



GREENHOUSE GAS MANAGEMENT PLAN

SOUTH32 WORSLEY ALUMINA

WORSLEY MINE EXPANSION REVISED
PROPOSAL EPA ASSESSMENT NO. 2216

MARCH 2024

Greenhouse Gas Management Plan

Business Blueprint



Worsley Alumina

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1 DECLARATION OF ACCURACY

I declare that:

1. To the best of my knowledge, all the information contained in or accompanying this **Greenhouse Gas Management Plan Version 1.3** is complete, current and correct.
2. I am the designated proponent or the approval holder for this action.
3. I am aware that:
 - a. Section 490 of the Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act) makes it an offence for an approval holder to provide information in response to an approval condition where the person is reckless as to whether the information is false or misleading.
 - b. Section 491 of the EPBC Act makes it an offence for a person to provide information or documents to specified persons who are known by the person to be performing a duty or carrying out a function under the EPBC Act or the Environment Protection and Biodiversity Conservation Regulations 2000 (Cth) where the person knows the information or document is false or misleading.
 - c. Section 112 of the EP Act makes it an offence to give or cause to be given information that to the person's knowledge is false or misleading to the Minister, the Authority, the CEO, a police officer, an inspector or an authorised person.
 - d. The above offences are punishable on conviction by imprisonment, a fine or both.

Signed

Full name (please print)

Position (please print)

Date: / /

2 EXECUTIVE SUMMARY

This Greenhouse Gas Management Plan (GHGMP) has been prepared in accordance with Part IV of the *Environmental Protection Act 1986 (WA)* (EP Act) and associated guidance from the Environmental Protection Authority (EPA), to support the assessment, approval and implementation of the proposed Worsley Mine Expansion Revised Proposal (the Revised Proposal) which was referred to the EPA for assessment on 5 April 2019. Table 1 summarises the context and purpose of the GHGMP in line with the EPA's *Greenhouse Gas Emissions Environmental Factor Guideline* (EPA, 2023a) and the *Template: Greenhouse Gas Environmental Management Plan* (EPA, 2023b).

Table 1: Summary of the Proposal and Key Provisions

| Proposal Name | Worsley Mine Expansion (Revised Proposal) |
|------------------------------------|---|
| Proponent Name | South32 Worsley Alumina Pty Ltd (Worsley Alumina) |
| Proposal Description and Scope | The Worsley Alumina Project is comprised of the Boddington Bauxite Mine (BBM) and the Refinery and has been operating since 1984. The BBM is located 130 km southeast of Perth, Western Australia, and the Refinery is located 47 km south-west of the BBM. The Worsley Alumina Project has been subject to a number of incremental expansions of mining areas and increases in the overall production rate at the Refinery. The Revised Proposal for the Worsley Mine Expansion includes the continuation of existing operations at the BBM, Refinery and overland bauxite conveyor as approved under existing operating approvals, while the assessment component of the Revised Proposal is based on expansion activities being undertaken over a 15 year period in three development envelopes, namely the Worsley Mine Development Envelope, Bauxite Transport Corridor and Contingency Bauxite Mining Envelope. Therefore, this GHGMP accounts for the Worsley Alumina operations holistically and will remain an adaptive management plan over time through periodic review and updates. |
| Purpose of the GHGMP | <p>The purpose of this GHGMP is to support reductions in greenhouse gas (GHG) emissions from the Revised Proposal to as low as reasonably practicable and contribute to the Western Australian Government and South32's respective goals of reaching net zero GHG emissions by 2050. The GHGMP also addresses the requirements of Condition 6 of Ministerial Statement 719.</p> <p>If the Revised Proposal is approved and a new Ministerial Statement issued, this GHGMP will be updated to reflect the associated conditions.</p> |
| Emissions Estimates | <ul style="list-style-type: none"> • Current Annual Emission limit for Scope 1 and 2 (MS719): 3.74 Mtpa CO₂-e • Baseline Emissions Value (Based on FY21 Scope 1 and 2): 3.74 Mtpa CO₂-e • Total maximum emissions for this proposal (15 years) <ul style="list-style-type: none"> • Operational emissions (Scope 1 and 2): 46.4 Mt CO₂-e¹ • Value chain emissions (Scope 3): 243 Mt CO₂-e |
| Trajectory of Emissions Reductions | <ul style="list-style-type: none"> • Minimum total emissions reduction for this proposal (15 years): 9.65 Mtpa CO₂-e • Worsley emission reduction targets see attainment of the following: <ul style="list-style-type: none"> • 9.1% reduction in operational emissions (Scope 1 and 2) by FY29 against an FY21 baseline • 21.9% reduction in operational emissions (Scope 1 and 2) (by FY34) against an FY21 baseline • 40% reduction in operational emissions (Scope 1 and 2) (by FY39) against an FY21 baseline |

¹ Assuming no additional decarbonisation projects are pursued above and beyond the proposed interim targets (see section 4.2.3).

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| Proposal Name | Worsley Mine Expansion (Revised Proposal) |
|--|--|
| Other statutory decision-making processes which require reduction in GHG emissions | <ul style="list-style-type: none"> A discussion of the projects currently under investigation to achieve the emission reduction targets outlined above are provided in Sections 4.4 and 4.6. The use of offsets, in accordance with the mitigation hierarchy, where required to ensure achievement of the emission reduction targets, is discussed in Section 4.9. Worsley's Scope 1 emissions are covered by the Australian Government's Safeguard Mechanism, which is enacted through the <i>National Greenhouse and Energy Reporting Act 2007 (the NGER Act)</i> and other legislation. In 2023, the Safeguard Mechanism was reformed to ensure that industrial facilities contribute to Australia's emission reduction targets of 43% below 2005 levels by 2030 and net zero by 2050. The Safeguard Mechanism sets legislated limits (known as baselines), which will decline, predictably and gradually, on a trajectory consistent with achieving Australia's emission reduction targets, which is aligned with the EPA's GHG objectives. |
| Key components in the GHGMP | <p>To deliver a reduction in GHG emissions at Worsley Alumina through a transparent, practicable, reasonable and feasible approach using the following key provisions:</p> <ul style="list-style-type: none"> Establish goals that set a minimum reduction target for Worsley Alumina which reflect the uncertainties of the operations and project, including the State infrastructure and availability of renewable technologies and energy to reduce net operations emissions (ie Scope 1& 2) over the life of the Revised Proposal; Build on existing studies and emission reduction activities to develop and implement where reasonably practicable a pipeline of projects that support the delivery of the interim targets in accordance with the mitigation hierarchy, focusing on four key themes: <ul style="list-style-type: none"> Energy Efficiency (Section 4.4.1.1), Fuel Switching (Section 4.4.1.2), Long-term Studies and Future Technology (Section 4.4.1.3) and Carbon Offsets (Section 4.9). Utilising an adaptive management approach to improve and optimise the delivery of the proposed and future management actions; Committing to annual reporting against this GHGMP, an initial two year review and five-yearly reviews and revision to monitor and improve the effectiveness of emission reduction measures, with revised versions of the GHGMP to be approved by DWER; Participating in just transition planning in collaboration with multiple stakeholders to support a responsible and fair energy transition; Working with customers and industry partners to address value chain emissions; and Transparent and regular reporting of performance against regulatory (e.g. <i>National Greenhouse and Energy Reporting Act 2007 (NGER Act)</i>) and voluntary schemes (e.g. TCFD). |
| GHGMP reviews and reporting | <ul style="list-style-type: none"> Annual Reporting against this plan will be included in the Worsley Alumina Annual Environmental Report and through applicable government mechanisms (NGER Act, etc). This GHGMP will be reviewed within two years of approval to include updates in accordance with Safeguard, third party review (as outlined in the EPA Factor Guideline (EPA, 2023a)) and emissions associated with native vegetation clearing. This review also presents an opportunity to review the targets presented in this GHGMP. After the initial two-year review, this GHGMP will be reviewed and updated at least every five years. |

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| | |
|---|---|
| Proposal Name | Worsley Mine Expansion (Revised Proposal) |
| Proposed construction date | N/A - Revised Proposal |
| GHGMP required pre-construction? | N/A. Worsley Alumina currently has in place an approved GHGMP (as per condition 6-1 of MS719). This version represents an update to the current plan to reflect the proposed changes to the proposal and updated GHG policy and guidelines. |
| Proposed project end of life/decommissioning date | The proposal seeks to extend the mine life by approximately 15 years however, the overall Worsley Project is anticipated to continue operating beyond 2050. |

3 CONTEXT, SCOPE AND RATIONALE

3.1 INTRODUCTION

This GHGMP has been prepared by Worsley Alumina to support the assessment, approval and implementation of the proposed Worsley Mine Expansion (the Revised Proposal – Refer to Section 3.1), referred to the EPA for assessment under Section 38 of the EP Act on 5 April 2019.

Amongst other matters, this GHGMP details Worsley Alumina's approach to the management and reduction of GHG emissions associated with the Worsley Alumina Project at a whole of operations level inclusive of the Boddington Bauxite Mine (BBM) and the Worsley Alumina Refinery (the Refinery), establishes interim emission reduction targets and demonstrates how reasonable and practicable measures are, and will, be applied to avoid, reduce and offset the GHG emissions associated with the Revised Proposal.

The GHGMP also describes Worsley Alumina's contribution towards the Western Australian Government's aspiration of net zero emissions by 2050, which aligns with South32's support for the objectives of the Paris Agreement and contributes to our group level emissions reduction target to halve operational emissions (Scope 1 and 2) by 2035² and our goal of net zero GHG emissions (Scope 1, 2 and 3) by 2050. The proposed interim GHG emissions reduction targets are aligned with South32's group-wide GHG emissions reduction target but they do not replicate them, noting South32's group-wide decarbonisation strategy to meet its medium-term target has been developed at a whole-of-portfolio level.

The contents of the first version of this GHGMP (October 2021) were developed in accordance with EPA guidance *Content of a Greenhouse Gas Management Plan* (EPA, 2020a; draft), and with reference to the *Greenhouse Gas Emissions Policy for Major Projects* (DWER, 2019), *GHG Emissions Environmental Factor Guideline* (EPA, 2020b), and *Instructions on how to prepare EP Act Part IV Environmental Management Plans* (EPA, 2017). Subsequent to this the EPA *Template: Greenhouse Gas Environmental Management Plan* (EPA, 2023b) and *GHG Emissions Environmental Factor Guideline* (EPA, 2023a) have been published and this version of the GHGMP has been amended to reflect the requirements of these documents where possible.

3.2 DESCRIPTION OF THE WORSLEY ALUMINA PROJECT AND THE REVISED PROPOSAL

The Worsley Alumina Project is comprised of the Boddington Bauxite Mine (BBM) and the Refinery and has been operating since 1984. The BBM is located 130 km southeast of Perth, Western Australia, and the Refinery is located 47 km south-west of the BBM. The Worsley Alumina Project has been subject to a number of incremental expansions of mining areas and increases in the overall production rate at the Refinery. The Revised Proposal for the Worsley Mine Expansion includes the continuation of existing operations at the BBM, Refinery and overland bauxite conveyor as approved under existing operating approvals, while the assessment component of the Revised Proposal is based on expansion activities being undertaken in three development envelopes, namely the Worsley Mine Development Envelope (WMDE), Bauxite Transport Corridor (BTC) and Contingency Bauxite Mining Envelope (CBME). Therefore, this GHGMP accounts for the Worsley Alumina operations holistically and will remain an adaptive management plan over time through periodic review and updates.

The indicative life of the expanded mining the subject of the Revised Proposal is approximately 15 years. The Worsley Alumina operations were established in 1984, and will continue beyond 2050 under existing authorised extents (i.e. approved extended mining areas).

The Revised Proposal will allow operations to sustain the currently approved bauxite mining rate of 18.8 Mtpa (dry), whilst the alumina production rate will remain unchanged at 4.7 Mtpa. These production rates form the basis of the historical authorised net GHG emission limit of 3.75 Mtpa CO₂-e under MS719 (see Section 4.1).

The continued operation of the Worsley Mine Expansion will maintain significant economic benefits and stable employment opportunities for individuals and businesses in the South West Region and will provide on-going community and social benefits. Beyond this regional value, the alumina produced at Worsley Alumina is used to produce aluminium, which South32 considers will play a key role in the transition to a low-carbon, global economy, due to its wide-ranging applications in transportation, electrification, packaging and consumer goods.

² Reduction target is based on FY21 baseline.

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3.3 PURPOSE

The purpose of this GHGMP is to support reductions in GHG emissions from the Revised Proposal to as low as is reasonable and practicable and contribute to Western Australia's and South32's respective goals of reaching net zero GHG emissions by 2050. The GHGMP also addresses the requirements of Condition 6 of Ministerial Statement 719.

3.3.1 Condition Requirements

Worsley Alumina has a current and approved GHGMP as required under Condition 6: Greenhouse Gas Abatement (clauses 6-1 to 6-3) of MS719 (see Table 2). Worsley Alumina will continue to implement the applicable requirements of MS719 until a revised and consolidated Ministerial Statement and associated conditions are released as a part of the approval process for the Revised Proposal.

