}$	Kilotonnes of CO_2 equivalent
kV	Kilovolt
KW	Kilowatt
L	litre
LOA	Life of Asset
M	Million
MRIWA	Minerals Research Institute of Western Australia
Mt	Million Tonnes
Mt/a	Million Tonnes Per Annum
MtPellet	Million Tonnes of Pellet
MW	Megawatt
MWh	Megawatt-hour
N_2O	Nitrous oxide
NG	Natural Gas
NGER	National Greenhouse and Energy Reporting
NGO	Non-governmental Organisation
NH_3	Ammonia
Nm^3/hr	Normal Cubic Metres Per Hour
NPI	Non-processing Infrastructure
NWIS	Northwestern Interconnected System
OEM	Original Equipment Manufacturer
OPEX	Operating Expenditure
PHGS	Port Hedland Green Steel
QSC	Qatar Steel Company
SMO	South Korea-based Steel Making Operations
SWIS	Southwestern Interconnected System
t	Metric Tonne
T&D	Transmission and Distribution
t/a	Tonnes Per Annum
t/h	Tonnes Per Hour
t/t	Tonnes Per Tonne
tCO_{2e}	Tonnes of CO_2 Equivalent

Acronym	Term
tHBI	Tonnes of Hot Briquetted Iron
tPellet	Tonnes of Pellet
UK	United Kingdom
US$	United States Dollar
WA	Western Australia

2 Introduction

The steel industry consumes 5.9% of global energy and emits 6-9% of global CO_2 emissions. Moreover, the world has seen an unprecedented increase in steel demand since the industrial revolution and that demand is expected to rise to 1.5 times the current demand in the next 30 years [1]. These facts set the tone for decarbonising the steel-making processes so that the steel industry can maintain its eminent presence in a low-carbon world.

Globally, POSCO is the 7th largest steel manufacturer producing 38.64 Mt of crude steel (in 2022) from two steel mills located in Pohang and Gwangyang in South Korea [2]. POSCO recognise that greenhouse gas (GHG) emissions are a global issue that requires a global solution. POSCO has committed to decarbonising their steel manufacturing processes by implementing green technologies to achieve net zero GHG emissions by 2050.

To progress towards this target, POSCO propose to change the way steel is produced for a portion of their South Korea-based Making Operations (SMO). POSCO will systematically replace a portion of their existing blast furnaces (BF) with electric arc furnaces (EAF) which can be operated using renewable energy technology (as opposed to the combustion of fossil fuels as required for the BF; Proposal). POSCO proposes to develop the PHGS project which will produce hot briquetted iron (HBI), a suitable feedstock for steel manufacturing using EAF. HBI can be produced using natural gas or hydrogen (or a blend of both) as a reducing agent, instead of coking coal which is used in POSCOs current BF-based processes. The Proposal has the potential to significantly reduce the GHG emissions intensity of the SMO.

PHGS have identified Western Australia as a prime location for producing HBI due to its proximity to high-quality iron ore (feedstock), potential for renewable energy and green hydrogen production, as well as access to import and export infrastructure.

2.1 Port Hedland Green Steel Project

PHGS is a joint venture between POSCO Holdings Inc, Marubeni Corporation, and China Steel Corporation (jointly referred to as the JV Parties). The JV Parties are evaluating the feasibility of developing the PHGS, a large-scale downstream iron ore processing facility at the Boodarie Strategic Industrial Area (BSIA) in Port Hedland, Western Australia (WA). The BSIA is approximately 10 km southwest of Port Hedland in the Pilbara region. The Proposal's regional location is shown in Figure 2.1.

The Project will process magnetite concentrate from iron ore operations in the Pilbara to produce HBI for export to customers who will convert the HBI into a low-carbon emission steel overseas.

The Project will be developed in stages. Stage 1 will involve the design and construction of a HBI plant, consuming approximately 3-3.5 Mt/a of iron ore. The first processing step is to produce iron ore pellets (3-3.5 Mt/a). Most of the pellets will be fed into the HBI plant to produce approximately 2 Mt/a HBI. The remainder of the pellets (~0.7 Mt/a) will be exported from the port as pellets. HBI export volume will be relatively small (2 Mt/a for Stage 1 to 10-13 Mt/a for Stage 6) compared to total iron ore exports through Port Hedland. The disturbance footprint for Stage 1 of the Project will likely be around 390 ha within the BSIA.

Figure 2.1: Project Location

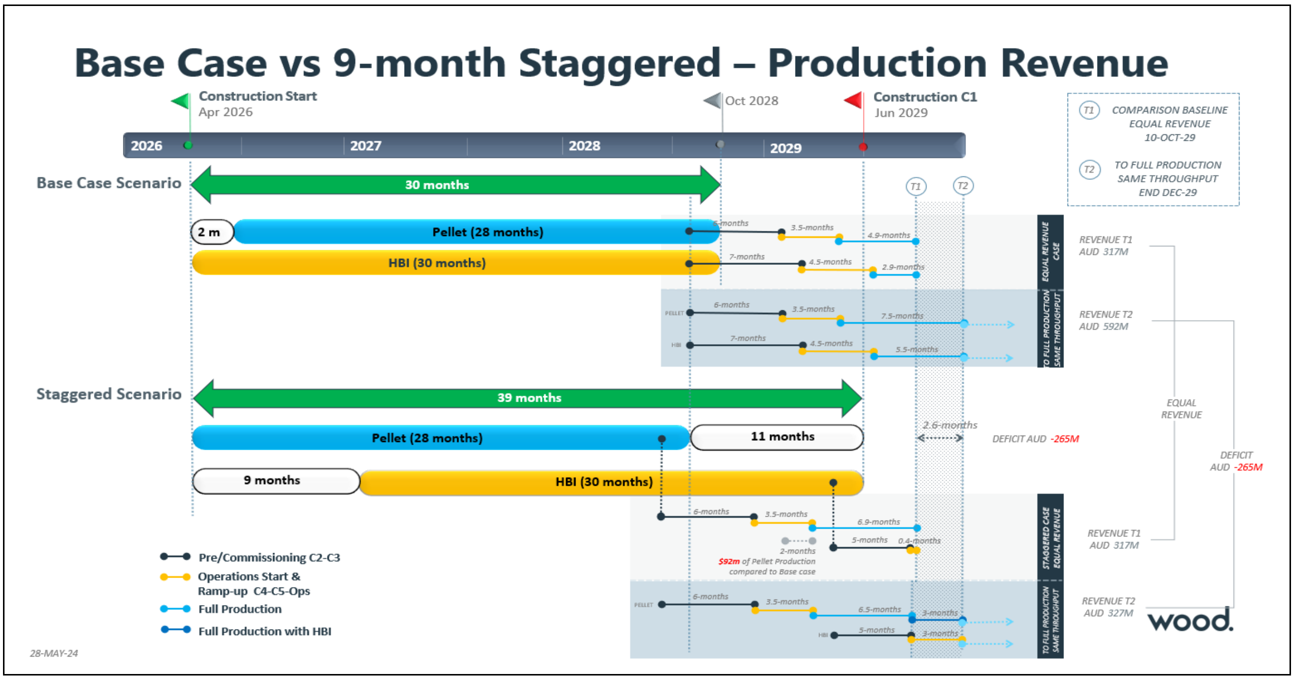
2.2 Project Schedule

The project schedule used in this study is provided in Figure 2.2. The following assumptions have been made with regarsds to the project schedule:

- The second option of the staggered scenario has been used throughout the study as project schedule for different phases of the Project
- Construction starts from April 2026. This will be the construction for the pellet plant and the construction of HBI plant will not be commenced until January 2027.

- The construction, pre-commissioning and commissioning have been grouped together as the construction phase, as there will be no production during these phases. By merging these phases, construction will continue for 43 months. During this period, there will be some pellet production which has been taken into account in calculations.
- HBI plant will ramp-up from middle of October 2029 till middle of January 2030 (3 months). During this period, HBI plant will be in full production.
- Operation phase starts from January 2030.

Figure 2.2: Project Schedule for the Pellet and HBI Plant



2.3 Purpose and Scope

PHGS have requested the Wood Decarbonisation Team to assess the Scope 1, 2, and 3 emissions (in tCO_{2e}/tHBI product) that can be expected from the Project over Stage 1 of the operation phase (99 years), based on the information available in June 2024. This includes emissions over the construction phase and the operating phase.

The report aims to support applications for approval and discussion with the Australian Commonwealth and WA State Government.

Wood has calculated a Baseline Emissions Assessment, which is representative of two scenarios, with and without carbon abatement options, incorporated into the Project.

3 Emissions Assessment – Description

PHGS have requested a **Baseline Emissions Assessment** for the Project in WA.

This section describes the system boundaries of the Emissions Assessment of the Project including the activities that are included or excluded from the assessment.

3.1 System Boundary

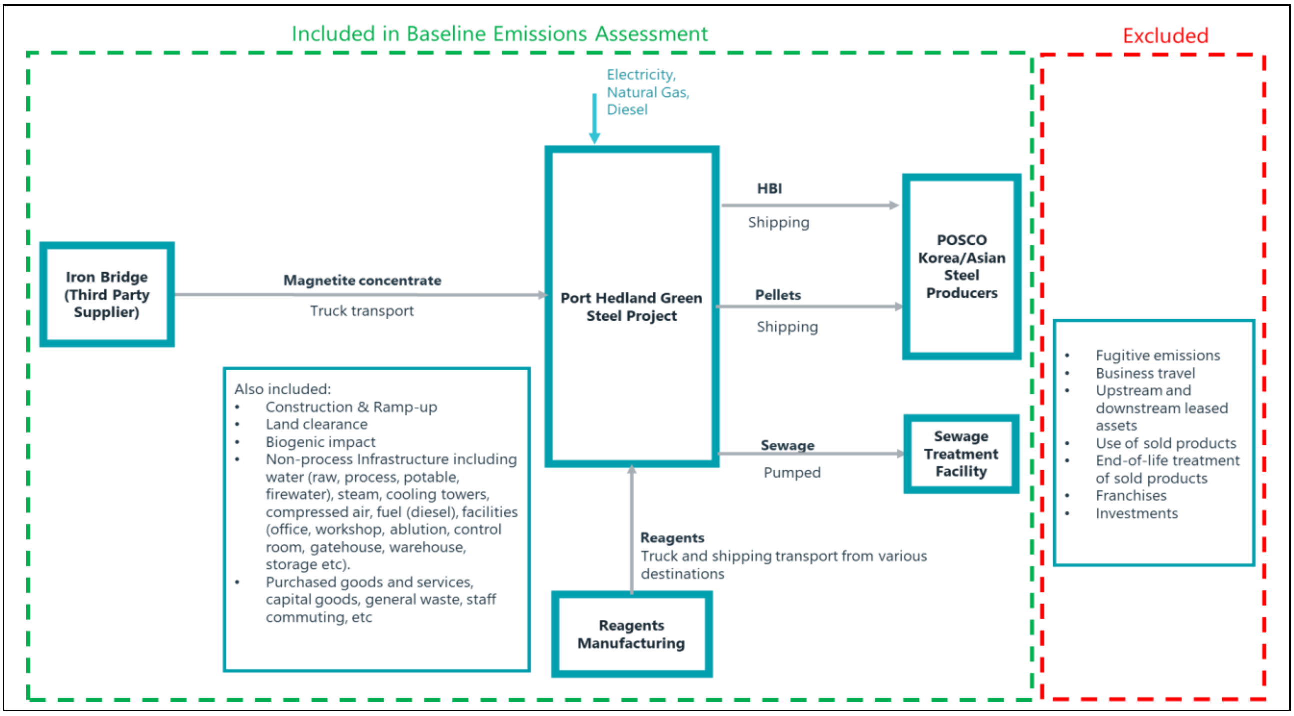
The battery limits of the Emissions Assessment are shown in Figure 3.1, with the assessments including Scope 1, 2, and 3 emissions from:

- Pellet plant
- HBI plant
- All associated non-process infrastructure (NPI)[1] designed to support the Project.

The basis of the Emissions Assessment calculation will be each year of operation, reported in tonnes CO_2 equivalent (CO_{2e}) per annum.

CO_{2e} will account for all relevant GHG emissions listed under the United Nations Framework Convention on Climate Change and Kyoto Protocol [3], [4]. However, the most common GHGs – carbon dioxide, methane, and nitrous oxide – will be the focus of the assessment, see Appendix B for the methodology.

Figure 3.1: Port Hedland Green Steel Project System Boundaries



[1] The non-process infrastructure includes water (raw, process, potable, firewater), steam, cooling towers, compressed air, fuel (diesel), facilities (office, workshop, ablution, control room, gatehouse, warehouse, storage, etc.)

3.2 Organisational Boundaries

In this assessment, the Project is treated as an isolated operating division of PHGS, 100% owned and operated by PHGS (POSCO 51%, Marubeni 24.5% and CSC 24.5%).

The projects in WA (or other locations) that PHGS has planned or proposed are not considered in this Emissions Assessment.

3.3 Operational Boundaries

The Project is treated as an isolated operating facility in the Port Hedland area of WA.

The Emissions Assessment will include Scope 1, 2, and 3 emissions from the pellet plant, HBI plant, and all the associated non-process infrastructure that has been designed to support the Project.

It is assumed that the Project facilities will be owned, controlled, leased, or operated by PHGS at the Project site, where the magnetite concentrate and reagents will be received and the HBI and pellets will be dispatched.

The battery limits for this study begin at the facility described above and end at the Project area boundary, as shown in Figure 3.1.

PHGS's planned or proposed future development of the Project, including future stages, is not included in this assessment.

PHGS's other facilities outside of the Project (e.g. offices in Perth, etc.) are not included in this assessment.

3.4 Inclusions

The Emissions Assessment will include the following Scope 1, 2, and 3 emissions from the operation of the Project as designed, as of June 2024:

- Physical or chemical processing
- Stationary combustion (on-site generation of electricity, heat or steam, fire water pump, and bore pumps)
- Mobile combustion (transportation of materials and products)
- Land clearance
- Biogenic impact of sewage treatment and solid waste
- Emissions from the generation of purchased electricity
- Manufacturing of reagents used in the Project
- Capital goods
- Fuel and energy-related activities not included in Scope 1 or Scope 2
- Upstream transportation of reagents and feed
- Waste generated in operations
- Employee commuting

- Downstream transportation of products
- Processing of the HBI and pellets.

3.5 Exclusions

Scope 3 emissions that were considered immaterial or not applicable have been excluded from the assessment. This includes:

- Business Travel
- Upstream leased assets
- Use and end-of-life treatment of sold products
- Downstream leased assets
- Franchises and investments.

Fugitive emissions – e.g. equipment leaks from joints, seals, packing, and gaskets; hydrofluorocarbon (HFC) emissions during the use of refrigeration and air conditioning equipment; and methane leakages from gas transport have also been excluded from this assessment.

3.6 Assumptions

A baseline emission assessment will be evaluated over Stage 1 of the Project. An additional scenario has also been included to evaluate the impact of carbon abatement opportunities (H_2 substitution and CCS) and other options such as electrified vehicles and a higher uptake of renewables in the electrical grid. This scenario is named the Low-carbon Case. Table 3.1 below summarises the assumptions made for the Base Case and the Low-carbon Case.

It should be noted that the assumptions related to timelines are reliant on the best estimates for project approval and hence may vary from those stated in this report.

Table 3.1: Baseline Emissions Assumptions

Emission Category	Description	Base Case	Low-carbon Case
General			
	Project	Project begins in Y01 with the construction	Same as Base Case
		It is assumed that Y01 is 2026 (starting from April 2026)	
		Construction phase includes construction, pre-commissioning and commissioning as there is no production during these phases	
		Construction phase (combined construction, pre-commissioning and commissioning) is 43 months (3.58 years, Starting April 2026 and ending October 2029)	
	Processing	The pellet plant will be in full production when the HBI plant is ramping up. The duration of ramp-up phase is from mid-October 2029 till mid-Jan 2030.	
		Stage 1 operation lifespan is 99 years, beginning at the start of 2030 and operating until 2128. Average annual quantities have been reported for the Stage 1 operating phase.	
		Processing activities will occur according to the HBI plant schedule provided by PHGS	
		The pellet plant will have a general 90.4% operating availability, i.e. will operate for 7 919 h/a, with the balance being planned and unplanned downtime. The HBI plant will have a general 89% operating availability, i.e. will operate for 7 796 h/a. The Bulk Materials handling will have a 95% operating availability, i.e. will operate for 8 322 h/a.	

Table 3.1: Baseline Emissions Assumptions			
Emission Category	**Description**	**Base Case**	**Low-carbon Case**
		A total of **2 000 000 tonnes of HBI** (2 Mt/a) and **3 500 000 tonnes of pellet** (from which 736 117 tonnes of pellet is sold directly) will be produced annually, as provided by PHGS. The pellet export in 2029 (when HBI plant is under construction, commissioning and ramping up) is reported to be 2.771 Mt/a.	
	Carbon Abatement	Not Applicable	The impact of the proposed carbon abatement strategies were assessed. They are listed below: • Implementing hydrogen substitution • Carbon capture and storage • Electrification of operating vehicles and product transport to port • Introducing a higher uptake of renewables in the electrical grid.
	General	NGER fuel emissions factors have been used in the calculations	Same as Base Case
		Verifiable fuel quality and physical properties (calorific value, density etc) for gas and diesel in WA have been utilised where available. The values used and their references are identified in the report.	
		The sources of other emissions factors used in this report are referenced throughout	

Table 3.1: Baseline Emissions Assumptions			
Emission Category	**Description**	**Base Case**	**Low-carbon Case**
Scope 1			
	Land Clearing	Only the removal of vegetation for Stage 1 has been considered in this assessment. It is assumed that there will be 390 ha of cleared land in total. This includes an additional 90 ha clearing required for the establishment of the corridors. It is assumed that 50% of the area to be cleared is hummock grassland and 50% is eucalypt open woodlands. Emissions factors have been sourced from FullCAM (78.52 tCO_{2e}/ha). Emissions due to land clearance for the borefield and their respective pipelines has not been considered as the water supply option has not been finalised, yet.	Same as Base Case
	Process Emissions	Process emissions from the HBI plant are based on a nominal production rate of 260 t/h. Magnetite concentrate is sourced from FMG – Iron Bridge. The assumption was made to consider the most energy-intensive feedstock for pellet production.	The impact of the following abatement strategies were assessed: • H_2 injection to replace natural gas in HBI plant phased over the project lifespan in Stage 1 • CCS implementation phased over the project lifespan.
	Natural Gas Combustion	Natural gas combustion rate is assumed to remain constant on an annual basis during Stage 1 – operating phase.	
	Biogenic Impact	Biogenic impact is assumed to be higher during the 2.5 years of construction phase, with between 132-1 388 people on site on a yearly average basis. It is then assumed to remain steady during operating phase with an estimated number of 350 people on site per year.	Same as Base Case

Table 3.1: Baseline Emissions Assumptions			
Emission Category	**Description**	**Base Case**	**Low-carbon Case**
	Diesel Mobile – Construction	100% diesel mining vehicles during construction phase including haul trucks, excavators, service vehicles and light vehicles. Diesel consumption, correlating to the construction activities, has been provided by Wood where: • Diesel fuel consumptions are sourced either from the Caterpillar Performance Handbook Edition 49 2020 or other references. It is assumed that the vehicles operating on-site are maintained as per OEM requirements (i.e. meet published fuel efficiency data).	Same as Base Case. It is assumed that vehicles won't be electrified until the operating phase.
	Diesel Mobile – Operations	On-site vehicles will be 100% diesel during the operating phase. It is assumed that there will be approximately 50 light vehicles and 6 x 30-seater buses. Where vehicle makes and models have not been specified by PHGS, or performance data (e.g. fuel consumption) is not published, values from the Wood OPEX database have been used (these instances are identified in the report). Vehicle utilisation has been determined from the Wood database. It is assumed that the vehicles operating on-site are maintained as per OEM requirements (i.e. meet published fuel efficiency data).	On-site operating vehicles will be transitioned to electric vehicles as follows: • Electric buses from the start of operations • 25% of all vehicles electric by 2029 • 100% electric by 2032.

Table 3.1: Baseline Emissions Assumptions

Emission Category	Description	Base Case	Low-carbon Case
	Diesel – Plant Stationary Equipment (emergency generators, firewater pumps, bore field pumps)	100% diesel plant stationary equipment during construction and operating phase. Construction phase: 3x emergency generators, 1x emergency diesel firewater pumps and 6x borefield pumps. Operation phase: 4x emergency generators 1x emergency diesel firewater pumps, and 6x borefield pumps. 1% utilisation (88 h/a) is assumed for emergency generators and firewater pumps. 66% utilisation (5 869 h/a) is assumed for borefield pumps.	Same as Base Case
	Downstream transportation and distribution	The downstream transportation of products within PHGS's battery limits have been evaluated as a Scope 1 emission. The downstream transportation comprises the transportation of products to the Lumsden/Utah port via truck. Transportation of HBI and pellets from the Project to BSIA and steel producers by shipping has been evaluated in Scope 3 downstream transportation emissions.	Truck vehicles used for the product transport will be transitioned to electric vehicles as follows: • 25% of all vehicles electric by 2031 • 100% electric by 2034.

Table 3.1: Baseline Emissions Assumptions			
Emission Category	**Description**	**Base Case**	**Low-carbon Case**
Scope 2			
	Emission Factor	It is assumed that the PHGS will be connected to the NWIS grid with electricity supply from Horizon Power. Horizon Power has an initial emissions factor of 0.52 tCO_{2e}/MWh. A conservative approach has been taken to assume that the emissions factor will remain constant over the life of the Project.	It is assumed that the NWIS EF will reduce over time as Horizon Power increases their uptake of renewable energy. A conservative approach has been taken to assume that the NWIS EFs will start to reduce from 2027. It is assumed to reduce by 40% from the initial factor by 2030, followed by a steady decline to 0 tCO_{2e}/MW by 2050. This assumption is aligned with the emissions reduction target for WA [3] to reduce their overall emissions by 80% by 2030 (based on 2020 levels). As this strategy includes all of WA's supply, not the NWIS specifically, a conservative assumption of a 40% reduction in the NWIS EF by 2030 has been incorporated into the assessment. The electrical load will increase as the uptake of electric vehicles increases over the operating phase.

Table 3.1: Baseline Emissions Assumptions			
Emission Category	**Description**	**Base Case**	**Low-carbon Case**
	Electrical Load	The plant electrical load is assumed to remain constant over the operating phase. The consumed power for each area has been supplied by Midrex. The annual availability of the pellet plant, HBI plant, and bulk materials are as follows (as per the PFS): • Pellet plant – 90.4% • HBI plant – 89% • Bulk materials handling – 95%. An annual availability of 92% has been assumed for all other areas.	Same as Base Case

Table 3.1: Baseline Emissions Assumptions			
Emission Category	**Description**	**Base Case**	**Low-carbon Case**
Scope 3			
Category 1	Purchased goods and services	Embodied carbon (i.e. the emissions produced during the manufacturing of reagents) has been assessed. Included reagents are limestone, bentonite, coating material, diesel, and natural gas. NH_3 is used in the pellet plant in De-NOx. The emissions of this reagent have been neglected due to the lack of information. Emissions from refractory and catalysts were excluded due to either their minor impact or lack of accurate information regarding their consumption rate. It was assumed that natural graphite is used as the coating material for HBI production. The reagent consumtion in the pellet plant during the ramp-up (3.5 months in 2029) and full production time of pellets (6.5 months in 2029) were taken into account. It was assumed the pellet plant are in full production during the HBI ramp-up. Therefore, the reagents consumed in the pellet and HBI plant were adjusted accordingly.	Same as Base Case

Table 3.1: Baseline Emissions Assumptions

Emission Category	Description	Base Case	Low-carbon Case
Category 2	Capital Goods	Indirect emissions from embodied carbon in capital goods purchased (including all vehicles, processing equipment and other infrastructure) have been included. It is assumed that all the mechanical equipment and vehicles consist of steel only. The average weight of each vehicle/ processing equipment has been used for estimating Scope 3 emissions embodied in capital goods. Embodied carbon in construction materials and equipment are assumed to be purchased in CY26. Embodied carbon in steel and concrete purchases for plant construction was calculated from the materials quantities (including concrete, structural steel and processing equipment). When the type of vehicle was noted as "misc", an average weight of the category was assumed to account for their emissions of the capital goods. Wood has assumed that all light/service vehicles (except for buses) are purchased in CY28.	Same as Base Case
Category 3	Fuel and energy-related activities not included in Scope 1 or Scope 2	Emissions from the extraction, production, and transport of fuel burned by companies generating electricity and the emissions attributable to the electricity lost in delivery in the transmission and distribution network have been included. The Scope 3 emissions factor for the SWIS (0.04 tCO_{2e}/MWh) has been used as there is no reported factor for the NWIS.	Same as Base Case

Table 3.1: Baseline Emissions Assumptions			
Emission Category	**Description**	**Base Case**	**Low-carbon Case**
Category 4	Upstream transportation and distribution	Emissions vary based on annual reagent consumption rate. Emissions from the transportation of reagents to site via shipping and tankers (diesel combustion) have been included. It is assumed that Bentonite will be shipped from a supplier in India (from the Port of Chennai). Limestone will be shipped from Korea (from the Port of Busan). Coating material will be sourced from a local supplier in Malaga and transported via triple road trains to the site. Diesel will be supplied from Ampol in Port Hedland and will be trucked to site. Most reagents are assumed to be transported via shipping to the Lumsden Port in Port Hedland. Emissions from unladen backhaul (i.e. the return journey of the empty vehicle) have been included in the calculation of transportation of feedstock, reagents, and waste as outlined in the GHG Protocol Technical Guidance for Calculating Scope 3 Emissions Version 1.0.	Same as Base Case
Category 5	Waste generated in operations	Emissions from solid waste generated from operations has been calculated. It is assumed that 132-1388 people will be on-site on an average basis during construction and 350 people on-site during operations.	Same as Base Case
Category 6	Business Travel	Included in the number of employee commuting flights.	Same as Base Case

Table 3.1: Baseline Emissions Assumptions

Emission Category	Description	Base Case	Low-carbon Case
Category 7	Employee commuting	Employee plane commute from Perth airport to the PHGS site has been included. Assumed to be 6 370 employee flights per year during operations with 90% FIFO workers on a 8/6 roster. Flights are varied during construction phase (132-1 388 people) with number of employees being constant at ~350 people on-site over the operating phase. The average number of employees on a yearly basis has been used in calculations.	Same as Base Case
Category 8	Upstream leased assets	This category is not applicable. No upstream leased assets have been identified.	Same as Base Case
Category 9	Downstream transportation and distribution	Transportation of HBI and Pellets from the Project to Kobelco in Japan, POSCO in South Korea and China Steel in Taiwan by Panamax vessel has been included in the downstream transportation calculation. It is assumed the pellets will be exported from the Utah port and the HBI will be exported from the Lumsden port. Downstream truck transportation of HBI and Pellets from the plant site to the Lumsden and Utah port has been evaluated in the Scope 1 emissions	Same as Base Case
Category 10	Processing of sold products	Emissions from the processing of pellets and HBI into steel have been included. An emission factor of 0.72 tCO_{2e}/tHBI has been assumed for the processing of HBI into steel. An emission factor of 1.19 tCO_{2e}/tPellet has been assumed for the processing of pellets into steel. It is assumed the production rate of pellets and HBI remains constant over the Stage 1 operating phase.	Same as Base Case
Category 11	Use of sold products	Considered immaterial	Same as Base Case

Table 3.1: Baseline Emissions Assumptions			
Emission Category	**Description**	**Base Case**	**Low-carbon Case**
Category 12	End-of-life treatment of sold products	Considered immaterial	Same as Base Case
Category 13	Downstream leased assets	This category is not applicable. No downstream leased assets have been identified.	Same as Base Case
Category 14	Franchises	This category is not applicable. No franchises have been identified.	Same as Base Case
Category 15	Investments	This category is not applicable. No investments have been identified.	Same as Base Case
Offsets			
Vegetation Offsets	N/A		

4 Baseline Emissions Assessment – Results

The balance of this report presents the PHGS Project carbon intensity data in the format prescribed by the World Economic Forum's Greenhouse Gas (GHG) Protocol Corporate Accounting and Reporting Standard (GHG Protocol Corporate Standard) [5].

4.1 Scope 1 Emissions

Scope 1 GHG emissions are defined as the emissions from sources the reporting company owns or controls. The Scope 1 emissions of the PHGS are summarised in this section.

4.1.1 Land Clearing

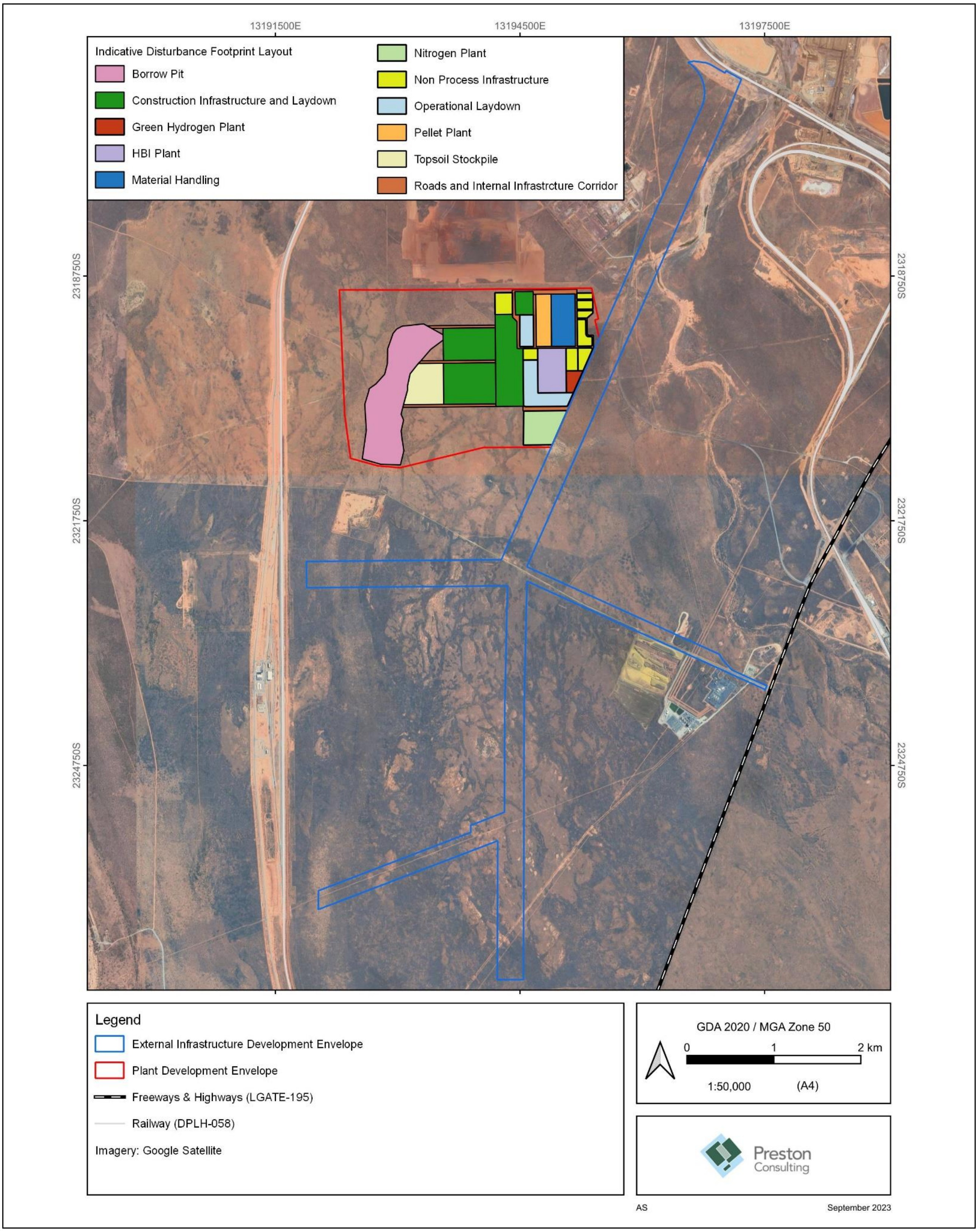
The extent of land disturbance required for the Project and associated infrastructure and facilities has been estimated. The impact of the clearance is due to the loss of carbon sinks associated with land clearing.

The development envelope is 500 ha and up to 390 ha of disturbance is proposed. This includes an additional 90 ha clearing required for the establishment of the corridors. The Project is located in BSIA approximately 10 km southwest of Port Hedland in the Pilbara region. The indicative footprint and development envelopes are shown in Figure 4.1.

A land clearance emission factor of **78.52 tCO_{2e}/ha** was used to calculate the overall land clearance emissions, outlined in Table D1.1 in Appendix D. This factor is an estimate from the full carbon accounting model (FullCAM) and is based on the Project being in a vegetation area of mainly hummock grasslands and eucalypt open woodlands.

The overall emissions due to land clearance is 30 623 tCO_{2e} for Stage 1 of the Project. The clearance schedule is assumed to be in the first construction year (2026), as shown in Table D1.2 in Appendix D.

Figure 4.1: Development Envelops and Indicative Layouts



4.1.2 Process Emissions

Based on the information provided by Primetal for the HBI plant, there are six point sources from which GHGs are emitted (Figure 4.2). GHG emissions from the pellet plant is discharged through the main stack (Figure 4.3). The emissions will be the result of limestone reactions and natural gas combustion. All point source emissions reported here are the combined emissions from burning natural gas (NG) and embodied carbon of the reagents emitted during the process. The identified point source emissions in the HBI plant and pellet plant are listed below.