Table 2: MS719 Approval Conditions

| Cond. | Condition Requirement | Ref |
|-------|--|---|
| 6-1 | <p>Prior to commencement of construction, the proponent shall prepare a Greenhouse Gas Emissions Management Plan to:</p> <ul style="list-style-type: none"> ensure that through the use of best practice, the total net "greenhouse gas" emissions and/or "greenhouse gas" emissions per unit of product from the project are minimised; and manage "greenhouse gas" emissions in accordance with the <i>Framework Convention on Climate Change, 1992</i>, and consistent with the National Greenhouse Strategy; <p>to the requirements of the Minister for the Environment on advice of the Environmental Protection Authority.</p> <p>This Plan shall include:</p> <ol style="list-style-type: none"> calculation of the "greenhouse gas" emissions associated with the proposal, as advised by the Environmental Protection Authority; specific measures to minimise the total net "greenhouse gas" emissions and/or the "greenhouse gas" emissions per unit of product associated with the proposal using a combination of "no regrets" and "beyond no regrets" measures estimation of the "greenhouse gas" efficiency of the project (per unit of product and/or other agreed performance indicators) and comparison with the efficiencies of other comparable projects producing a similar product, both within Australia and overseas; actions for the monitoring and annual reporting of "greenhouse gas" emissions and emission reduction strategies; a target set by the proponent for the reduction of total net "greenhouse gas" emissions and/or "greenhouse gas" emissions per unit of product and as a percentage of total emissions over time, and annual reporting of progress made in achieving this target. Consideration should be given to the use of renewable energy sources such as solar, wind or hydro power; consideration by the proponent of entry (whether on a project-specific basis, company-wide arrangement or within an industrial grouping, as appropriate) into the Commonwealth Government's "Greenhouse Challenge" voluntary cooperative agreement program. Components of the agreement program include: <ul style="list-style-type: none"> an inventory of emissions; opportunities for abating "greenhouse gas" emissions in the organisation; a "greenhouse gas" mitigation action plan; regular monitoring and reporting of performance; and independent performance verification. | <p>4.1</p> <p>4.4</p> <p>4.2, 4.3.1</p> <p>6</p> <p>4.2</p> <p>No longer Applicable</p> |
| 6-2 | The proponent shall implement the Greenhouse Gas Emissions Management Plan required by condition 6-1. | 5 |
| 6-3 | Prior to the commencement of construction, the proponent shall make the Greenhouse Gas Emissions Management Plan required by condition 6-1 publicly available. | N/A |

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3.3.2 Rationale and Approach

This section outlines the key information sources and aspects informing the rationale and approach of the management provisions outlined in Section 4. It includes:

- A description of the objectives of the GHGMP and approach;
- Benchmarking against similar facilities;
- Summary of findings from key studies undertaken to date to inform Worsley Alumina's current emission reduction workstreams; and
- Key assumptions and uncertainties.

3.3.2.1 Management Objectives and Approach

The objectives of this GHGMP are to:

- Support the assessment, approval and implementation of the Revised Proposal under Part IV of the EP Act in accordance with relevant Western Australian Government policies and guidelines including:
 - *Greenhouse Gas Emissions Policy for Major Projects* (DWER, 2019);
 - *Western Australian Climate Policy* (DWER, 2020);
 - *GHG Emissions Environmental Factor Guideline* (EPA, 2023a);
 - *Instructions on how to prepare EP Act Part IV Environmental Management Plans* (EPA, 2017); and
 - *Template: Greenhouse Gas Environmental Management Plan* (EPA, 2023b).
- Provide for ongoing GHG emission reductions at Worsley Alumina over the life of the Revised Proposal, consistent with South32's goal to reach net zero GHG emissions by 2050 and the Western Australian Climate Policy aspiration of net zero GHG emissions by 2050;
- Outline current and future strategies and activities that demonstrate all reasonable and practicable measures are considered and applied in accordance with the mitigation hierarchy to avoid, reduce and offset the Revised Proposal's operational emissions in line with the interim targets;
- Provide for the adoption of best practice design, technology and management to mitigate GHG emissions over the life of the Revised Proposal, including adaptive management to respond to current uncertainties and future developments in technology, markets and government policy;
- Understand and address impacts from the energy transition and seek to realise new opportunities including jobs, technologies and emerging industries for affected people, communities and businesses; and
- Set out regular review provisions and prepare a revised GHGMP at least every five years.

A key challenge for decarbonising Worsley Alumina is developing feasible solutions for generating process steam at scale for refining bauxite to alumina which requires a significant amount of thermal energy, noting this cannot easily be met by the large-scale deployment of renewable energy sources that do not generate thermal energy directly, such as solar PV and wind. Section 4.1.2.3.1 provides further details on emission reduction studies and projects, which are focused on addressing these primary emission sources by reducing energy consumption and transitioning our energy sources to lower carbon alternatives.

These challenges are compounded by the need to integrate feasible solutions with the operation of the existing, established infrastructure at the Refinery which was designed and constructed over 40 years ago. Unlike some other 'newer' projects, where the materials used may allow them to change the existing infrastructure and make use of the cleaner mechanisms that are available in today's markets. The retrofitting of vintage infrastructure presents a series of unique challenges that require Worsley Alumina to think differently about how to efficiently reduce and transition our energy supply.

4 GHGMP COMPONENTS

This section describes the reasonable and practicable management provisions that will support Worsley Alumina to meet the objectives of the GHGMP (see section 3.3.2.1).

4.1 GHG EMISSION ESTIMATES

The largest source of GHG emissions for Worsley Alumina is associated with the Refinery operations due to the energy demand to generate steam for the Bayer alumina refining process. Process steam is currently generated from a mix of coal fired boilers, gas fired boilers and multi-fuel co-generation steam and power generation plants (MFC's). Electricity is generated as a by-product of steam generation using the existing onsite power stations, with electricity either consumed at the BBM and the Refinery, or exported to the grid.

Worsley Alumina calculates Scope 1 and 2 GHG emissions in according to the World Resources Institute and World Business Council for Sustainable Development Greenhouse Gas Protocol (revised edition) as well as the requirements of the *NGER Act 2007* (Cth) and associated subsidiary legislation and guidelines. Worsley applies the operational control approach and use the Global Warming Potentials (GWPs) from the IPCC Assessment Report 5 (AR5) - 100-year time horizon. A list of greenhouse gases emitted by Worsley Alumina and their associated Global Warming Potential are included in Table 3.

Table 3: Warming Potential for Greenhouse Gases Emitted from Worsley Alumina Operation

| Greenhouse Gas | Chemical Formula | Global Warming Potential |
|----------------------|------------------|--------------------------|
| Carbon dioxide | CO ₂ | 1 |
| Methane | CH ₄ | 28 |
| Nitrous oxide | N ₂ O | 265 |
| Sulphur hexafluoride | SF ₆ | 23,500 |

Worsley calculates Scope 3 GHG emissions in accordance with the methodologies in the World Resources Institute Greenhouse Gas Protocol Corporate Value Chain (Scope 3) Accounting and Reporting Standard. Detail on the specific methodologies used for each Scope 3 category can be found in the South32 Sustainability [Databook](#).

Over the period FY18 to FY22, Worsley Alumina's net operational GHG emissions³ varied from 3.64 Mt CO₂-e to 3.74 Mt CO₂-e. The highest emission year was FY21 which was a direct result of Worsley delivering near full production. If Worsley Alumina's full production capacity were achieved this would result in emission levels reaching the approved 3.75 Mt CO₂-e per annum. If Worsley Alumina were to continue to operate under the existing authorised limits, sustain its existing mining and production rates and take no further action to reduce its GHG emissions, total Scope 1 and Scope 2 emissions would be in the order of 56.1 Mt CO₂-e over the life of the Revised Proposal (i.e. 3.74 Mt CO₂-e per year over the indicative 15 year period).

Sections 4.1.1 and 4.1.2 provide a detailed breakdown of the material emission sources at the BBM and Refinery respectively.

GHG emission forecasts are maintained within the Worsley Alumina Life of Operations Plan (LoOP), which contains identified production variables and associated emissions intensities. The maintenance and review of the LoOP helps to determine and design the mitigation measures identified in Section 4.3, which are reviewed and updated on a regular basis.

The baseline proposed for use in the trajectory of emissions reductions (Section 4.2) is the FY21 GHG emissions of 3.74 Mtpa CO₂-e. This has been proposed as it is consistent with the baseline used for South32's medium and long term targets and goals, is comparable to the current authorised emission limits under MS719 and is representative of a year in which Alumina production was close to the approved 4.7 Mtpa of calcined alumina (>4.6 Mt). The total GHG emissions from the operation over the last 5 years have closely aligned with this annual value.

³ Net operational emissions include total Scope 1 and 2 emissions (calculated using methodologies and emissions criteria in the *NGER(Measurement) Determination 2008* (Cth)) and adjusted to account for the net emissions balance between import and export electricity between the Refinery and the SWIS (and may include electricity supplied through renewable energy power purchase agreements).

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The other alternative considered for use in this GHGMP was the Safeguard Mechanism baseline (average annual operational GHG emissions over period FY2018-FY2022). This was considered to be inappropriate at this time given that the baseline has not yet been submitted to the Clean Energy Regulator (due 30 April 2024) and this baseline only covers Scope 1 emissions.

4.1.1 BBM – Operational GHG Emissions

Operational GHG emissions from the BBM represent only three per cent of Worsley Alumina’s reported net operational emissions. All of the BBM’s emissions are reported as Scope 1 emissions⁴, with the majority of these being attributed to the:

- combustion of coal (plus very minor amount of biomass) at the Refinery to generate electricity for use at the BBM; and
- diesel consumption from use of light and heavy mobile equipment.

Other minor sources of operational GHG emissions (<1%) at the BBM, include:

- diesel consumption for stationary equipment, pumps, and lighting towers; and
- sulfur hexafluoride (SF6) from switchgear.

Table 4 lists the material operational GHG emission sources for the BBM, as well as FY18-FY22 actual emissions and the percentage contribution of each source to the total operational emissions for the BBM and the Refinery.

Table 4: GHG Emissions for the BBM (FY18 - FY22)

| Source | Unit | Emissions (t CO ₂ -e) | | | | | % Emissions of BBM in FY21 (Baseline) | % Emissions of BBM and Refinery in FY21 (Baseline) |
|---|-----------------------|----------------------------------|---------------|---------------|-----------------|---------------|---------------------------------------|--|
| | | FY18 | FY19 | FY20 | FY21 (Baseline) | FY22 | | |
| Scope 1^a | | | | | | | | |
| Coal (and biomass) combustion – electricity | Kt CO ₂ -e | 55 | 55 | 56 | 49 | 43 | 44% | 1% |
| Diesel consumption - transport | | 54 | 54 | 56 | 62 | 61 | 56% | 2% |
| Other | | <1 | <1 | <1 | <1 | <1 | <1% | <1% |
| TOTAL SCOPE 1 + SCOPE 2 | | 110 | 110 | 113 | 112 | 105 | 100%^(b) | 3% |
| Bauxite (Mtpa dry) | | 16.830 | 16.537 | 16.943 | 17.540 | 16.783 | | |
| Intensity (t CO₂-e/t bauxite) | | 0.0065 | 0.0066 | 0.0067 | 0.0064 | 0.0063 | | |

(a) The split for energy consumption between the BBM and the Refinery is based on the amount of steam used in the Refinery and the relative ratio of power consumed at both the Refinery and the BBM.

(b) The sum of the sources may vary to total figure due to rounding.

The GHG emissions intensity for the FY21 activities, our baseline year, at the BBM is calculated as 0.0064 t CO₂-e/t of bauxite.

Given that the mining rate is not proposed to change, additional emissions generated from the Revised Proposal at the BBM are limited to increased fuel demand of longer haul distances.

4.1.1.1 Emissions from Clearing

As stated in Section 4.1, Worsley Alumina reports all GHG emissions in accordance with the legislated NGER requirements which does not include reporting of emissions from land clearing (decomposition of cleared vegetation and emissions associated with burning of forest residue). Consequently, Worsley has not historically included this source of emissions in its GHG emissions calculations and reporting and this emission source was not included in Table 2 of Ministerial Statement 719 (and subsequent targets) and has not been included in Table 4.

⁴ Worsley Alumina calculates Scope 1 and 2 GHG emissions in according to the World Resources Institute and World Business Council for Sustainable Development Greenhouse Gas Protocol (revised edition) as well as the requirements of the NGER Act 2007 (Cth) and associated subsidiary legislation and guidelines.

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The EPA GHG Factor Guideline (EPA, 2023a) requires proponents to determine all Scope 1 emissions including those from land clearing which conflicts with the NGER requirements. Worsley Alumina is in the process of completing an independent third-party review of the emissions associated with vegetation clearing (including emissions from burning of forest residues and decomposition of cleared vegetation) and the sequestration from rehabilitation and ecological restoration works included under the Revised Proposal. Preliminary findings indicate that estimated emissions from forest clearing activities are less than 200,000 tCO₂-e per annum average over the life of the Revised Proposal, noting that this does not take into consideration the sequestration resulting from rehabilitation and restoration activities. This work will be finalised in CY 2024 and will be incorporated into the next review of this GHGMP. Worsley continues to investigate opportunities to reduce burning of forest residue which results from the clearing operations.

4.1.2 Refinery – Operational GHG Emissions

The primary source of carbon emissions at the Refinery is from the combustion of energy coal and natural gas to generate steam for the alumina refining process (digestion and evaporation units) and associated generation of electricity, accounting for approximately 75% of Worsley Alumina’s emissions. Natural gas is also consumed for heating in calcination to ~950°C.

The steam is produced at high pressure (>10MPa) which is then reduced to 1300kPa and 450kPa for use in the Refinery. The most efficient method of reducing the steam pressure is through turbines which generate electricity as steam pressure declines, with the electricity then able to be used at the Refinery and BBM. The total electrical power generated is dependent on the total steam demand and the number of steam generation and turbine units online. The majority of electricity generated is consumed by the Refinery and BBM, with any excess (or shortfall) balanced by exporting (or importing) from the South West Interconnect System (SWIS) grid. Diesel consumption for stationary equipment and transport contributes less 1% of emissions at the Refinery.

Scope 2 emissions amount to a small portion of the operational emissions profile at the Refinery (2%), with electricity imported from the grid restricted to short-periods during maintenance activities and shutdowns. Worsley Alumina’s operational emissions are calculated in accordance with NGER, adjusted to account for the net emissions balance between import and export electricity between the Refinery and the SWIS grid, which may include electricity supplied through renewable energy power purchase agreements.

Other minor operational emission sources (<1%) at the Refinery (all Scope 1 emissions), include:

- petrol consumption for transport vehicles;
- stationary combustion of petroleum-based oils and greases, and gaseous fossil fuels; and
- SF₆ from switchgear;

Table 5 lists the material operational emission sources for the Refinery, FY18-FY22 actual emissions and the percentage contribution of each source to the total operational emissions for the Refinery and the BBM.

Table 5: GHG Emissions for the Refinery (FY18 - FY22)

| Source | Unit | FY18 | FY19 | FY20 | FY21 | FY22 | % Emissions of Refinery in FY21 (Baseline) | % Emissions of BBM and Refinery in FY21 (Baseline) |
|---|-----------------------|--------------|--------------|--------------|--------------|--------------|--|--|
| Scope 1 | | | | | | | | |
| Coal (and biomass) combustion - electricity | Kt CO ₂ -e | 691 | 726 | 768 | 655 | 623 | 18% | 17% |
| Coal (and biomass) combustion - steam | | 1924 | 1924 | 1974 | 1902 | 1853 | 52% | 51% |
| Gas combustion | | 858 | 841 | 851 | 976 | 958 | 27% | 26% |
| Diesel consumption (transport and stationary equipment) | | 12 | 14 | 13 | 12 | 12 | <1% | <1% |
| Other | | <1 | <1 | <1 | <1 | <1 | <1% | <1% |
| Total Scope 1 | | 3,586 | 3,566 | 3,607 | 3,546 | 3,447 | 97% | 95% |
| Scope 2 | | | | | | | | |
| Refinery electricity (from grid) | Kt CO ₂ -e | 75 | 60 | 22 | 80 | 81 | 2% | 2% |

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| Source | Unit | FY18 | FY19 | FY20 | FY21 | FY22 | % Emissions of Refinery in FY21 (Baseline) | % Emissions of BBM and Refinery in FY21 (Baseline) |
|-------------------------------------|--|--------------|--------------|--------------|--------------|--------------|--|--|
| Total Scope 2 | | 75 | 60 | 22 | 80 | 81 | 2% | 2% |
| TOTAL SCOPE 1 + SCOPE 2 | | 3,661 | 3,626 | 3,629 | 3,626 | 3,528 | 100% | 97% |
| Alumina and Hydrate Produced | Mt | 4.373 | 4.412 | 4.519 | 4.609 | 4.640 | | |
| Intensity | t CO₂-e/ t Alumina | 0.837 | 0.822 | 0.803 | 0.786 | 0.760 | | |

The GHG emissions intensity for FY21, the baseline year, at the Refinery are calculated as 0.797 t CO₂-e/t alumina product (inclusive of Scope 1 and 2). Note that the annual production rates of alumina for the Revised Proposal are proposed to remain within the currently approved limit of 4.7 Mtpa. Given that the annual alumina production rate is not proposed to change, it is assumed that the GHG emissions associated with the Refinery would remain consistent over the life of the Revised Proposal in the absence of specific emission reduction activities.

4.1.3 Scope 3 – Value Chain Emissions

Worsley Alumina's total Scope 3 emissions were calculated as 16.2 Mt CO₂-e in FY22⁶ (15.1 Mt CO₂-e in FY21, the baseline year), in accordance with the methodologies in the World Resources Institute Greenhouse Gas Protocol Corporate Value Chain (Scope 3) Accounting and Reporting Standard. It should be noted that the calculated Scope 3 emissions for the Revised Proposal account for South32's downstream ownership of two Aluminium smelters, Hillside Aluminium and Mozal Aluminium, where the alumina product is processed and include a proportional allocation of select Scope 3 categories that apply to South32's group operations (i.e. business travel and commuting employees is calculated at a whole of group level in accordance with the GHG protocol – not at facility level). The most material contributor to Worsley Alumina's Scope 3 emissions relates to processing of sold products making up 97%. This includes processing of alumina to aluminium at non-South32 operated smelters, and aluminium into aluminium ingot / aluminium ingot into aluminium sheet⁵.

Worsley Alumina's FY22⁶ Scope 3 emissions are assumed to be representative of the Scope 3 profile over the life of the Revised Proposal and are estimated to be in the order of 243 Mt CO₂-e, assuming the current South32 portfolio remains unchanged and in the absence of emission reduction activities in the value chain.

Other Scope 3 categories defined in the GHG Protocol account for only 3% of Scope 3 emissions for the Revised Proposal. These include:

- Purchased goods and services;
- Capital goods;
- Fuel and energy-related activities;
- Upstream emissions from purchased electricity;
- Upstream and downstream transport and distribution;
- Business travel and commuting employees; and
- Investments.

⁵ Data sources for the processing of sold products included the International Aluminium Institute's 'Life Cycle Inventory Data and Environmental Metrics' report (World Aluminium, 2015), and the European Aluminium Association's 'Environmental Profile Report' (European Aluminium Associations, 2013).

⁶ In 2022 the Global Warming Potentials for Aluminum were revised by the International Aluminum Institute in the *Life Cycle Inventory Data and Environmental Metrics for the Primary Aluminium Industry* (IAI, 2022). As a result FY22 provides a more accurate baseline for Scope 3 emissions than FY21.

4.2 TRAJECTORY OF EMISSIONS REDUCTIONS

Worsley Alumina’s current GHG emission estimates are detailed in Section 4.1. Given that the Worsley Alumina operation is an existing facility there are no project phases to be addressed other than current operational emissions and the application of emission reduction targets as discussed in Section 4.2.4. However, there are some forecast changes in emission trajectories that are applicable to the Worsley Alumina operation as discussed below.

4.2.1 Scope 2 Emissions Trajectory

Worsley Alumina currently imports a small amount of electricity from the SWIS, accounting for its scope 2 emissions. In December 2022, DCCEEW released *Australia’s emissions projections 2022*. Appendix C of the report detailed projected emission factors for Australia’s electricity grid. These projections have been used in the Scope 2 forecasts included in this GHGMP.

SWIS Projected Electricity Grid Emission Factor

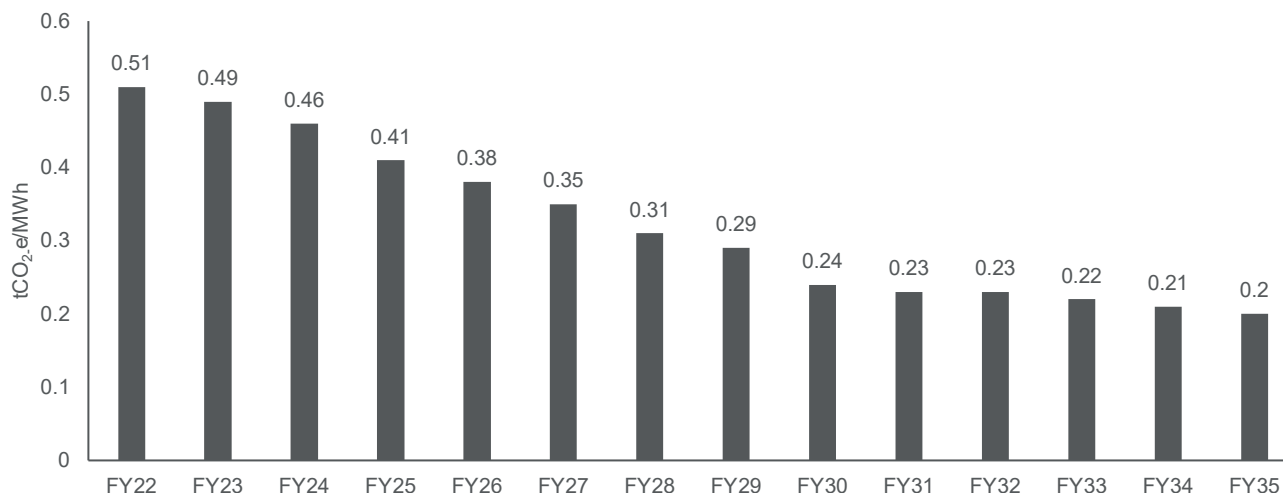


Figure 1: SWIS emission projections (DCCEEW, 2022)⁷

⁷ Note; Figure 1 presents the location based emissions factor rather than market based factor reflecting the data that was available at the time of preparation. NGER now includes a residual mix factor which will be adopted in future revisions.

4.2.2 Scope 3 Emissions Trajectory

As discussed in Section 4.1.3 Worsley Alumina’s FY22 Scope 3 emissions are assumed to be representative of the Scope 3 profile over the life of the Revised Proposal and are estimated to be in the order of 243 Mt CO₂-e, assuming the current South32 portfolio remains unchanged, no additional Worsley Alumina decarbonisation projects that impact Scope 3 emissions are implemented and in the absence of emission reduction activities at non-South32 operated smelters that process Worsley Alumina’s product. Figure 2 provides the annual trajectory of Scope 3 emissions split between Western Australia and Global emissions.

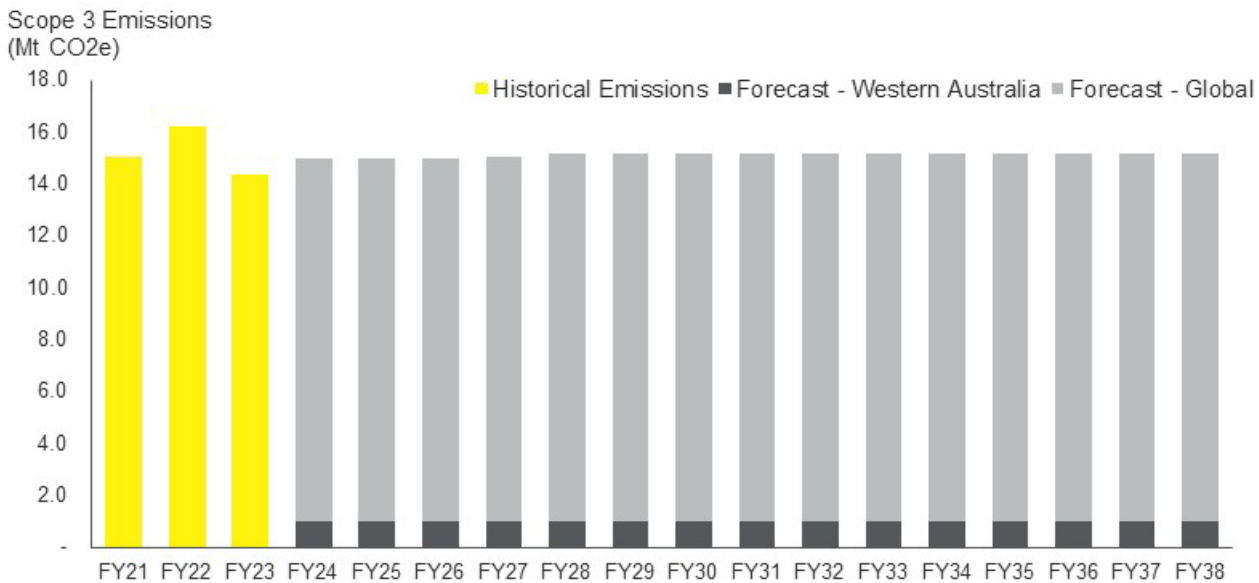


Figure 2: Scope 3 emissions trajectory for Worsley Alumina split between Western Australian and Global emissions.

4.2.3 MA1 - Interim Emission Reduction Targets

As a part of this GHGMP, Worsley Alumina has proposed specific interim emissions reduction targets for its net operational emissions (Scope 1 and Scope 2), inclusive of both the BBM and Refinery. The proposed interim targets are based on five yearly increments, using the FY21 baseline level of 3.74 Mt CO₂-e⁸ and aligned with the 15-year indicative life of this proposal. The pipeline of emission reduction studies and projects described in Section 4.4 are designed to support Worsley Alumina to meet these targets with an aspiration, where reasonable and practical, to deliver reductions beyond the interim reduction targets.

Worsley Alumina completed the conversion of the first coal-fired boilers to natural gas in 2023. The converted gas-fired boiler commenced operation in late-September 2023 and the conversion of a second boiler is planned for 2024.

Figure 3 depicts the proposed minimum interim reduction targets of the Revised Proposal in absolute and % reduction terms, using the FY21 emissions as a baseline. These targets reflect measures to decarbonise Worsley Alumina with the ultimate goal of reaching net zero by 2050 on a linear trajectory so far as practicable. Worsley Alumina will look to accelerate emission reductions towards net zero as new technologies and solutions, including lower carbon energy and developments in Western Australian energy markets, become available (see Section 4.4.1.3). The proposed interim targets for the Revised Proposal are aligned with South32’s group-wide emission reduction targets and goals, but they do not replicate them, noting South32’s group-wide decarbonisation strategy and medium-term emissions reduction target (i.e. to halve our operational emissions by 2035) have been developed at a whole-of-portfolio level. The interim reduction targets for Worsley Alumina reflect the uncertainties of the operations and project, including the State infrastructure and availability of renewable technologies and energy to reduce net operations emissions (ie Scope 1 & 2) over the life of the Revised Proposal

⁸ This baseline is consistent with the baseline used for South32’s medium and long term targets and goals, comparable to the current authorised emission limits under MS719 and representative of a year in which Alumina production was close to the approved 4.7 Mtpa of calcined alumina (>4.6 Mt).