Point Source 1 – Flue Gas Stack – This is the main source of process emissions in the HBI plant. Flue gas is withdrawn from the reformer in two flue gas headers located on either side of the reformer and is released into the atmosphere. The flue gases leaving the reformer at a temperature of about 1150°C are fed to the recuperator for waste heat recovery. CO_2 is emitted as a result of using natural gas as the reducing agent in the Midrex process.

Point Source 2 – Bottom seal gas dedusting – The bottom seal gas system supplies and exhausts seal gas for sealing the bottom of the shaft furnace. The bottom seal gas is vented through the product discharge chamber (PDC) vent line, collected in the dilution hood, cleaned in the dust collection scrubber, and exhausted through the bottom seal dust collection fan and stack. The hood captures sufficient air to maintain a mixture of gases that remains below minimum explosive limits in the dust collection system. The gas stream exhausted from the stack is mainly composed of CO and CO_2.

Point Source 3 – Briquetter dedusting- The dust collection system is designed to minimise the escape of dust at the briquette machines. The gas passes through a venturi scrubber and then is pulled by the exhaust fan and discharged into the atmosphere through the stack.

Point Source 4 and 5 – Degasser -Top Gas Weir Drain and Cone Drain– The top gas scrubber receives hot, dust-laden gases from the furnace. The degasser system (CO_2 stripper) is used to liberate dissolved gases from the top gas scrubber weir drain and cone drain water.

Point Source 6 – Degassing unit Process Water Clean– The degasser unit is used to liberate dissolved gases from the reformed gas cooler and sealed gas cooler.

Point Source 7 – Main Stack – GHG gases generated during limestone addition and natural gas combustion are channelled to the main stack and subsequently released into the atmosphere. The quantity of GHG emissions varies based on the ore source, whether it is Ridley or FMG Iron Bridge. For the purposes of this study, it is assumed that the iron ore exclusively originates from FMG Iron Bridge, known to be the most emission-intensive source. This assumption is made due to the absence of a finalised decision on the iron ore supplier at the time of conducting this study.

Figure 4.2: Point Source Emissions from the HBI Plant of the Port Hedland Green Steel Project

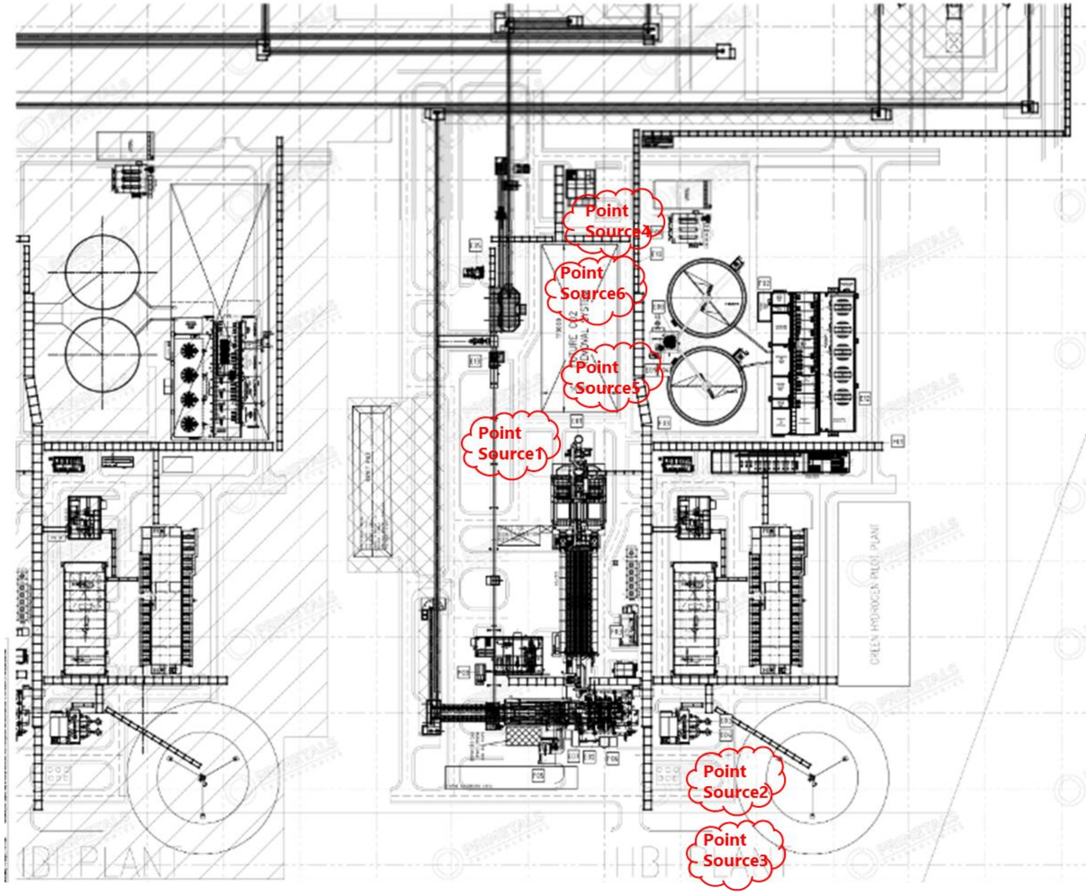
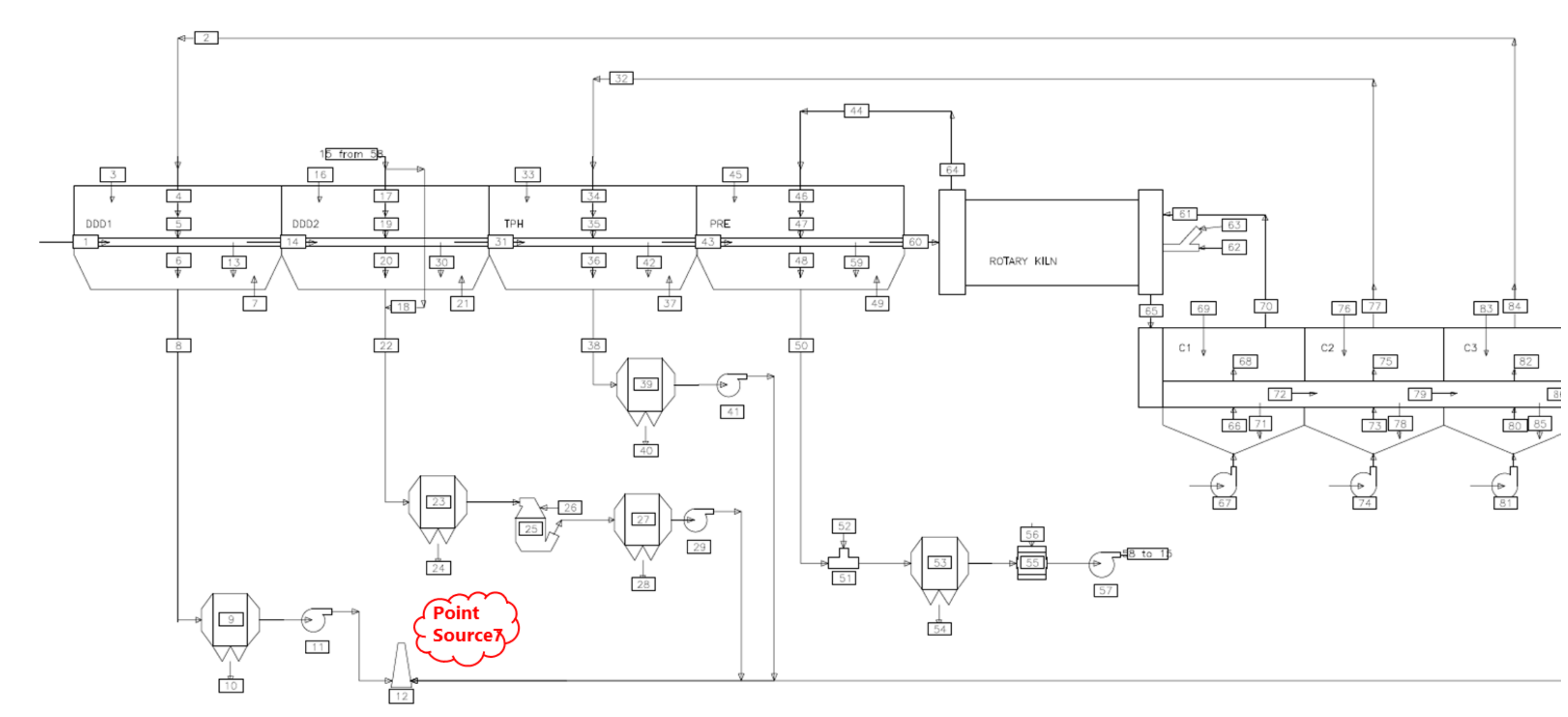
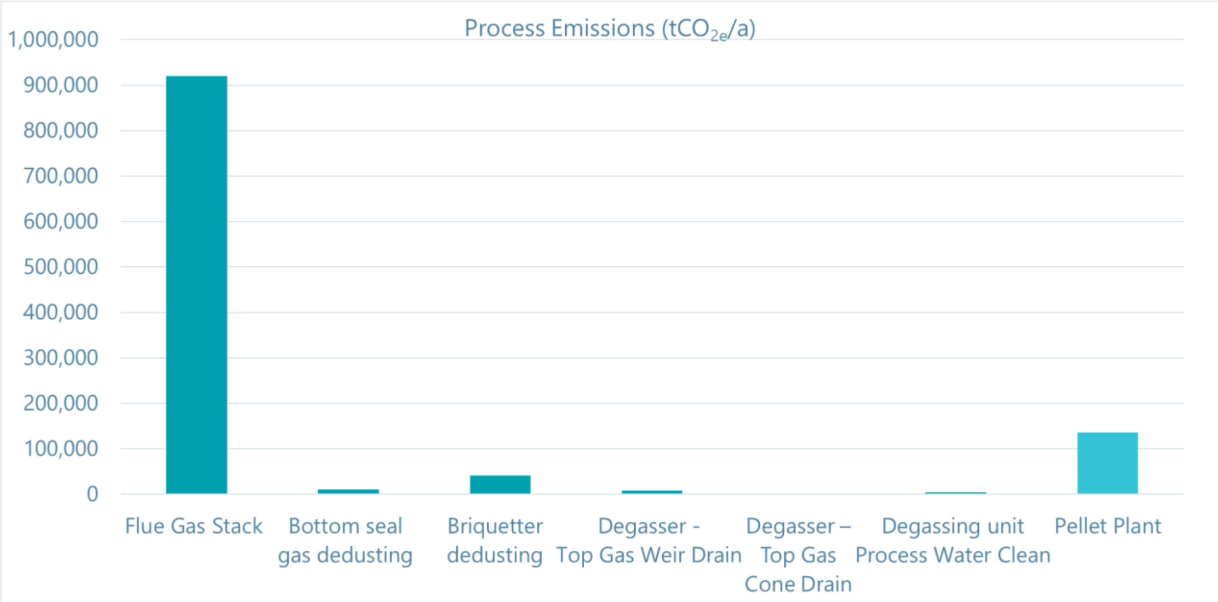


Figure 4.3: Point Source Emissions from the Pellet Plant of the Port Hedland Green Steel Project



The annual average emissions from the process and natural gas combustion during the operation phase are shown below in Figure 4.4 and summarised in Table D1.3 in Appendix D.

Figure 4.4: Annual CO_{2e} Emissions from Process Sources (tCO_{2e}/a) – Including NG Combustion



4.1.3 Process Combustion – NG

Sources of emissions from process combustion generally include boilers, heaters, furnaces, kilns, ovens, flares, thermal oxidisers, dryers, and any other equipment or machinery that combusts carbon-bearing fuels or waste stream materials.

The sources of stationary combustion in the PHGS are the areas where natural gas (NG) is used as the fuel source in pellet and HBI plants. It has been assumed that NG is supplied to the processing plant via a lateral gas pipeline with a pressure let down and metering station.

The GHG evolved as a result of NG combustion has been already taken into account in Scope 1 – Process Emissions (Section 4.1.2). However, the calculations for NG combustion emissions reveal that approximately 88% and 98% of the total GHGs emitted from the processing plant originate from NG combustion in the pellet plant and HBI plant, respectively. The contribution of process and NG combustion to Scope 1 is shown in Table 4.1 and summarised in Table D1.4 and Table D1.5 in Appendix D.

Table 4.1 Scope 1 – Process and NG Combustion Emissions (tCO_{2e}/a)

CY	Process Emissions (tCO_{2e}/a)		NG Combustion Emissions (tCO_{2e}/a)	
	Pellet Plant	HBI Plant	Pellet Plant	HBI Plant
CY26 (Q2-Q4)	–	–	–	–
CY27	–	–	–	–
CY28	–	–	–	–
CY29 (Q1-Q3)	11 038	–	79 356	–
CY29 (Q4)	4 139	2 749	29 759	161 461

Table 4.1 Scope 1 – Process and NG Combustion Emissions (tCO_{2e}/a)				
CY	**Process Emissions (tCO_{2e}/a)**		**NG Combustion Emissions (tCO_{2e}/a)**	
	Pellet Plant	**HBI Plant**	**Pellet Plant**	**HBI Plant**
CY30	16 557	16 496	119 034	968 764
CY31	16 557	16 496	119 034	968 764
CY32	16 557	16 496	119 034	968 764
CY33	16 557	16 496	119 034	968 764
CY34	16 557	16 496	119 034	968 764
CY35	16 557	16 496	119 034	968 764
CY36	16 557	16 496	119 034	968 764
CY37	16 557	16 496	119 034	968 764
CY38	16 557	16 496	119 034	968 764
CY39	16 557	16 496	119 034	968 764
CY40	16 557	16 496	119 034	968 764
CY41	16 557	16 496	119 034	968 764
CY42	16 557	16 496	119 034	968 764
CY43	16 557	16 496	119 034	968 764
CY44	16 557	16 496	119 034	968 764
CY45	16 557	16 496	119 034	968 764
CY46	16 557	16 496	119 034	968 764
CY47	16 557	16 496	119 034	968 764
CY48	16 557	16 496	119 034	968 764
CY49	16 557	16 496	119 034	968 764
CY50	16 557	16 496	119 034	968 764
CY51-CY128	1 291 423	1 286 708	9 284 675	75 563 592
TOTAL (LOA)	**1 654 290**	**1 635 879**	**11 893 510**	**96 069 097**

4.1.4 Stationary Combustion – Diesel

Diesel consumption will occur in the operation of one fire water pump and three emergency diesel generators during construction years, while four emergency diesel generators will be utilised during operational years. This consumption will either be in line with their intended operation or when conducting tests to ensure their fitness for service.

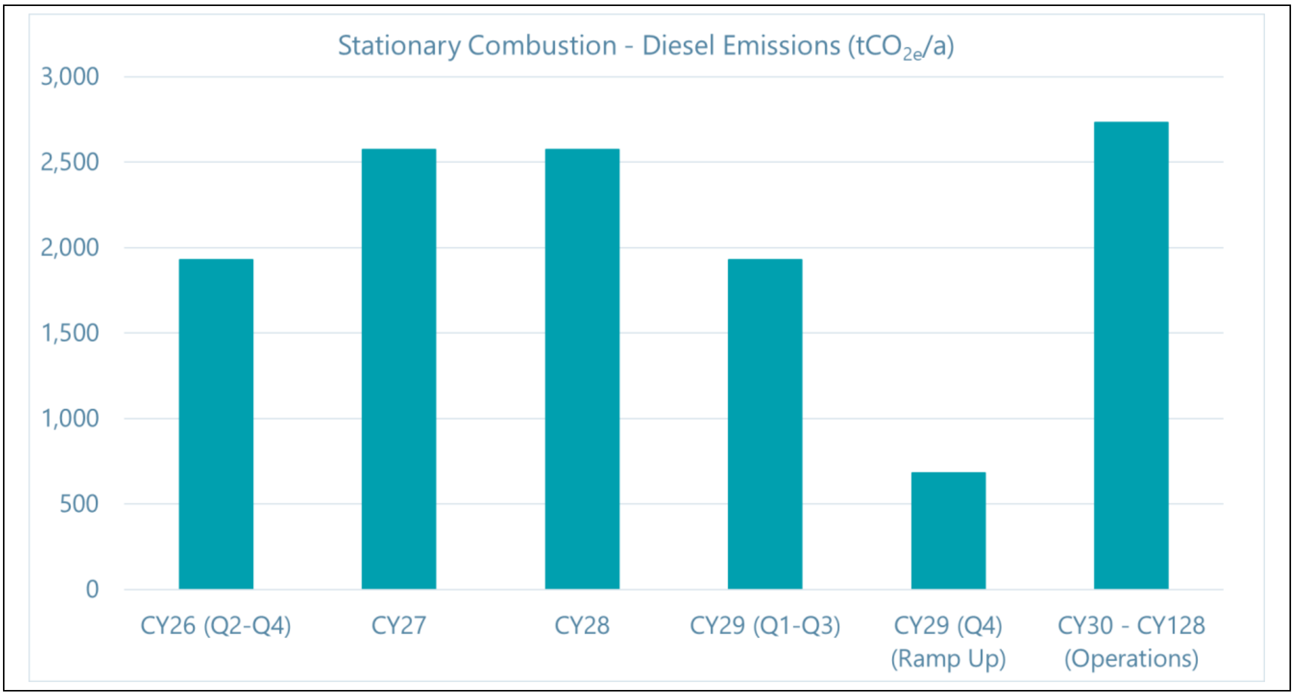
It has been assumed that the diesel fire water pump will have 1% availability (88 h/a). It has been assumed that the emergency diesel generators will be operated on the same basis to ensure operational readiness, i.e. 88 hours a year. In addition, an allowance has been made for annual operations due to power outages.

The emergency diesel generator fuel consumption has been estimated based on an average emergency power demand requirement of 3.0 MW and has been summarised in Table D1.6.

It was assumed that six borefield pumps would be in operation for both construction and operation years (Groundwater Supply Feasibility Study Report – PW_WODPOSC_R00A). The availability of borefield pumps was assumed to be 67% or 5869 hours.

Using the National Greenhouse and Energy Reporting (NGER) emissions factors for the stationary combustion of diesel, specified in Table B1.2 in Appendix B, the CO_{2e} for the stationary combustion of diesel is summarised in Table D1.6 in Appendix D and shown below in Figure 4.5.

Figure 4.5: Annual CO_{2e} Emissions from Stationary Combustion - Diesel (tCO_{2e}/a)



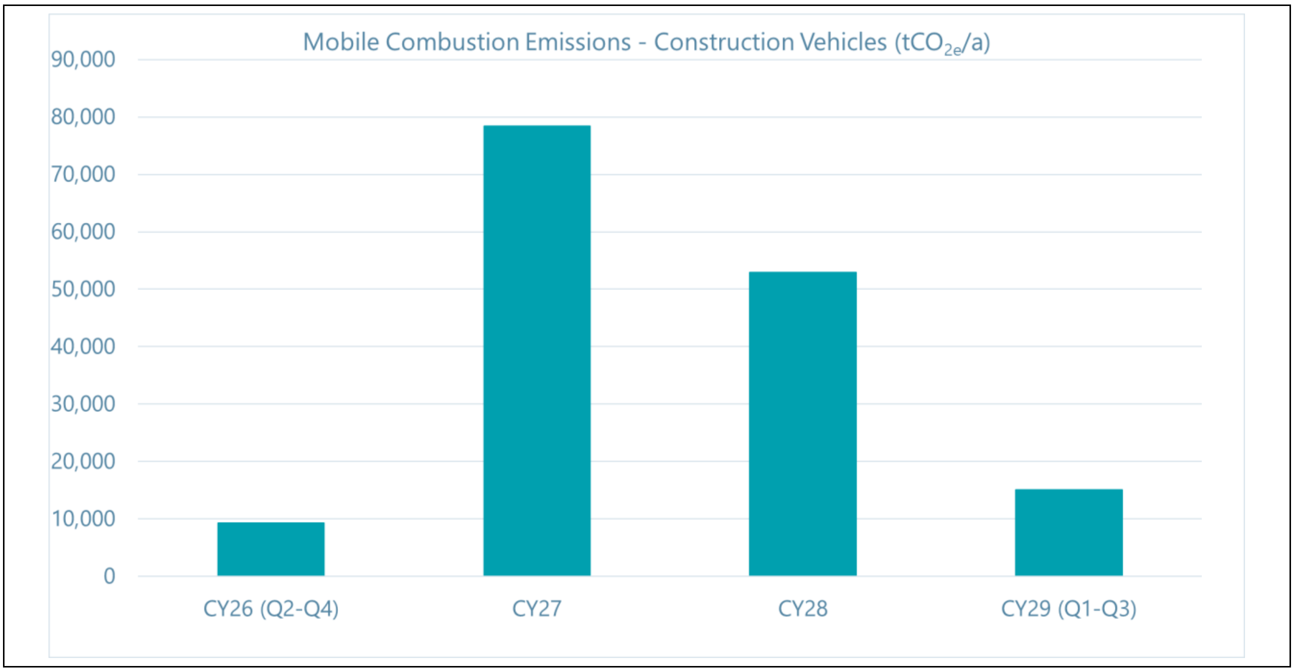
4.1.5 Mobile Combustion – Construction Vehicles

According to the Greenhouse Gas Protocol Corporate Standard, emissions from mobile equipment that is "owned or controlled" are accounted as Scope 1 emissions. That is, mobile equipment that is owned, operated, or leased for the exclusive use on the company's site is considered under the category of Scope 1 emissions.

The emissions estimation assumes that all construction vehicles use diesel. Annual consumption of diesel is either assumed values from the Wood's Database or has been collected from the vehicles' datasheet and specifications. The type of vehicles and machinery for the construction years are provided by PHSG.

Using the NGER emissions factors for the stationary combustion of diesel, specified in Table B1.2 in Appendix B, the CO_{2e} emissions for the mobile combustion of diesel from construction vehicles and machinery are summarised in Table D1.7 and shown below in Figure 4.6.

Figure 4.6: Annual CO_{2e} Emissions from Mobile Combustion – Construction Vehicles and Machinery (tCO_{2e}/a)



4.1.6 Mobile Combustion – Plant Operation Vehicles

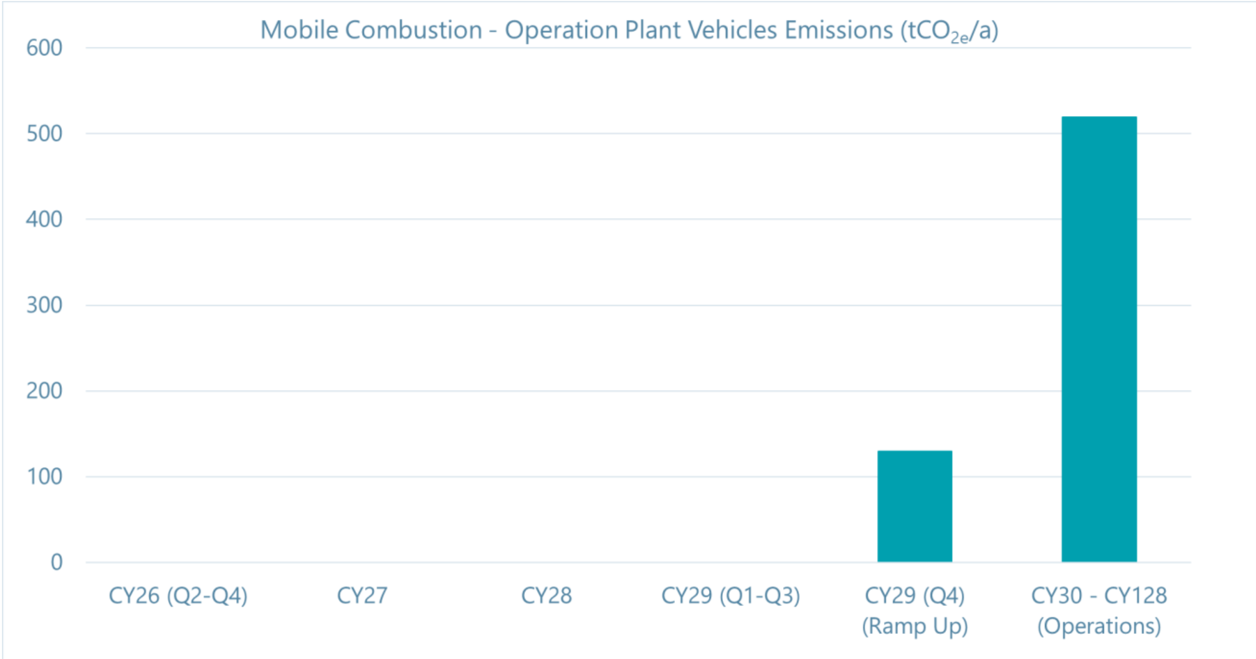
As above, mobile equipment that is owned, operated, or leased for the exclusive use on the company's site is considered under the category of Scope 1 emissions.

For the Base Case Scenario, it has been assumed that all the plant operation vehicles use diesel over Stage 1 of the operation years. Annual consumption of diesel has been calculated using Wood's database. It was assumed that a total of 50 light vehicles (a combination of light trucks, forklifts, cranes, lighting towers, etc.) and six 30-seater buses would be used. Annual consumption of diesel is either assumed values from the Wood's Database or has been collected from the vehicles' datasheet and specifications.

See Appendix E for a discussion of the Greenhouse Gas Protocol Corporate Standard Selected Consolidation approach to mobile equipment.

Using the NGER factors for mobile combustion of diesel, the CO_{2e} for plant operations mobile combustion are summarised in Table B1.2 and Table D1.8 and Table D1.9 in Appendix D and shown below in Figure 4.7.

Figure 4.7: Annual CO_{2e} Emissions from Mobile Combustion – Plant Operation Vehicles (tCO_{2e}/a)



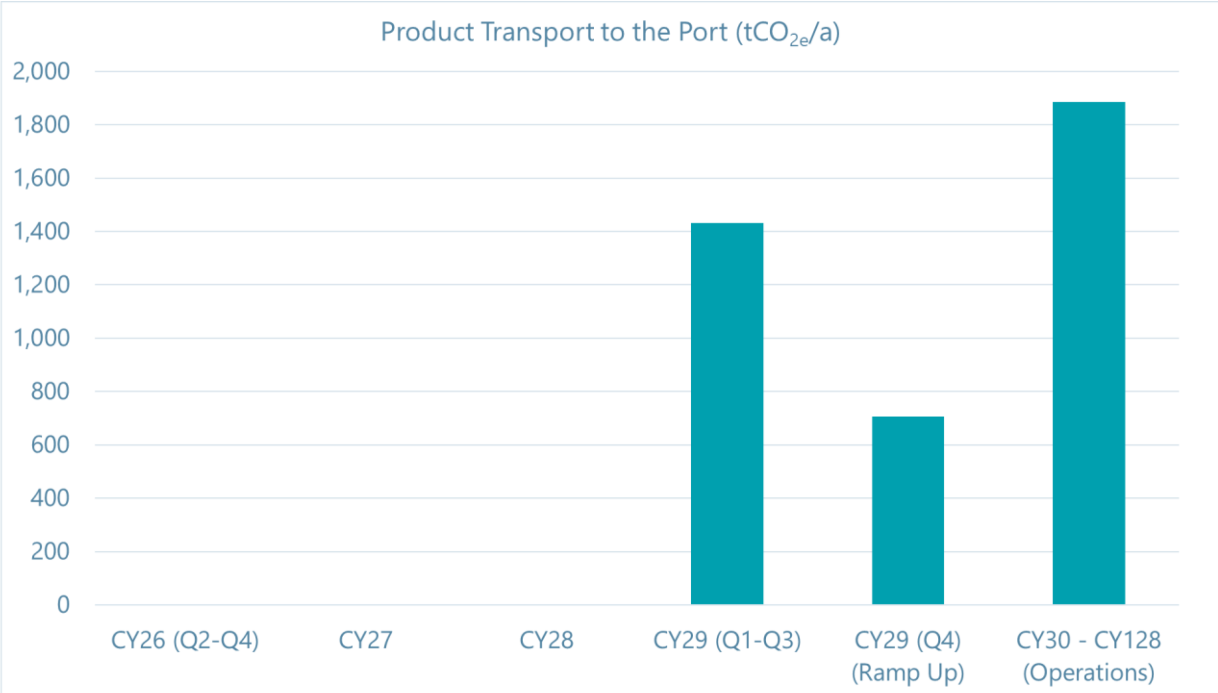
4.1.7 Product Transportation to the Port

The transportation of products (pellets and HBI) from the processing plant to the Lumsden Port and Utah Port is considered as a Scope 1 emission according to the EPA guidance. It is assumed that the products are transported to the port via triple road trains. In the Base Case scenario, diesel consumption by triple road trains contributes to Scope 1 emissions.

The average annual emissions from the transport of products from the processing plant to Lumdsen/Utah Port during the Stage 1 operating phase is approximately **1,886 tCO_{2e}/a**. This is detailed in Table D1.10 in Appendix D and shown below in Figure 4.8.

The emissions reported for product transport in Q1-Q3 CY29 are attributed to pellet production. Additionally, during the ramp-up period, emissions arise from both full pellet production and the production of HBI.

Figure 4.8: Annual CO_{2e} Emissions from the Product Transport to the Port



4.1.8 Biogenic Impact

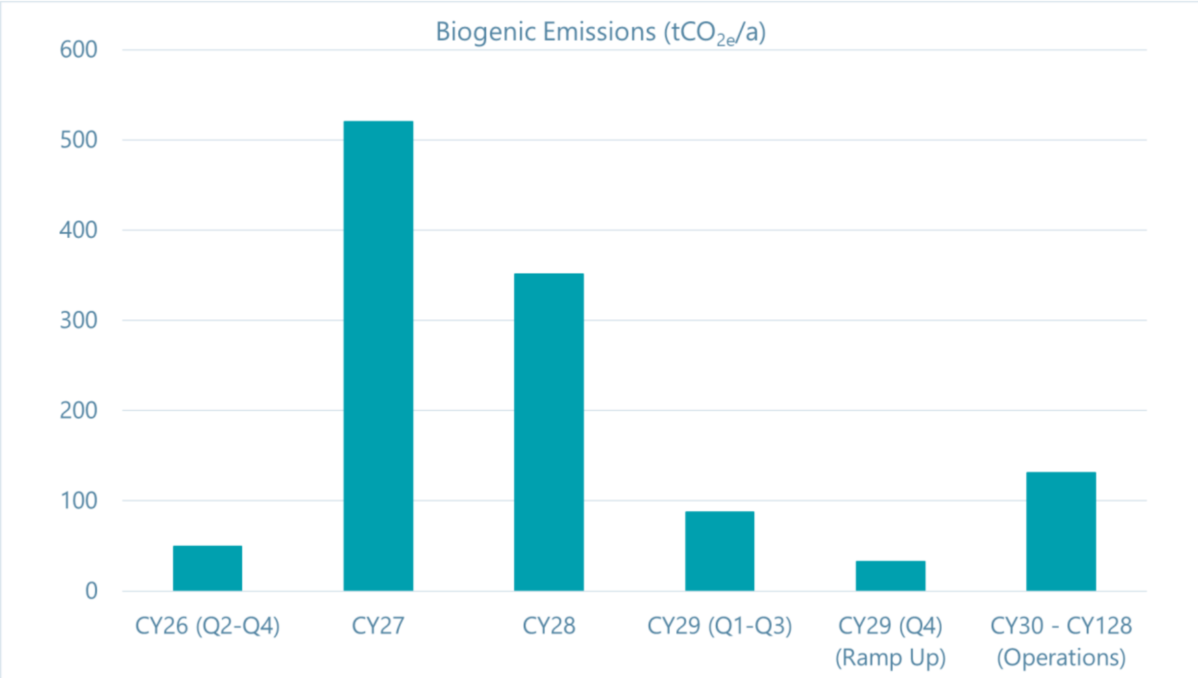
The Project is expected to include a wastewater treatment plant as part of the NPI. An assessment of the biogas emissions has been estimated from the chemical oxygen demand (COD) estimated to be released from wastewater treatment.

The amount of wastewater generated during construction years and an average year of operation has been estimated using the number of personnel on-site during operations specified in Table D1.11.

Using the global warming potential for biogenic methane from the Global Battery Passport [6], the CO_{2e} from wastewater treatment has been calculated and shown in Table D1.11 in Appendix D.

The biogenic emissions will vary over the project life depending on the number of people on-site. During construction, emissions vary depending on the number of personnel on-site while during operation, emissions are expected to be stable at approximately 131.2 tCO_{2e}/a. This is shown below in Figure 4.9.

Figure 4.9: Biogenic Emissions (tCO_{2e}/a)



4.1.9 Summary of Scope 1 Emissions

Table 4.2, Figure 4.10, and Figure 4.11 below summarise the total Scope 1 emissions from the Stage 1 – POSCO PHGS Project.