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Interim emission reduction targets beyond FY39 will be developed alongside planning for Worsley Alumina's operations for that time. This will also ensure subsequent interim reduction targets are based on the best available technology and results from further studies and investigations, are reasonable and practicable, and aligned with South32's and Western Australia's medium and long-term emission reduction targets and goals.

Table 6 presents the proposed interim emissions reduction targets in absolute and percentage reduction terms for the Revised Proposal against the proposed baseline. It also displays the trajectory of annual and 5 yearly cumulative GHG emissions and emission reductions that would be achieved by meeting the proposed interim targets. The minimum cumulative emission reduction of 9.65 Mt CO₂-e also represents the minimum emission reductions that the Revised Proposal would contribute to lowering Western Australia's emissions towards the State's net zero goal, compared to maintaining Worsley Alumina's net emissions at the FY21 baseline level of 3.74 Mt CO₂-e.

Table 6: GHG emissions trajectory by year showing 5 yearly cumulative emissions totals and Life of Project GHG emissions and reductions in accordance with reduction targets.

| Financial Year | 5 Yearly Reduction Targets | Emissions Trajectory (Mt CO ₂ -e) | Max. 5 Yearly Cumulative Emissions (Mt CO ₂ -e) | Min. Emission Reductions (Mt CO ₂ -e) | Min 5 Yearly Cumulative Emission Reductions (Mt CO ₂ -e) ⁹ |
|----------------|---------------------------------------|--|--|--|--|
| 2025 | | 3.71 | | 0.03 | |
| 2026 | | 3.65 | | 0.09 | |
| 2027 | 9.1% reduction from baseline by 2029 | 3.57 | 17.78 | 0.17 | 0.92 |
| 2028 | | 3.45 | | 0.29 | |
| 2029 | | 3.40 | | 0.34 | |
| 2030 | | 3.36 | | 0.38 | |
| 2031 | 21.9% reduction from Baseline by FY34 | 3.27 | 15.69 | 0.47 | 3.01 |
| 2032 | | 3.14 | | 0.60 | |
| 2033 | | 3.00 | | 0.74 | |
| 2034 | | 2.92 | | 0.82 | |
| 2035 | 40% reduction from Baseline by FY39 | 2.85 | 12.98 | 0.89 | 5.72 |
| 2036 | | 2.78 | | 0.96 | |
| 2037 | | 2.62 | | 1.12 | |
| 2038 | | 2.48 | | 1.26 | |
| 2039 | | 2.24 | | 1.49 | |
| TOTAL | | 46.4 | 46.4 | 9.65 | 9.65 |

⁹ The minimum cumulative reduction is calculated using the minimum year on year GHG savings that could be achieved across each five-year target period versus Worsley Alumina continuing to operate at FY21 levels. I.

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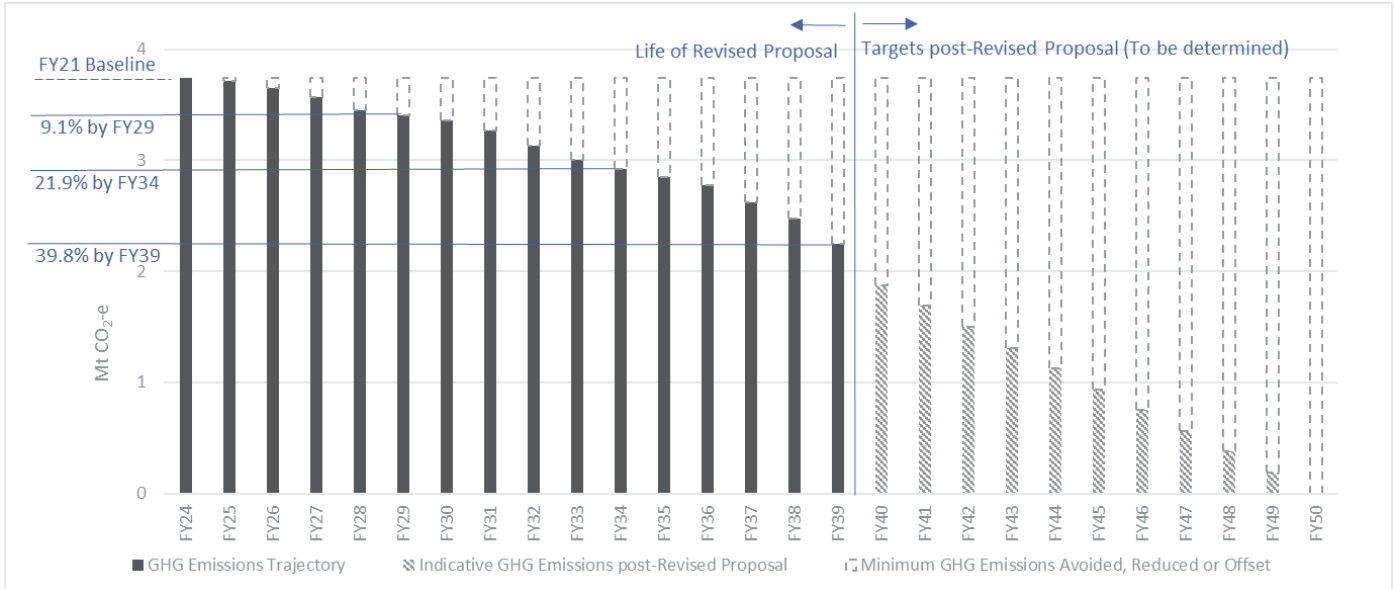


Figure 3: Forecast GHG emissions showing minimum reductions on a year by year basis in alignment with emission reduction targets.

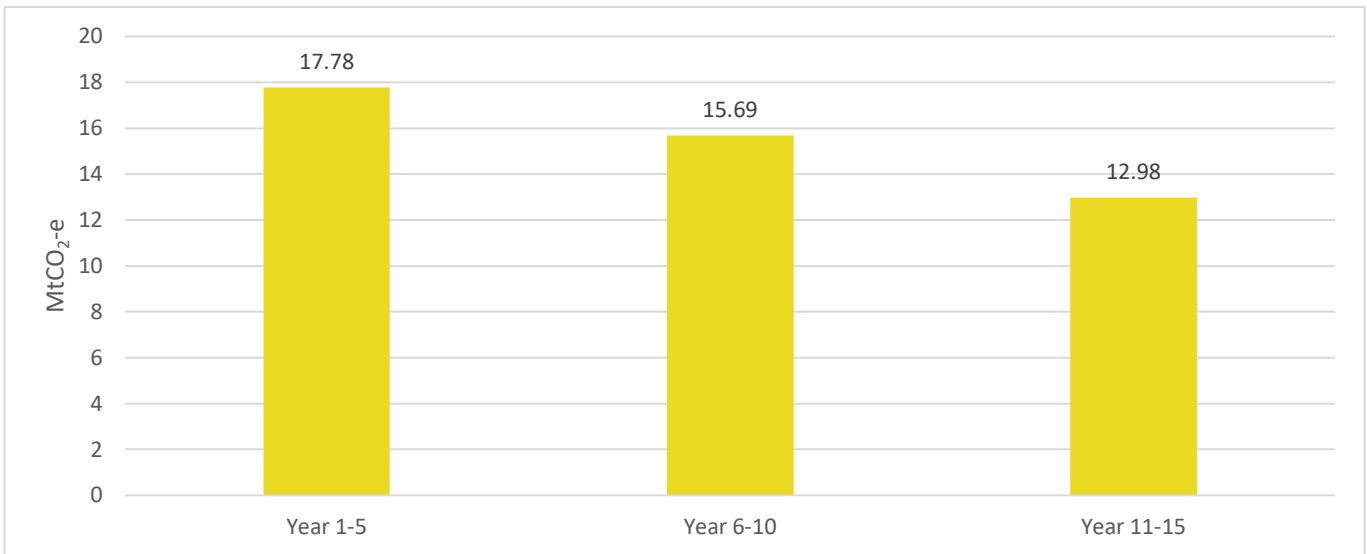


Figure 4 Maximum five yearly cumulative emissions

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4.3 MITIGATION MEASURES

As discussed in Section 3.3.2, a key challenge for decarbonising Worsley Alumina is developing feasible solutions for generating process steam and calcination at scale for refining bauxite to alumina which requires a significant amount of thermal energy. Technologies that are able to address this technical need are not yet commercially available, however studies to date indicate that electrification of steam generation and calcination are the likely pathway for a decarbonised Worsley Alumina. Such technology adoption will likely result in a significant increase in Worsley Alumina's electricity consumption and will likely require a significant redesign of the refinery's internal electrical infrastructure.

In addition, work to date has shown that existing external utility infrastructure (e.g. electricity grid) is significantly undersized to deliver the large volumes of renewable electricity required to support electrification at Worsley Alumina. Similarly, renewable electricity is not currently available at the required scale to support Worsley Alumina's future demand. Worsley Alumina is in discussions with both government and industry to facilitate the development of both transmission infrastructure in the South West Interconnected System (SWIS), as well as additional renewable electricity generation such as solar PV or wind. Development of such infrastructure requires coordination with relevant government agencies industry and communities.

Should the SWIS be unable to achieve 100% supply of green electricity to the Worsley operation this could also impact the delivery of timely and meaningful emission reductions in the medium to long term.

4.3.1 Benchmarking

A benchmarking exercise was undertaken in 2020 utilising forecast FY22 emission intensities. In recognition that no changes to the alumina production rate associated with the Refinery are proposed with the implementation of the Revised Proposal, benchmarking was completed in the context of:

- providing discrete discussion as related to the continued operation and expansion of mining activities at the BBM; and
- continued operation of Refinery activities.

The outcomes of the benchmarking assessment are summarised below. The full report prepared by Ramboll (2020) on the benchmarking assessment is provided as Appendix A.

The process for engaging an additional independent expert review, in accordance with the EPA's *Environmental Factor Guideline - Greenhouse Gas Emissions* (EPA, 2023a), and commenced. The review will be completed within 2 years of receipt of Environmental Approval for the Revised Proposal.

4.3.1.1 Boddington Bauxite Mine

Australia is the world's largest producer of bauxite, with five mines supplying around 30% of global production. These include the BBM, Rio Tinto's Gove (Northern Territory) and Weipa (Queensland), and Alcoa's Huntly (WA) and Willowdale (WA) (Australian Aluminium Council, 2020a). As bauxite mining consumes a relatively small amount of energy compared to other parts of the aluminium life cycle, limited data is available on the total GHG emissions and emissions intensities from the Australian bauxite mining sector (Ramboll, 2020).

Information compiled for the purposes of benchmarking the BBM includes average emissions intensities for the Australian bauxite mines identified above and one international bauxite mine; CBG's Sangaredi Mines (Guinea). These were selected based on availability of public data and with selection of comparable operations producing a similar product to Worsley Bauxite-Alumina, both within Australia and overseas. Average emissions intensities (Scope 1) were compared against:

- the Commonwealth Safeguard default emissions intensity for bauxite mining (0.00401 t CO₂-e/t bauxite¹⁰), as outlined in the Safeguard Mechanism document: Prescribed production variables and default emissions intensities (DISER, 2020);
- the calculated average of Australian benchmarked bauxite mines identified above (0.00751 t CO₂-e/t bauxite); and
- the calculated average of all benchmarked bauxite mines identified above (0.01001 t CO₂-e/t bauxite) (Ramboll, 2020).

Forecast Scope 1 emissions for FY22 (0.00552 CO₂-e/t bauxite¹¹) were used in the Ramboll 2020 benchmarking exercise for BBM. The results of the benchmarking assessment for the BBM are shown in Figure 1 and indicate that the GHG emissions intensity for the BBM is the lowest among the benchmarked examples. The benchmarking indicated that BBM was approximately 46% lower than the average of all benchmarked bauxite mines identified above and approximately 36% lower than the average of the benchmarked

¹⁰ This value does not include emissions associated with production of electricity.

¹¹ FY22 was selected by Ramboll for the benchmarking year as it has the highest production forecast production rate and is considered a conservative approach for the assessment. It is noted that the FY22 GHG measured emissions intensity at BBM was 0.0063 t CO₂-e/t bauxite.

Australian bauxite mines. The actual calculated FY22 operational emissions intensity was 0.0063 CO₂-e/t bauxite, which remains below the calculated average emission intensities forming part of the benchmarking exercise and remains comparable to the average emissions intensity at the neighbouring Alcoa Willowdale bauxite mine (0.006 t CO₂-e/t bauxite). This is assumed to be related to haul distances and proximity to crusher and conveyor infrastructure, of comparable mining operations.

As diesel consumption for transport provides the majority of GHG emissions from the BBM (See Table 4), it is considered that efforts to reduce GHG emissions from mining and mineral processing should focus on loading and haulage activities (KASA, 2020), albeit these contribute less than 2% of the overall emissions of the BBM and the Refinery. Coal combustion for electricity is also a major contributor to the BBM emissions profile, however, the coal combustion activity occurs using infrastructure located at the Refinery. Efforts to reduce GHG emissions associated with coal combustion are discussed with reference to the Refinery throughout this GHGMP.

Greenhouse Gas Emission Intensities of Bauxite Mines
(tCO₂-e / t bauxite)

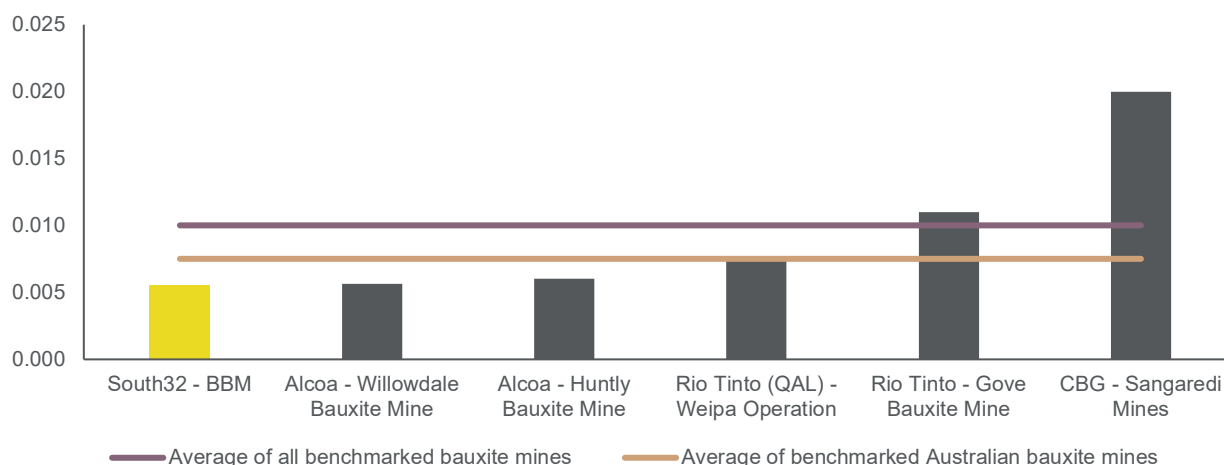


Figure 5: GHG emissions intensities for the BBM and benchmarked facilities (Source: Ramboll, 2020)

4.3.1.2 Refinery

China is the world's leading producer of alumina, producing an estimated 71,284 kt of alumina in 2019, which equates to approximately 54% of global production. Australia is the second highest producer with an estimated 20,491 kt of alumina produced in 2019, which equates to approximately 15% of global production (International Aluminium Institute, 2020). There are six alumina refineries operating in Australia, namely the Worsley Alumina Refinery, Alcoa's Kwinana, Pinjarra and Wagerup refineries (WA), and Rio Tinto's Queensland Alumina Ltd and Yarwun refineries (Queensland) (Australian Aluminium Council, 2020b).

Information compiled for the purposes of benchmarking the Worsley Alumina Refinery includes average emissions intensities for the Australian refineries identified above and seven international alumina refineries namely Hydro's Alunorte (Brazil), Alcoa's San Ciprian Alumina (Spain) and Point Comfort Alumina (United States), RUSAL's Aughinish Alumina (Ireland) and Friguia Alumina (Guinea), Rio Tinto's Jonquiere (Vaudreuil) (Canada), and Noranda's Alumina refinery (United States). These were selected based on availability of public data. Average emissions intensities (Scope 1) were compared against:

- the Commonwealth Safeguard default emissions intensity for alumina refineries (0.545 t CO₂-e/t alumina and equivalent tonne of alumina trihydrate product) as outlined in the Safeguard Mechanism document: Prescribed production variables¹² and default emissions intensities (DISER, 2020),
- the calculated average of Australian benchmarked alumina refineries identified above (0.663 t CO₂-e/t) (Ramboll, 2020); and
- the calculated average of all benchmarked alumina refineries identified above (0.685 t CO₂-e/t) (Ramboll, 2020).

The results of the benchmarking assessment for the Worsley Alumina Refinery are shown in Figure 2. A full summary of all facilities data used to inform the benchmarking study are provided in Appendix A (and specifically Appendix 1 of Ramboll, 2020). The results

¹² Production variables for alumina exclude the production of electricity.

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show that the GHG emissions intensity for the Worsley Alumina Refinery (0.786 t CO₂-e/t alumina, Scope 1 forecast for FY22) was 13% higher than the average emissions intensities for all benchmarked alumina refineries, 16% higher than benchmarked Australian refineries and 31% higher than the Safeguard default value. The actual calculated operational GHG emissions intensity for the Refinery for FY22 was calculated to be 0.760 t CO₂-e/t alumina.

Of the benchmarked refineries, the lowest emissions intensity is at Rio Tinto Jonquiere (Vaudreuil) in Canada, which utilises hydroelectric power. The primary fuel source used in Australia is gas (68%), seconded by coal (23%). The Worsley Alumina Refinery currently uses coal as its primary fuel source, as do the RUSAL refineries in Ireland and Guinea. When compared with facilities using similar fuel types (as the most accurate indicator of a like-for-like comparison, with the information available), the Worsley Alumina Refinery is considered to have one of the lowest GHG emissions intensities (Ramboll, 2020). It is recognised that the type of bauxite ore (e.g. gibbsite, boehmite or diaspore) determines if high temperature digestion is required and consequently could have a significant influence on the energy efficiency of that facility, which is relevant when comparing refineries.

While facility specific data was not able to be obtained from refineries in China and Russia, it is understood that coal is also used extensively at these locations and is considered to be one of the main drivers of the elevated global average (Ramboll, 2020). The inclusion of China and Russia drives the global average up to 1.345 t CO₂-e/t alumina, which Worsley Alumina is well under (by 41%). The use of thermal coal as a primary energy source elevates Worsley Alumina's emissions intensity, although it is noted that Worsley Alumina's energy intensity (10.5-10.6 GJ/t alumina) is lower than the global (11.4 GJ/t alumina) and Oceania (10.7 GJ/t alumina) average for alumina refineries (cite IEA reference, 2018), demonstrate that Worsley Alumina is well positioned to improve its relative position against benchmarked refineries in a scenario where it is able to transition its current thermal coal consumption for the required process steam, to a lower carbon alternative.

The outcomes of the benchmarking study also show that one of the greatest opportunities to reduce GHG emissions from the Refinery is through fuel switching. More information on fuel switching and other decarbonisation initiatives being considered for the Refinery are included in Section 4.4.

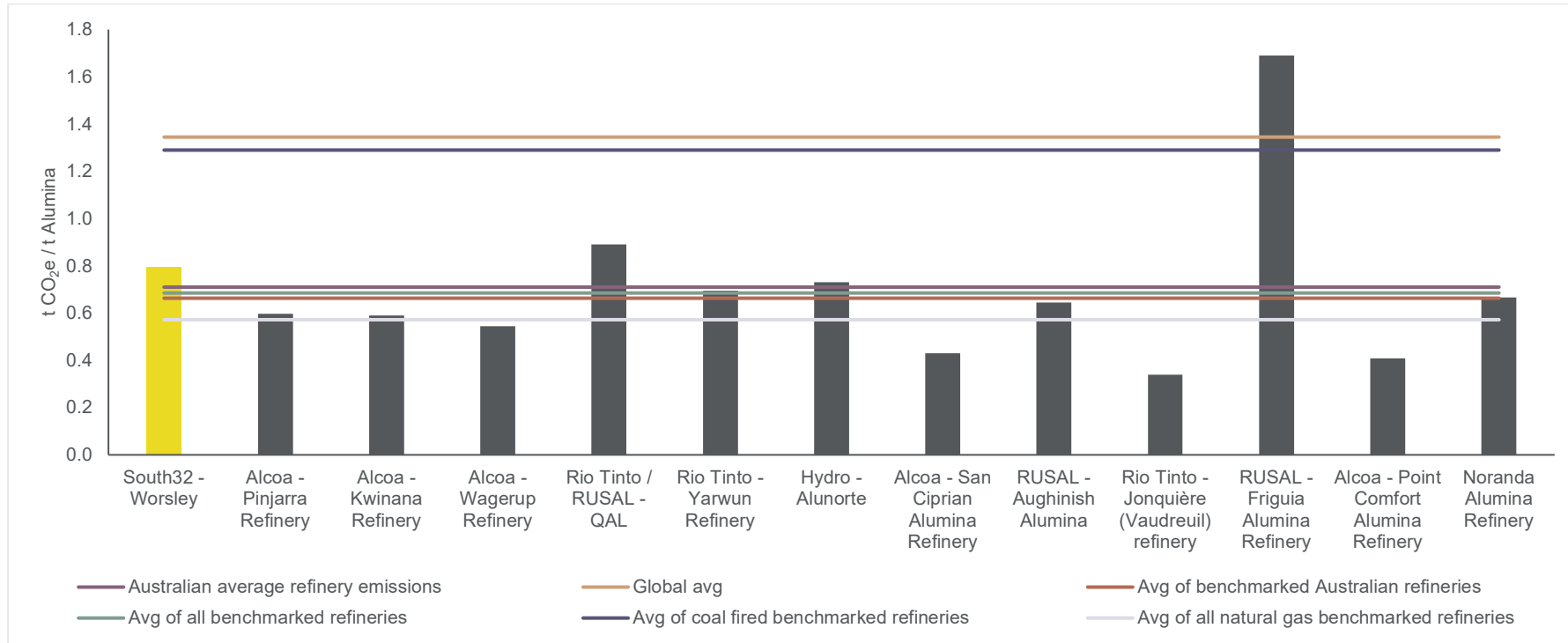


Figure 6: GHG emissions intensities for the Worsley Alumina Refinery and benchmarked facilities (Source: Ramboll, 2020)¹³

¹³ Value shown for South32 Worsley represents the FY22 forecast Scope 1 and Scope 2 emissions intensity of 0.795 t CO₂-e/t alumina. Actual FY22 emissions intensity was calculated to be 0.760 t CO₂-e/t alumina.

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4.3.2 Study Findings

Table 7 presents the findings of key studies that have been undertaken that have informed the current approach relating to this GHGMP. Many of the studies were undertaken as part of Worsley Alumina's decarbonisation program and continue to inform Worsley Alumina's current study and projects portfolio that are outlined in Section 4.4 of this GHGMP.

Table 7: Summary of GHG Studies to Date

| Study | Description of Findings |
|---|---|
| Decarbonisation Pathway Valuation (2023) | A strategy assessment was undertaken to assess the alternative pathways on decarbonising Worsley Alumina. Alternatives include the use of technologies that rely on renewable electricity and technologies that rely on renewable hydrogen. The study included both qualitative as well as quantitative assessment. Outcomes of the study recommended a pathway towards electrification for the Bayer process, but a decision on electric calciner or hydrogen calciner will require further studies. |
| Steam Electrification (2023) | A concept study to evaluate alternative options for steam generation was completed for the Worsley Alumina refinery. The study reinforced the view that the end state for the refinery is likely to be a highly or fully electrified operation, and that conversion to gas boilers remains a necessary interim step. More information on the assessment is provided in Section 4.4.1.2.2. |
| Long Duration Energy Storage (2023) | A study was undertaken to review the suite of technologies that could provide energy storage solutions to compliment an electrified Worsley Alumina refinery. Options considered include the use of a Thermal Energy Storage, as well as a Pumped Hydro Energy Storage. More information on the study is provided in Section 4.4.1.2.3. |
| Mud Washing (2024) | A study is underway to investigate the technical and commercial feasibility of the addition of new high efficiency washers to reduce the amount of water required to wash the mud, which will in turn reduce the amount of evaporation which is required and therefore reduce the need for coal fired steam requirements. More information on the assessment is provided in Section 4.4.1.1.1. |
| Coal to Gas Conversion (Active) | To date the first boiler conversion has been mechanically completed and is in commissioning phase. The second boiler is planned to commence conversion in Q2 of FY2024. A coal to gas conversion study is underway to evaluate the technical and commercial feasibility of displacing coal as the primary fuel source for the remaining coal and multi-fuel boilers on site. More information on the feasibility assessment is provided in Section 4.4.1.2.1. |
| Coal Alternative Steam Supply (Active) | A pre-feasibility study is underway to evaluate the alternatives to transition 100% away from coal, including the potential to use electric technologies to 'leapfrog' the use of natural gas for some of the refinery's steam requirements. |
| Digestion Energy Efficiency (Active) | A pre-feasibility study is ongoing to evaluate the potential to recover and re-use waste heat in the refinery's Digestion process area and thus reduce the 'fresh' steam needed to be generated from fossil fuels. |
| 'Behind the Meter' Renewable Energy Generation Study (2023) | A concept study was completed to evaluate the potential to develop a renewable electricity source through solar PV and / or wind within the vicinity of the refinery and mine. |
| Electricity Infrastructure Constraint Study (2023) | A concept study was completed to evaluate the constraints in electrical infrastructure inside the refinery, as well as external to the refinery (IE: SWIS). This study identified the constraints within the current SWIS infrastructure to support an electrified Worsley Alumina and the need for a coordinated regional response with government to facilitate a decarbonised industry. |
| Calciner Waste Heat Recovery Study (2023) | A concept study was completed to evaluate the opportunity to recover and re-use waste heat in the refinery's Calcination process area to reduce the need for 'fresh' steam from fossil fuels. The study also identified an opportunity to recover and re-use water within the refinery process that would have otherwise been emitted as water vapour into the atmosphere. |

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| Worsley Alumina Environmental Constraints Study (2021) | This study reviewed CY2020 performance, energy intensity, carbon emissions, particulate emissions, flue gas emissions and residue deposition to support Worsley Alumina's future planning and to ensure Worsley Alumina complies with the existing conditions under MS719. Amongst other matters, the study confirmed that energy efficiency and coal to gas studies currently underway should continue to be progressed. |
| Beyond Capability Project (2021) | The Beyond Capability Project is a study into debottlenecking facilities at the Refinery in order to increase the Refinery throughput up to 4.7 Mtpa and improve the Refinery energy intensity. The Beyond Capability Project identified 40+ facilities that have potential to be de-bottlenecked, which are currently under further individual investigation, including potential energy efficiency projects. |
| Worsley Mine Expansion GHG Assessment (2020) | Emissions sources and GHG intensity were calculated as related to the BBM only (KASA, 2020). In comparing BBM operations to other bauxite mines, it was identified that the BBM has a comparatively low emissions intensity. It also identified that for the BBM, addressing loading and haulage activities are likely to provide the greatest opportunity at the BBM for emissions reductions (See Section 4.3.1.1). |
| Decarbonisation Concept Study (2019) | The Decarbonisation Concept Study identified over 80 potential decarbonisation initiatives through planning and assessment work for the Refinery. The initiatives identified through the study have informed the Worsley Alumina portfolio of current studies and projects that are the focus for delivering the emission reduction targets outlined in this GHGMP. More information on the Decarbonisation Concept Study and subsequent initiative assessments is provided in Section 4.4. |
| Concentrated Solar Thermal (2017) | Pre-feasibility assessment to investigate the use of concentrated solar thermal for the Refinery operations. This included a review of various technologies on the market, that could potentially be employed by Worsley Alumina. Whilst the current technologies appear to be able to provide a moderate level of stability, the maintenance and the scale of the use of any single technology is not currently conducive to the requirements of the Refinery operations. This is discussed further in Section 4.5.2. |
| Geothermal Initiative Concept Level Assessment (2008) | A concept level assessment to investigate the feasibility of establishing a geothermal direct use for processing operations at the Refinery. The assessment included a desktop assessment and shallow drilling campaign, which confirmed little prospect in having a sufficient geothermal resource at a practical and commercially viable depth. More information on the assessment is provided in Section 4.5.1. |
| Long-Term Regional Decarbonisation Plan (2022) | A high-level scenario assessment that informed our focus on electrification and the need for collaboration. |

4.3.3 Key Assumptions and Uncertainties

Table 8 details the key uncertainties and assumptions that Worsley Alumina has identified, and which underpin the reasonable and practicable approach it is proposing for managing GHG emissions.