Table 4.2: Scope 1 Emissions Summary (tCO_{2e}/a)

Emission Source	Construction Emissions (tCO_{2e}/a)				Stage 1 – Operations Emissions (tCO_{2e}/a)		Total Stage 1 Emissions (tCO_{2e})
	CY26 (Q2-Q4)	CY27	CY28	CY29 (Q1-Q3)	CY29 (Q4) Ramp Up	CY30 - CY125	LOA
Land Clearing	30 623	–	–	–	–	–	30 623
Process and Stationary combustion (Natural gas)	–	–	–	90 394	198 108	1 120 851	111 252 777
Stationary Combustion (Diesel)	1 931	2 575	2 575	1 931	684	2 734	280 397
Mobile Combustion – Construction Vehicles (Diesel)	9 303	78 384	52 919	15 044	–	–	155 650
Mobile Combustion – Plant Vehicles (Diesel)	–	–	–	–	130	520	51 583
Product Transport to the Port	–	–	–	1 432	707	1 886	188 808

Table 4.2: Scope 1 Emissions Summary (tCO_{2e}/a)							
Emission Source	**Construction Emissions (tCO_{2e}/a)**				**Stage 1 – Operations Emissions (tCO_{2e}/a)**		**Total Stage 1 Emissions (tCO_{2e})**
	CY26 (Q2-Q4)	**CY27**	**CY28**	**CY29 (Q1-Q3)**	**CY29 (Q4) Ramp Up**	**CY30 - CY125**	**LOA**
Biogenic	49	520	351	88	33	131	14 030
TOTAL (tCO_{2e}/a)	**41 907**	**81 479**	**55 845**	**108 889**	**199 661**	**1 126 122**	**111 973 868**

Figure 4.10: Scope 1 Carbon Emissions Summary (tCO_{2e}/a) – Construction and Ramp-up

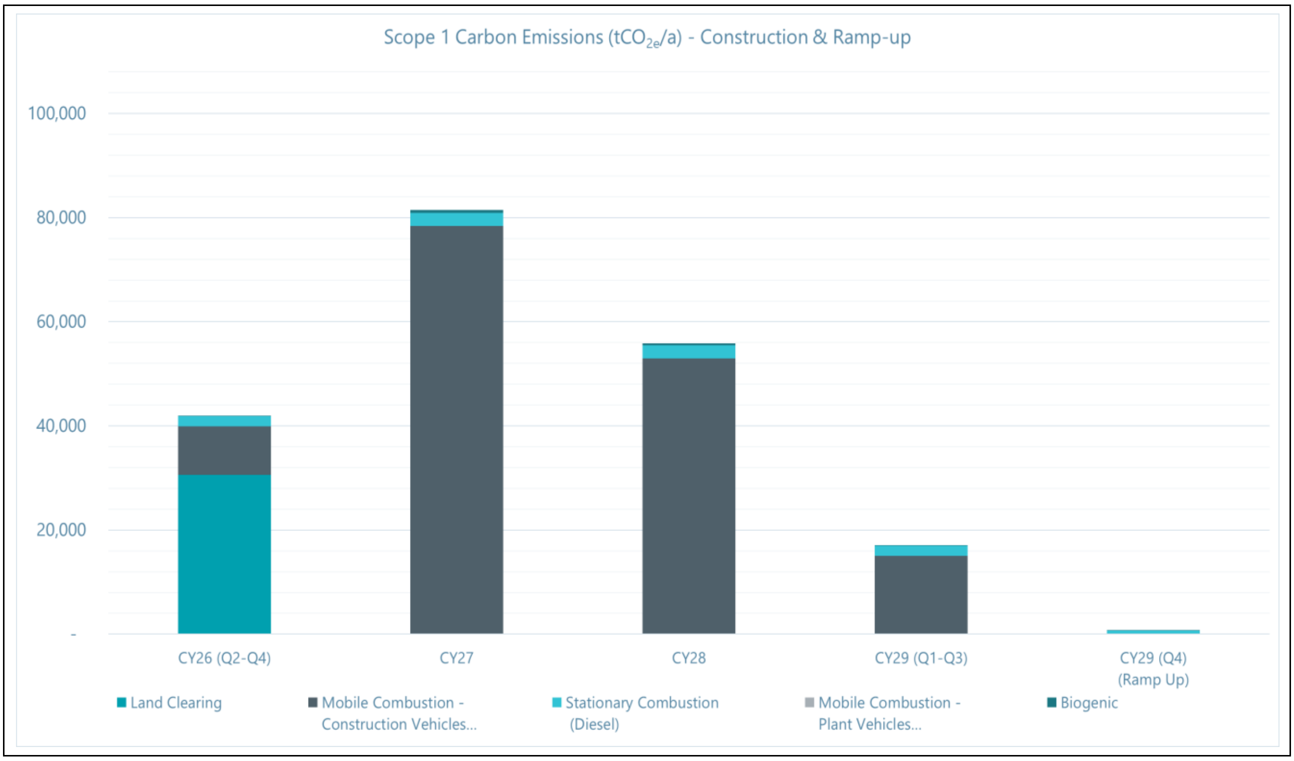
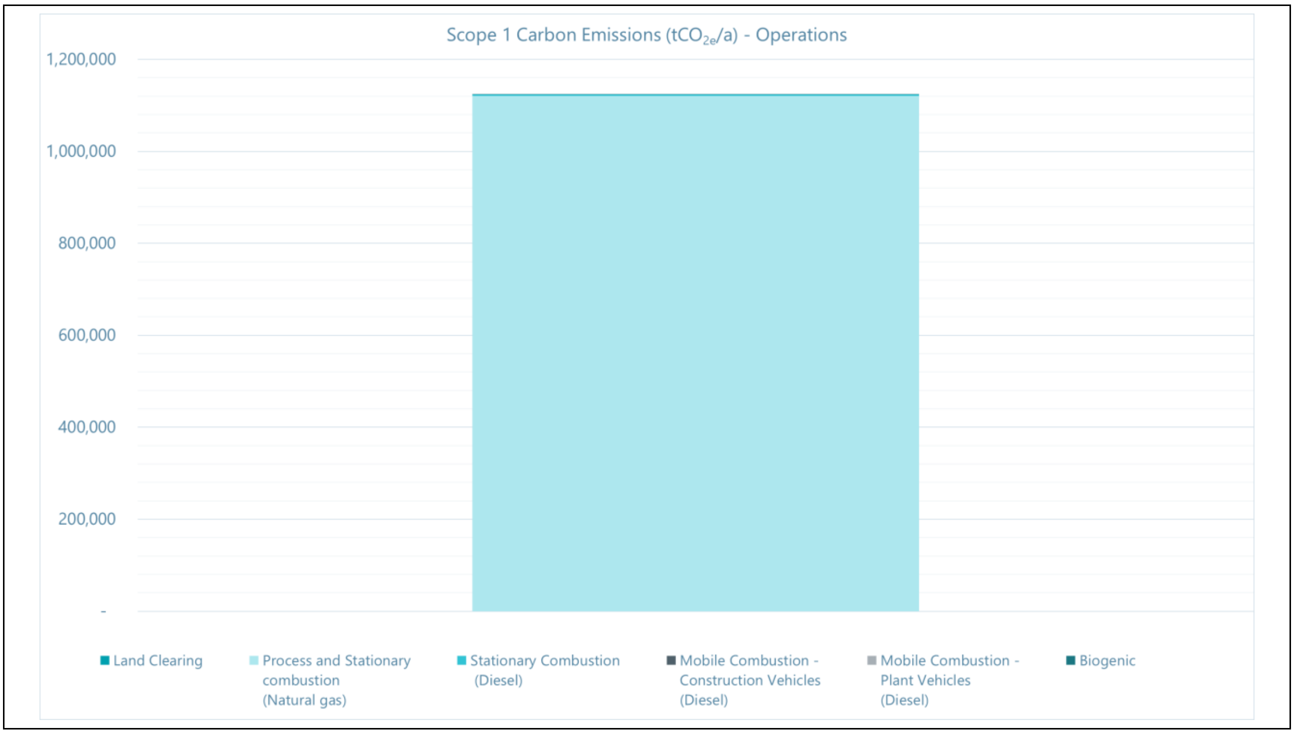


Figure 4.11: Scope 1 Carbon Emissions Summary (tCO_{2e}/a) – Operations



4.2 Scope 2 Emissions

Scope 2 GHG emissions are defined as the emissions from the generation of purchased electricity that is consumed in a Company's owned or controlled equipment or operations. The Scope 2 emissions of the Project are summarised in this section.

4.2.1 Electrical Load

The overall electrical load for the pellet and HBI plant was provided by PHGS. The predicted operating load is current as of October 2023 and is subject to change as the PHGS progresses into the later stages of the Project.

Assumptions applied in this section are detailed in Section 3.6, with operating loads according to plant area shown in Table 4.3. A constant emission factor has been assumed for the purchased power over Stage 1 of operation in the Base Case as confirmed by PHGS. This will exclude any opportunities the power suppliers take to reduce their emissions by introducing renewable energy into their grid.

Table 4.3: Operating Load

Area Description	Total Installed Power (kW)	Area Availability (%)	Annual Operating Hours	Operating MWh/a
Pellet Plant	26 190	90.4	7 919	207 400
HBI Plant	39 744	89.0	7 796	309 860
No. 1 Raw Material Plant	4 698	95.0	8 322	30 097
No. 2 Raw Material Plant	3 672	95.0	8 322	30 558
Other (6.6 kV Load)	4 005	92.0	8 059	32 277

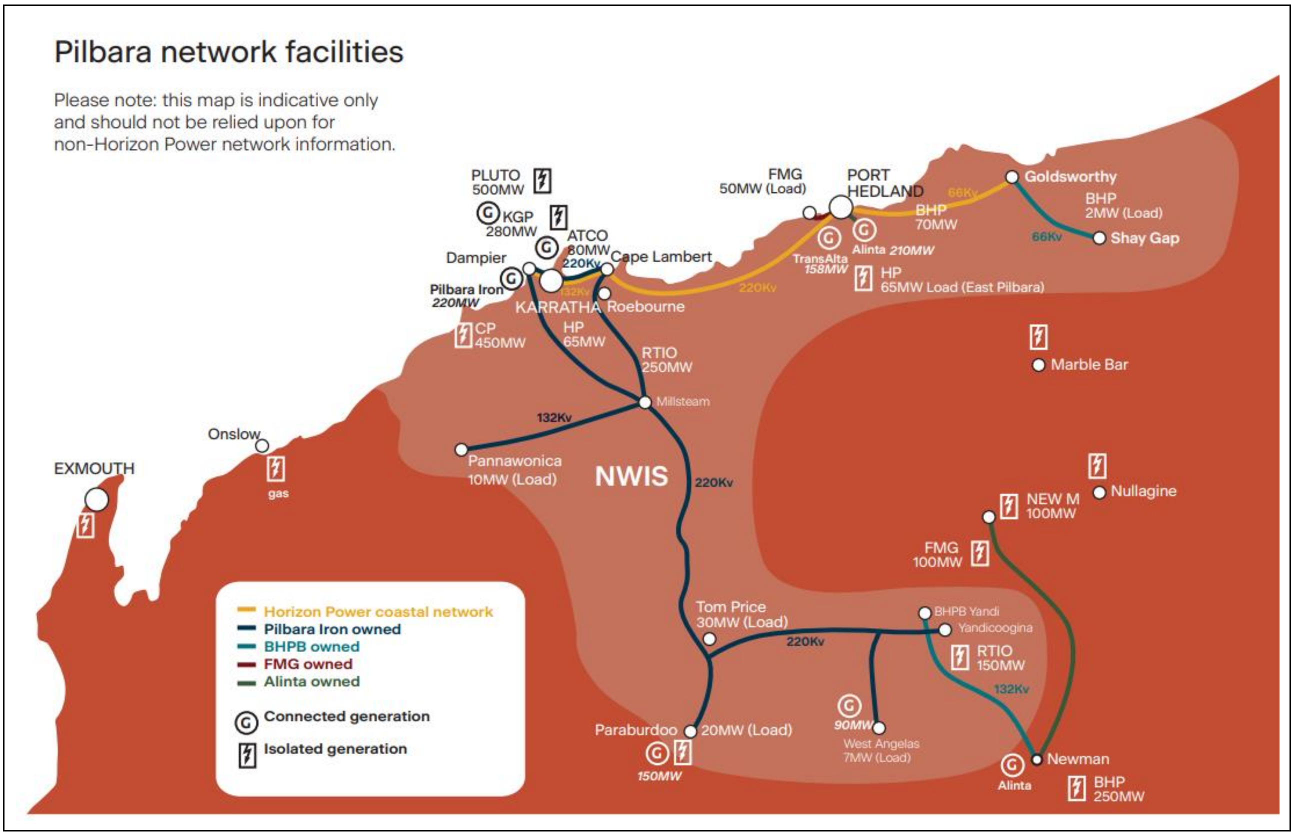
Loss	2 934	92.0	8 059	23 646
TOTAL				**642 838**

4.2.2 Emission Factor for Western Australian Power

The Project will be connected to the Northwest Interconnected System (NWIS) electricity grid in WA, as shown in Figure 4.12 [7] below. The NWIS is currently supplied by non-renewable generation resources (open-circuit or combined-cycle gas-fired turbines).

According to the publicly available information from the power generators, the power supplier has an emissions factor of 0.52 tCO_{2e}/MWh as of 2022 [8].

Figure 4.12: Pilbara Network Facilities



In the Pilbara region, there are ongoing developments and plans for the construction of renewable energy sources, coupled with the expansion of a high-voltage distribution network. Several power providers are dedicated to executing additional renewable energy generation projects and have set ambitious targets to achieve net-zero greenhouse gas emissions by 2050. The emission reduction objectives declared by these power suppliers should be incorporated into the emission factors utilised for Scope 2 emissions once PHGS makes a final decision regarding their power procurement.

Assumptions for power supply emissions factors are described in Section 3.6.

4.2.3 Summary of Scope 2 Emissions

The emissions factor from Section 4.2.2 was used in the calculation of Scope 2 emissions as shown in Table 4.4 below. The calculation has been summarised in Table D1.12 in Appendix D.

Table 4.4: Scope 2 Emissions (tCO_{2e}/a)

Emission Source	Construction Emissions (tCO_{2e}/a)				Stage 1 – Operations Emissions (tCO_{2e}/a)		Total Stage 1 Emissions (tCO_{2e})
	CY26 (Q2-Q4)	CY27	CY28	CY29 (Q1-Q3)	CY29 (Q4) Ramp Up	CY30 - CY128	LOA
Electrical Load (Grid)	–	–	–	71 899	64 700	334 276	33 229 884

4.3 Scope 3 Emissions

Scope 3 GHG emissions are the result of activities from assets not owned or controlled by the reporting company, but that the organisation indirectly affects in its value chain.

The calculation of PHGS' Scope 3 emissions outlined in the assumptions table in Section 3.6 have been included in the scope of this assessment and summarised in this section.

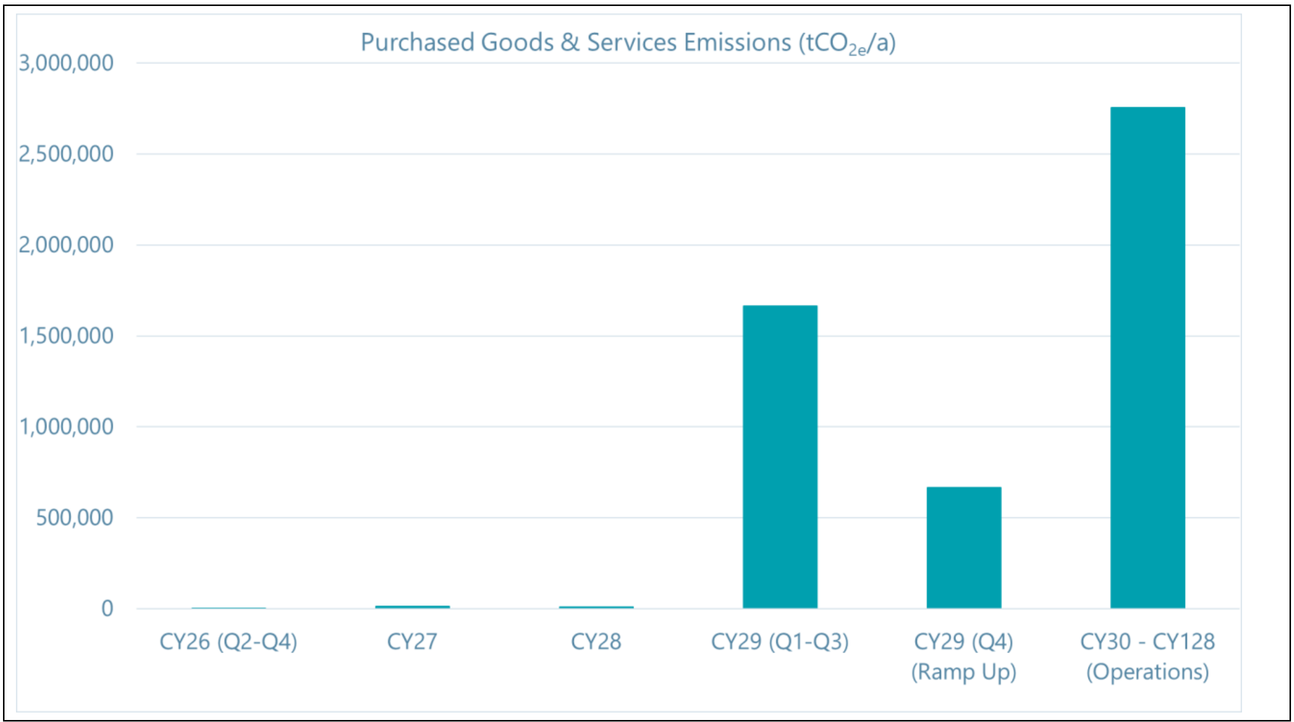
4.3.1 Category 1 – Purchased Goods and Services

The Scope 3 emissions contribution for purchased goods and services has been estimated from the production of reagents used in the PHGS. Emission factors of the reagents were obtained from the suppliers where available or online sources.

Assumptions made regarding the emissions associated with the manufacturing of reagents can be found in Section 3.6. The emissions factors used are shown in Appendix C.

Table D1.13 in Appendix D summarises the Scope 3 emissions from the manufacturing of reagents used in the pellet and HBI plant. Annual emissions are shown below in Figure 4.13.

Figure 4.13: Annual CO_{2e} Emissions from Purchased Goods and Services (tCO_{2e}/a)



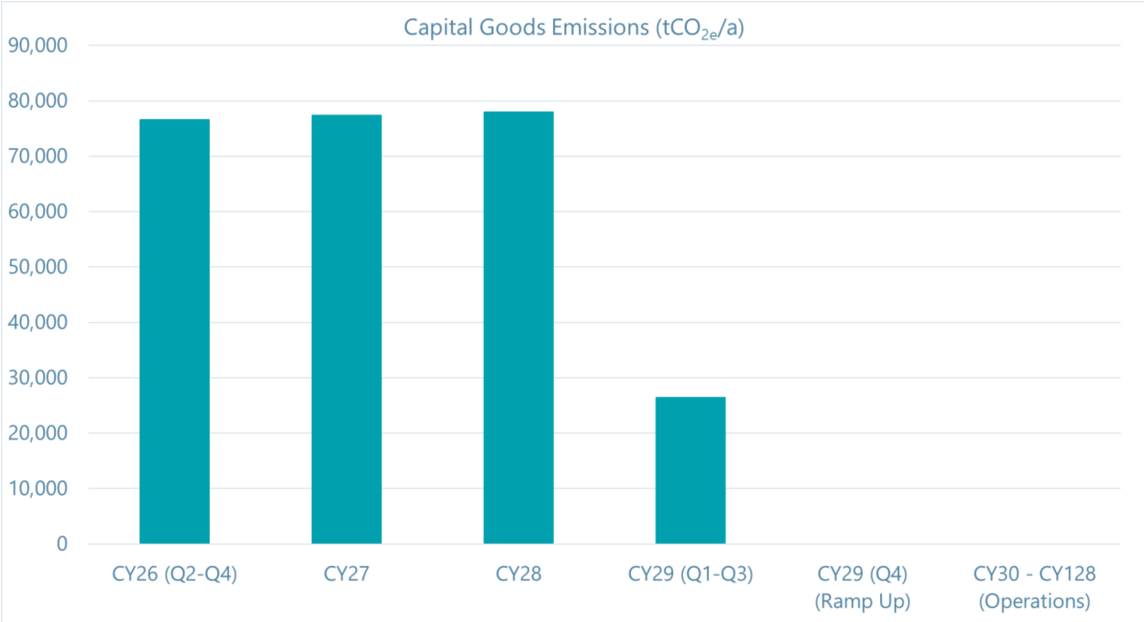
4.3.2 Category 2 – Capital Goods

Indirect emissions from embodied carbon in capital goods purchased (including all vehicles, processing equipment and other infrastructure) have been included. This has been summarised in Table D1.14 in Appendix D.

Annual emissions are shown in Figure 4.14 below. Emissions from the capital goods are evaluated from the following sub-categories:

- Materials used for manufacturing vehicles and machinery utilised during construction and operation years
- Capital goods utilised in the construction phase, including concrete and steel
- Materials used for manufacturing mechanical equipment.

Figure 4.14: Annual CO_{2e} Emissions from Capital Goods (tCO_{2e}/a)



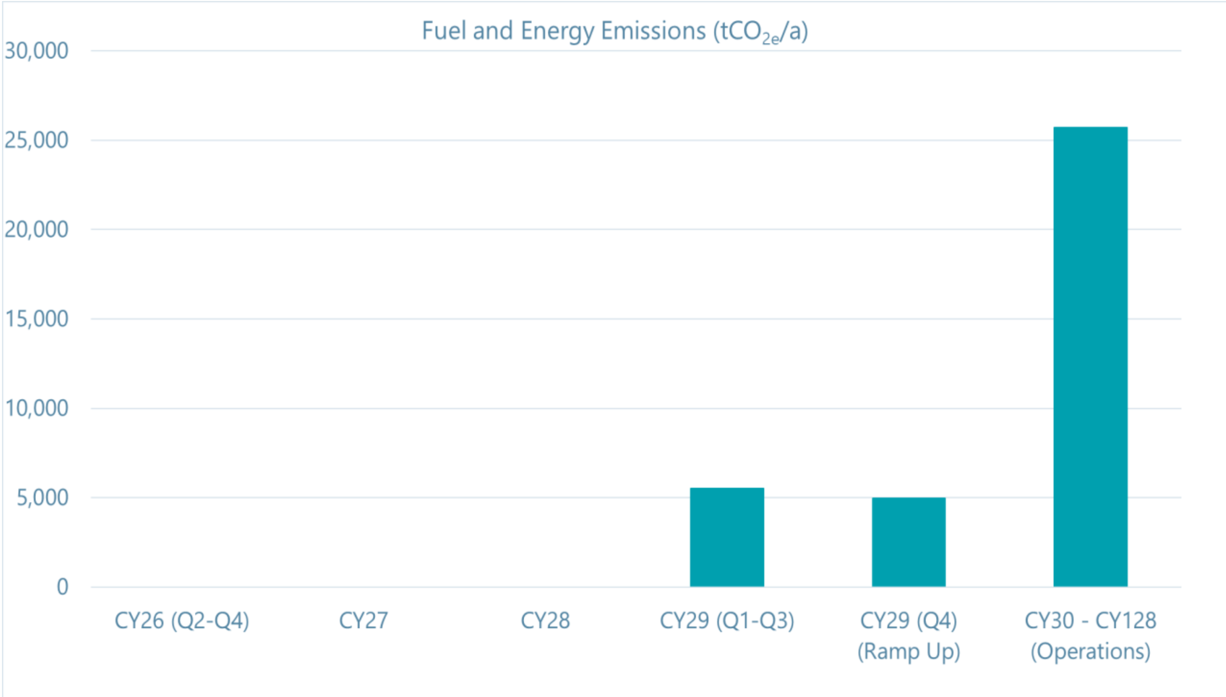
4.3.3 Category 3 – Fuel and Energy

This category includes the emissions from the extraction, production, and transport of fuel burned by companies generating electricity and the emissions attributable to the electricity lost in delivery in the transmission and distribution network.

The Scope 3 emissions factor for the SWIS (0.04 tCO_{2e}/MWh) has been used as there is no reported factor for the NWIS.

Scope 3 – Fuel and energy emissions are shown in Figure 4.15 below and summarised in Table D1.15 in Appendix D.

Figure 4.15: Annual CO_{2e} Emissions from Scope 3 Fuel and Energy (tCO_{2e}/a)

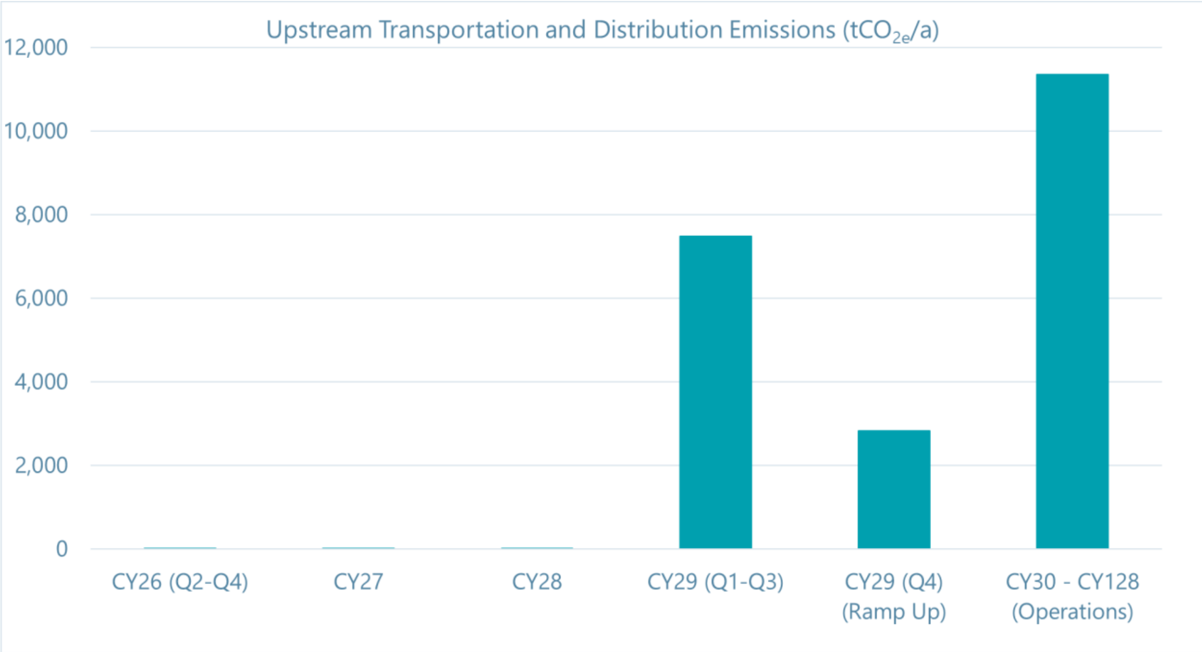


4.3.4 Category 4 – Upstream Transportation and Distribution

Assuming all reagents are traveling from various destinations that are not owned or operated by PHGS in WA, the emissions from this transportation, in addition to the transport of feedstock, will contribute to the Scope 3 emissions. This has been summarised in Table D1.16 in Appendix D.

Scope 3 emissions from upstream transportation of reagents and feedstock are shown in Figure 4.16 below.

Figure 4.16: Annual CO_{2e} Emissions from Upstream Transportation and Distribution (tCO_{2e}/a)

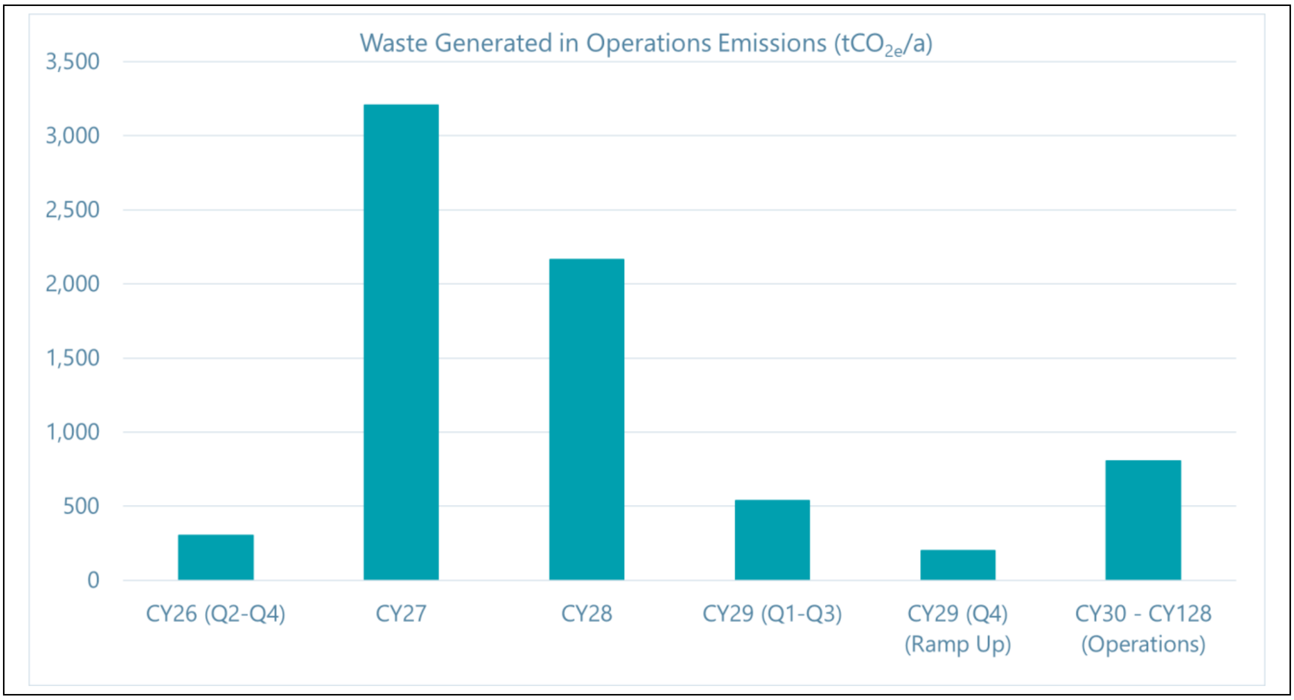


4.3.5 Category 5 – Waste Generated in Operations

This category describes the emissions resulting from the treatment of solid waste generated by the camp accommodation. It has been assumed that there are between 132-1388 people on-site during construction and 350 people on-site during Stage 1 operating phase.

Emissions from waste during construction are approximately **6 216 tCO_{2e} total**, **202 tCO_{2e} total** during ramp-up, and during operations approximately **809 tCO_{2e}/a** during Stage 1 (see Table D1.17 in Appendix D).

Figure 4.17: Annual CO_{2e} Emissions from Waste Generated in Operations (tCO_{2e}/a)



4.3.6 Category 7 – Employee Commuting

The employee commuting to and from Perth to the Project will be done from the Perth Airport and PHGS' airstrip, which is located within close proximity to the village.

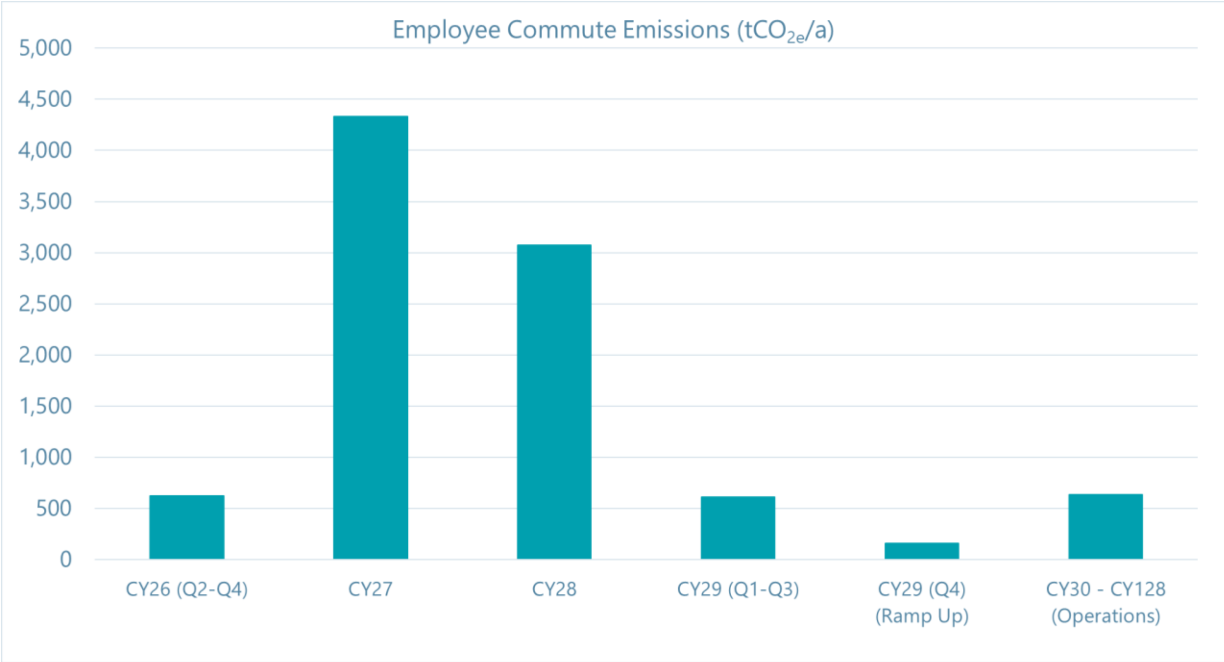
Based on the proposed personnel numbers, roster patterns, and assumptions for visitors, it is assumed that a total of 6370 flights per annum, will be required over the operational phase of the LOA. This is assuming that 90% of occupants will be FIFO on a 8/6 roster.

During the construction phase, it is assumed that there will be approximately between 132-1388 people on-site, resulting in an estimated total of 88 293 flights total over the construction years between 2026 and 2029. It is assuming that all construction personnel will be on 2x1 rosters with 1005 FIFO arrangement.

Employee commuting to and from the mine site and the airport has been assessed based on the proposed site location.

Total emissions for employee commuting during construction are approximately **8 642 tCO_{2e}**, and during operations approximately **635 tCO_{2e}/a,** as shown below in Figure 4.18 (see Table D1.19 in Appendix D).

Figure 4.18: Annual CO_{2e} Emissions from Employee Commute (tCO_{2e}/a)

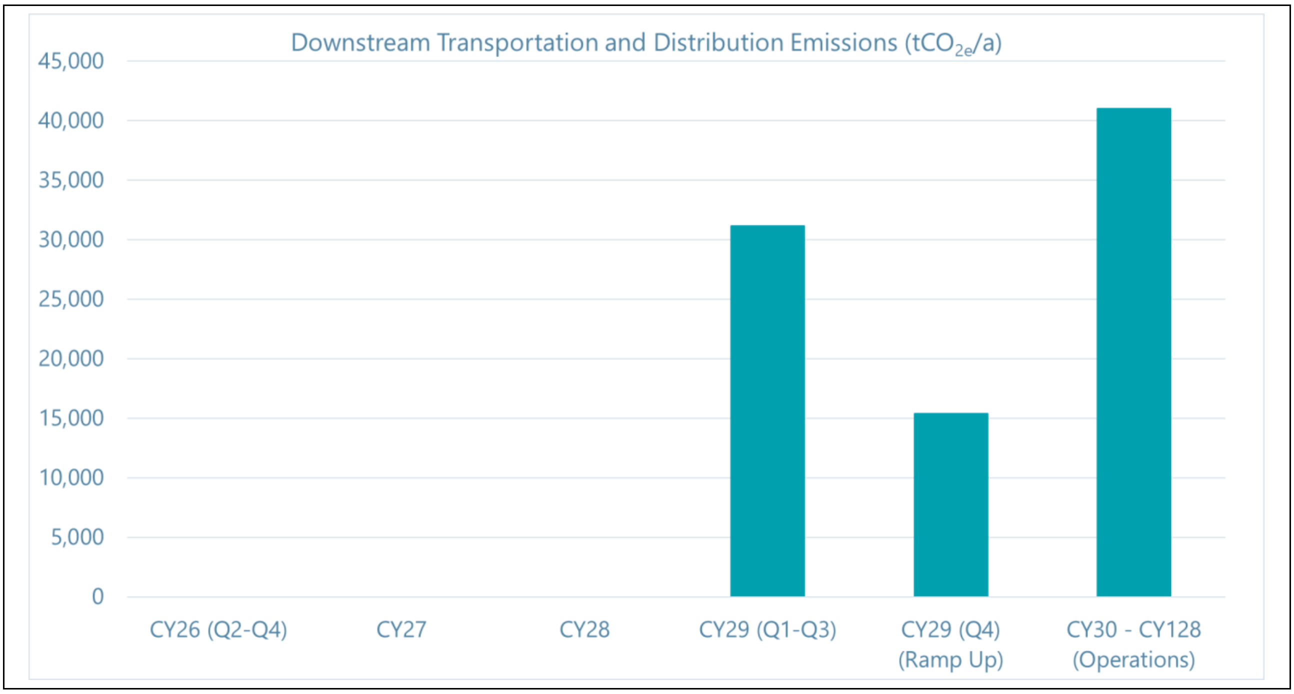


4.3.7 Category 9 – Downstream Transportation and Distribution

The transport of pellets and HBI will be done by shipping. It has been assumed that the product will be shipped to Steel Producers in Japan, South korea and Taiwan via Utah Port and Lumsden Port in a panamax shipping bulk vessel. It should be noted that the transportation of the product from the Project site to the Utah and Lumsden port via road transportation has been considered as part of Scope 1 as per the EPA guidance and the balance of product travel has been calculated as a Scope 3 emission.

The average annual emissions from downstream transportation during the Stage 1 operating phase is approximately **41 022** tCO_{2e}/a. This is detailed in Table D1.20 in Appendix D and shown in Figure 4.19.

Figure 4.19: Annual CO_{2e} Emissions from Downstream Transportation and Distribution (tCO_{2e}/a)

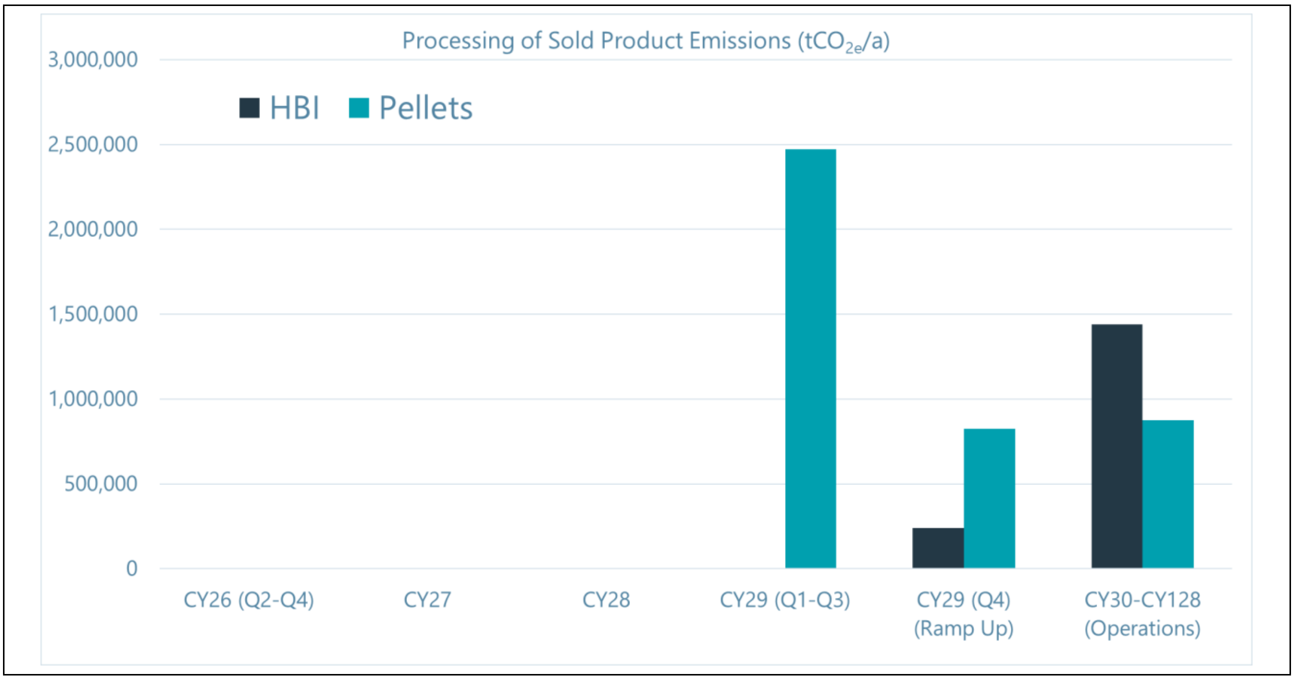


4.3.8 Category 10 – Processing of Sold Products

The processing of HBI product and a fraction of iron pellets that is sold (in the form of pellet) to steel producing companies contributes to PHGS' Scope 3 emissions. The emissions have been calculated based on the GHG emitted to convert HBI or pellets to the final steel product, using an indicative emission factor of 0.72 tCO_{2e}/t HBI and 1.19 tCO_{2e}/tPellet [9]. This has been summarised in Table D1.21 in Appendix D and shown below in Figure 4.20.

The relatively high amount of emissions in Q1-Q3 CY29, is due to the high export rate of pellet product prior to the start up of the HBI plant in CY30. Once the HBI plant is fully operational, the export of surplus pellets, those not used as feed in the HBI plant, will decrease and hence there is a significant reduction in emissions arising from the processing of pellets.

Figure 4.20: Annual CO_{2e} Emissions from Processing of Sold Products (tCO_{2e}/a)



4.3.9 Summary of Scope 3 Emissions

Figure 4.21, Figure 4.22, and Table 4.5 below summarises the Scope 3 emissions from the Project.

Figure 4.21: Scope 3 Emissions Summary (tCO_{2e}/a) – Construction and Ramp-up

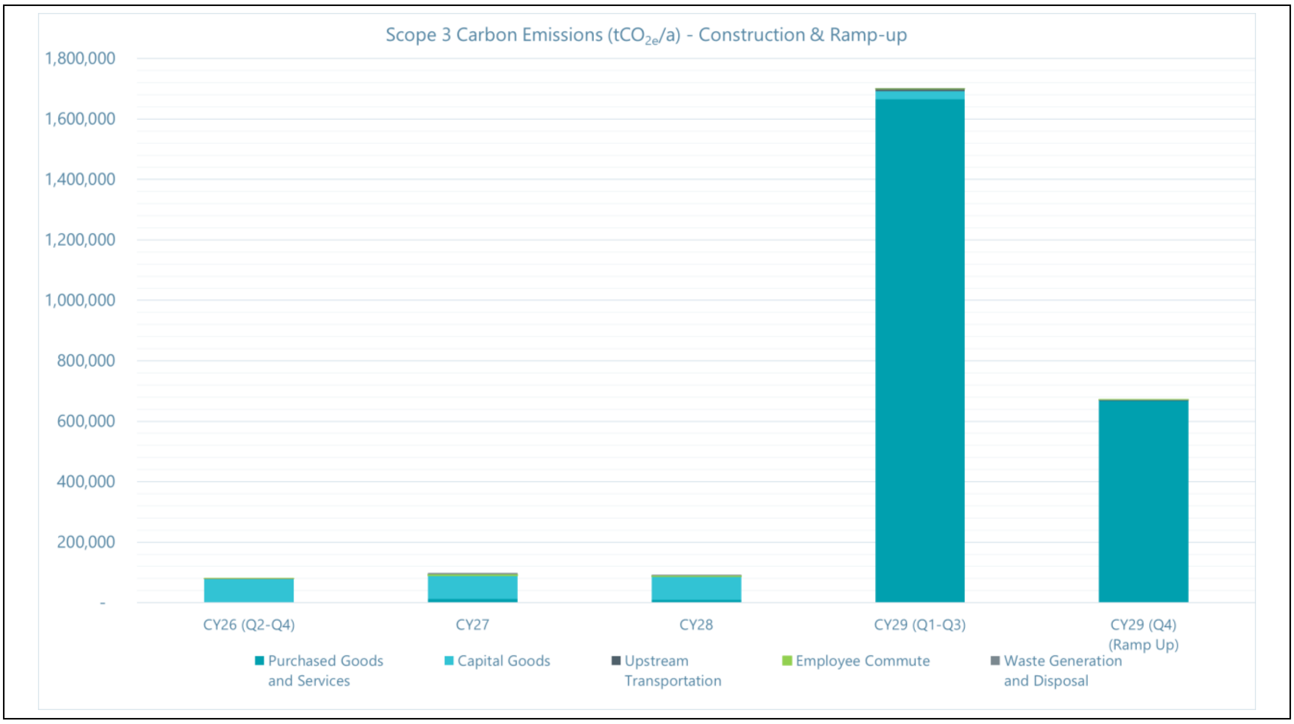


Figure 4.22: Scope 3 Emissions Summary (tCO_{2e}/a) – Operations

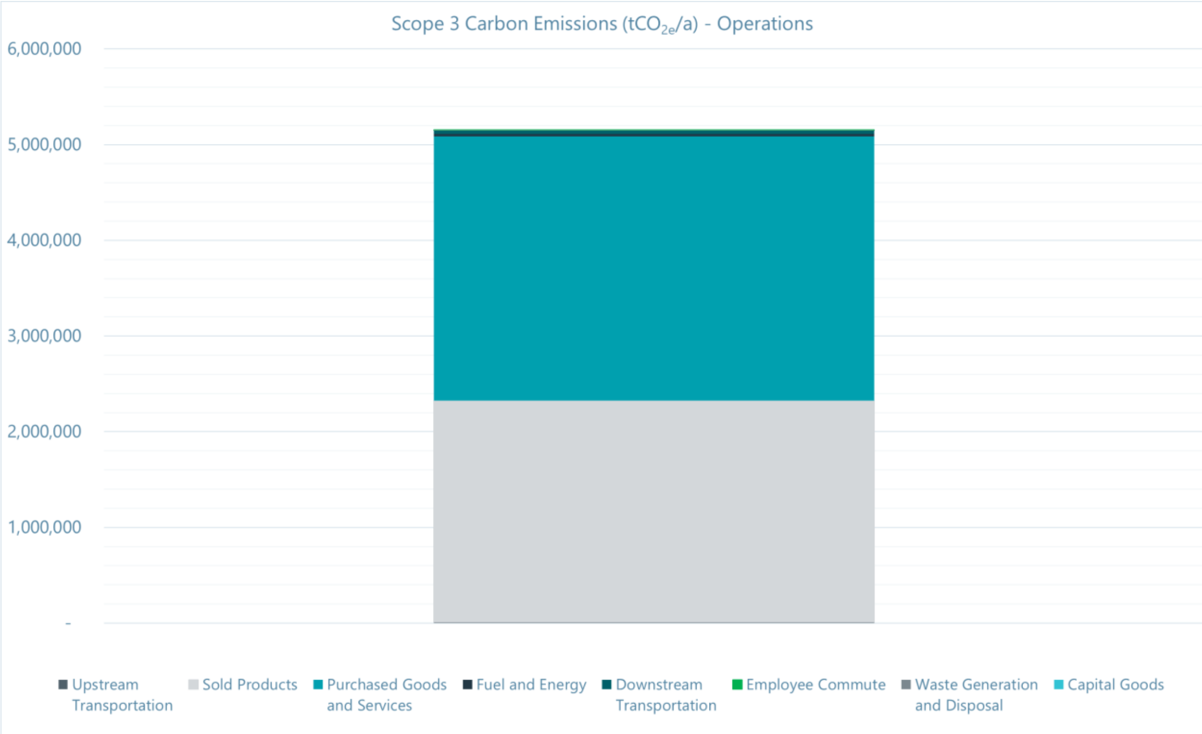


Table 4.5: Scope 3 Emissions Summary (tCO_{2e}/a)

Emission Source	Construction Emissions (tCO_{2e}/a)				Stage 1 – Operations Emissions (tCO_{2e}/a)		Total Stage 1 Emissions (tCO_{2e})
	CY26 (Q2-Q4)	CY27	CY28	CY29 (Q1-Q3)	CY29 (Q4) Ramp Up	CY30 - CY125	LOA
Purchased Goods and Services	1 779	12 820	8 788	1 664 722	667 224	2 756 561	275 254 861
Capital Goods	76 619	77 361	77 999	26 477	–	–	258 456
Fuel and Energy	–	–	–	5 531	4 977	25 714	2 556 145
Upstream Transportation	3	23	16	7 489	2 828	11 353	1 134 278
Waste Generation and Disposal	305	3 206	2 164	541	202	809	86 460
Employee Commute	622	4 333	3 072	614	159	635	71 656
Downstream Transportation	–	–	–	31 158	15 384	41 022	4 107 682
Sold Products	–	–	–	2 473 118	1 064 373	2 315 979	232 819 434
TOTAL	**79 328**	**97 743**	**92 039**	**4 209 650**	**1 755 146**	**5 152 071**	**516 288 972**

5 Emissions Abatement Opportunities

Decarbonisation of the Project requires addressing emissions from multiple sources. This section summarises the areas and opportunities planned by PHGS or assessed by Wood for Scope 1 emissions reduction in the Low-carbon Case.

5.1 Hydrogen Injection to Replace NG

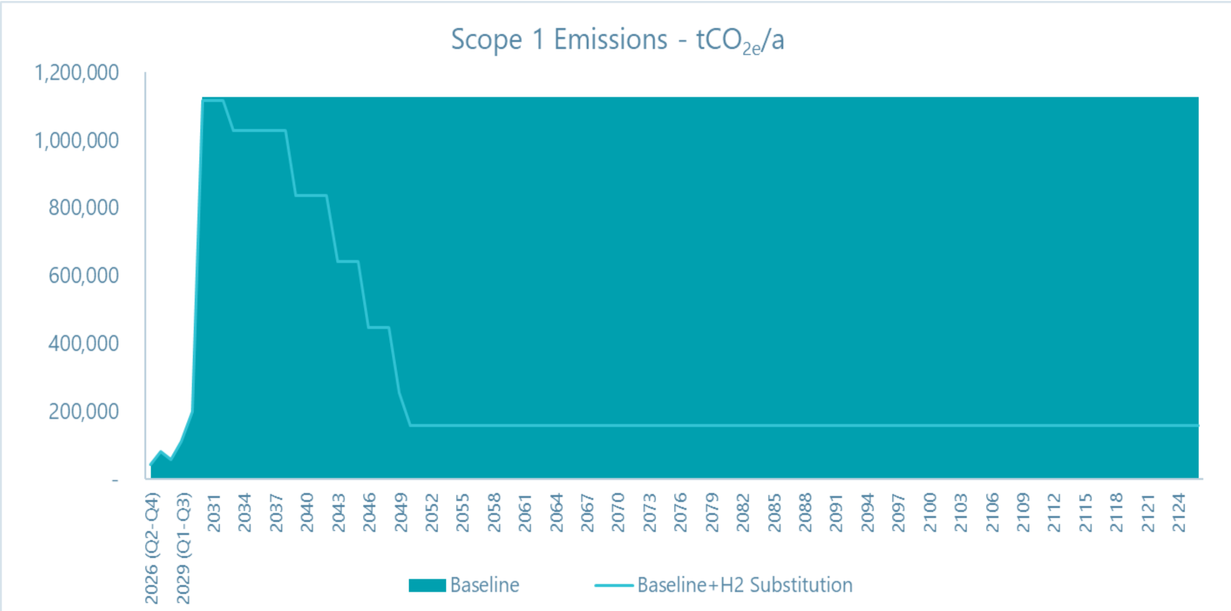
PHGS have taken a strategic approach that involves gradual integration of hydrogen throughout the Project's lifecycle, aimed at significantly mitigating CO_2 footprint associated with HBI production. The proposed schedule for substituting natural gas with hydrogen is outlined in Appendix F.

Table 5.1: HBI Hydrogen Injection Rate

CY	Year	Hydrogen Injection Substitution
CY26 (Q2) – CY29 (Q3)	Y01 – Y04 Construction	0%
CY29 (Q4)	Y01 Ramp Up	0%
CY30 – CY32	Y01- Y03 Operation	1%
CY33 – CY38	Y04 – Y09 Operation	10%
CY39 – CY42	Y10 – Y13 Operation	30%
CY43 – CY45	Y14 – Y16 Operation	50%
CY46 – CY48	Y17 – Y19 Operation	70%
CY49	Y20 Operation	90%
CY50 – CY128	Y21 – Y99 Operation	100%

The integration of hydrogen into the HBI production process results in a significant reduction in HBI plant's CO_2 emissions. According to projections illustrated for Stage 1 Scope 1 emissions in Figure 5.1, the implementation of hydrogen is expected to lead to a clear decrease in carbon emissions over time as opposed to PHGS continuing their production using 100% Natural Gas. The results are summarised in Table F1.1 and Table F1.2 in Appendix F.

Figure 5.1: Total Scope 1 Emissions for Stage 1 – Base Case (100% NG) and Abated Case Using H_2 Injection



5.2 Carbon Capture Storage

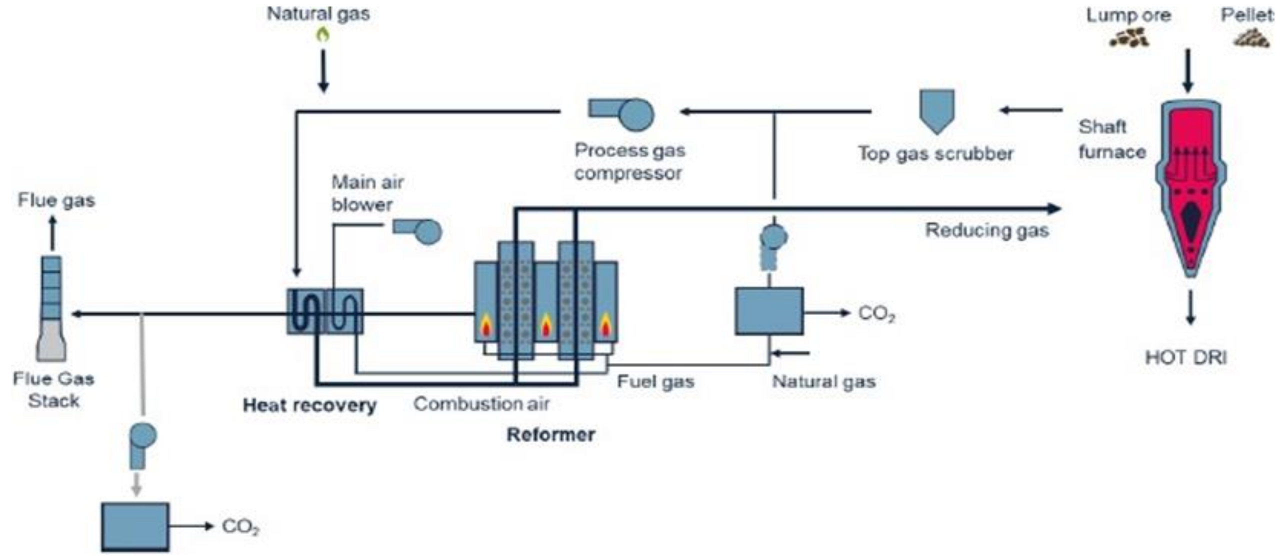
Carbon Capture Storage (CCS) are processes that are able to capture CO_2 emissions and prevent them from being released into the atmosphere. This becomes particularly important for emissions that are difficult to avoid, such as capturing CO_2 released from Midrex process during HBI production.

According the information provided by PHGS and the process licensor, there are two possible points for pre-combustion and post-combustion capture of CO_2 (Figure 5.2).

According to PHGS and the process licensor, top gas fuel separated from the gas can capture up to 44% of the CO_2 before combustion, and post-reformer flue gas can capture up to 84% of the CO_2 before leaving the flue gas stack. In this study, it was assumed that CO_2 is captured after reformer before leaving the flue gas stack.

The reformer flue gas contains approximately 0.92 Mt CO_2 at a concentration of 15%, based on a flow rate of 400 000 Nm^3/hr.

Figure 5.2: Potential CO_2 Capture Points from Modrex Process (HBI Plant)

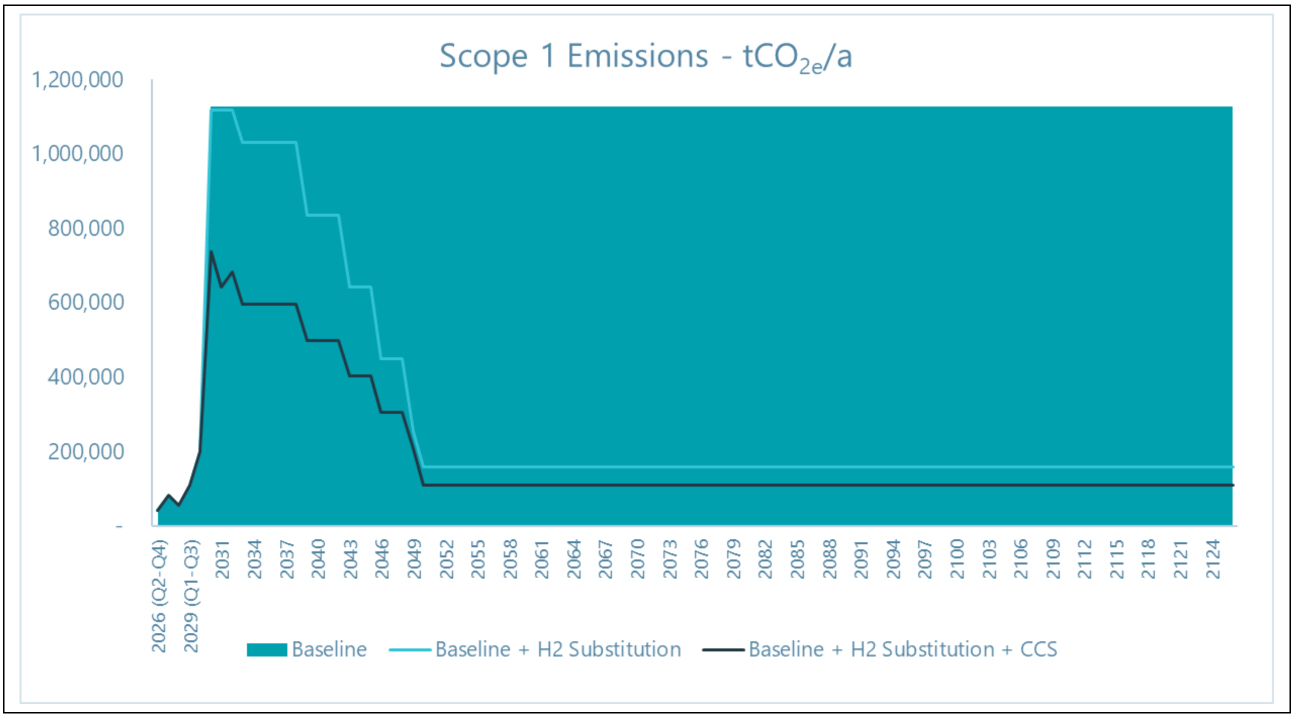


PHGS have provided the CCS rates as tabulated in Table 5.2 below. The application of CCS technology to further reduce emissions, complementing the already abated levels through H_2 substitution, is illustrated in Figure 5.3. The assessment is also provided in Table F1.1 and Table F1.2 in Appendix F.

Table 5.2: HBI Carbon Capture Rate

CY	Year	CCS Rate (tCO_2/a)
CY26 (Q2) – CY29 (Q3)	Y01 – Y04 Construction	0
CY29 (Q4)	Y01 Ramp Up	0
CY30	Y01 Operation	380 952
CY31	Y02 Operation	476 190
CY32 – CY38	Y03 – Y09 Operation	432 900
CY39 – CY42	Y10 – Y13 Operation	336 700
CY43 – CY45	Y14 – Y16 Operation	240 500
CY46 – CY48	Y17 – Y19 Operation	144 300
CY49 – CY128	Y20 – Y99 Operation	48 100

Figure 5.3: Total Scope 1 Emissions for Base Case (100% NG) and Abated Case Using H_2 Injection and CCS



5.3 Electrification of Fleet

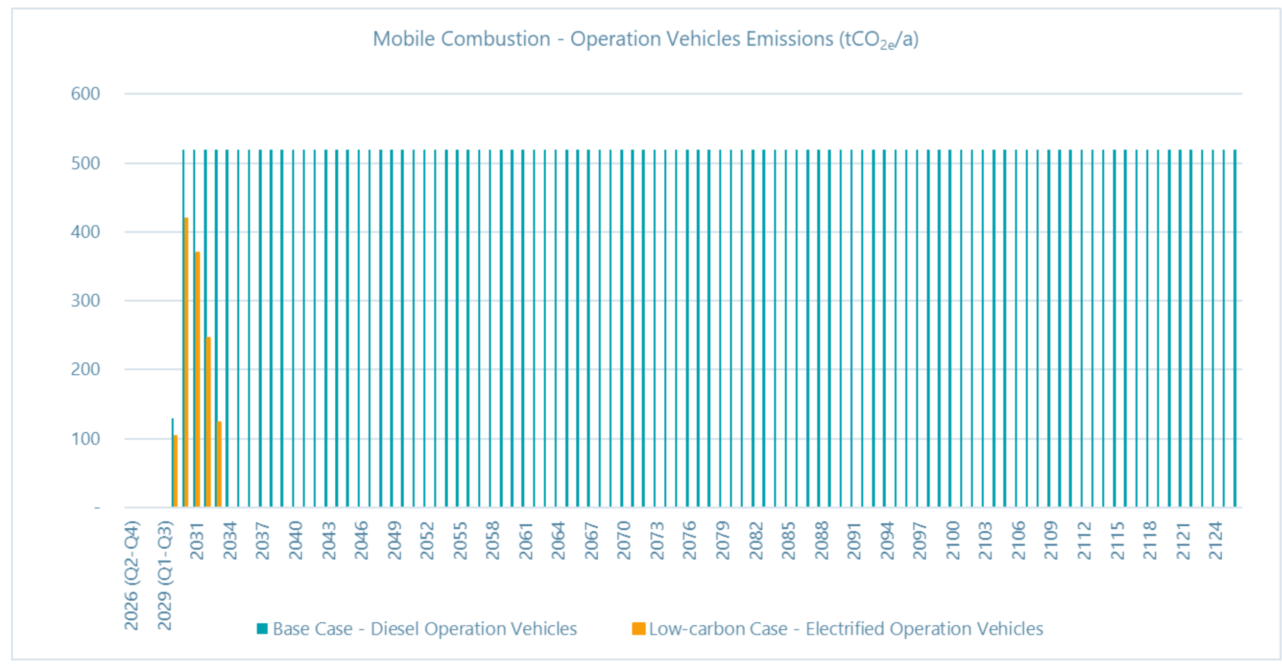
5.3.1 Electrification of Operation Vehicles

Wood have assessed the opportunity to electrify the operating vehicles assuming the following schedule:

- Construction vehicles remain as diesel vehicles throughout construction years
- Operation Vehicles are electrified according to the following schedule:
  - Electric buses from the start of the operation
  - 25% of all vehicles are transitioned to electric vehicles by 2031
  - 100% of all vehicles are transitioned to electric vehicles by 2034.

Figure 5.4 compares CO_{2e} emissions from mobile combustion for the Base Case and Low-carbon Case. No carbon is expected to be emitted from operation vehicles in the Low-carbon Case after CY34 as vehicles will be electrified.

Figure 5.4: Mobile Combustion – Operation Vehicles Emissions (tCO_{2e}/a)



Electrifying vehicles results in a higher operating load (i.e. higher electricity power consumption). This has been taken into account in the Scope 2 emissions calculations for the Low-carbon Case.

5.3.2 Electrification of Product Transport Fleet

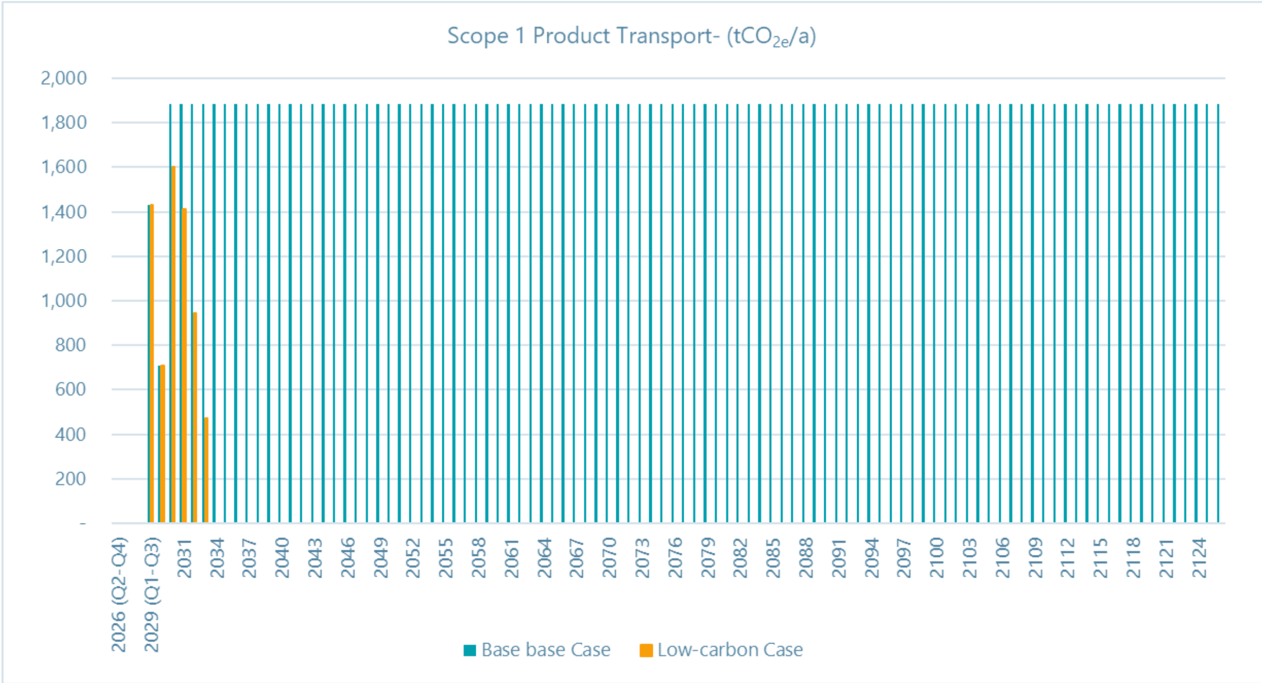
The products (iron pellets and HBI) are transported via triple road trains to Utah Port and Lumsden Port from the processing plant. Wood have assessed the opportunity where road trains are electrified over the time to decarbonise the product transportation. The product will be shipped via Panamax vessels from Lumsden Port to Asian steel producers.

The vehicle electrification is scheduled as per the following assumptions:

- 25% of all vehicles are transitioned to electric vehicles by 2031
- 100% of all vehicles are transitioned to electric vehicles by 2034.

Figure 5.5 provides a comparison for the Scope 1 production transportation for the Base Case and Low-carbon Case.

Figure 5.5: Scope 1 Product Transport Emissions tCO_{2e}/a – Base Case and Low-carbon Case



5.4 Using Less Emission Intensive Electricity

Renewable energy sources are being constructed or planned in the Pilbara along with an expanded high-voltage distribution network. Power suppliers have commitments/agreements in place to implement more renewable energy generation projects and aim for net zero GHG emissions by 2050 [10].

The emissions factors used to calculate the Scope 2 emissions over the LOA are depicted in Figure 5.6 for the Base Case and Low-carbon Case.