Table 8: Assumptions and Uncertainties in GHGMP

| Assumption | Discussion |
|---|---|
| Alternative and/or innovative energy sources, infrastructure and energy efficiency technologies may become available in the future that can avoid or minimise GHG emissions | This GHGMP has been prepared based on the capacity of existing State energy infrastructure and available emission reduction technologies. Worsley Alumina will continue to explore feasible alternatives, including developments in State infrastructure, innovative energy sources and energy efficiency technologies (such as renewables and green hydrogen) as they develop, mature and become viable for the scale required for the Refinery which will ultimately prevent more emissions reductions opportunities/possibilities. However, at present, the nature of these alternative options and technologies, or when they may be available, is not known. More information on the consideration of renewable energy is discussed in Section 4.4.1.2.2. |
| Consideration of renewable energy | South32 has assumed that the market price for renewable energy technology in Western Australia will reduce over time (in alignment with increasing efficiency). The practicability of renewable energy installation for the Worsley Alumina operation is driven by the operational |

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| Assumption | Discussion |
|--|---|
| | need for steam (see Section 4.1.2). Consideration of renewable energy will occur in alignment with the additional abatement (Section 4.5) and adaptive management approach (Section 5.1). |
| GHG emissions estimates | Scope 1 and Scope 2 GHG emissions have been estimated based on available monitoring information and published energy content and emission factors contained in <i>National Greenhouse and Energy Reporting (Measurement) Determination 2008</i> (as amended). Scope 3 GHG emissions have been estimated in accordance with <i>Technical Guidance for Calculating Scope 3 Emissions (World Resources Institute, 2013)</i> and data sources from the <i>International Aluminium Institute (World Aluminium, 2015)</i> and <i>European Aluminium Association (European Aluminium Associations, 2013)</i> . For the purposes of emission projections over the life of the proposal it is assumed that there will be no change in emission factors. |
| Emissions reduction estimates | Emissions reduction estimates are based on numerical modelling calibrated against Worsley Alumina's plant performance, and where available demonstrated through existing technology already installed. |
| Carbon price | Consideration of carbon price is as per South32's economic assumptions. South32's view on carbon price is updated annually in response to changes in policy, technology and price benchmarks, and is reported in the South32 annual Sustainability Development Report. South32 has a near-term view that reflects existing or imminent carbon markets, and a long-term view of a single global carbon price in our base case of US\$64 per t CO ₂ -e from FY40, as reported in our 2023 Sustainable Development Report. |
| Uncertainty | Discussion |
| State, Commonwealth and International GHG Policy | <p>GHG policy at both State and Commonwealth Government levels are continuing to evolve. In 2023, alone there have been a number of developments and reforms in GHG emissions reduction policy. These reforms and flow through to regulatory updates and guidance create uncertainties in implementation and integration of schemes. For example, both the Western Australian and Australian Governments are currently developing sector specific reduction pathways for industry versus other sectors (e.g. power, transport, agriculture, buildings).</p> <p>Similarly, international climate policy and carbon markets continue to evolve at pace creating additional uncertainty for businesses. Worsley Alumina will continue to monitor and assess the evolution of GHG policy at both State and Commonwealth Government levels, and international market developments and adapt where necessary.</p> |
| Biomass availability | Increasing the use of biomass for fuel presents a potential opportunity for emissions reduction at the Refinery. However, the availability of current and future biomass supply in the region is uncertain. The WA Government announced new protections for native forests in the South-West, alongside a commitment to expand WA's softwood timber plantations from FY2024. The impact of these announcements on biomass supply are unclear at this early stage (see Section 4.4.1.2.2). |

4.4 MA2 - MITIGATION MEASURES TO BE ADOPTED – OPERATIONAL EMISSIONS (SCOPE 1 AND 2)

This section summarises the key emission reduction studies and projects that Worsley Alumina are pursuing that are intended to achieve the minimum interim reduction targets proposed for the Revised Proposal by identifying and implementing decarbonisation initiatives. These emission reduction studies and projects build on previous studies undertaken at Worsley Alumina (see Section 4.3.2) including the initial high-level decarbonisation conceptual study completed in 2019 which identified over 80 potential decarbonisation projects comprising short-term and technologically mature initiatives (e.g. process efficiency, coal to gas conversion) through to long-term, research and development initiatives (e.g. integration of renewables, process electrification).

The current emission reduction studies and projects for the Worsley Alumina Project and the Revised Proposal are focused on three primary themes:

- process efficiency activities to reduce energy consumption (Section 4.4.1.1);
- energy or fuel switching to shift our energy supply to lower carbon alternatives (Section 4.4.1.2); and;
- over the longer-term, renewable energy, technology and partnerships (Section 4.4.1.3).

In the event that it is unreasonable or impracticable for Worsley Alumina to meet the proposed interim targets through the identified studies and projects, in accordance with the mitigation hierarchy, Worsley will seek to acquire and retire carbon offsets¹⁴ to address the remaining shortfall (see Section 4.9).

Table 9 shows an indicative breakdown of emission reduction activities that will support Worsley Alumina to apply measures to achieve the minimum interim emission reduction targets of the Revised Proposal. This includes initial coal to gas conversions for achievement of the 9.1% reduction target by FY29 and continued coal to gas conversions with the addition of energy efficiency projects to achieve the 21.9% reduction target by FY34. Achievement of the 40% reduction target relies partially on successful implementation of renewable energy solutions as part of the steam generation process (Steam Electrification). As discussed in section 4.3 this conversion is complicated, expensive and reliant on significant changes to operations by third party suppliers. As outlined above, in the event that the delivery of projects to reduce the total GHG emissions become unreasonable or impractical for Worsley to meet the proposed minimum targets, Worsley will seek to acquire and retire carbon offsets to address the shortfall.

It is important to note the contribution of the emission activities to the reduction pathway presented in Table 9 is indicative only and based on current information. It is expected that the abatement potential of some projects which are being pursued will change as they move through their respective study phases to confirm whether they are reasonable and practicable. Given the varying stages of assessment and maturity of the emission reduction initiatives presented in this GHGMP, it is expected that the relative contribution of different initiatives to meet or exceed the minimum interim targets will shift over time and the realised trajectory to net zero by 2050 may differ. As detailed in Section 4.9, based on Worsley Alumina's operations and current technology development trajectories, it is anticipated that residual emissions will remain in the longer-term, requiring the use of carbon offsets to achieve South32's net zero GHG emissions by 2050 goal.

¹⁴ Carbon offsets available for use may include ACCUs, Safeguard Mechanism Credits (SMCs) and international credits.

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Table 9: Interim emission reduction targets and indicative breakdown of proposed emission reduction activities to achieve targets and net zero goal.

| Emission Reduction Target | Category | Project Name | % Contribution to Reduction Target |
|---------------------------|----------------------------|---|------------------------------------|
| 9.1% by 2029 | Fuel Switching | Coal to gas conversion phase 1 | 100% |
| | Fuel Switching | Coal to gas conversion phase 2 | 60% |
| 21.9% by 2034 | Energy Efficiency Projects | Process heat recovery and re-use Dilution Reduction Process Efficiency | 40% |
| | Offsets | May be required whilst new technologies are developed, tested and implemented. | Uncertain at this time |
| 40% by 2039 | Fuel Switching | Balance of coal to gas conversions Steam Electrification Phase 1 | 100% |
| | Energy Efficiency Projects | Process heat recovery and re-use Dilution Reduction Process Efficiency | Uncertain at this time |
| | Offsets | May be required whilst new technologies are developed, tested and implemented. | Uncertain at this time |
| Net Zero | Fuel Switching | Balance of Steam Electrification Next Generation Calcination Mine Fleet Electrification | 100% |
| | Energy Efficiency Projects | Process heat recovery and re-use Dilution Reduction Process Efficiency | Uncertain at this time |
| | Offsets | Likely to be required for residual hard to abate emissions whilst new technologies are developed, tested and implemented. | Uncertain at this time |

Worsley Alumina will continue to evaluate new and existing initiatives over the life of the Revised Proposal, against a number of criteria, including safety, technical performance, operability, emissions reduction, maturity, scale, economic return and time required to adapt to changes in process or energy efficiency technologies (including technology commercialisation). Worsley Alumina proposes to provide an update on the status and maturity of these studies (and others, as appropriate) annually through the Worsley Alumina Annual Environmental Report, and also as part of the five-yearly review of the GHGMP outlined in Table 11.

4.4.1.1 Energy Efficiency Projects

Worsley Alumina is pursuing energy efficiency projects which are likely to represent material opportunities to contribute to achieving the second and third interim emissions reduction targets.

The energy efficiency projects are designed to identify practicable opportunities to reduce energy consumption, operating costs, and carbon emissions by reducing the operational need for steam or more effectively using industrial heat. The projects are in various phases of study to determine which initiatives are reasonable and practicable, with the most mature and material of these summarised below.

4.4.1.1.1 Mud Washing

Mud separation, washing and residue pumping is a key part of the refining (Bayer) process at the Refinery. The addition of new high efficiency washers is currently under investigation to reduce the amount of water required to wash the mud, which will in turn reduce the amount of evaporation needed, reducing the amount of energy and coal consumed to meet the reduced steam requirements. This technology has already been trialled at Worsley Alumina on mud washing Train 3. The project aims to decommission the old flat bottom washers used on trains 1 and 2 and replace with deep cone thickening technology.

The most recent estimates suggest that the project has the potential to reduce operational GHG emissions by up to 245,000 t CO₂-e per year. The cost estimate for the project has also risen considerably due to inflationary pressures on equipment, materials and labour, requiring the team to revisit the delivery model to identify potential cost efficiencies and optimise the delivery of the project.

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4.4.1.1.2 Waste Heat to Digestion

The digestion facility of the Refinery uses steam generated directly from Worsley Alumina's coal fired boilers to heat up incoming process streams. At another area of the Refinery, excess energy is rejected into the cooling lake as waste heat. The objective of the Waste Heat to Digestion study is to investigate modifications and upgrades to the Refinery that will allow the re-use of the waste heat to pre-heat incoming process streams into the digestion circuit. This reuse of the waste heat will reduce the amount of direct steam required in the digestion facility and consequently reduce the Refinery's coal consumption and GHG emissions.

The waste heat to digestion pre-feasibility scope selection study was completed in FY23 and is currently in pre-feasibility stage. This study recommended the progression of two scopes as separate projects for pre-feasibility:

- 1) Digestion vapour duct upgrades: increase duct size to reduce pressure losses and associated energy consumption, with estimated GHG abatement in the order of 72,000 tonnes of CO₂-e per year; and
- 2) Digestion liquor heater upgrades: install more efficient heat exchangers to improve energy recovery, with estimated GHG abatement in the order of 63,000 tonnes of CO₂-e per year.

Further engineering investigations are required as part of the prefeasibility study to confirm if the proposed initiatives are reasonable and practicable, and if each will progress through the prefeasibility tollgate to feasibility.

4.4.1.1.3 Calciner Waste Heat Re-use

Calcination is a critical process in the alumina refining process to turn Hydrate into Smelter Grade Alumina. This is achieved through the use of high temperature gas fired furnaces that drive off moisture. The waste heat and vapour (including water) is then released to the atmosphere through the calciner stacks. A concept study was conducted in FY23 to review the potential to reuse this waste heat within the refinery. The study found that, whilst benefits exist, the changes required to allow the utilisation of this waste heat is very capital intensive and is likely to be 'regret capital' given the future changes to the Calcination process as Worsley Alumina transitions to a renewable energy source.

4.4.1.2 Fuel Switching

Switching our primary source of energy to lower carbon alternatives is a key strategy for reducing emissions from the Revised Proposal. This transition is also important to support the development of lower carbon energy markets in Western Australia and to improve our long-term energy security.

Worsley Alumina are completing studies to detail the optimal approach to reduce the use of coal, with conversion of the existing coal-fired boilers to natural gas commencing in FY23 (see Section 4.4.1.2.1). As previously stated, the Refinery has been in operation for over 35 years with the design in advance of 40 years of age. The Concept Level Decarbonisation studies undertaken in 2019 acknowledged that there will be significant challenges in the adaptation and retrofitting required for the conversion from coal to an alternative fuel source.