Figure 5.6: Electricity Production Emission Factor (tCO_{2e}/MWh)

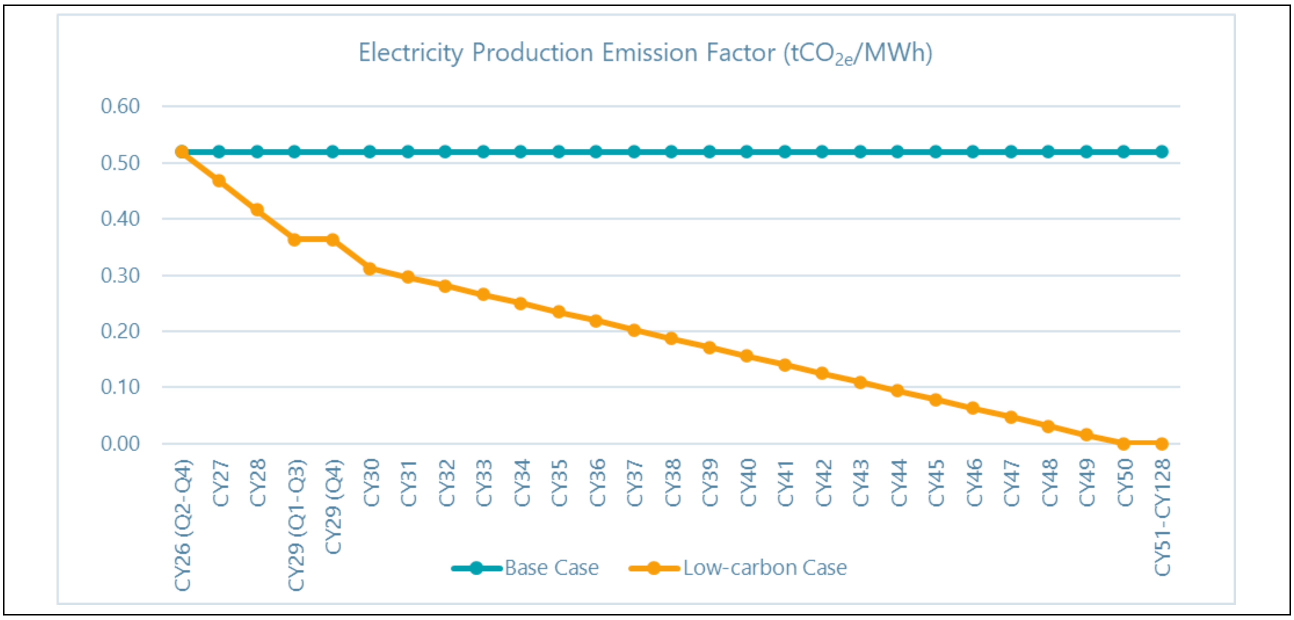
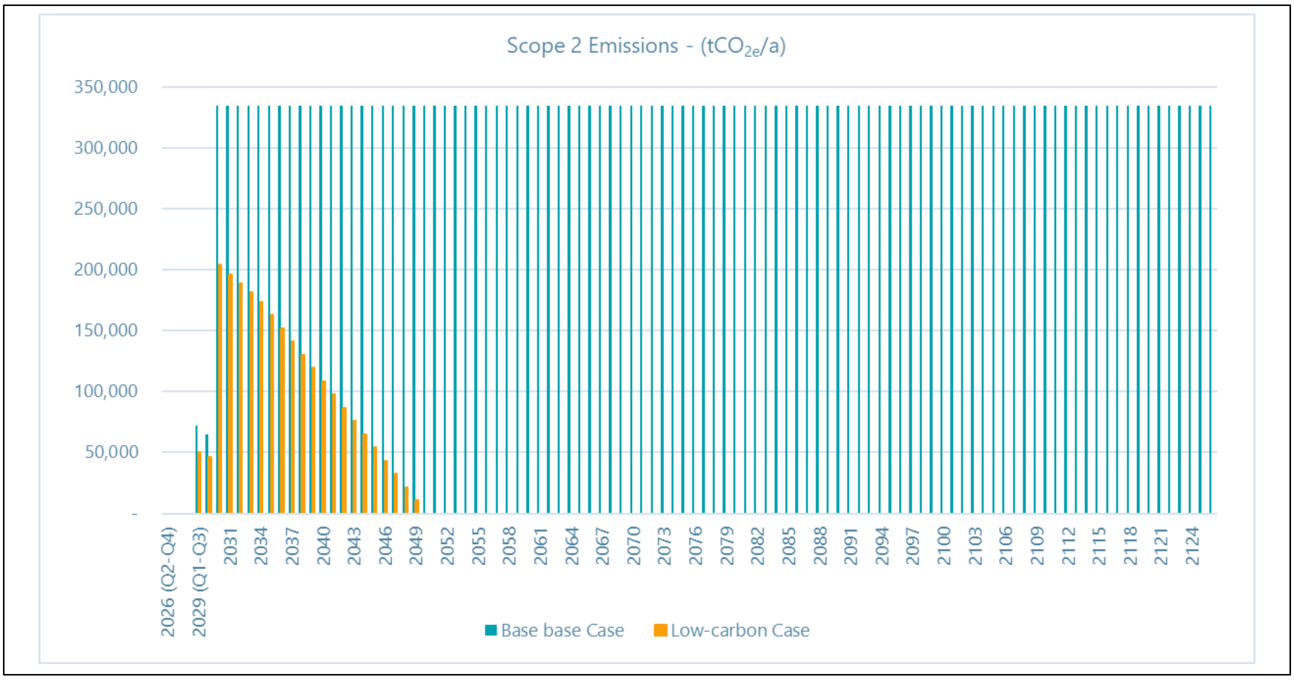


Figure 5.7 depicts the Scope 2 emissions for the Base Case (where the EF remains constant throughout the LOA) and Low-carbon Case (where the EF reduces over the year as per the power supplier's commitment).

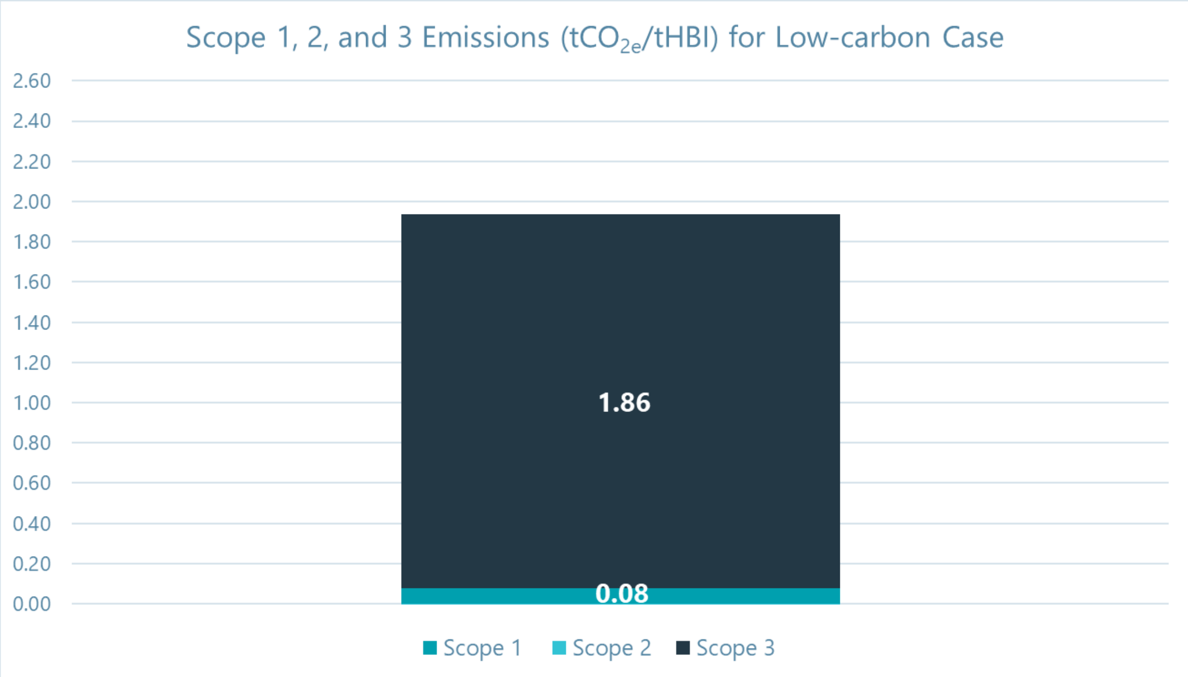
Figure 5.7: Scope 2 Emissions tCO_{2e}/a – Base Case and Low-carbon Case



5.5 Product Emissione Intensity of Low-carbon Case

Integration of emissions abatement opportunities results in lower emission intensive products as shown in Figure 5.8.

Figure 5.8: Average Annual Carbon Intensity ($tCO_{2e}/tHBI$) (Scope 1, 2, and 3) for Low-carbon Case



5.6 Other Abatement Opportunities

In addition to the decarbonisation strategies evaluated in the previous sections, there are other opportunities that can be assessed in the future, especially for abating Scope 3 emissions. At a very high-level, some of these opportunities are listed below:

- Waste heat recovery
- Optimising equipment choice, redundancy and sizing
- Sustainable buildings
- Using less emission intensive reagents
- Using green ammonia or biofules for bulk transport via shipping
- Using sustainable aviation fuel.

6 Emissions Summary

The total Scope 1, Scope 2, and Scope 3 emissions during construction years and Stage 1 – operation years from the Project Base Case have been summarised below in Table 6.1, Figure 6.1 and Figure 6.2.

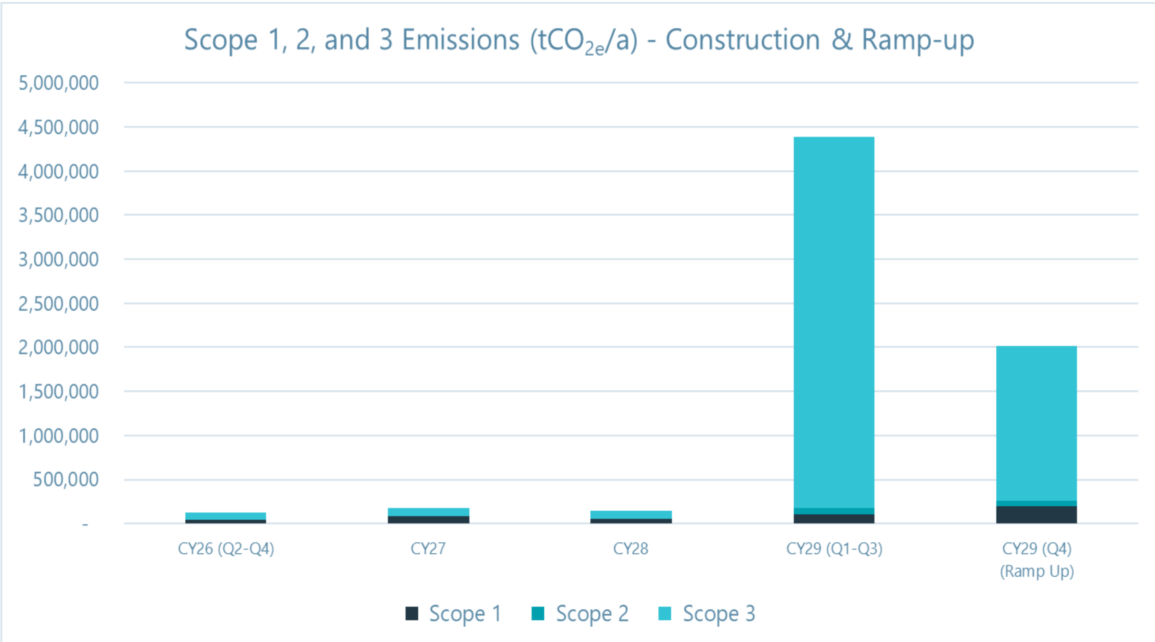
The carbon intensity from each category is shown for an average operation year in Table 6.2 and Figure 6.3 for HBI and in Figure 6.4 for pellets.

Table 6.1: Total Carbon Emissions over LOA (tCO_{2e}/a)

Emission Category	Emission Source	Construction Emissions (tCO2e/a)			Stage 1 – Operation Emissions	Total Stage 1 Emissions	
		CY25	CY26	CY27 1H	CY27 2H	CY28-CY125	LOA
Scope 1	Land Clearing	30 623	–	–	–	–	30 623
	Process and Stationary combustion (Natural gas)	–	–	–	90 394	198 108	111 252 777
	Stationary Combustion (Diesel)	1 931	2 575	2 575	1 931	684	280 397
	Mobile Combustion – Construction Vehicles (Diesel)	9 303	78 384	52 919	15 044	–	155 650
	Mobile Combustion – Plant Vehicles (Diesel)	–	–	–	–	130	51 583
	Product Transport to the Port	–	–	–	1 432	707	188 808
	Biogenic	49	520	351	88	33	14 030
Scope 2	Stationary Electrical Load	–	–	–	71 899	64 700	33 229 884
Scope 3	Purchased Goods and Services	1 779	12 820	8 788	1 664 722	667 224	275 254 861
	Capital Goods	76 619	77 361	77 999	26 477	–	258 456
	Fuel and Energy	–	–	–	5 531	4 977	2 556 145
	Upstream Transportation	3	23	16	7 489	2 828	1 134 278
	Waste Generation and Disposal	305	3 206	2 164	541	202	86 460
	Employee Commute	622	4 333	3 072	614	159	71 656

Table 6.1: Total Carbon Emissions over LOA (tCO_{2e}/a)							
Emission Category	**Emission Source**	**Construction Emissions (tCO2e/a)**			**Stage 1 – Operation Emissions**	**Total Stage 1 Emissions**	
		CY25	**CY26**	**CY27 1H**	**CY27 2H**	**CY28-CY125**	**LOA**
	Downstream Transportation	–	–	–	31 158	15 384	4 107 682
	Sold Products	–	–	–	2 473 118	1 064 373	232 819 434
	TOTAL (Scope 1 + 2)	**41 907**	**81 479**	**55 845**	**180 788**	**264 361**	**145 203 752**
	TOTAL (Scope 1 +2 +3)	**121 235**	**179 222**	**147 884**	**4 390 437**	**2 019 507**	**661 492 724**

Figure 6.1: Carbon Emissions: Scope 1, 2, and 3 (tCO_{2e}/a) – Construction and Ramp-up



Note that there are no Scope 2 emissions during the construction phase as it is assumed that there will be no connection to the grid and everything will be connected to a diesel generator.

Figure 6.2: Carbon Emissions: Scope 1, 2, and 3 (tCO_{2e}/a) – Operations

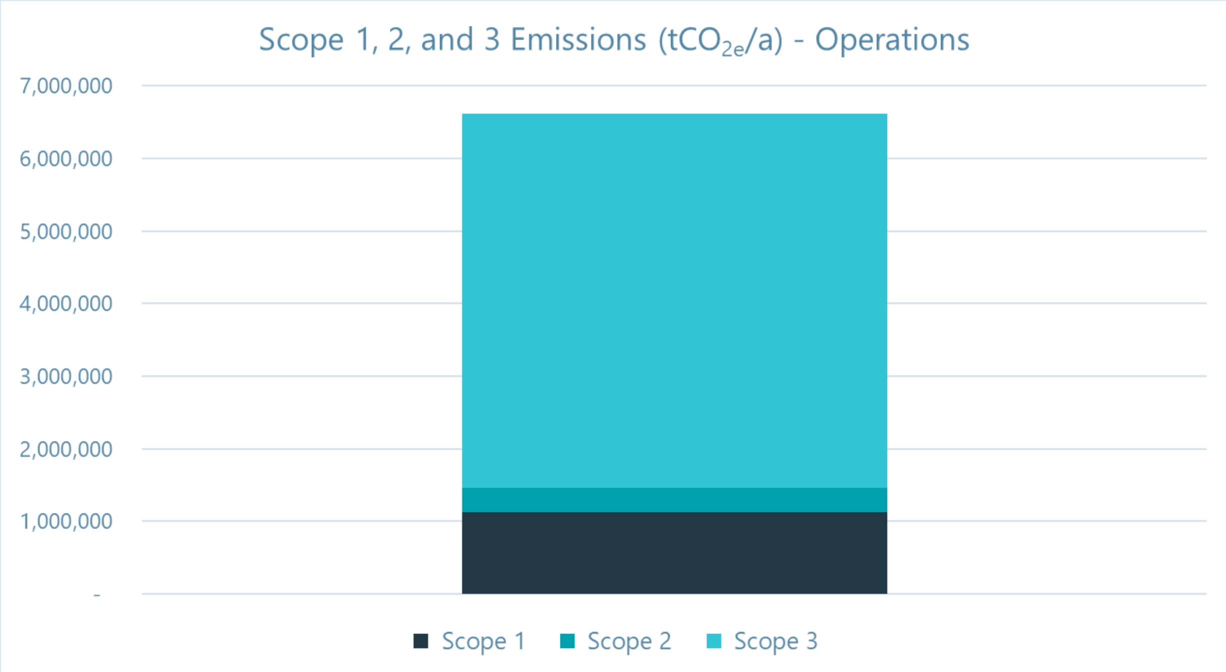


Table 6.2: Average Carbon Intensity ($tCO_{2e}/tHBI$)

Emission Category	Emission Source	Emission Intensity ($tCO_{2e}/tHBI$)	
Scope 1	Land Clearing	–	0.55
	Process and Stationary Combustion (Natural gas)	0.55	
	Stationary Combustion (Diesel)	0.0012	
	Mobile Combustion – Construction Vehicles (Diesel)		
	Mobile Combustion – Plant Vehicles (Diesel)	0.0002	
	Product Transport to the Port	0.0013	
	Biogenic	0.0001	
Scope 2	Stationary Electrical Load	0.16	0.16
Scope 3	Purchased Goods and Services	1.12	1.87
	Capital Goods	–	
	Fuel and Energy	0.012	
	Upstream Transportation	0.004	
	Waste Generation and Disposal	0.00036	
	Employee Commute	0.00028	
	Downstream Transportation	0.02	
	Sold Products	0.72	

Table 6.2: Average Carbon Intensity ($tCO_{2e}/tHBI$)			
Emission Category	**Emission Source**	**Emission Intensity ($tCO_{2e}/tHBI$)**	
TOTAL (Scope 1 + 2)			**0.70**
TOTAL (Scope 1 +2 +3)			**2.57**

Table 6.3: Average Carbon Intensity ($tCO_{2e}/tPellet$)			
Emission Category	**Emission Source**	**Emission Intensity ($tCO_{2e}/tPellet$)**	
Scope 1	Land Clearing	–	0.04
	Process and Stationary Combustion (Natural gas)	0.04	
	Stationary Combustion (Diesel)	0.0004	
	Mobile Combustion – Construction Vehicles (Diesel)	–	
	Mobile Combustion – Plant Vehicles (Diesel)	0.0001	
	Product Transport to the Port	0.0002	
	Biogenic	0.00002	
Scope 2	Stationary Electrical Load	0.03	0.03
Scope 3	Purchased Goods and Services	0.709	1.92
	Capital Goods		
	Fuel and Energy	0.002	
	Upstream Transportation	0.003	
	Waste Generation and Disposal	0.00012	
	Employee Commute	0.00009	
	Downstream Transportation	0.018	
	Sold Products	1.190	
TOTAL (Scope 1 + 2)			**0.07**
TOTAL (Scope 1 +2 +3)			**1.99**

Figure 6.3: Carbon Intensity: Scope 1, 2, and 3 (tCO_{2e}/tHBI)

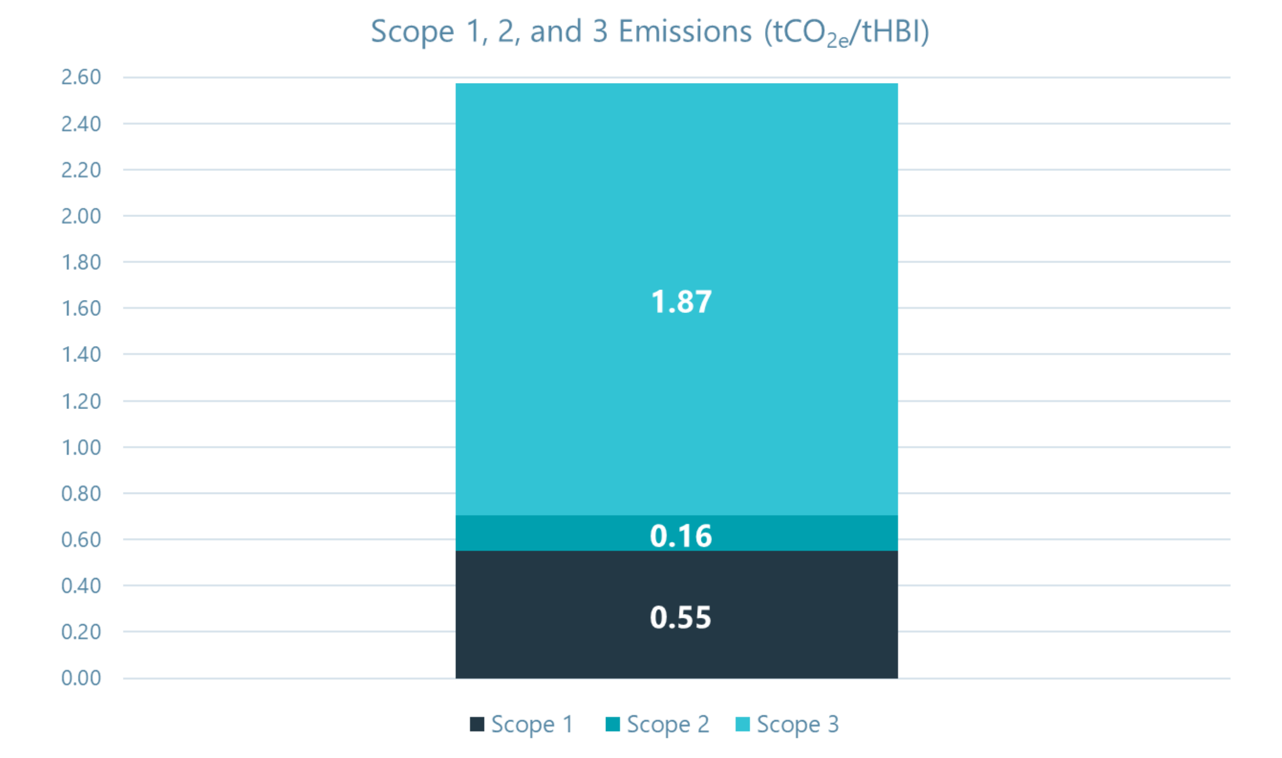
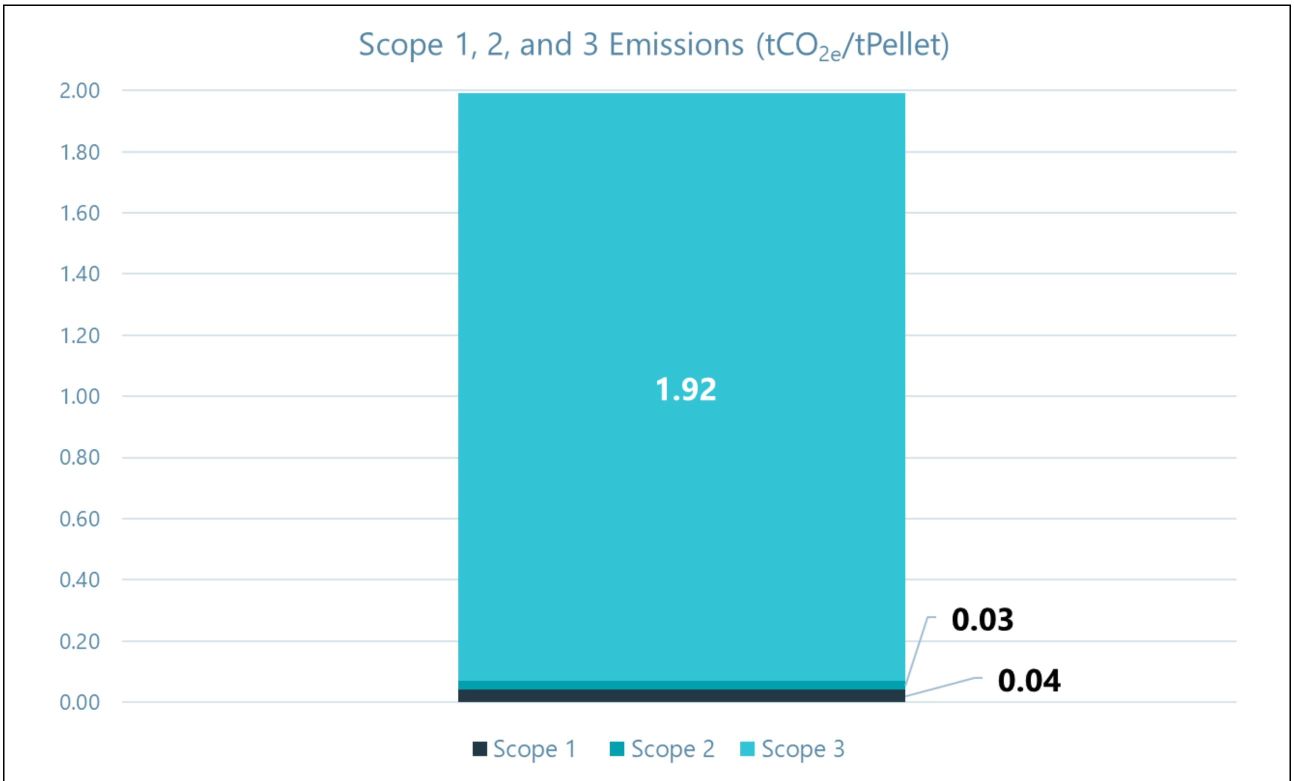


Figure 6.4: Carbon Intensity: Scope 1, 2, and 3 (tCO_{2e}/tPellet)



7 Uncertainty

The GHG Corporate Protocol principle of accuracy states "Data should be sufficiently precise to enable intended users to make decisions with reasonable assurance that the reported information is credible. GHG measurements, estimates, or calculations should be systemically neither over nor under the actual emissions value, as far as can be judged, and that uncertainties are reduced as far as practicable. The quantification process should be conducted in a manner that minimises uncertainty. Reporting on measures taken to ensure accuracy in the accounting of emissions can help promote credibility while enhancing transparency."

While every attempt has been made to ensure accuracy in calculations performed in this report, the following sources of uncertainty have been identified.

7.1 Activity Data

- Wood cannot endorse the accuracy of mass balance of the HBI plant, as the information provided by the third party (Primetals) and only restricted to the emission points. No mass balance data on the gaseous emission is provided for the pellet plant. Reagents and other consumables usage have been taken from FS Report.
- The electrical power demand has been calculated using data provided by PHGS outlining the overall consumption rate for HBI and pellet plants.
- Testing and operation protocols for firewater diesel pump and standby generators during Stage 1 – operating phase of the Project is based on 1% availability. This can be seen as a conservative assumption and might need to be updated in later stages.
- Reagent suppliers are yet to be confirmed, any changes may affect the transportation distance and emissions.

7.2 Physical Properties and Conversion Factors

- Physical properties used in the report, such as gas calorific values and diesel density are only specific to Australia where available.

7.3 Emissions Factors

- The Emission Factors for some reagents are not well-publicised and few references were found. Assumptions were made where required. All emissions factors used in this report are shown in Appendix C.

8 Benchmarking

This section will cover a benchmarking assessment on iron pellets, HBI, and steel in accordance with the Safeguard Mechanism as outlined in Appendix G.

8.1 Methodology

To ensure the accuracy and reliability of comparison, this benchmarking section relies on publicly available data from diverse sources, such as annual reports, sustainability disclosures, and industrial/academic publications.

The analysis focuses primarily on steel production either using blast furnace-basic oxygen furnace (BF-BOF) route or secondary production from EAF. The emission intensity of interim products such as HBI and direct reduced iron (DRI) were investigated and included in the report where data was available from the producers. Direct GHG emissions stem from steel production, processes, mining, extraction, smelting, and refining. Indirect emissions that arise from energy generation, upstream and downstream transportation, reagent production, etc. may also be taken into consideration where reported by the steel production companies.

The emission intensity metrics employed in this report will be expressed as GHG emissions per unit of product produced, typically measured in metric tonnes of CO_2 equivalent (CO_{2e}) per metric tonne of crude/liquid steel (tCO_{2e}/t Steel). Emission intensity of interim products (resulting from the reduction of oxide iron) was reported as metric tonnes CO_{2e} per metric tonne of DRI or iron pellet. Normalising emissions to steel output allows for meaningful comparison between suppliers of varying scales and production volumes.

8.2 Limitations

It is crucial to acknowledge the inherent limitations of this benchmarking section. The accuracy and reliability of the data hinge upon the transparency and consistency of reporting among the suppliers included in the analysis. Discrepancies in methodologies, data availability, and reporting practices may impact the comparability of emission intensity metrics. Furthermore, this benchmarking analysis may not encompass the entirety of the environmental impacts linked to steel production, such as water consumption, land use, and waste management.

Notwithstanding these limitations, this benchmarking report endeavours to provide a comprehensive overview of emission intensity performance across different steel (or intermediate product) suppliers. By identifying sustainability leaders and pinpointing areas for improvement, it aims to facilitate informed decision-making, foster transparency, and encourage the adoption of environmentally friendly practices within the steel industry.

8.3 Benchmarking of Downstream Steel Plants

Steel production is a significant contributor to total global CO_2 emissions. It is estimated that steel products are responsible for 11% of all CO_2 emissions according to Carbon Brief [11]. Other sources like Our World in Data estimate that the emissions contribution is closer to 7.2% [12]. A remarkable fact in these statistics is that more than half of all steel and thus emissions are produced in China. In 2019, 1875 Mt of steel were produced, equating to 3375 Mt of CO_2 emitted [13].

The majority of today's CO_2 emissions is the result of BF-BOF steel production, which mainly uses coking coal in the BF to turn iron oxide into iron which is then cast into steel. BF-BOF steelmaking currently accounts for

1.4 billion tonnes of the 1.9 Billion tonnes in annual steel production and has an emissions intensity of an average of 2.2 tonnes of CO_{2e} per tonne of steel [14].

The use of scrap in steelmaking is predicted to increase over the coming decades, meaning that achieving a zero-carbon emissions steel industry by 2050 is predominantly reliant on making net zero primary steel [14].

The amount of CO_{2e} produced per tonne of steel is generally higher in China, with the emission intensity reaching as high as 3 $tCO_{2e/}$t steel. This is because most of China's steel is produced in BF ovens which is the most carbon-intensive process. These ovens mainly produce steel from iron ore which is heated to 1500°C. Oxygen is blasted on the liquid iron to remove unwanted elements [13].

Steel production in Europe is less carbon-intensive. The reason is attributed to the fact that 40% of Europe's steel is produced in a 'cleaner' method which incorporates the EAF route. The heat required to melt the metal comes from an electric arc that arises when the electrodes contact the metal. Temperatures can go up to 3500°C, while the temperature of the steel is around 1800°C [13].

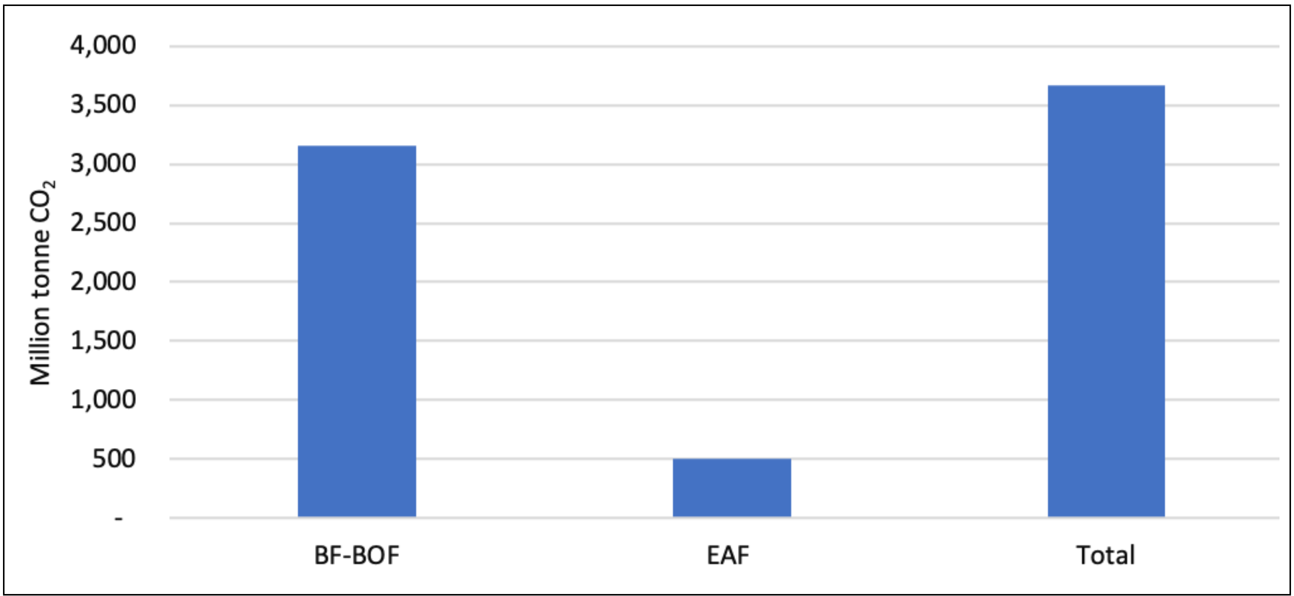
8.3.1 Emission Intensity of Downstream Steel Production

The primary route is what is used most across the world, which is why the average amount of CO_2 emitted per metric tonne of steel produced is 1.85 according to the World Steel Association [15].

8.3.1.1 Emission Intensity Based on the Production Route

The BF-BOF route, the traditional method, involves the extraction of iron from iron ore in a blast furnace and subsequent conversion into steel through the basic oxygen process. This route typically results in higher emission intensity due to the reliance on coke and coal in the BF, leading to significant CO_2 emissions. On the other hand, the EAF route utilises scrap steel as the primary raw material, which is melted using electricity in an EAF. The EAF route generally exhibits lower emission intensity compared to BF-BOF, as it relies on electricity rather than coal-based energy sources (Figure 8.1). Moreover, the EAF route offers the advantage of producing steel with a lower overall carbon footprint when using recycled steel scrap, reducing the demand for virgin iron ore extraction. As sustainability and environmental concerns continue to drive innovation in the steel industry, the adoption of the EAF route and the promotion of scrap recycling contribute significantly to reducing the emission intensity of steel production.

Figure 8.1: Global Steel Industry CO_2 Emissions in 2019



8.3.1.2 Emission Intensity Based on the Product Type

The emission intensity of various steel products can vary significantly based on their production processes and characteristics. Product types such as plates, sections, tubes, hot-dip galvanised (HDG) steel, and others differ in their manufacturing methods and energy requirements, which ultimately affect their carbon emissions. For example, HDG, commonly used for corrosion protection, involves a coating process that requires additional energy and can influence the emission intensity of the final product. Table 8.1 shows the carbon intensity of various steel products and has been derived from Worldsteel database [16].

Table 8.1: Carbon and Energy Impacts of Steel Products

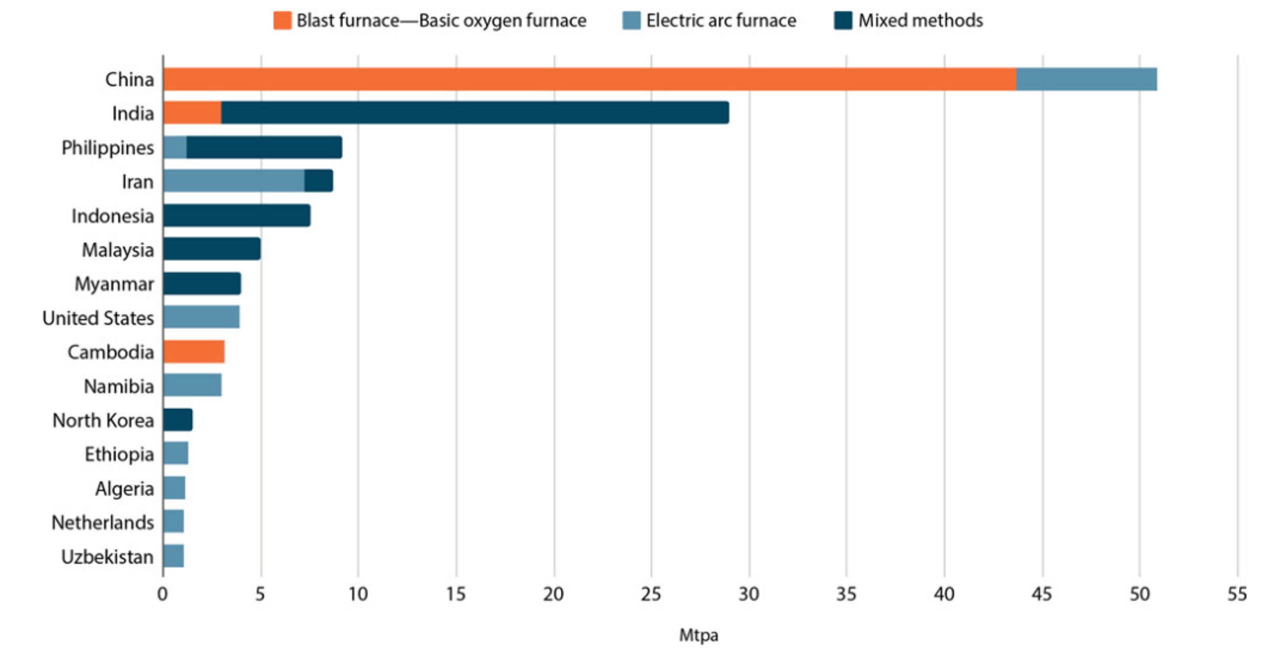
	Plate	Section	Tubes	HDG	Purlins and Rails
CO_2 (t/t steel)	0.919	0.762	0.857	1.350	1.100
Energy (GJ/t steel)	17.37	13.12	15.42	21.63	19.38

8.3.1.3 Emission Intensity Based on the Region

Operating steel plants in China account for more than half the global total, followed by Japan and India [11]. More than 60% of installed steelmaking capacity uses the high-carbon BF-BOF method, in which iron ore is smelted with heat from burning coal, which also acts as the "reducing" agent needed to turn the ore into metal. China's steel fleet is particularly reliant on this method, and it notably accounts for 62% of global BF-BOF capacity [11].

Carbon Brief reports that at least 65% of the current global capacity uses the BF-BOF method (orange bars), of which 88% (44 Mt/a) is in China. (The figure for India is likely to be higher than shown given that the method for its remaining 26 Mt/a of proposed capacity has not been disclosed.)

Figure 8.2: Capacity of Steel Plants Around the World, by Country and Type, Mt/a (Only Includes Proposals With Capacity Of At Least 1 Mt/a) [11]

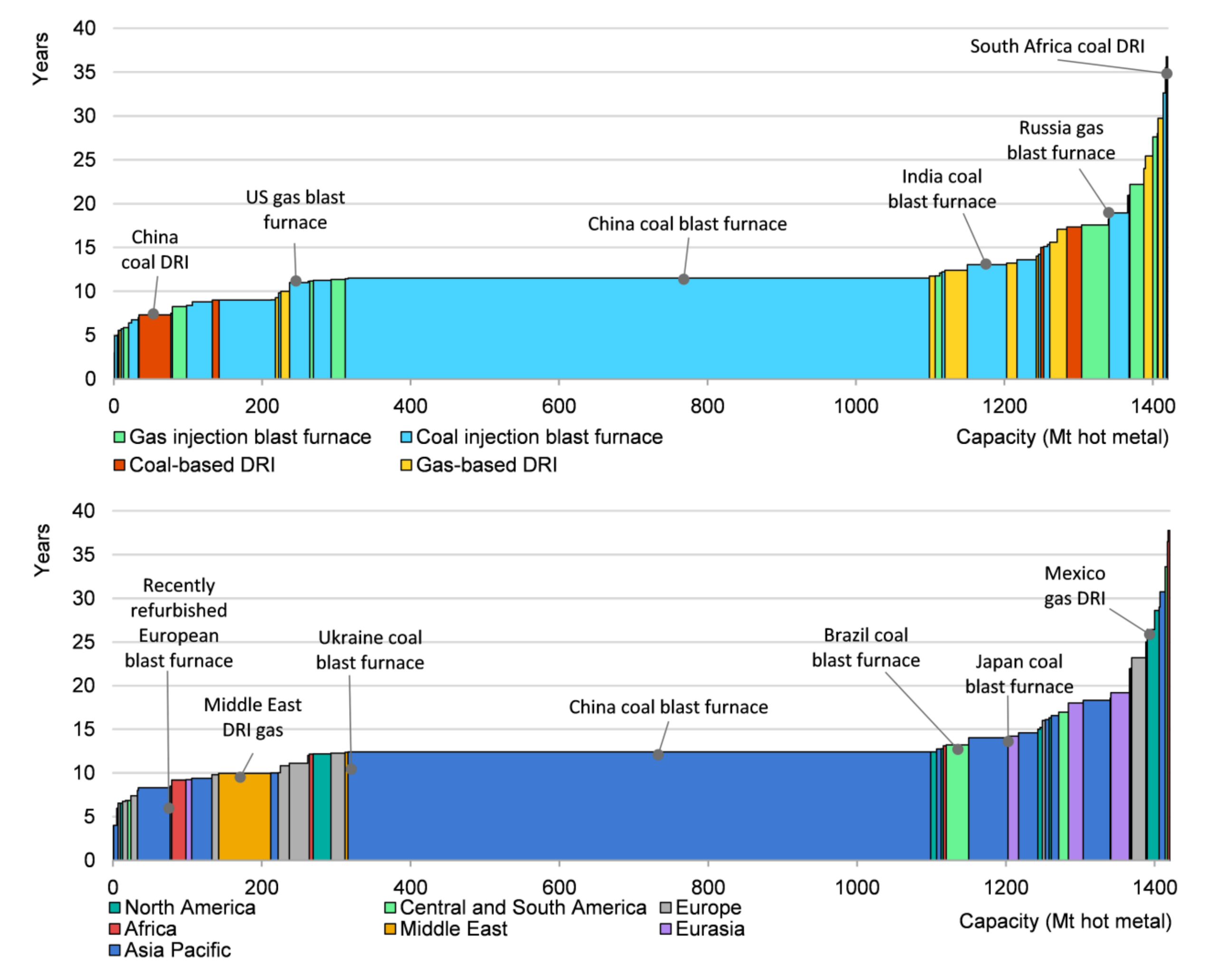


In terms of plants under development using the EAF method (light blue bars above), China and Iran each plan to develop 7.2 M/ta of capacity, together accounting for 53% of the EAF total.

Roughly every 25 years after commissioning a BF in a near-continuous operation mode, it will need to have its internal refractory lining replaced. During operation, this lining is subjected to temperatures in excess of 1400-1500°C and corrosive compounds present in the slag and molten iron, which eventually cause it to degrade. The initial installation cost of a blast furnace is around US$200-300 M per Mt of capacity, and the relining cost (happening approximately every 25 years) is typically around half of this figure. This significant level of additional investment to renew the life of the furnace must be considered in the context of several competing outlets for capital expenditure, including greenfield investments in a new location [17].

Assuming a typical lifetime of 40 years, alongside an interim investment cycle of 25 years, it is possible to assemble the regional average age profile of the existing fleet of blast furnaces and DRI furnaces (Figure 8.3). The weighted global average age of these regional figures is approximately 13 years for blast furnaces and 14 years for DRI furnaces. Coal injection blast furnaces tend to be a little younger at 13 years, whereas gas injection installations stand at around 16 years. For coal- and gas-based DRI furnaces, the figures are 13 years and 14 years respectively. Underlying these global figures is considerable regional differentiation [17].

Figure 8.3: Geographic Distribution and Average Age of Main Assets in the Iron and Steel Sector by Production Route and Region [17]

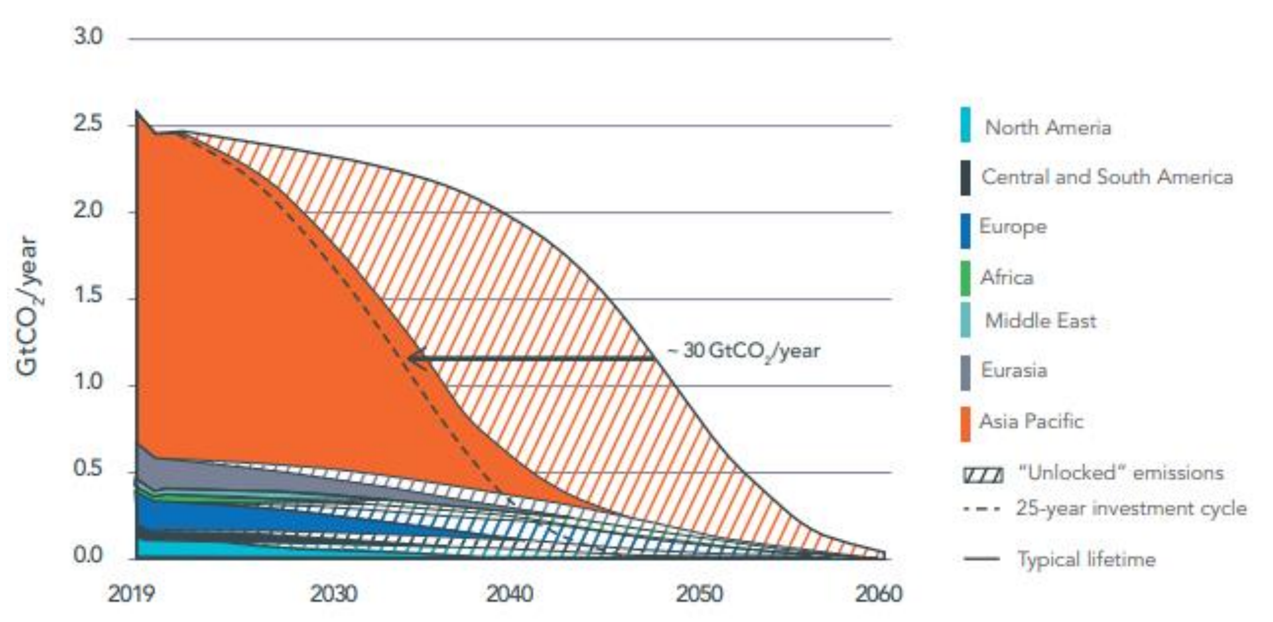


As mentioned before, China accounts for over 50% of all ironmaking capacity (both DRI and BF). Its relatively young blast furnace fleet (around 12 years on average) is the main factor explaining the youth of the global fleet overall. Its coal-based DRI furnaces are younger still, at just 8 years on average. The range of ages of individual plants within the country will vary considerably, but China's growth in steel output over the past 20 years (more than eightfold) shows the relatively short timeframe over which most of these installations have been added [17].

On either side of the giant share of Chinese capacity in the middle of the age profile curve is a significant variation in average age across the other regions. At either extreme are some of the recently refurbished European BFs (less than 10 years) and coal-based DRI furnaces in South Africa (around 35 years). The other major producing regions at the younger end of the spectrum are the United States (gas injection BFs around 12 years) and the Middle East (gas-based DRI furnaces around 10 years). At the older end are Russian gas injection blast furnaces (around 20 years) and Mexico's gas-based DRI fleet (around 25 years). India and Japan's coal blast furnaces are similar in average age to China's at 15 years and 14 years respectively [17].

The age profiles and typical lifetimes of these larger assets are a good guide to the rate at which the existing stock of equipment in the iron and steel sector will be decommissioned. Without any further investment in new capacity, emissions from the steel industry would decline, but not as fast as one might think. If operated under the conditions typically observed in recent years, existing steel industry infrastructure could lead to roughly 65 Gt CO_2 of cumulative emissions between now and 2060 (Figure 8.4) [18].

Figure 8.4: Projected Emissions from the Existing Equipment in the Steel Industry



8.3.2 Major Steelmaking Companies

8.3.2.1 ArcelorMittal

ArcelorMittal is one of the largest steel producers in the world and has been actively addressing the issue of carbon emissions in its operations. Arceromittal reported 160.3 $MtCO_{2e}$/a as their absolute CO_{2e} emissions in 2020 for their steel and mining operations. This corresponds to an emission intensity of 2.08 tCO_{2e}/t steel. By comparison, the global average figure provided by the World Steel Association is 1.83 tCO_{2e}/t steel [15]. ArcelorMittal pointed out that the key reason for their higher carbon intensity was that the share of ArcelorMittal production from the more carbon-intensive primary steelmaking route stood at 81% – compared with 72% in the global steel market as a whole [14].

8.3.2.2 Tata Steel UK

Tata Steel UK, a subsidiary of Tata Steel, operates steel production facilities primarily in the United Kingdom (UK). The company has been committed to reducing its carbon footprint and has set ambitious targets to achieve significant emissions reductions.

One notable initiative by Tata Steel UK is its involvement in carbon capture and utilisation (CCU) projects. The company has been exploring and investing in innovative technologies that capture and utilise CO_2 emissions from steelmaking processes. By capturing and repurposing CO_2, Tata Steel UK aims to minimise its emissions and contribute to the development of a more sustainable steel industry. The details about Tata Steel CO_2 emissions are provided in Table 8.2 [19].

8.3.2.3 POSCO

POSCO, a leading steel producer based in South Korea, has been actively addressing carbon emissions and working towards reducing its environmental impact. The company has been investing in research and development to develop and adopt innovative technologies that improve energy efficiency and reduce CO_2 emissions throughout the steelmaking process. The company has been actively exploring and implementing new methods for eco-friendly steel production, such as hydrogen-based processes, to reduce carbon emissions during steel production. The details on the current CO_2 emission from POSCO steelmaking facilities are provided in Table 8.2 [20].

8.3.2.4 Nippon Steel

Nippon Steel is a key player in the global steel market. Nippon Steel operates a wide range of steel production facilities, both in Japan and around the world, catering to diverse industries such as automotive, construction, energy, and infrastructure.

Nippon Steel has been committed to implementing measures that mitigate greenhouse gas emissions throughout its operations. The company understands the significance of sustainability and has set ambitious targets to decrease its carbon footprint. Nippon Steel has been investing in research and development to adopt innovative technologies and processes that enhance energy efficiency and reduce CO_2 emissions in steel production. They aim to optimise their manufacturing processes, employ cleaner energy sources, and develop low-carbon production methods [21].

8.3.2.5 ThyssenKrupp Steel

Thyssenkrupp, a renowned multinational conglomerate with operations in various industries, including steel production, is actively addressing carbon emissions, and working towards reducing its environmental impact. They have reported emitting 20 $MtCO_{2e}$/a in their steel production location in Europe. Since 2021, ThyssenKrupp started producing CO_2-reduced bluemint® which is greener steel. Thyssenkrupp has announced up to 70% reduction in CO_2 emissions with no quality difference from the existing grades [22], [23].

8.3.2.6 Cleveland-Cliffs

Cleveland-Cliffs Inc. is a US-based company and prominent company in the steel mining industry. Cleveland-Cliffs has taken significant strides to address its carbon emissions and reduce its overall environmental impact. By focusing on energy efficiency, adopting cleaner technologies, and investing in renewable energy sources, Cleveland-Cliffs aims to mitigate its greenhouse gas emissions and contribute to a more sustainable future for the industry. Cleveland-Cliffs reported their crude steel emission intensity of 1.97 tCO_{2e}/t steel in 2022 [24]. More details can be found in Table 8.2.

8.3.2.7 Hyundai Steel

Hyundai Steel is a member of Hyundai Motor Group and is headquartered in South Korea. According to the Sustainability Report issued in 2022, the emission intensity of Hyundai's crude steel is 1.14 tCO_{2e}/t steel, including Scope 1 and Scope 2 emissions. Hyundai Steel is planning to implement a carbon-neutral manufacturing system called 'Hy-Cube and introduce a 'hydrogen-based steel manufacturing system' in line with the 2050 carbon neutrality scenario and the 2030 NDC (Nationally Determined Contribution) [25]. More details can be found in Table 8.2.

8.3.2.8 Metalloinvest, OEMK Enterprise

Metalloinvest is based in Russia and holds the world's largest proven reserves of iron [26]. OEMK is a major enterprise and a part of the Metalloinvest group, one of the leading global producers and suppliers of iron ore and steel products. It is an integrated steel plant that specialises in the production of long products, such as rails, wire rods, and rebar, which are used in various industries, including construction, infrastructure, and transportation. Metalloinvest group has reported an emission intensity of 2.09 tCO_{2e}/t steel for their OEMK enterprise in 2022. More details can be found in Table 8.2.

8.3.2.9 Qatar Steel Company

Qatar Steel Company (QSC) has two MIDREX-based Direct Reduction Plants, three electric arc furnaces, two rolling mills, and two lime calcination plants. The plants are run on electric power supplied by the local electricity distributing entity, KAHRAMAA, and natural gas supplied by Qatar Energy. The use of cleaner energy sources reduces the pollutants emissions substantially. QSCs reported emission intensity of 0.985 tCO_{2e}/t steel in 2021 is well below the industry standard [27]. However, it is worth noting that the reported carbon intensity does not include Scope 3 emissions. Emissions from QSC's steelmaking facilities are provided in Table 8.2.

8.3.2.10 Jindal Shaded Iron and Steel

Jindal Shadeed Iron & Steel (JSIS) is a large privately-owned integrated steel producer in Oman. Approximately 71% of global steel production emits an average of 2.32 tCO_{2e} for every tonne of steel produced through the BF-BOF route. JSIS belongs to the 7% of primary steel producers worldwide (excluding scrap and EAF users) employing the DRI-EAF route with non-scrap based steel production, which results in 30% lower CO_2 emissions compared to the BF-BOF route. By adopting this steel-making process, JSIS achieves emissions of 1.57 tCO_{2e}/t steel, leading to an annual saving of 1.68 million tCO_{2e} compared to the BF-BOF route [28].

8.3.2.11 Nucor Corporation

Nucor is a US-based company that produces sheet steel, plate steel, structural steel, and bar steel in its steel mills facilities. Nucor manufactures steel principally from scrap steel and scrap steel substitutes using EAFs, paired with continuous casting and automated rolling mills. Nucor is committed to an additional 35% combined reduction in the Scope 1 and Scope 2 GHG emissions intensity of its steel mills by 2030. At present, Nucor's GHG emissions are just 0.47 tCO_{2e}/t steel. However, it is worth noting that Nucor's steel carbon intensity does not include Scope 3 emissions [29]. Emissions from Nucor's steelmaking facilities are provided in Table 8.2.

8.3.3 Summary of Steel Emission Intensity Reported by Major Steel Producers

A high-level summary of the information available from the literature study can be found in Table 8.2.

Table 8.2: Summary of Crude Steel Emissions Intensity Reported by Steel Producing Companies

Company	Year	Process Type	Scope 1 ($MtCO_{2e}$/a)	Scope 2 ($MtCO_{2e}$/a)	Scope 3 ($MtCO_{2e}$/a)	Total ($MtCO_{2e}$/a)	Production (Mt Steel)	tCO_{2e}/t Steel	Energy (TJ/a)
ArcelorMittal	2020	BF-BOF	124.40		35.90	160.30	77.07	2.08	NS[4]
Tata Steel	2022	BF-BOF	5.67	1.02		6.69	2.93	2.18	68 269
POSCO [1]	2021	NS	0.16	0.47	NS	0.62	NS	NS	1 283
Nippon Steel	2021	BF & EAF	71.29	12.48	19.52	103.29	44.45	2.32	1 025 000
Thyssen Krup[2]	2023	BF	NS	NS	NS	0.20	0.26	0.75	NS
JFE Steel Corporation	2013	BF & EAF	NS	NS	NS	58.10	NS	NS	NS
Cleveland-Cliffs[3]	2022	BOF & EAF	25.40	4.60	NS	30.00	15.23	1.97	380 523
Hyundai Steel	2021	BF & EAF	25.86	2.63	NS	28.49	24.93	1.14	168 120
Metalloinvest, OEMK	2022	BF & EAF	3.1	1.3	2.9	7.2	3.45	2.09	55 779
Qatar Steel	2021	EAF	5.91	3.67	NS	9.58	NS	0.95	NS
Jindal Shaded Iron & Steel	2023	EAF	NS	NS	NS	NS	NS	1.57	NS
Nucor	2022	EAF	4.3	4.85	NS	20.5	20.5	0.45	NS

[1] POSCO reported 1.84 tCO_{2e}/krw billion
[2] The reported emissions are for a greener steel product called "bluemint®"
[3] Cleveland-Cliffs reported an energy intensity of 25 GJ/t crude steel
[4] NS: Not Specified

8.4 Benchmarking for DRI/HBI plants

There is currently limited emission intensity information available for intermediate iron products such as HBI and iron ore pellets. Sections 8.4 and 8.5 summarises all the information that could be found for HBI, DRI, and pellet plants.

8.4.1 Major HBI/DRI Producer Companies

8.4.1.1 Metalloinvest

The core business of the companies integrated into Metalloinvest Group is the production and sales of metallised products (HBI and DRI), iron ore products (concentrate, iron ore, and metallised pellets), as well as high-quality long products, including SBQ (special bar quality). According to the company structure, LGOK and MGOK are the operational assets for the production and sale of iron ore products, whereas OEMK is the enterprise for the production and sale of steel products. Table 8.3 summarises the Scope 1-3 emissions from the Metalloinvest enterprises that produce HBI and DRI, which are used as the feed to the steel plant [26].

Table 8.3: GHG Emissions from HBI/DRI Producing Sites of Metalloinvest in 2020-2022

	Unit	LGOK	MGOK
Scope 1	tCO_{2e}/a	2 931 616	530 584
Scope 2	tCO_{2e}/a	1 140 852	803 377
Scope 3	tCO_{2e}/a	11 171 896	21 280 644
Total	**tCO_{2e}/a**	**15 244 364**	**22 614 605**

8.4.2 Summary of Reported DRI/HBI Emission Intensity

A high-level summary of the information available from the literature study can be found in Table 8.4.

Table 8.4: Summary of DRI Emissions Intensity

Company	Production (Mt HBI, DRI)	tCO_2/t DRI	Process Type	Boundary	Comment	Ref
tkSE (Modelling)	DRI	0.41-0.5	NS	NS	• Natural Gas Based • The emission intensity has been reported from Yilmaz 2017	[30]
Research Paper	DRI	0.413	Midrex (Shaft furnace)	DRI to BF, excluding any pelletisation	• Only scope 1 • Natural gas • 4% Total C • 10 GJ/t DRI	[31]
Research Paper	DRI	0.0066	Midrex (Shaft furnace)	DRI to BF, excluding any pelletisation	• Only scope 1 • 86% Hydrogen • 2% Total C • 9.4 GJ/t DRI	[31]
Research Paper	HBI	0.4965	Energiron (Shaft furnace)	DRI to BF, excluding any pelletisation	• Only scope 1 • Natural gas • 1.5% Total C • 10 GJ/t DRI	[31]

Table 8.4: Summary of DRI Emissions Intensity

Company	Production (Mt HBI, DRI)	tCO_2/t DRI	Process Type	Boundary	Comment	Ref
Research Paper	HBI	0.0015	Energiron (Shaft furnace)	DRI to BF, excluding any pelletisation	• Only scope 1 • 96% Hydrogen • 0.5% Total C • 8.6 GJ/t DRI	[31]
Worldsteel Report	DRI	1.5	NS	NS	NS	[32]
Kobelco	2.93 (DRI)	0.597	Midrex (Shaft furnace)	DRI to BF, excluding any pelletisation	• 0.68 tCO_{2e}/t HBI reported (for both Scope 1 and 2) • Assumption made to separate Scope 1 and 2 and to estimate total emissions (1.99 $MtCO_{2e}$/tunit)	[33]
Nucor	4.5 (DRI)	0.43	Midrex (Shaft furnace)	DRI to BF, excluding any pelletisation	• DRI and Steel • Some assumptions made to separate Scope 1 and Scope 2 for DRI and other plants from 2022 sustainability report	[34]
Nucor	4.5 (DRI)	0.41	Midrex (Shaft furnace)	DRI to BF, excluding any pelletisation	• DRI and Steel. • Some assumptions made to separate Scope 1 and Scope 2 for DRI and other plants from 2021 sustainbility report	[35]

8.5 Benchmarking of Pellet Plants

Current iron and steelmaking technologies rely on being fed with iron ore feedstock above a characteristic size (diameter). Lump hematite is an ore of sufficient quality and mined rock diameter that can be directly fed to further processing stages. All other ore must first be agglomerated before it can be used.

This process can be decarbonised through the process of pelletisation which uses a hydrogen indium furnace to help form the pellets. Green pellets are a potential next step in the value chain beyond the supply of green hematite ore or magnetite concentrate.

Pelletisation involves heating and binding fine iron ore into larger-sized material. Pellets can be made from extremely finely ground product, and so is a suitable technology to pelletise both magnetite concentrates and processed haematite fines [36].

8.5.1 Major Iron Pellet Producers

8.5.1.1 LKAB

LKAB is a Swedish mining company that mines ores at Kiruna and at Malmberget in northern Sweden. The iron ore is processed into pellets and sinter fines and the product is sold throughout much of the world, with the principal markets being European steel mills, as well as North Africa, the Middle East, and Southeast Asia [37]. LKAB has reported an 84% reduction per tonne of pellet product from 1960 [38]. Based on a note from LKAB project manager, heating in the pelletising plants is the major source of carbon dioxide emissions in the process. LKAB is planning to move towards carbon-free products by step-wise substituting hydrogen [39]. According to the LKAB environmental roadmap, their product will be carbon-free by 2045. CO_2 emissions from LKAB facilities are provided in Table 8.5.

8.5.1.2 Vale

Vale has announced the production of green briquette as an alternative to pellets. This can reduce CO_2 emissions of steel-making companies by up to 10%. The green briquette is part of Vale's strategy to reduce by 15% Scope 3 emissions, related to its value chain, by 2035. Long-term estimates are that the company will have the capacity to produce more than 50 Mt of green briquette per year resulting in a potential reduction in emissions of 6 $MtCO_{2e}$/year through the use of this technology [40].

8.5.1.3 Samarco

Samarco is a company based in Brazil that produces iron ore pellets through its operating units in Minas Gerais and Espírito Santo states. In 2022, Samarco produced over 9.2 Mt of iron ore pellets and fines. Samarco have reported Scope 1, Scope 2, and Scope 3 emissions in accordance to the Brazillian GHG Protocol Program and are actively working on studies to reduce climate risks and develop a decarbonisation plan for their operations [41].

8.5.1.4 U.S. Steel

U.S. Steel is a global steel producer that combines integrated BF, BOF and mini mill steel process technologies to produce steel. U.S. Steel is working to develop lower GHG emission steels with all the performance characteristics of existing steel grades and are transparent in reporting their emissions from all their operations including the mini mill and pelletising plant in their sustainability report [42].

8.5.2 Summary of Reported Iron Pellet Emissions Intensity

Minerals Research Institute of Western Australia (MRIWA, 2023) has reported that the use of green pellets in steelmaking would reduce the steel emissions intensity by 0.12 tCO_2/t steel [36]. According to guidelines for national emission inventories (IPCC, 2019), pellet production has an EF of 0.19 tCO_2/tPellet (chosen as the maximum reported value and only exclusive to CO_2 emissions (not including CH_4 and N_2O emissions) [35] [43]. Table 8.5 provides a summary of reported iron pellets emissions intensity.

Table 8.5: Summary of Iron Pellets Emissions Intensity								
Company	**Location**	**Year**	**total ($ktCO_2/a$)**	**Production (MtPellet)**	**Energy (TJ/a)**	**tCO_2/t product**	**Energy (MJ/t product)**	**Product**
LKAB	Sweden	2022	661	25	57 060	0.02644	634	Mainly pellet (88%)
LKAB	Sweden	2021	713	26.7	60 940	0.0267	634	Mainly pellet (83%)
Vale	Chile	2021	Reduce by 6 Mt/a	50	NS	NS	NS	Green briquette
Research paper	China	2019	NS	NS	NS	0.0585	793	Pellet
U.S. Steel	USA	2021	3.276[2]	23.4	NS	0.09	NS	Pellet
U.S. Steel	USA	2022	3.066[2]	21.9	NS	0.09	NS	Pellet
Samarco	Brazil	2021	0.635[1]	7.68	NS	0.083	NS	Pellet
Samarco	Brazil	2022	0.488[1]	9.288	NS	0.052	NS	Pellet

[1] Scope 1 emissions only

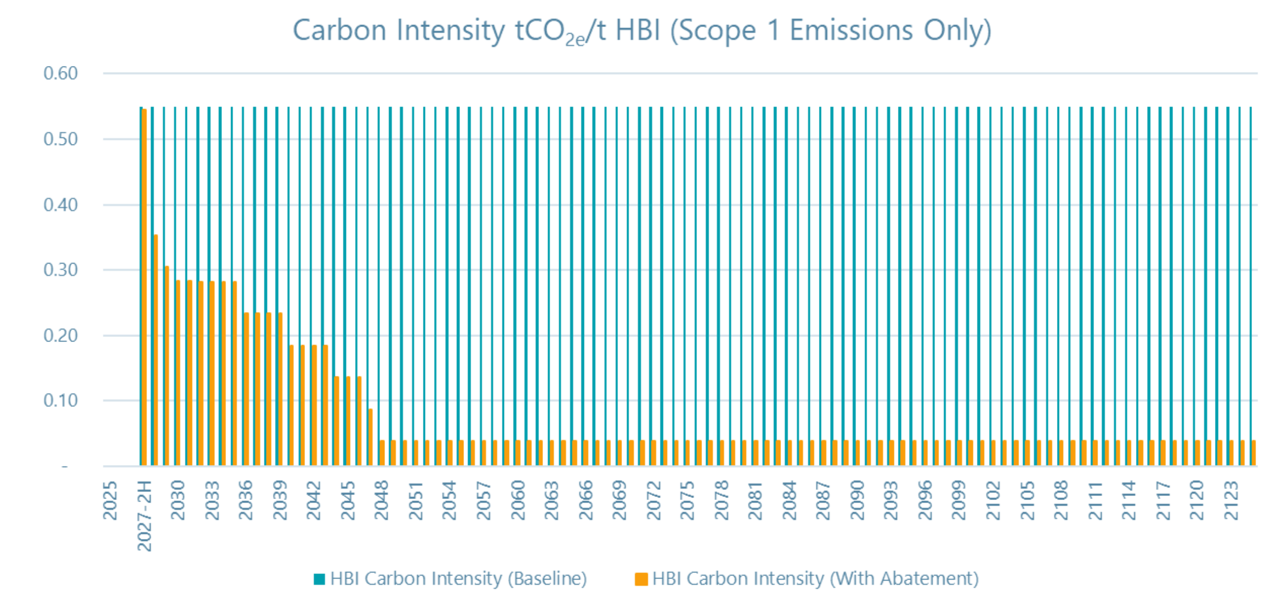
[2] Scope 1 and Scope 2 emissions

8.5.3 Safeguard Mechanism Benchmarking

According to the Safeguard Mechanism Document, HBI falls under the Primary Iron production variable which has a best practice benchmark emission intensity of 1.77 tCO_{2e}/unit, where the unit is tonnes of metallic iron products [44].