South32 considers that the conversion to natural gas serves as a transitional fuel solution. Worsley Alumina proposes to continue to investigate and progress studies to achieve the final state energy supply requirements. This will include consideration of sourcing power from green hydrogen and electrification with renewable power supplies (see 4.4.1.2.2).

4.4.1.2.1 Coal to Gas Conversion

Worsley Alumina's coal to gas conversion studies evaluated the technical and commercial feasibility of displacing coal as the primary fuel source to the coal and multi-fuel cogeneration boilers on site. Fuel switching initiatives such as coal to gas conversion are a short to medium-term decarbonisation initiative and are proposed to be the major contributor in achieving the first and second interim emissions reduction targets.

In May 2023, Worsley Alumina commenced conversion of the first conventional pulverised fuel boiler from coal to natural gas fired, which was completed in September 2023. Planning is underway to convert the second boiler in 2024. If this occurs, the conversion of these two boilers are expected to reduce Worsley Alumina's operational GHG emissions by approximately 300,000 t CO₂-e per annum, or just over 8 per cent. Analysis of realised emissions reductions from the first boiler conversion have commenced and have been incorporated into the reductions outlined in this plan.

A concept study of the multi-fuel cogeneration facility has also been completed, investigating the full conversion to gas and removing the capability for solid fuel firing (i.e. coal and biomass). This facility consists of two fired natural circulation reheat circulating fluidised bed boilers which are currently fired by coal (main), biomass (alternative supplementary) or diesel (start-up). A coal and gas co-firing option (allowing up to 100% gas firing) remains possible for the boilers associated with this facility.

It is important to note that our transition away from thermal coal may impact the Collie community and surrounding region, which has a long history of coal mining. Our management approach takes account of these impacts to ensure they are well managed and aim to create new opportunities for people and businesses impacted by the transition. Section 4.1.4 details our approach to Just Transition.

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4.4.1.2.2 Steam Electrification

In FY23, a concept study to evaluate alternative options for steam generation was completed for the Worsley Alumina refinery. The study reinforced the view that the end state for the refinery is likely to be a highly or fully electrified operation, and that conversion to gas boilers remains a necessary interim step. Full electrification of the refinery would place a new load on the South-West Interconnected System (SWIS) of around one third of current total system average demand, which the current network capacity cannot meet. Government and industry collaboration is essential for the electrification and decarbonisation of the south-west region. In FY23, Worsley Alumina actively participated in the SWIS Demand Assessment, which identified demand growth scenarios associated with the energy transition in the southwest of Western Australia. The Demand Assessment is a key input into the upcoming revision to the Whole of System Plan, and Worsley Alumina will continue to engage with Government on associated actions and activities. Worsley Alumina also collaborated with alumina industry peers, contributing to the Australian Renewable Energy Agency report "A Roadmap for Decarbonising Australian Alumina Refining", published in November 2022.

South32 continue to assess the technical potential for behind-the-meter renewable electricity generation and options for managing balance sheet implications. However, Worsley Alumina consider that procuring renewable energy via the grid remains the most viable option for long-term decarbonisation. In the interim, Worsley Alumina are progressing multiple projects and studies investigating new and existing technologies to support increased electrification, as well as broader investment in shared energy infrastructure to source affordable renewable power at the necessary scale for Worsley Alumina and other industrial users in the region.

Worsley Alumina are continuing to study steam electrification technologies, such as mechanical vapour recompression, which is an energy recovery process used to recycle waste heat, and calciner flue gas heat recovery. Worsley Alumina participate in the Heavy Industry Low-Carbon Transition Cooperative Research Centre (HILT CRC) which provides access to emerging views of the use of hydrogen in difficult-to-electrify applications such as calcination.

4.4.1.2.3 Long Duration Energy Storage

It is anticipated the end state for the Worsley Alumina refinery is likely to be a highly or fully electrified operation, such that the value of long duration energy storage (LDES) should be explored. In FY23, an initial study was conducted to survey the breadth of technology options and it was found that Thermal Energy Storage (TES) was the most practical solution as an energy storage option for Worsley Alumina, and that TES is likely to complement steam electrification plans for the refinery.

A range of TES technology options including high and low Technology Readiness options were explored and a concept study is currently underway to assess how such technology options can be integrated into the refinery and whether they pose complimentary or competing benefits to those technologies explored in 4.4.1.2.2. Due to the low maturity of some of the technologies considered, an initial Pilot may be required to assess the benefits and risks associated with the technologies.

4.4.1.2.4 Biomass

In 2018, Worsley Alumina commenced a trial to utilise timber waste product (biomass) as a fuel source in the multi-fuel cogeneration boilers to reduce coal use and carbon emissions. Biomass is sourced via the Forest Products Commission and includes waste residues from saw log operations, mine site thinning's or energy crop material. Worsley Alumina has successfully utilised between 10,000 and 40,000 bone dry metric tonnes per financial year since the commencement of the trial, and while the emissions abatement per tonne of biomass consumed varies between loads (due to level of moisture and/or varying calorific value of the timber waste product) it is estimated that carbon emissions have been reduced by more than 160,000 t CO₂-e since the commencement of the project to the end of FY23.

In FY20, Worsley Alumina progressed a pre-feasibility study to increase biomass to up to 30% of the multi-fuel cogeneration facility's capacity, which is in the order of 200,000 bone dry metric tonnes per year. While the study found increased biomass usage at these rates is technically feasible and may support regional economic diversification, it also identified supply chain and safety challenges associated with sourcing and processing higher volumes of biomass. Accordingly, biomass is expected to remain a short-term complementary activity as Worsley Alumina deliver its more material efficiency and energy transition projects. It is also unclear what impacts the WA Government's new protections for native forests in the South-West, alongside a commitment to expand WA's softwood timber plantations will have on biomass supply at this early stage.

It should be noted that the use of biomass will cease if the multi-fuel cogeneration boilers are converted to gas firing (see Section 4.1.2.2.1).

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4.4.1.3 Long-term Studies and Future Technology

4.4.1.3.1 Renewables

Worsley Alumina continue to assess the technical potential for behind-the-meter renewable electricity generation and options for managing balance sheet implications. However, it is considered that procuring renewable energy via the grid remains the most viable option for long-term decarbonisation. In the interim, Worsley Alumina are progressing multiple projects and studies investigating new and existing technologies to support increased electrification, as well as broader investment in shared energy infrastructure to source affordable renewable power at the necessary scale for Worsley Alumina and other industrial users in the region.

As previously noted, the practicability of renewable energy installation for the Worsley Alumina operation is driven by the operational need for steam (not for electricity) in the Bayer alumina refining process. This means that large-scale deployment of renewable energy such as solar PV and wind, which do not generate steam directly, would require a fundamental change to the energy infrastructure of the refinery, connection with the grid and the broader network to realise the abatement potential.

4.4.1.3.2 Next Generation Calcination

Calcination is a critical process in the alumina refining process to turn Hydrate into Smelter Grade Alumina. This is achieved through the use of high temperature gas fired furnaces that drive off moisture. The Calcination process at Worsley Alumina generates ~20% of operational GHG emissions. Natural gas is currently used as the primary energy source for this process. Due to the technical complexities in the calcination process, including the need for high temperatures, technology to decarbonise the Calcination process is not currently commercially available however, a number of research and development projects are underway in the industry.

South32 is collaborating with the HILT CRC to undertake research on possible pathways to decarbonise the Calcination process, participating in joint research projects on the use of renewable energy in Calcination.

4.4.1.3.3 Industry Partnerships

In addition to Worsley Alumina's own emission reduction studies and project activities, leveraging and accelerating efforts by collaborating with other companies, industry groups and research organisations to investigate low-cost and innovative solutions. These are summarised in Table 10 and are being pursued to identify practical and reasonable future emission reduction solutions that can be applied to the Revised Proposal and further reduce emissions in the longer term.

Table 10: Summary of current partnerships and industry forums relevant to long-term studies

| Membership / Partnership | Description |
|--|---|
| International Council on Mining and Metals | <p>South32 is a member of the International Council on Mining and Metals (ICMM), an international organisation dedicated to a safe, fair and sustainable mining and metals industry. The ICMM works to strengthen environmental and social performance and serve as a catalyst for change, enhancing the mining industry's contribution to society.</p> <p>One initiative that the ICMM are working on is the 'Innovation for Cleaner, Safer Vehicles' (ICSV) initiative. The ICSV initiative aims to reduce GHG emissions by promoting operational and technological innovation, achieved by introducing greenhouse gas emission-free surface mining vehicles by 2040, and minimising the operational impact of diesel exhaust by 2025.</p> |
| Heavy Industry Low-carbon Transition Collaborative Research Centre | <p>South32 is a founding member of the Heavy Industry Low-carbon Transition (HILT) CRC, which is a collaborative venture between industry, government and research organisations, formed to develop and accelerate technologies for heavy industry to transition to net zero. It is based on creating a framework to collaborate and share knowledge with industry partners and lower the cost of trialling new technology.</p> <p>The evaluation of potential low-carbon solutions for alumina production is a key interest for Worsley Alumina, given the limited maturity of alternative low-carbon processing and technology options. HILT CRC programs of specific interest to Worsley Alumina include investigations into technologies and processes for high-temperature calcination and low temperature heat in the Bayer refining process.</p> <p>The Australian Government has provided A\$39 million of funding under its CRC Grants program. This is backed by an additional A\$176 million of funding and in-kind support from industry, government and research institutions.</p> |

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| Membership / Partnership | Description |
|--|---|
| Electric Mine Consortium | <p>In FY21, South32 became a founding member of the Electric Mine Consortium (EMC). The EMC aims to accelerate progress toward a fully electrified zero carbon and zero particulates mining operation. Five of the EMC's six core workstreams align to Worsley Alumina's needs including:</p> <ul style="list-style-type: none"> • Mine design; • Light battery electric vehicles and ancillary equipment; • Surface and long road haulage; • Energy storage; and • Electrical infrastructure. <p>Participation in the EMC will enable Worsley Alumina to make informed decisions about technology options through an improved understanding of readiness, while also accelerating the intake of knowledge through direct and indirect trials.</p> |
| Long Duration Energy Storage Council | <p>In FY23, South32 became a member of the Long Duration Energy Storage Council (LDESC). The LDESC is an international council focused on accelerating the deployment of long duration energy storage technologies. South32's participation on the LDESC provides access to fact-based guidance, research, technology providers and other users that can support South32 in accelerating and de-risking the transition of its operations, including Worsley.</p> <p>In FY23, this included access to technology providers who assisted with a pre-concept study of thermal energy storage at Worsley Alumina and a related steam electrification study.</p> |
| International Aluminium Institute (IAI) | <p>South32 is a member of the International Aluminium Institute (IAI), an international body representing the global primary aluminium industry. Greenhouse gas and sustainability are some of the key focus areas for the IAI. Members have the opportunity to collaborate in joint research projects on key focus areas including greenhouse gas emissions reduction and energy transition.</p> |
| Australian Aluminium Council | <p>Worsley Alumina is a member of the Australian Aluminium Council (AAC), an industry association representing the Australian aluminium industry. The council recognises the key role of energy transition towards a low carbon aluminium industry particularly the use of electrification technologies.</p> |
| Australian Renewable Energy Agency (ARENA) | <p>In FY22, South32, along with other Australian alumina producers collaborated with the Australian Renewable Energy Agency (ARENA) to identify the key pathways to emissions reductions for the alumina industry in Australia. This led to the publication of ARENA's report on "A Roadmap for Decarbonising Australian Alumina Refining". The report considered the technical, commercial and market implications for emerging low emissions alumina refining and identified key pathways to emissions reduction for one of Australia's hard to abate industries.</p> <p>At the core of the Roadmap are four key themes for decarbonisation that could transform the way refineries consume and use energy by enabling the uptake of renewables and removing the use of fossil fuels. Each of these themes should be considered during future design and planning of decarbonisation initiatives. The Roadmap provides a framework for future policy and investment decisions and serves as a call to action for public and private sectors to collaboratively transition a 'hard-to-abate' sector into an industry at the forefront of the transition to net zero.</p> <p>In FY23, South32 participated in joint round table discussion along with other Australian producers in an Australian Alumina Decarbonisation Working Group that was established by ARENA to encourage cross collaboration and acceleration of decarbonisation in the industry.</p> |

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4.5 ALTERNATIVE ABATEMENT OPTIONS

As referenced in Sections 4.3.2 and 4.4, the management measures proposed in this GHGMP build on previous studies undertaken at Worsley Alumina, such as the high-level decarbonisation conceptual study completed in 2019 and subsequent pathway strategy sessions in 2021 and 2022. While not all of these projects have been progressed into subsequent study phases, they will continue to be revisited over time to test whether previous technological or economic barriers have shifted to a degree that justifies further study.

Similarly, should Worsley Alumina's engagement with government, industry and other partners, realise new low-carbon energy markets or technologies South32 may revisit many of the concepts previously studied, but not considered reasonable or practicable at that time.

While the projects described in the sections below were not reasonable or practicable for the Worsley Alumina Project at the time they were completed, they have informed the direction of Worsley Alumina's decarbonisation studies and activities, as described in Sections 4.3 and 4.4.

4.5.1 Geothermal

A preliminary assessment of geothermal potential at Worsley Alumina investigated the feasibility of establishing a geothermal direct use system within close proximity (10 km) of the Refinery. The concept was based on the premise that hot water (at the required temperature of between 120-130°C) was available in the surrounding area, thus eliminating the requirement to heat water at the Refinery for use in processing operations, as per normal operational practice.