Based on Wood's assessment, PHGS emission intensity for HBI is expected to be 0.55 tCO_{2e}/ t HBI (Scope 1 emissions only), which is lower than the Safeguard mechanism best practice benchmark of the Primary Iron production variable. With the inclusion of abatement measures (CCS and replacing natural gas with H_2), this emission intensity is expected to decline over time, as depicted in Figure 8.5.

Figure 8.5: PHGS HBI Plant Carbon Intensity



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Appendix A The Wood Decarbonisation Process

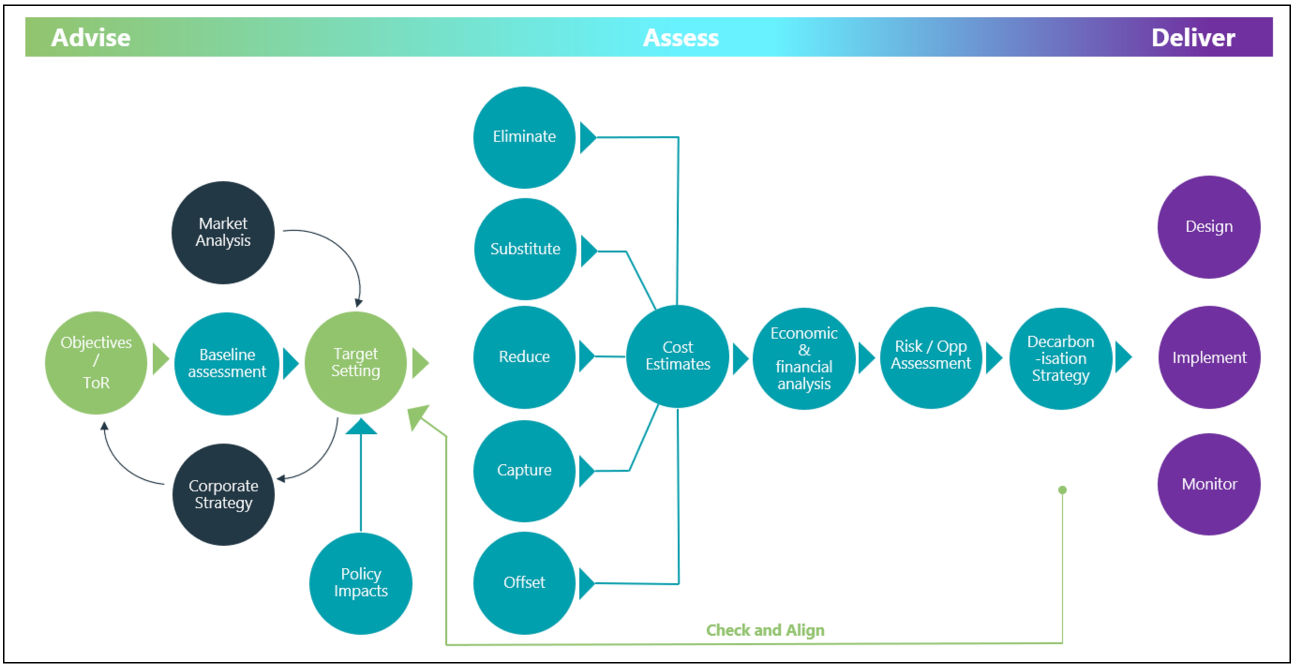
A1 The Wood Decarbonisation Process

Responsible and future-looking companies are aligning themselves with the global standards and best-practice of clean energy supply chains. Investors, banks, shareholders, stakeholders and customers are beginning to prefer those companies who are Environmental, Social, and Governance-compliant (ESG), whose processes and products have low-carbon intensity and who have a decarbonisation roadmap.

Minimising the greenhouse gas emissions from the supply, processing and distribution chain is most effectively done in the earlier stages of project development – in the study phase – by applying decarbonisation targets to the design and undertaking a process of assessment, analysis, and optimisation.

Wood applies a methodology for greenhouse gas emission assessment and decarbonisation strategy development. The process is illustrated in Figure A1.1 below and includes the preparation of an emissions assessment, minimisation of the carbon intensity of the design, cost estimation, financial analysis, risk assessment and development of decarbonisation strategy.

Figure A1.1: Wood Decarbonisation Process



Wood can prepare a Decarbonisation Strategy report summarising recommended options for decarbonisation of the plant design and can provide details of technological and financial implications for the Project. This will be an input into the plant design and environmental applications for regulatory approvals.

The following is included in the complete Wood Decarbonisation Strategy process:

A1.1 Base Case and Low-carbon Case Emissions Assessment

The **Base Case and Low-carbon Case Emissions Assessment** of the design (with comparison and reference to the Client's emission reduction targets where applicable) including Scope 1, 2 and, as far as possible, Scope 3 emissions.

A1.2 Decarbonisation Opportunities

Recommendations for feasible decarbonisation opportunities via **Elimination, Substitution and Reduction** (and **Capture** and **Offset** where applicable) that can be applied to the design. Where possible and in collaboration with the Client, these adjustments can be made during the design process to optimise the final DFS engineering deliverables.

A1.3 Marginal Cost of Abatement Curves

Costing and Economic Analysis of the decarbonisation opportunities over the short, medium, and long term, include forecast availability of future technologies and commodities, policies and market impacts (development of Marginal Abatement Cost curves).

A1.4 Risk Assessment

- **Risk and Opportunity Register** with likelihoods, consequences, and prioritisation
- Risk **elimination and mitigation** identification
- **Residual Risk Ranking.**

A1.5 Decarbonisation Strategy

Development of a **Decarbonisation Strategy** which is the strategy for:

- An optimised design that balances cost and benefit, including low-carbon choices for, e.g.:
  - Product
  - Process
  - Site
  - Schedule
  - Procurement strategy.
- Future Actions (e.g. risk mitigation, negotiation of supply and offtake agreements, technology investigation and investment, long-lead equipment procurement)
- Project Capital and Operating Budget for decarbonisation investment for the short, medium and long term for input into the business capital planning cycle.

Appendix B Assessment Methodology

B1 Assessment Methodology

This report has been prepared in compliance with the Greenhouse Gas Protocol and the Intergovernmental Panel on Climate Change (IPCC) guidelines. The assessment includes Scope 1, 2, and 3 emissions, as described below.

B1.1 The Greenhouse Gas Protocol

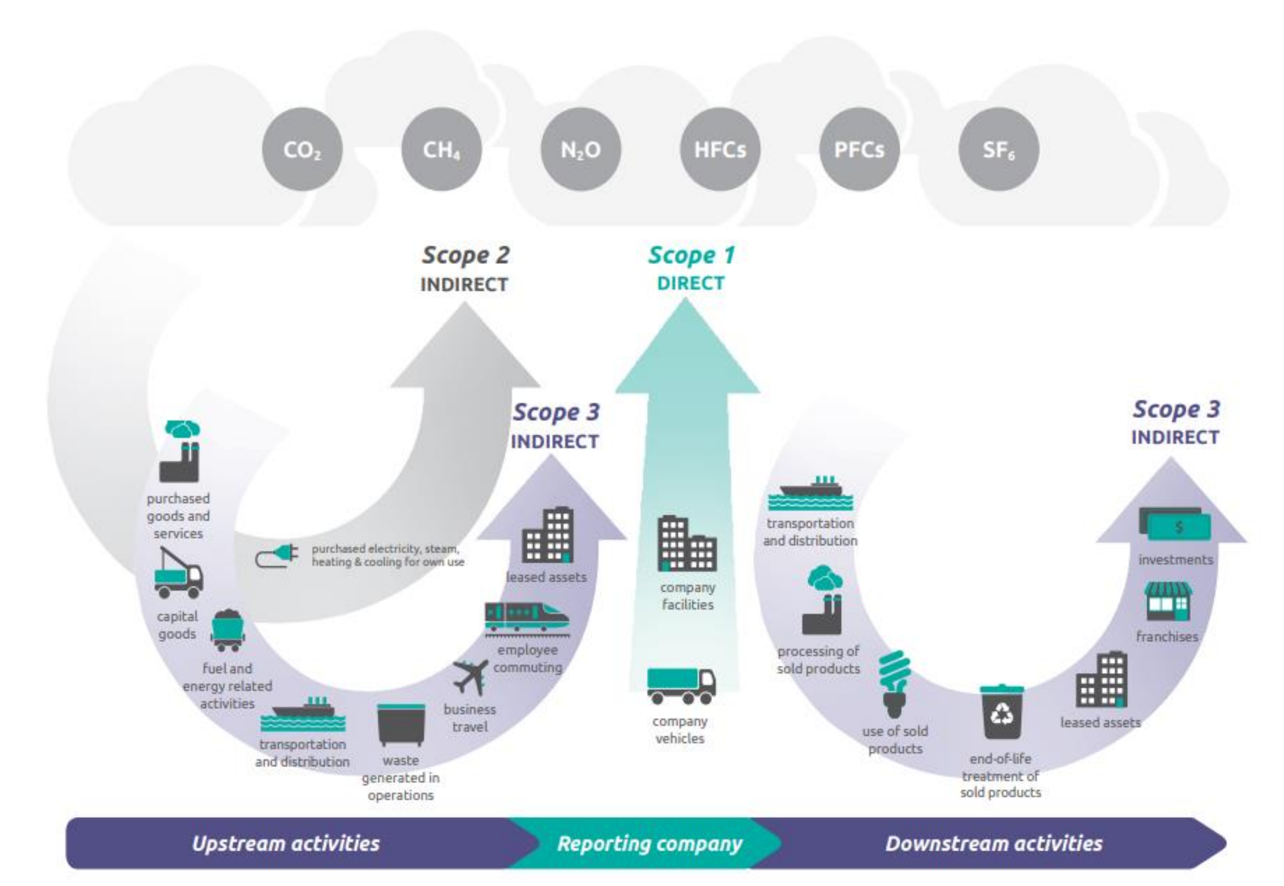
The GHG Protocol Corporate Accounting and Reporting Standard (GHG Protocol Corporate Standard), was first published in September 2001 and is now adopted and acceptance globally by businesses, non-governmental organisations (NGOs), and governments as the guidance standard for greenhouse gas accounting and reporting [1].

Businesses benefit from using a common standard for GHG inventory, it improves the consistency, transparency, and understandability of reported information, making it easier to track and compare progress over time.

The latest version of GHG Protocol Corporate Standard (3.51) published in 2015 provides requirements and guidance for companies and other organisations, such as NGOs, government agencies, and universities, that are preparing a corporate-level GHG emissions inventory. It has been used as the basis for this assessment as this assessment assumes the Port Hedland Green Steel Project is built and operating as designed, in which case this is the standard that would be applicable for calculating and reporting the GHG emissions.

Greenhouse gas emissions are classified as Scope 1, 2, and 3. See below for an overview of the classification.

Figure B1.1: Overview of the Scope 1, 2, 3 Classification System



B1.2 Scope 1 Emissions

The GHG Protocol Corporate Standard defines Scope 1 GHG emissions as the emissions from sources a company owns or controls. They are generally direct GHG emissions and are principally the result of the following types of activities undertaken by the company:

- **Stationary Combustion –** On-site generation of electricity, heat, or steam. These emissions result from combustion of fuels in stationary sources, e.g. boilers, furnaces, turbines
- **Physical or Chemical Processing –** Most of these emissions result from manufacture or processing of chemicals and materials, e.g. cement, aluminium, adipic acid, ammonia manufacture, and waste processing
- **Mobile Combustion –** Transportation of materials, products, waste, and employees. These emissions result from the combustion of fuels in company owned/controlled mobile combustion sources (e.g. trucks, trains, ships, airplanes, buses, and cars)
- **Fugitive Emissions –** These emissions result from intentional or unintentional releases, e.g. equipment leaks from joints, seals, packing, and gaskets; methane emissions from coal mines and venting; HFC emissions during the use of refrigeration and air conditioning equipment; and methane leakages from gas transport.

B1.3 Scope 2 Emissions

The GHG Protocol Corporate Standard defines Scope 2 GHG emissions as the emissions from the generation of purchased electricity that is consumed in its owned or controlled equipment or operations. Scope 2 emissions are a special category of indirect emissions. For many companies, purchased electricity represents one of the largest sources of GHG emissions and the most significant opportunity to reduce these emissions. Accounting for scope 2 emissions allows companies to assess the risks and opportunities associated with changing electricity and GHG emissions costs.

B1.4 Scope 3 Emissions

Scope 3 GHG emissions are the result of activities from assets not owned or controlled by the reporting company, but that the organisation indirectly affects in its value chain.

The GHG Protocol Corporate Value Chain (Scope 3) Standard [2] categorises the Scope 3 emissions into 15 distinct categories. Table B1.1 summarises the Scope 3 emissions from the indirect upstream (Category 1-8) and down-stream (Category 9-15) activities and outlines a brief description of each category.

Table B1.1: Scope 3 Emissions Categories

	GHG Protocol Category	Description
1.	Purchased Goods and Services	• Extraction, production, and transportation of goods and services purchased or acquired by the reporting company in the reporting year, not otherwise included in Categories 2-8.
2.	Capital Goods	• Extraction, production, and transportation of capital goods purchased or acquired by the reporting company in the reporting year.
3.	Fuel and energy-related activities not included in Scope 1 or Scope 2	• Extraction, production, and transportation of fuels and energy purchased or acquired by the reporting company in the reporting year, not already accounted for in Scope 1 or Scope 2, including: a) Upstream emissions of purchased fuels (extraction, production, and transportation of fuels consumed by the reporting company) b) Upstream emissions of purchased electricity (extraction, production, and transportation of fuels consumed in the generation of electricity, steam, heating, and cooling consumed by the reporting company) c) Transmission and distribution (T&D) losses (generation of electricity, steam, heating and cooling that is consumed (i.e. lost) in a T&D system) – reported by end user d) Generation of purchased electricity that is sold to end users (generation of electricity, steam, heating, and cooling that is purchased by the reporting company and sold to end users) – reported by utility company or energy retailer only.

Table B1.1: Scope 3 Emissions Categories		
	GHG Protocol Category	**Description**
4.	Upstream transportation and distribution	• Transportation and distribution of products purchased by the reporting company in the reporting year between a company's tier 1 suppliers and its own operations (in vehicles and facilities not owned or controlled by the reporting company). • Transportation and distribution services purchased by the reporting company in the reporting year, including inbound logistics, outbound logistics (e.g. of sold products), and transportation and distribution between a company's own facilities (in vehicles and facilities not owned or controlled by the reporting company).
5.	Waste generated in operations	• Disposal and treatment of waste generated in the reporting company's operations in the reporting year (in facilities not owned or controlled by the reporting company).
6.	Business Travel	• Transportation of employees for business-related activities during the reporting year (in vehicles not owned or operated by the reporting company).
7.	Employee Commuting	• Transportation of employees between their homes and their worksites during the reporting year (in vehicles not owned or operated by the reporting company).
8.	Upstream Leased Assets	• Operation of assets leased by the reporting company (lessee) in the reporting year and not included in Scope 1 and Scope 2 – reported by lessee.
9.	Downstream Transportation and Distribution	• Transportation and distribution of products sold by the reporting company in the reporting year between the reporting company's operations and the end consumer (if not paid for by the reporting company), including retail and storage (in vehicles and facilities not owned or controlled by the reporting company).
10.	Processing of Sold Products	• Processing of intermediate products sold in the reporting year by downstream companies (e.g. manufacturers).
11.	Use of Sold Products	• End use of goods and services sold by the reporting company in the reporting year.
12.	End-of-life Treatment of Sold Products	• Waste disposal and treatment of products sold by the reporting company (in the reporting year) at the end of their life.
13.	Downstream Leased Assets	• Operation of assets owned by the reporting company (lessor) and leased to other entities in the reporting year, not included in Scope 1 and Scope 2 – reported by lessor.
14.	Franchises	• Operation of franchises in the reporting year, not included in Scope 1 and Scope 2 – reported by franchisor.
15.	Investments	• Operation of investments (including equity and debt investments and project finance) in the reporting year, not included in Scope 1 or Scope 2.

B1.5 Calculation Methodology

The calculation of GHG emissions is done as follows:

[Activity Data] x [Emission Factor] = [GHG Emissions]

Where:

- **Activity data** is quantity or usage data in t/a, GJ/a, etc. It can be measured (e.g. from data received from a plant in operation) or calculated (e.g. from a mass balance model or stoichiometric chemical balance) or estimated (e.g. from published specifications on a vehicle type).
- **Emission Factor** is a factor or ratio that has been calculated by relating GHG emissions to a measure of activity at an emissions source. Emissions factors can be determined by experimental measurement, or published, generic emissions factors can be used from reputable organisations globally or locally. Published emissions factors can vary slightly.
- **GHG Emissions** are the mass of carbon dioxide and / or all equivalent greenhouse gases over a period of time, in units such as tCO_{2e}/a.

B1.6 NGER Emission Factors

The NGER emissions factors for stationary and mobile combustion are summarised in Table B1.2 [3].

Table B1.2: NGER Emissions Factors

Emission Source	Emissions Factor (kg/GJ)		
	CO_2	CH_4	N_2O
Stationary Combustion – Natural Gas	51.4	0.1	0.03
Stationary Combustion – LPG	60.2	0.2	0.2
Stationary Combustion – Diesel	69.9	0.1	0.2
Mobile Combustion – Diesel	69.9	0.01	0.5

B1.7 References

In this assessment, the most credible and applicable references for emissions factors, physical properties and conversion factors have been used.

The Australian National Greenhouse Accounts Factors (NGER) August 2021 emissions factors has been used as a source of emissions factors as PHGS is currently based in Australia and this will also allow for comparison with facilities in Australia.

All references for source data, physical properties, and conversion factors have been provided throughout the report.

Appendix C Emissions Factors

Table C1.1 Summary of Emissions Factors				
Emission Category	**Emission Type**	**Emission Factor**	**Unit**	**Reference/Note**
Scope 1	Land Clearance	78.52	tCO_{2e}/ha	[45]
	Diesel (Stationary)	3.21	tCO_{2e}/t Unit	Refer to Table B1.2
	Diesel (Mobile)	3.21	tCO_{2e}/t Unit	Refer to Table B1.2
	NG (Stationary)	2.57	tCO_{2e}/t Unit	Refer to Table B1.2
	Biogenic	70	mg COD removed per L of Wastewater	[46], [47]
		0.25	kg CH_4/kg COD Removed	[46], [47]
		34	GWP of CH_4	[6]
Scope 2	Electricity Supply	0.52	tCO_{2e}/MWh	[8]
Scope 3 – Purchased Goods and Services	Bentonite	0.46	tCO_{2e}/t Unit	[48]
	Limestone	0.02	tCO_{2e}/t Unit	[49]
	NG	0.64	tCO_{2e}/t Unit	[50]
	Diesel	0.48	tCO_{2e}/t Unit	[50]
	Magnetite Concentrate	0.70	tCO_{2e}/t Unit	[49]
	Coating Material	2.00	tCO_{2e}/t Unit	[51]
Scope 3 – Capital Goods	Concrete	0.3	tCO_{2e}/m^3	Wood Database
	Steel	2	tCO_{2e}/t	Wood Database
Scope 3 – Fuel and Energy	SWIS Scope 3 emission factor	0.04	tCO_{2e}/MWh	[52]
	NWIS Scope 3 emission factor	Not Available	tCO_{2e}/MWh	[52]
Scope 3 – Transportation	Shipping	2.21	gCO_{2e}/tonne-km	[53]
Scope 3 – Employee Commute	Plane			Refer to Table D1.18
Scope 3 – Waste Generation and Disposal	Solid Waste	2.31	tCO_{2e}/no of people	[54]
Scope 3 – Processing of Sold Products	HBI Processing	0.72	(tCO_{2e}/tHBI)	[9]
	Pellet Processing	1.19	(tCO_{2e}/tPellet)	[9]

Appendix D Data Tables

Table D1.1: Land Clearance Emissions Factor			
Vegetation Type	**Percentage**	**Emission Factor (tCO_{2e}/ha)**	**Overall Emission Factor (tCO_{2e}/ha)**
Eucalypt Open Woodlands	50%	152.31	76.16
Hummock Grasslands	50%	4.73	2.37
TOTAL			**78.52**

Table D1.2: Annual CO_{2e} Emissions from Land Clearance				
CY	**Year**	**Area (ha)**	**Emission Factor (tCO_{2e}/ha)**	**Land Clearance Emissions (tCO_{2e}/a)**
CY26 (Q2-Q4)	Y01 (Construction)	390	78.52	30 623
CY27	Y02 (Construction)	–	78.52	–
CY28	Y03 (Construction)	–	78.52	–
CY29 (Q1-Q3)	Y04 (Construction)	–	78.52	–
CY29 (Q4)	Y04 (Ramp Up)	–	78.52	–
CY30-CY128	Y01-Y99 (Operation)	–	78.52	–
TOTAL (Stage 1 – LOA – 99 Years)		**390**		**30 623**

Table D1.3: Annual CO_{2e} Emissions from Process Point Sources (Including NG Combustion)

CY	Year	HBI Plant							Pellet Plant	HBI + Pellet
		Flue Gas Stack (tCO_2/a)	Bottom Seal Gas Dedusting (tCO_2/a)	Briquetter Dedusting (tCO_2/a)	Degasser - Top Gas Weir Drain (tCO_2/a)	Degasser – Top Gas Cone Drain (tCO_2/a)	Degassing Unit Process Water Clean (tCO_2/a)	TOTAL HBI Plant (tCO_2/a)	TOTAL Pellet Plant (tCO_2/a)	TOTAL HBI_Pellet (tCO_2/a)
CY26 (Q2-Q4)	Y01 (Construction)	–	–	–	–	–	–	–	–	–
CY27	Y02 (Construction)	–	–	–	–	–	–	–	–	–
CY28	Y03 (Construction)	–	–	–	–	–	–	–	–	–
CY29 (Q1-Q3)	Y04 (Construction)	–	–	–	–	–	–	–	90 394	90 394
CY29 (Q4)	Y01 (Ramp-up)	153 377	1 700	6 792	1 441	171	730	164 210	33 898	198 108
CY30-CY128	Y01-Y99 (Operation)	920 260	10 199	40 753	8 646	1 024	4 377	985 260	135 591	1 120 851
TOTAL (Stage 1 – LOA – 99 Years)		**91 259 117**	**1 011 441**	**4 041 349**	**857 430**	**101 585**	**434 054**	**97 704 976**	**13 547 801**	**111 252 777**

Table D1.4: Stationary Gas Combustion Consumption Rates					
	Production Rate (t/a)	**Consumption Rate (GJ/t Product)**	**Gas Usage (GJ/a)**	**Gas Usage (t/a)**	**CO_{2e} Emissions (tCO_{2e}/a)**
HBI Plant	2 000 000	9.40	18 800 000	410 929.0	968 764
Pellet Plant	3 500 000	0.66	2 310 000	50 491.8	119 034
TOTAL (Yearly)				**461 420.8**	**1 087 798**
TOTAL (Stage 1 – LOA – 99 Years)				**45 680 656**	**107 692 032**

Table D1.5: Annual CO_{2e} Emissions from NG Combustion					
CY	**Year**	**HBI Plant Natural Gas Consumption Rate (t/a)**	**Pellet Plant Natural Gas Consumption Rate (t/a)**	**Total Natural Gas Consumption Rate (t/a)**	**Total Natural Gas Emissions (tCO_{2e}/a)**
CY26 (Q2-Q4)	Y01 (Construction)	–	–	–	–
CY27	Y02 (Construction)	–	–	–	–
CY28	Y03 (Construction)	–	–	–	–
CY29 (Q1-Q3)	Y04 (Construction)	–	33 661	33 661	79 356
CY29 (Q4)	Y04 (Ramp Up)	68 488	12 623	81 111	191 219
CY30-CY128	Y01-Y99 (Operation)	410 929	50 492	461 421	1 087 798
TOTAL (Stage 1 – LOA – 99 Years)		**40 750 455**	**5 044 973**	**45 795 428**	**107 962 607**

Table D1.6: Annual CO_{2e} Emissions Diesel Combustion (Stationary Equipment)								
CY	**Year**	**Diesel Fire Water Pump (L/a)**	**Emergency Gensets (L/a)**	**Bore Pumps (L/a)**	**Total Annual Use (L/a)**	**Total Annual Fuel Use (t/a)**	**Total Annual Energy Usage (GJ/a)**	**Emissions (tCO_{2e}/a)**
CY26 (Q2-Q4)	Y01 (Construction)	1 320	138 600	607 442	747 362	635	27 512	1 931
CY27	Y02 (Construction)	1 760	184 800	809 922	996 482	846	36 683	2 575
CY28	Y03 (Construction)	1 760	184 800	809 922	996 482	846	36 683	2 575
CY29 (Q1-Q3)	Y04 (Construction)	1 320	138 600	607 442	747 362	635	27 512	1 931
CY29 (Q4)	Y04 (Ramp Up)	440	61 600	202 481	264 521	225	9 738	684
CY30-CY128	Y01-Y99 (Operation)	1 760	246 400	809 922	1 058 082	898	38 951	2 734
TOTAL (Stage 1 – LOA – 99 Years)		**180,840**	**25 102 000**	**83 219 486**	**108 502 326**	**92 118**	**3 994 257**	**280 397**

Table D1.7: Annual CO_{2e} Emissions from Diesel Combustion (Construction Machinery and Vehicles)						
CY	**Year**	**No of Vehicles/ Machinery**	**Annual Fuel Use (L/a)**	**Annual Fuel Use (t/a)**	**Annual Energy Usage GJ/a**	**Emissions (tCO_{2e}/a)**
CY26 (Q2-Q4)	Y01 (Construction)	21	3 599 972	3 056	132 524.5	9 303
CY27	Y02 (Construction)	193	30 331 320	25 751	1 116 576.0	78 384
CY28	Y03 (Construction)	132	20 477 499	17 385	753 830.8	52 919
CY29 (Q1-Q3)	Y04 (Construction)	35	5 821 458	4 942	214 303.2	15 044
CY29 (Q4)	Y04 (Ramp Up)	–	–	–	–	–
CY30-CY128	Y01-Y99 (Operation)	–	–	–	–	–
TOTAL (Stage 1 – LOA – 99 Years)		–	**60 230 249**	**51 135**	**2 217 234**	**155 650**

Table D1.8: Annual CO_{2e} Emissions from Diesel Combustion (Light Vehicles)					
CY	**Year**	**Annual Fuel Use (L/a)**	**Annual Fuel Use (t/a)**	**Annual Energy Usage GJ/a**	**Emissions (tCO_{2e}/a)**
CY26 (Q2-Q4)	Y01 (Construction)	–	–	–	–
CY27	Y02 (Construction)	–	–	–	–
CY28	Y03 (Construction)	–	–	–	–
CY29 (Q1-Q3)	Y04 (Construction)	–	–	–	–
CY29 (Q4)	Y04 (Ramp Up)	50 279	43	1 851	130
CY30-CY128	Y01-Y99 (Operation)	201 115	171	7 404	520
TOTAL (Stage 1 – LOA – 99 Years)		**19 96 664**	**16 947**	**734 805**	**51 583**

Table D1.9: Annual Diesel Consumption from Non-Mining Mobile Equipment										
Usage	**Type**	**Description**	**Qty**	**Make/Source**	**Fuel Consumption (L/d)**	**Fleet Fuel Usage (L/a)**	**Fuel type**	**Annual Fuel Use (t/a)**	**Annual Energy Usage GJ/a**	**Emissions (tCO_{2e}/a)**
Management	Vehicle	Dual Cab Utilities	6	ANY	4.7	10 293	Diesel Oil	8.74	378.91	26.60
Reagents	Forklift	4WD Teleporter Type	4	ANY	20	29 200	Diesel Oil	24.79	1074.93	75.46
Process Plant	Light Trucks	4WD 5 t flat bed with Hiab	2	ANY	20	14 600	Diesel Oil	12.40	537.46	37.73
Process Plant	Bobcats	Skid Steer loader 4:1 Bucket	2	ANY	20	14 600	Diesel Oil	12.40	537.46	37.73
Product Handling	Forklift	4WD Teleporter Type	2	ANY	20	14 600	Diesel Oil	12.40	537.46	37.73
Maintenance	Light Trucks	5 t flat bed with Hiab	2	ANY	20	14 600	Diesel Oil	12.40	537.46	37.73
Maintenance	Forklift	8 t high lift	2	ANY	20	14 600	Diesel Oil	12.40	537.46	37.73
Maintenance	Lift	Cherry Picker Boom Lift	2	ANY	20	14 600	Diesel Oil	12.40	537.46	37.73
Maintenance	Crane	15 t Franna	1	ANY	10	3 650	Diesel Oil	3.10	134.37	9.43
Maintenance	Vehicle	Dual Cab Utilities	6	ANY	4.7	10 293	Diesel Oil	8.74	378.91	26.60
Maintenance	Vehicle	Lube truck	1	ANY	10	3 650	Diesel Oil	3.10	134.37	9.43
Maintenance	Lighting Tower	Lighting Tower	2	ANY	20	14 600	Diesel Oil	12.40	537.46	37.73
Maintenance	Compressors	Diesel Compressors	2	ANY	5	3 650	Diesel Oil	3.10	134.37	9.43
Maintenance	Welding Units	Diesel Welding Units	2	ANY	5	3 650	Diesel Oil	3.10	134.37	9.43
Admin General	Vehicle	Dual Cab Utilities	4	ANY	4.7	6 862	Diesel Oil	5.83	252.61	17.73
Admin General	Vehicle (GM)	Toyota Prado eq.	2	ANY	4.7	3 431	Diesel Oil	2.91	126.30	8.87
Environmental	Vehicle	Dual Cab Utilities	2	ANY	4.7	3 431	Diesel Oil	2.91	126.30	8.87

Table D1.9: Annual Diesel Consumption from Non-Mining Mobile Equipment										
Usage	**Type**	**Description**	**Qty**	**Make/Source**	**Fuel Consumption (L/d)**	**Fleet Fuel Usage (L/a)**	**Fuel type**	**Annual Fuel Use (t/a)**	**Annual Energy Usage GJ/a**	**Emissions (tCO_{2e}/a)**
Safety	Vehicle	Dual Cab Utilities	2	ANY	4.7	3 431	Diesel Oil	2.91	126.30	8.87
Safety	Vehicle	Ambulance	2	ANY	4.7	3 431	Diesel Oil	2.91	126.30	8.87
Safety	Light Truck	Fire Truck	2	ANY	5	3 650	Diesel Oil	3.10	134.37	9.43
Transport	Light Truck	30-seater Bus	6	ANY	4.7	10 293	Diesel Oil	8.74	378.91	26.60
TOTAL			**56**			**201 115**		**170.7**	**7 403.6**	**519.7**

Table D1.10: Annual CO_{2e} Emissions from the Product Transport to the Port					
CY	**Year**	**Diesel Usage**			**CO_{2e} Emissions**
		L/a	**t/a**	**GJ/a**	**(tCO_{2e}/a)**
CY26 (Q2-Q4)	Y01 (Construction)	-	-	-	-
CY27	Y02 (Construction)	-	-	-	-
CY28	Y03 (Construction)	-	-	-	-
CY29 (Q1-Q3)	Y04 (Construction)	554 200	470.5	20 402	1 432
CY29 (Q4)	Y04 (Ramp Up)	273 622	232	10 073	707
CY30-CY128	Y01-Y99 (Operation)	729 631	619	26 860	1 886
Total (Stage 1 – LOA – 99 Years)		**73 061 311**	**62 029**	**2 689 580**	**188 808**

Table D1.11: Annual CO_{2e} Emissions from Wastewater Treatment								
CY	**Year**	**Number of Personnel on-site**	**Average Wastewater Generated (L/a) [4]**	**Initial Chemical Oxygen Demand (COD) mg/a** [55]	**COD After Treatment mg/a [5]**	**COD Removed mg/a** [55]	**CH4 Emitted from COD kg/a** [6]	**Emissions tCO2e/a**
CY26 (Q2-Q4)	Y01 (Construction)	132	9 240 000	6 468 000 000	646 800 000	5 821	1 455	49
CY27	Y02 (Construction)	1 388	97 160 000	68 012 000 000	6 801 200 000	61 211	15 303	520
CY28	Y03 (Construction)	937	65 590 000	45 913 000 000	4 591 300 000	41 322	10 330	351
CY29 (Q1-Q3)	Y04 (Construction)	234	16 380 000	11 466 000 000	1 146 600 000	10 319	2 580	88
CY29 (Q4)	Y04 (Ramp Up)	88	6 125 000	4 287 500 000	428 750 000	3 859	965	33
CY30-CY128	Y01-Y99 (Operation)	350	24 500 000	17 150 000 000	1 715 000 000	15 435	3 859	131
TOTAL (Stage 1 – LOA – 99 Years)			**2 619 995 000**	**1 833 996 500 000**	**183 399 650 000**	**1 650 597**	**412 649**	**14 030**

Table D1.12: Annual CO_{2e} Emissions from Purchased Electricity						
CY	**Year**	**Total Installed Power (kW)**	**Operating Power (kW)**	**Operating (MWh/a)**	**EF (tCO_{2e}/MWh)**	**Emissions (tCO_{2e}/a)**
CY26 (Q2-Q4)	Y01 (Construction)	-	-	-	0.520	-
CY27	Y02 (Construction)	-	-	-	0.520	-
CY28	Y03 (Construction)	-	-	-	0.520	-
CY29 (Q1-Q3)	Y04 (Construction)	17 460	17 460	138 266	0.520	71 899
CY29 (Q4)	Y04 (Ramp Up)	15 723	15 723	124 423	0.520	64 700
CY30-CY128	Y0-Y99 (Operation)	81 243	81 243	642 838	0.520	334 276
Total (Stage 1 – LOA – 99 Years)		**8 076 240**	**8 076 240**	**63 903 622**	**0.520**	**33 229 884**

Table D1.13: Annual CO_{2e} Emissions from Reagents Manufacturing								
CY	**Year**	**CO_2 Emissions (tCO_{2e}/a)**						**Total CO_{2e} (tCO2e/a)**
		Bentonite	**Limestone**	**NG**	**Diesel**	**Magnetite Concentrate**	**Coating Material**	
CY26 (Q2-Q4)	Y01 (Construction)	–	–	–	1 779	–	–	1 779
CY27	Y02 (Construction)	–	–	–	12 820	–	–	12 820
CY28	Y03 (Construction)	–	–	–	8 788	–	–	8 788
CY29 (Q1-Q3)	Y04 (Construction)	10 966	560	21 543	2 688	1 628 964	–	1 664 722
CY29 (Q4)	Y04 (Ramp Up)	4 112	210	51 911	129	610 862	1 333	667 224
CY30-CY128	Y01-Y99 (Operation)	16 450	840	295 309	515	2 443 447	8 000	2 756 561
Total (Stage 1 – LOA – 99 Years)		**1 643 589**	**83 930**	**29 309 074**	**77 217**	**244 141 051**	**793 333**	**275 254 861**

Table D1.14: Annual CO_{2e} Emissions from Capital Goods					
CY	**Year**	**Vehicles & Machinery – Construction Emissions**	**Vehicles & Machinery – Operations Emissions**	**General Construction and MEL**	**Total Emissions tCO_{2e}/a**
CY26 (Q2-Q4)	Y01 (Construction)	12 496	–	64 123	76 619
CY27	Y02 (Construction)	–	–	77 361	77 361
CY28	Y03 (Construction)	–	638	77 361	77 999
CY29 (Q1-Q3)	Y04 (Construction)	–	–	26 477	26 477
CY29 (Q4)	Y04 (Ramp Up)	–	–	–	–
CY30–CY128	Y01-Y99 (Operation)	–	–	–	–
Total (Stage 1 – LOA – 99 Years)		**12 496**	**638**	**245 322**	**258 456**

Table D1.15: Annual CO_{2e} Emissions from Scope 3 Fuel and Energy				
CY	**Year**	**Operating MWh/a**	**SWIS EF tCO_{2e}/MWh**	**Emissions tCO_{2e}/a**
CY26 (Q2-Q4)	Y01 (Construction)	–	0.040	–
CY27	Y02 (Construction)	–	0.040	–
CY28	Y03 (Construction)	–	0.040	–
CY29 (Q1-Q3)	Y04 (Construction)	138 266	0.040	5 531
CY29 (Q4)	Y04 (Ramp Up)	124 423	0.040	4 977
CY30-CY128	Y01-Y99 (Operation)	642 838	0.040	25 714
Total (Stage 1 – LOA – 99 Years)		**63 903 622**	**-**	**2 556 145**

Table D1.16: Annual CO_{2e} Emissions from Upstream Reagents and Feedstock Transportation							
CY	**Year**	**Diesel Usage**			**Road Emissions**	**Shipping and Rail**	**TOTAL**
		L/a	**t/a**	**GJ/a**	**(tCO_{2e}/a)**	**(tCO_{2e}/a)**	**(tCO_{2e}/a)**
CY26 (Q2-Q4)	Y01 (Construction)	1 230	1.0	45	3.2	0.0	3.2
CY27	Y02 (Construction)	8 866	7.5	326	22.9	0.0	22.9
CY28	Y03 (Construction)	6 077	5.2	224	15.7	0.0	15.7
CY29 (Q1-Q3)	Y04 (Construction)	1 302 723	1 106	47 957	3 367	4 122	7 489
CY29 (Q4)	Y04 (Ramp Up)	496 018	421	18 260	1 282	1 546	2 828
CY30-CY128	Y01-Y99 (Operation)	2 000 280	1 698	73 636	5 169	6 184	11 353
Total (Stage 1 – LOA – 99 Years)		**199 842 614**	**169 666**	**7 356 734**	**516 443**	**617 835**	**1 134 278**

Table D1.17: Annual CO_{2e} Emissions from Waste Generated in Operations				
CY	**Year**	**Personnel On-site (No of people)**	**Waste EF (tCO_{2e}/no people)**	**Emissions (tCO_{2e}/a)**
CY26 (Q2-Q4)	Y01 (Construction)	132	2.31	305
CY27	Y02 (Construction)	1 388	2.31	3 206
CY28	Y03 (Construction)	937	2.31	2 164
CY29 (Q1-Q3)	Y04 (Construction)	234	2.31	541
CY29 (Q4)	Y04 (Ramp Up)	88	2.31	202
CY30-CY128	Y01-Y99 (Operation)	350	2.31	809
Total (Stage 1 – LOA – 99 Years)				**86 460**

Table D1.18: Plane Transportation Emission Factors				
Vehicle Type	**CO2 Factor (kg/unit)**	**CH4 Factor (g/unit)**	**N2O Factor (g/unit)**	**Units**
Air Travel – Medium Haul (>=482 km, <3 701 km)	0.080	0.0004	0.003	passenger-km

Table D1.19: Annual CO_{2e} Emissions from Employee Commuting					
CY	**Year**	**Personnel On-site (No of people)**	**Total Number of Flights per Year (#flights-Passenger/year)**	**One Way Distance (km)**	**Emissions (tCO_{2e}/a)**
CY26 (Q2-Q4)	Y01 (Construction)	132	6 242	1 243	622
CY27	Y02 (Construction)	1388	43 472	1 243	4 333
CY28	Y03 (Construction)	937	30 821	1 243	3 072
CY29 (Q1-Q3)	Y04 (Construction)	234	6 165	1 243	614
CY29 (Q4)	Y04 (Ramp Up)	88	1 593	1 243	159
CY30-CY128	Y01-Y99 (Operation)	350	6 370	1 243	635
Total (Stage 1 – LOA – 99 Years)			**718 923**		**71 656**

Table D1.20: Annual CO_{2e} Emissions from Downstream Shipping and Rail Transportation and Distribution		
CY	**Year**	**Shipping and Rail (tCO_{2e}/a)**
CY26 (Q2-Q4)	Y01 (Construction)	0.0
CY27	Y02 (Construction)	0.0
CY28	Y03 (Construction)	0.0
CY29 (Q1-Q3)	Y04 (Construction)	31 159
CY29 (Q4)	Y04 (Ramp Up)	15 384

Table D1.20: Annual CO_{2e} Emissions from Downstream Shipping and Rail Transportation and Distribution		
CY	**Year**	**Shipping and Rail (tCO_{2e}/a)**
CY30-CY128	Y01-Y99 (Operation)	41 022
Total (Stage 1 – LOA – 99 Years)		**4 107 682**

Table D1.21: Annual CO_{2e} Emissions from Processing of Sold Products								
CY	**Year**	**HBI Plant**			**Pellet Plant**			**HBI + Pellet**
		HBI (t/a)	**Emission Factor (tCO_{2e}/ tHBI)**	**Emissions (tCO_{2e}/a)**	**Pellet (tonne/a)**	**Emission Factor (tCO_{2e}/ tPellet)**	**Emissions (tCO_{2e}/a)**	**Emissions (tCO_{2e}/a)**
CY26 (Q2-Q4)	Y01 (Construction)	–	0.72	–	–	1.19	–	–
CY27	Y02 (Construction)	–	0.72	–	–	1.19	–	–
CY28	Y03 (Construction)	–	0.72	–	–	1.19	–	–
CY29 (Q1-Q3)	Y04 (Construction)	–	0.72	–	2 078 250	1.19	2 473 118	2 473 118
CY29 (Q4)	Y04 (Ramp Up)	333 333	0.72	240 000	692 750	1.19	824 373	1 064 373
CY30-CY128	Y01-Y99 (Operation)	2 000 000	0.72	1 440 000	736 117	1.19	875 979	2 315 979
Total (Stage 1 – LOA – 99 Years)		**198 333 333**		**142 800 000**	**75 646 583**		**90 019 434**	**232 819 434**

Appendix E Selected Consolidation of Mobile Equipment

E1 Selected Consolidation of Mobile Equipment

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"Selected Consolidation" approach, which was used to determine if up-and down-stream transportation of HBI and iron pellet are Scope 1 emissions.

E1.2 Leased Assets, Outsourcing and Franchises

The selected consolidation approach (equity share or one of the control approaches) is also applied to account for and categorise direct and indirect GHG emissions from contractual arrangements such as leased assets, outsourcing, and franchises. If the selected equity or control approach does not apply, then the company may account for emissions from the leased assets, outsourcing, and franchises under Scope 3. Specific guidance on leased assets is provided below:

E1.3 Using Equity Share or Financial Control

The lessee only accounts for emissions from leased assets that are treated as wholly owned assets in financial accounting and are recorded as such on the balance sheet (i.e. finance or capital leases).

The lessee only accounts for emissions from leased assets that it operates (i.e. if the operational control criterion applies). Guidance on which leased assets are operating and which are finance leases should be obtained from the company accountant. In general, in a finance lease, an organisation assumes all rewards and risks from the leased asset, and the asset is treated as wholly owned and is recorded as such on the balance sheet. All leased assets that do not meet those criteria are operating leases.

E1.4 The Selected Consolidation Approach

For the delivery of reagents to the Western Australian Port Hedland Green Steel Project from suppliers in Perth, it is assumed that PHGS will enter into contracts with transportation companies. It is assumed that these contracts will not constitute equity share, financial or operational control of the transportation companies' assets therefore their emissions will not form part of PHGS's Scope 1 emissions. They will be included in any calculation of PHGS's Scope 3 emissions.

Assuming all reagents are travelling from a facility not owned or operated by PHGS to the Port Hedland Green Steel Project in Western Australia, the emissions from this transport will need to be included as a Scope 3 contribution.

It is also assumed that, for the transport of HBI and Pellet products from the Port Hedland Green Steel Project to overseas Steel companies in Japan, Taiwan and South Korea, PHGS will enter into contracts with transportation companies and this impact will be included in the Scope 3 emissions.

Appendix F Emission Abatement Table

Table F1.1: Summary of Low-carbon Case Emissions from CY26 to CY38														
Year	**CY26 (Q2-Q4)**	**CY27**	**CY28**	**CY29 (Q1-Q3)**	**CY29 (Q4)**	**CY30**	**CY31**	**CY32**	**CY33**	**CY34**	**CY35**	**CY36**	**CY37**	**CY38**
Production Plan (Mt/a)														
Pellet	–	–	–	2.1	0.7	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
HBI	–	–	–	–	0.3	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Baseline Scope 1 Emissions (tCO_2/a)														
Process Emissions (including NG Emissions) (tCO_2/a)														
Pellet	–	–	–	90 394	33 898	135 591	135 591	135 591	135 591	135 591	135 591	135 591	135 591	135 591
HBI	–	–	–	–	164 210	985 260	985 260	985 260	985 260	985 260	985 260	985 260	985 260	985 260
NG Emissions (tCO_2/a)														
Pellet	–	–	–	79 356	29 759	119 034	119 034	119 034	119 034	119 034	119 034	119 034	119 034	119 034
HBI	–	–	–	–	161 461	968 764	968 764	968 764	968 764	968 764	968 764	968 764	968 764	968 764
Process Only Emissions (Total Minus NG Emissions) (tCO_2/a)														
Pellet	–	–	–	11 038	4 139	16 557	16 557	16 557	16 557	16 557	16 557	16 557	16 557	16 557
HBI	–	–	–	–	2 749	16 496	16 496	16 496	16 496	16 496	16 496	16 496	16 496	16 496
Diesel Plant Stationary (tCO_2/a)														
Pellet+HBI	1 931	2 575	2 575	1 931	684	2 734	2 734	2 734	2 734	2 734	2 734	2 734	2 734	2 734
Land Clearing (tCO_2/a)														
Pellet+HBI	30 623	–	–	–	–	–	–	–	–	–	–	–	–	–
Diesel Mobile (tCO_2/a)														
Pellet+HBI	9 303	78 384	52 919	15 044	130	520	520	520	520	520	520	520	520	520
Biogenic Impact (tCO_2/a)														
Pellet+HBI	49	520	351	88	33	131	131	131	131	131	131	131	131	131
Product Transportation to the Port (tCO_2/a)														
Pellet+HBI	–	–	–	1 432	707	1 886	1 886	1 886	1 886	1 886	1 886	1 886	1 886	1 886
Total Scope 1 – Baseline Emissions (tCO_2/a)														
Pellet+HBI	41 907	81 479	55 845	108 889	199 661	1 126 122	1 126 122	1 126 122	1 126 122	1 126 122	1 126 122	1 126 122	1 126 122	1 126 122
H2 Substitution (tCO_2/a)														
Pellet	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
HBI	0%	0%	0%	0%	0%	1%	1%	1%	10%	10%	10%	10%	10%	10%
Emissions Abated by H_2 Substitution (tCO_2/a)														
Pellet	–	–	–	–	–	–	–	–	–	–	–	–	–	–
HBI	–	–	–	–	–	9 688	9 688	9 688	96 876	96 876	96 876	96 876	96 876	96 876
Total Scope 1 – Emissions with H_2 Substitution (tCO_2/a)														
Pellet+HBI	41 907	81 479	55 845	108 889	199 661	1 116 434	1 116 434	1 116 434	1 029 246	1 029 246	1 029 246	1 029 246	1 029 246	1 029 246

Table F1.1: Summary of Low-carbon Case Emissions from CY26 to CY38														
Year	**CY26 (Q2-Q4)**	**CY27**	**CY28**	**CY29 (Q1-Q3)**	**CY29 (Q4)**	**CY30**	**CY31**	**CY32**	**CY33**	**CY34**	**CY35**	**CY36**	**CY37**	**CY38**
Emissions Abated by CCS (tCO_2/a)														
Pellet	–	–	–	–	–	–	–	–	–	–	–	–	–	–
HBI	–	–	–	–	–	380 952	476 190	432 900	432 900	432 900	432 900	432 900	432 900	432 900
Total Scope 1 – Emissions with H2 Substitution and CCS (tCO_2/a)														
Pellet+HBI	41 907	81 479	55 845	108 889	199 661	735 482	640 244	683 534	596 346	596 346	596 346	596 346	596 346	596 346
Diesel Mobile (Pellet+HBI) (tCO_2/a)														
Base Case – Operation +Construction	9 303	78 384	52 919	15 044	130	520	520	520	520	520	520	520	520	520
Base Case – Operation	–	–	–	–	130	520	520	520	520	520	520	520	520	520
Base Case – Construction	9 303	78 384	52 919	15 044	–	–	–	–	–	–	–	–	–	–
LC Case – Operations	–	–	–	–	103	419	370	247	123	–	–	–	–	–
LC Case – Operation+ Construction	9 303	78 384	52 919	15 044	103	419	370	247	123	–	–	–	–	–
LC – Fleet Electrification Savings	–	–	–	–	27	101	150	273	396	520	520	520	520	520
LC Product Transportation to the Port (tCO_2/a)														
Base Case	–	–	–	1 432	707	1 603	1 414	943	471	–	–	–	–	–
LC – Product Transport Emissions Abated	–	–	–	–	–	283	471	943	1 414	1 886	1 886	1 886	1 886	1 886
Scope 2 Emissions (tCO_2/a)														
Base Case	–	–	–	71 899	64 700	334 276	334 276	334 276	334 276	334 276	334 276	334 276	334 276	334 276
Scope 2 – Renewables	–	–	–	50 329	46 453	204 378	195 563	188 596	181 260	173 554	162 707	151 860	141 013	130 166
LC - Renewables Grid savings	–	–	–	21 570	18 247	129 898	138 713	145 679	153 016	160 721	171 569	182 416	193 263	204 110
Summary														
Year	**CY26 (Q2-Q4)**	**CY27**	**CY28**	**CY29 (Q1-Q3)**	**CY29 (Q4)**	**CY30**	**CY31**	**CY32**	**CY33**	**CY34**	**CY35**	**CY36**	**CY37**	**CY38**
Scope 1 – Baseline (tCO_{2e}/a)	41 907	81 479	55 845	108 889	199 661	1 126 122	1 126 122	1 126 122	1 126 122	1 126 122	1 126 122	1 126 122	1 126 122	1 126 122
Scope 1 – H_2 Substitution (tCO_{2e}/a)	41 907	81 479	55 845	108 889	199 661	1 116 434	1 116 434	1 116 434	1 029 246	1 029 246	1 029 246	1 029 246	1 029 246	1 029 246
Scope 1 – H_2 Substitution & CCS (tCO_{2e}/a)	41 907	81 479	55 845	108 889	199 661	735 482	640 244	683 534	596 346	596 346	596 346	596 346	596 346	596 346
Scope 1 – H_2 Substitution & CCS+ fleet electrification (operation + product transport) (tCO_{2e}/a)	41 907	81 479	55 845	108 889	199 635	735 099	639 623	682 319	594 535	593 940	593 940	593 940	593 940	593 940
Scope 2 (tCO_{2e}/a)	0	0	0	71 899	64 700	334 276	334 276	334 276	334 276	334 276	334 276	334 276	334 276	334 276
Scope 2 – LC Case (tCO_{2e}/a)	0	0	0	50 329	46 453	204 378	195 563	188 596	181 260	173 554	162 707	151 860	141 013	130 166
Scope 3 (tCO_{2e}/a)	79 328	97 743	92 039	4 209 650	1 755 146	5 152 071	5 152 071	5 152 071	5 152 071	5 152 071	5 152 071	5 152 071	5 152 071	5 152 071
Scope 1-3 Baseline (tCO_{2e}/a)	121 235	179 222	147 884	4 390 437	2 019 507	6 612 469	6 612 469	6 612 469	6 612 469	6 612 469	6 612 469	6 612 469	6 612 469	6 612 469

Table F1.1: Summary of Low-carbon Case Emissions from CY26 to CY38

Year	CY26 (Q2-Q4)	CY27	CY28	CY29 (Q1-Q3)	CY29 (Q4)	CY30	CY31	CY32	CY33	CY34	CY35	CY36	CY37	CY38
Scope 1-3 H_2 Substitution (tCO_{2e}/a)	121 235	179 222	147 884	4 390 437	2 019 507	6 602 781	6 602 781	6 602 781	6 515 593	6 515 593	6 515 593	6 515 593	6 515 593	6 515 593
Scope 1-3 H_2 Substitution & CCS (tCO_{2e}/a)	121 235	179 222	147 884	4 390 437	2 019 507	6 221 829	6 126 591	6 169 881	6 082 693	6 082 693	6 082 693	6 082 693	6 082 693	6 082 693
Scope 1-3 H_2 Substitution & CCS+fleet electrification (tCO_{2e}/a)	121 235	179 222	147 884	4 390 437	2 019 480	6 221 446	6 125 970	6 168 665	6 080 882	6 080 287	6 080 287	6 080 287	6 080 287	6 080 287
Scope 1-3 H_2 Substitution & CCS+fleet electrification+ Reduced power EF (tCO_{2e}/a)	121 235	179 222	147 884	4 368 868	2 001 233	6 091 548	5 987 258	6 022 986	5 927 866	5 919 566	5 908 719	5 897 872	5 887 025	5 876 177

Table F1.2: Summary of Low-carbon Case Emissions from CY39 to CY128

Year	CY39	CY40	CY41	CY42	CY43	CY44	CY45	CY46	CY47	CY48	CY49	CY50	CY51	CY52-CY128	TOTAL
Production Plan (Mt/a)															
Pellet	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	**349.3**
HBI	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	**198.3**
Baseline Scope 1 Emissions (tCO_{2e}/a)															
Process Emissions (including NG Emissions) (tCO_{2e}/a)															
Pellet	135 591	135 591	135 591	135 591	135 591	135 591	135 591	135 591	135 591	135 591	135 591	135 591	135 591	135 591	**13 547 801**
HBI	985 260	985 260	985 260	985 260	985 260	985 260	985 260	985 260	985 260	985 260	985 260	985 260	985 260	985 260	**97 704 976**
NG Emissions (tCO_{2e}/a)															
Pellet	119 034	119 034	119 034	119 034	119 034	119 034	119 034	119 034	119 034	119 034	119 034	119 034	119 034	119 034	**11 893 510**
HBI	968 764	968 764	968 764	968 764	968 764	968 764	968 764	968 764	968 764	968 764	968 764	968 764	968 764	968 764	**96 069 097**
Process Only Emissions (Total Minus NG Emissions) (tCO_{2e}/a)															
Pellet	16 557	16 557	16 557	16 557	16 557	16 557	16 557	16 557	16 557	16 557	16 557	16 557	16 557	16 557	**1 654 290**
HBI	16 496	16 496	16 496	16 496	16 496	16 496	16 496	16 496	16 496	16 496	16 496	16 496	16 496	16 496	**1 635 879**
Diesel Plant Stationary (tCO_{2e}/a)															
Pellet+HBI	2 734	2 734	2 734	2 734	2 734	2 734	2 734	2 734	2 734	2 734	2 734	2 734	2 734	2 734	**280 397**
Land Clearing (tCO_{2e}/a)															
Pellet+HBI	–	–	–	–	–	–	–	–	–	–	–	–	–	–	**30 623**
Diesel Mobile (tCO_{2e}/a)															
Pellet+HBI	520	520	520	520	520	520	520	520	520	520	520	520	520	520	**207 233**
Biogenic Impact (tCO_{2e}/a)															
Pellet+HBI	131	131	131	131	131	131	131	131	131	131	131	131	131	131	**14 030**
Product Transportation to the Port (tCO_{2e}/a)															
Pellet+HBI	1 886	1 886	1 886	1 886	1 886	1 886	1 886	1 886	1 886	1 886	1 886	1 886	1 886	1 886	**188 808**

Table F1.2: Summary of Low-carbon Case Emissions from CY39 to CY128

Year	CY39	CY40	CY41	CY42	CY43	CY44	CY45	CY46	CY47	CY48	CY49	CY50	CY51	CY52-CY128	TOTAL
Total Scope 1 – Baseline															
Pellet+HBI	1 126 122	1 126 122	1 126 122	1 126 122	1 126 122	1 126 122	1 126 122	1 126 122	1 126 122	1 126 122	1 126 122	1 126 122	1 126 122	1 126 122	**111 973 868**
H_2 Substitution (tCO_{2e}/a)															
Pellet	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	
HBI	30%	30%	30%	30%	50%	50%	50%	70%	70%	70%	90%	100%	100%	100%	
Emissions Abated by H_2 Substitution (tCO_{2e}/a)															
Pellet	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HBI	290 629	290 629	290 629	290 629	484 382	484 382	484 382	678 135	678 135	678 135	871 888	968 764	968 764	968 764	**82 664 632**
Total Scope 1 – Emissions with H_2 Substitution (tCO_{2e}/a)															
Pellet+HBI	835 493	835 493	835 493	835 493	641 740	641 740	641 740	447 987	447 987	447 987	254 234	157 358	157 358	157 358	**29 309 236**
Emissions Abated by CCS (tCO_{2e}/a)															
Pellet	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HBI	336 700	336 700	336 700	336 700	240 500	240 500	240 500	144 300	144 300	144 300	48 100	48 100	48 100	48 100	**10 236 642**
Total Scope 1 - Emissions with H2 Substitution and CCS (tCO_{2e}/a)															
Pellet+HBI	498 793	498 793	498 793	498 793	401 240	401 240	401 240	303 687	303 687	303 687	206 134	109 258	109 258	109 258	**19 072 594**
Diesel Mobile (Pellet+HBI) (tCO_{2e}/a)															
Base Case –Operation + Construction	520	520	520	520	520	520	520	520	520	520	520	520	520	520	**207 233**
Base Case – Operation	520	520	520	520	520	520	520	520	520	520	520	520	520	520	**51 583**
Base Case – Construction	–	–	–	–	–	–	–	–	–	–	–	–	–	–	**155 650**
LC Case – Operations	–	–	–	–	–	–	–	–	–	–	–	–	–	–	**1 262**
LC Case – Operation+Construction	–	–	–	–	–	–	–	–	–	–	–	–	–	–	**156 912**
LC – Fleet Electrification Savings	520	520	520	520	520	520	520	520	520	520	520	520	520	520	**50 321**
LC Product Transportation to the Port (tCO_{2e}/a)															
Base Case	–	–	–	–	–	–	–	–	–	–	–	–	–	–	**6 570**
LC – Product Transport Emissions Abated	1 886	1 886	1 886	1 886	1 886	1 886	1 886	1 886	1 886	1 886	1 886	1 886	1 886	1 886	**182 238**
Scope 2 Emissions (tCO_{2e}/a)															
Scope 2 – Baseline	334 276	334 276	334 276	334 276	334 276	334 276	334 276	334 276	334 276	334 276	334 276	334 276	334 276	334 276	**33 229 884**
Scope 2 – Renewables	119 318	108 471	97 624	86 777	75 930	65 083	54 236	43 389	32 541	21 694	10 847	–	–	–	**2 341 789**
LC - Renewables Grid savings	214 957	225 804	236 651	247 499	258 346	269 193	280 040	290 887	301 734	312 581	323 428	334 276	334 276	334 276	**30 888 095**
Summary															
Year	**CY38**	**CY39**	**CY40**	**CY41**	**CY42**	**CY43**	**CY44**	**CY45**	**CY46**	**CY47**	**CY48**	**CY49**	**CY50**	**2051-2125**	
Scope 1 – Baseline (tCO_{2e}/a)	1 126 122	1 126 122	1 126 122	1 126 122	1 126 122	1 126 122	1 126 122	1 126 122	1 126 122	1 126 122	1 126 122	1 126 122	1 126 122	1 126 122	

Table F1.2: Summary of Low-carbon Case Emissions from CY39 to CY128

Year	CY39	CY40	CY41	CY42	CY43	CY44	CY45	CY46	CY47	CY48	CY49	CY50	CY51	CY52-CY128	TOTAL
Scope 1 – H_2 Substitution (tCO_{2e}/a)	835 493	835 493	835 493	835 493	641 740	641 740	641 740	447 987	447 987	447 987	254 234	157 358	157 358	157 358	
Scope 1 – H_2 Substitution & CCS (tCO_{2e}/a)	498 793	498 793	498 793	498 793	401 240	401 240	401 240	303 687	303 687	303 687	206 134	109 258	109 258	109 258	
Scope 1 – H_2 Substitution & CCS+ fleet electrification (operation + product transport) (tCO_{2e}/a)	496 388	496 388	496 388	496 388	398 835	398 835	398 835	301 282	301 282	301 282	203 729	106 853	106 853	106 853	
Scope 2 (tCO_{2e}/a)	334 276	334 276	334 276	334 276	334 276	334 276	334 276	334 276	334 276	334 276	334 276	334 276	334 276	334 276	
Scope 2 – LC Case (tCO_{2e}/a)	119 318	108 471	97 624	86 777	75 930	65 083	54 236	43 389	32 541	21 694	10 847	0	0	0	
Scope 3 (tCO_{2e}/a)	5 152 071	5 152 071	5 152 071	5 152 071	5 152 071	5 152 071	5 152 071	5 152 071	5 152 071	5 152 071	5 152 071	5 152 071	5 152 071	5 152 071	
Scope 1-3, Baseline (tCO_{2e}/a)	6 612 469	5 152 071	5 152 071	5 152 071	5 152 071	5 152 071	5 152 071	5 152 071	5 152 071	5 152 071	5 152 071	5 152 071	5 152 071	5 152 071	
Scope 1-3, H_2 Substitution (tCO_{2e}/a)	6 321 840	6 321 840	6 321 840	6 321 840	6 128 087	6 128 087	6 128 087	5 934 334	5 934 334	5 934 334	5 740 581	5 643 705	5 643 705	5 643 705	
Scope 1-3, H_2 Substitution & CCS (tCO_{2e}/a)	5 985 140	5 985 140	5 985 140	5 985 140	5 887 587	5 887 587	5 887 587	5 790 034	5 790 034	5 790 034	5 692 481	5 595 605	5 595 605	5 595 605	
Scope 1-3, H_2 Substitution & CCS+fleet electrification (tCO_{2e}/a)	5 982 735	5 982 735	5 982 735	5 982 735	5 885 182	5 885 182	5 885 182	5 787 629	5 787 629	5 787 629	5 690 076	5 593 200	5 593 200	5 593 200	
Scope 1-3, H_2 Substitution & CCS+fleet electrification+Reduced power EF (tCO_{2e}/a)	5 767 777	5 756 930	5 746 083	5 735 236	5 626 836	5 615 989	5 605 142	5 496 742	5 485 895	5 475 048	5 366 648	5 258 924	5 258 924	5 258 924	

Appendix G Safeguard Mechanism – Prescribed Production Variables and Default Emissions Intensities.

G1.1 Safeguard Mechanism – Emission Intensity Values

The Safeguard Mechanism and National Greenhouse and Energy Reporting Act 2007 provides a framework for Australia's largest emitters to measure, report and manage their emissions.

The Department of Climate Change, Energy, the Environment and Water (DCCEEW) document outlining the production variables and default emissions intensities, referred to as the "Safeguard Mechanism document", is referred to in section 16 of the National Greenhouse and Energy Reporting (Safeguard Mechanism) Rule 2015 (Safeguard Rule). The purpose of this document is to define production variables for use in baselines made under the Safeguard Mechanism and determine what emissions are relevantly associated with each production variable in accordance with section 16 of the Safeguard Rule.

Production variable definitions and default emissions intensity values are published in Schedule 1 of the Safeguard Rule. Each production variable definition identifies the emissions sources that can contribute to the calculation of an emissions intensity value for the production variable.

There are three types of emissions intensity values:

- Default emissions intensity values: are set by the Government and published in the Safeguard Mechanism Rule. They represent the industry average emissions intensity of production, calculated in accordance with the Framework.
- Facility-specific emissions intensity values: are set by the Clean Energy Regulator, after an application by a responsible emitter. They represent the emissions intensity of production at an individual facility.
- Best practice (benchmarks): are set at international best practice, adapted for an Australia context, and apply to new facilities.

G1.2 Background – Defining Production Variables and Default Emission Intensities

The process of defining the production variables and default emissions intensity values was undertaken in accordance with the Framework for developing default production variables and emissions-intensity values (the Framework document). It involved extensive stakeholder consultation and independent technical expert review. As part of the reforms to the Safeguard Mechanism in 2023, production variables were reviewed to ensure they remain appropriate and effective in the context of shifting to declining baselines to contribute to Australia's emissions reduction targets.

G1.3 Background – Defining Production Variables and Emission Source Boundaries

Section 16 of the Safeguard Rule requires that when emissions are relevantly associated to production variables in an emissions intensity determination application, that must be done in a way that has regard to this document. This ensures that covered emissions are relevant to the default emissions intensity for that production variable.

It is intended that all scope 1 NGER-reported emissions from a facility can be assigned to a production variable. Where a facility produces multiple products, emissions must be apportioned in a justifiable manner, making sure no emissions are counted more than once and the total emissions counted cannot be more than the total emissions from the facility. In some cases, emissions from a particular process will need to be apportioned among two or more production variables.

The Safeguard Mechanism document provides guidance for businesses and auditors on the emissions sources used in the development of default emissions intensity values, which emissions sources can be used in facility-specific emissions intensity calculations and how apportioning should be done. The Safeguard Mechanism document set out the emissions sources that were either included in or excluded
from default emissions intensity calculations and specify which emissions sources can be included in the calculation of a facility-specific emissions intensity value for a production variable.

The Safeguard document sets out the emissions intensity values for each production variable. Global Warming Potential values from the Intergovernmental Panel on Climate Change Fifth Assessment Report (AR5) apply to baselines that relate to 2020-21 and later years.

As part of the Safeguard Mechanism reforms in 2023, the Department reviewed production variables to ensure they remained appropriate and effective in meeting the emissions reduction objective.

G1.4 Production Variable - Primary Iron

In accordance with sections 14A and 19A of the Safeguard Rule, if a facility has primary steel as a historical production variable, an emissions intensity determination for that facility may specify a facility-specific emissions intensity number for primary iron using covered emissions relevantly associated with the primary iron (steelmaking) production variable.

G1.5 Production Variable Definition

1. Subject to subsection (4), tonnes of metallic iron products, excluding any gangue that:
   a. are produced as part of carrying on the primary iron production activity at the facility; and
   b. are exported from the facility; and
   c. are of saleable quality.
2. The metric in subsection (1) is applicable to a facility that conducts the activity of the chemical and physical processing of iron feed materials into a crude iron product suitable for export from the facility Examples: Pig iron, hot briquetted iron (HBI), reduced iron and cast iron are each a crude iron product that may be suitable for export from a facility.
3. The activity in subsection (2) is the primary iron production activity.
   a. Example: The production of crude iron products from iron ore pellets using direct reduction.
4. For subsection (1), if the amount of coke oven coke imported into the facility to produce the metallic iron products is equal to or greater than 5% of the total amount of coke oven coke consumed in carrying on the primary iron production activity, then tonnes of metallic iron products are given by the following equation: metallic iron products = $Qp + 0.891\ Qi$ where:
   a. Qp is the quantity of metallic iron products, in tonnes, that meet the requirements of subsection (1) and are not produced using coke oven coke imported into the facility.
   b. Qi is the quantity of metallic iron products, in tonnes, that meet the requirements of subsection (1) and are produced using coke oven coke imported into the facility.
   c. Note 1: Qp may or may not have been produced with coke oven coke.
   d. Note 2: Qp and Qi do not need to be directly measured, they can be calculated from the consumed ratio of coke oven coke imported into the facility to coke oven coke used to produce metallic iron products that meet the requirements in subsection (1), multiplied by the quantity of iron produced using coke oven coke.