A desktop assessment was undertaken by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) (Horowitz et al, 2008) and involved the collation of available geothermal data for both the sedimentary and cratonic rocks of the region. This led to a targeted exploration program being developed, including both seismic and shallow drilling in the first phase (i.e. first two years), with deep drilling, proof of temperature, heat capacity and liquid flow assessments in the second phase (i.e. years three to six). The seismic and shallow drilling studies confirmed a lack of prospect in having a sufficient geothermal resource at a practical and commercially viable depth. Based on the outcomes of the desktop assessment, coupled with the results of the shallow drilling, the decision was made not to proceed with the second phase of the exploration program.

The geothermal initiative is currently not being progressed by Worsley Alumina due to the uncertainty and risk surrounding available geothermal resource and the required technical solution. It has been identified for further monitoring, particularly if future developments are made in high temperature heat pump technology.

4.5.2 Concentrated Solar Thermal

Worsley Alumina engaged CSIRO to gain a greater understanding of the options for incorporating a Concentrated Solar Thermal (CST) system to assist with energy production and heat generation and assess the site for its suitability and feasibility. CST technology is broadly defined as any technology that utilises mirrors or lenses to capture solar radiation in order to heat an object smaller than the area of incident natural solar radiation.

The Worsley Alumina site receives an annual energy exposure of over 2,000 kWh/year, which is considered to be fair in comparison to the global scale. However, the site does incur a high season variability (summer periods receiving 2 ½ times more energy than the winter periods) and can be exposed to periods of inclement weather.

Amongst other matters, a key hurdle for all of the options provided by CSIRO, was that the installation of a CST system would require a very large footprint of 500-800 ha, in order to provide any significant reduction in energy consumption, the size of which makes this technology unviable for the operation.

4.6 MITIGATION MEASURES ADOPTED –SCOPE 3 EMISSIONS

4.6.1 MA3 – Addressing Value Chain Emissions

As stated in section 4.1.3, the most material contributor to Worsley Alumina's Scope 3 emissions relates to processing of sold product, which includes processing of alumina to aluminium, aluminium into aluminium ingot, and aluminium ingot into aluminium sheet. Aluminium smelting involves the electrolytic reduction of alumina to produce liquid aluminium, with the electricity required for this process being a large source of carbon emissions. Achieving net zero operational carbon emissions in the aluminium value chain requires the development of low carbon electricity at scale, along with commercialisation of alternative processing and energy efficiency technologies, such as inert anodes and application of AP3XLE technology. In FY22 South32 approved the roll out of AP3XLE technology at the Hillside Aluminium smelter over a 5 year period, which if successful, will enable reductions for an estimated 150,000 to 200,000 t CO₂-e per annum once the programme is complete. Through FY23 Hillside completed 18% of the AP3XLE upgrade to their potlines. Hillside Aluminium is continuing to investigate the potential for EnPot technology, with four out of five trials completed in FY23. This technology enables aluminium smelters to modulate their energy consumption, making them more compatible with variable electricity supply provided by renewable power generation.

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The most material emission reduction opportunity in South32's aluminium value chain relates to securing low-carbon electricity for Hillside Aluminium, which sources its electricity from the thermal coal-fired South African electricity grid. At Mozal Aluminium, most electricity is supplied from hydroelectric power generated by Hidroelectric Cahora Bassa, situated on the Zambezi River in the northwest of Mozambique. Accordingly, in 2020 South32 established a project team to fast-track studies to assess affordable, low-carbon electricity options at Hillside Aluminium. Concurrently, South32 are also engaging with the South African Government, Eskom and other potential partners to identify options for renewable and low carbon energy infrastructure that will support the decarbonisation of the South African grid, beyond the South African Government's decarbonisation commitment, as outlined in South Africa's Integrated Resource Plan 2019. A coordinated approach is critical to reduce carbon emissions at Hillside Aluminium while supporting the growth of the South African economy as the world transitions to a low-carbon future.

While these initiatives will not impact Worsley Alumina's Scope 3 profile due to them already being accounted for as a downstream facility in accordance with the GHG Protocol Technical Guidance for Calculating Scope 3 Emissions (World Resources Institute, 2013), they do demonstrate South32's commitment to addressing GHG emissions throughout its value chain. Worsley Alumina will report on these value chain studies and initiatives, and potential impact on Worsley Alumina's Scope 3 emissions as part of Worsley Alumina's Annual Environmental Reports as described in Section 6.

Beyond South32's own facilities, the company is committed to addressing and reducing value chain emissions through building partnerships with customers and suppliers, participating in industry groups and product stewardship initiatives, and supporting innovative technology solutions. In 2023, South32 also committed to the goal of net zero GHG emissions (Scope 1, 2 and 3) by 2050.

South32's Mozal Aluminium smelter, which sources its alumina from Worsley Alumina, has joined the Aluminium Stewardship Initiative (ASI). The ASI is a global industry-led certification organisation focused on the responsible production of aluminium from mine to customer. A key criterion for ASI certification is emissions performance, which will be supported through decarbonisation initiatives across South32's alumina and aluminium activities, including at Worsley Alumina.

4.7 OTHER APPLICABLE STATUTORY DECISION-MAKING PROCESSES

Worsley Alumina's Revised Proposal is being assessed by both the Commonwealth (EPBC Act) and the State (EP Act) under an accredited assessment process.

Worsley Alumina's operational GHG emissions meet the reporting threshold for the NGER Act as well as the Safeguard Mechanism threshold. In accordance with the NGER Act, Worsley Alumina reports all emissions from facilities under its operational control to the Clean Energy Regulator on an annual basis.

Under the Safeguard Mechanism, facilities are given a baseline which is the reference point against which net-emissions levels will be assessed. Net-emissions are the covered emissions from the operation of the facility less any Australian Carbon Credit Units (ACCUs) or Safeguard Mechanism Credits (SMCs) surrendered for the facility, for that year. Facilities must keep their net emissions at or below their baseline (REF: [The Safeguard Mechanism \(cleanenergyregulator.gov.au\)](https://www.cleanenergyregulator.gov.au)). In accordance with the 2023 reforms to the Safeguard Mechanism, baselines are expected to reduce on a trajectory consistent with achieving Australia's recently legislated emission reductions targets. Worsley Alumina is in the process of finalising its emission intensity determination application for the Safeguard Mechanism for submission to the Clean Energy Regulator by April 2024.

The flexible compliance arrangements available under the Safeguard Mechanism reforms (such as Safeguard Mechanism Credits, banking and borrowing arrangements and extended multiyear monitoring periods) will allow Worsley to optimise and manage the inherent annual variability in GHG emissions performance. This optionality, together with the provisions for Trade Exposed facilities, and our decarbonisation planning, means that Worsley is well positioned to meet its obligations under the reformed Safeguard Mechanism and contribute to Australia's national GHG emissions reduction target.

Upon finalisation of Worsley Alumina's new Safeguard Mechanism baseline, confirmation of eligibility as a Trade Exposed facility and associated emission reduction requirements, Worsley Alumina will consult with the DWER with regard to the need to review and amend this GHGMP and associated interim reduction targets, to ensure complementarity between the State and Commonwealth schemes.

The Safeguard Mechanism is administered through the NGER scheme and is designed to minimise additional mandatory reporting requirements. This means that as well as keeping net emissions below the baseline, Safeguard facilities must adhere to the reporting and record keeping requirements of the NGER scheme.

4.8 CONSISTENCY WITH OTHER NON-STATUTORY GHG REDUCTION TOOLS

South32 supports the Paris Agreement and has a group level emissions reduction target to halve operational emissions (Scope 1 and 2) across the group by 2035 from the FY21 baseline and a long-term goal to achieve net zero GHG emissions (Scope 1, 2 and 3) by 2050. The mitigation measures described in Sections 4.2 - 4.6 will contribute to the successful achievement of South32's

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target and long-term goal. As stated previously, the proposed interim GHG emissions reduction targets in this GHGMP are aligned with South32's group-wide GHG emissions reduction target but they do not replicate them, noting South32's group-wide decarbonisation strategy to meet its medium-term target has been developed at a whole-of-portfolio level.

4.8.1 MA4 – Just Transition Planning

As one of two major industrial users of energy coal in Collie, our plan to transition away from this energy source will impact people and businesses that support the industry. Accordingly, Worsley Alumina is committed to working with government, the community and other stakeholders to support a fair and equitable transition for Collie.

Worsley is a member of the Collie Just Transition Working Group which developed the Just Transition Plan for Collie (DPC, 2020), released in December 2020. The purpose of this plan is to create a strong and sustainable future for Collie, its workforce and community as it shifts away from energy coal. The plan was developed in collaboration with a variety of stakeholders, including representatives from local industry, community, unions and government. In June 2021, Worsley Alumina signed the Just Transition Working Group Memorandum of Understanding, committing to support the implementation of the Just Transition Plan for Collie in a positive, collaborative and cooperative manner that seeks to deliver a sustainable and positive future for Collie, its workforce and community.

The management actions contained in this, and future GHGMPs, will take account of just transition impacts and seek to realise new opportunities including new jobs, technologies, emerging industries and increased investment, for the community.

In FY23, Worsley Alumina studied the potential workforce impacts and opportunities associated with decarbonisation planning at the refinery, taking into account internal and external drivers of workforce supply and demand in the region. The report identified that, in the long-term, there is potential for a shortfall in required skills, with a likely increase in new high-speed, high-voltage equipment and electrification skills driving high demand for 'electric' workers. As the transition to electrification progresses, it is anticipated that there will be increased competition for the roles required to support the energy transition for Worsley Alumina and the broader region. The study also confirmed that there is a need to maintain and mature training pathways for the workforce that aligns with Worsley Alumina's decarbonisation plans.

4.9 OFFSETS

In accordance with the objectives of this GHGMP and GHG Emissions Environmental Factor Guideline (EPA, 2023a), Worsley Alumina will seek to avoid and mitigate emissions as a first priority. Given the current understanding and schedule of mitigation studies and projects as outlined in section 4.4 it is not expected that offsets will be required to meet the interim emission reduction targets outlined in section 4.2.3. In the event that it is unreasonable or impracticable for Worsley Alumina to meet the proposed interim targets through the identified studies and projects, in accordance with the mitigation hierarchy, Worsley Alumina may, if it is practicable, procure and retire carbon offsets to address the remaining shortfall, with a goal to achieve net zero by 2050 in accordance with South32's goals, following a linear trajectory so far as practicable.

Based on Worsley Alumina's expectations of the life of project operations and current technology development trajectories, it is anticipated that some carbon credits may be required to offset the residual and 'hard to abate' emissions in the long term under the Safeguard Mechanism scheme, particularly where decarbonisation alternatives remain undeveloped, or are not technically or economically feasible.

Worsley Alumina may generate and subsequently retire Safeguard Mechanism Credits (SMCs) to meet the regulatory liability under the *Safeguard Mechanism (Crediting) Amendment Act 2023 (Cth)*, subject to the successful completion of decarbonisation projects. Any further requirement of offsets will preferably be met with Australian Carbon Credit Units (ACCUs), generated under the Emission Reduction Fund and with SMCs generated by other Safeguard Facilities. Worsley Alumina will prefer, where practical, the procurement of ACCUs from the vegetation, agriculture, and other project types that meet the Chubb Review Recommendations. The current forecast by a third-party analyst suggests sufficient ACCUs available in the market until FY30, however, depending upon the scale and pace of decarbonisation initiatives by the safeguard facilities, this position may change. In the future, Worsley Alumina may seek to procure credits from international markets following approval by the CEO of the DWER.

Carbon offset acquisition strategies and retirement of offsets (if required) will be reported in Worsley Alumina's Annual Environmental Report, and as part of the five-yearly review of the GHGMP.

4.10 OPERATIONS BEYOND 2050

This GHGMP has been developed to support the Revised Proposal which extends Worsley Alumina's operating life by 15 years and supports ongoing operations beyond this timeframe. Worsley Alumina has developed targets to reflect measures to decarbonise Worsley Alumina with the ultimate goal of reaching net zero by 2050 following a linear trajectory so far as practicable. Worsley Alumina will look to accelerate emission reductions towards net zero as new technologies and solutions, including lower carbon energy and developments in Western Australian energy markets, become available (see Section 4.4.1.3). The proposed interim targets for the Revised Proposal are aligned with South32's group-wide emission reduction targets and goals, but they do

not replicate them, noting South32's group-wide decarbonisation strategy and medium-term emissions reduction target (i.e. to halve our operational emissions by 2035) have been developed at a whole-of-portfolio level. The interim reduction targets for Worsley Alumina reflect the uncertainties of the Revised Proposal, including the State infrastructure and availability of renewable technologies and energy to reduce net operations emissions (ie Scope 1 & 2) over the life of the Revised Proposal.

Worsley Alumina is also required to comply with legislation in place to support operations up to and beyond 2050 .

Worsley Alumina will continue to apply a consistent approach to seek to minimise and mitigate emissions from the Revised Proposal beyond 2050.

5 ADAPTIVE MANAGEMENT, CONTINUOUS IMPROVEMENT AND REVIEW

5.1 MA5 - ADAPTIVE MANAGEMENT APPROACH

Worsley Alumina will apply this GHGMP in accordance with an adaptive management approach that enables Worsley Alumina to adapt and respond to changing circumstances, optimise the delivery of the proposed and future management actions, with an aspiration, where reasonable and practical, to out-perform and not just meet the interim reduction targets. In line with this, Worsley Alumina will regularly monitor, evaluate, review and update its approach to take account of:

- Changes to the key uncertainties or assumptions, as outlined in Section 4.3.3;
- New and relevant data / information gained as a result of implementing this GHGMP;
- Maturation of emerging low-carbon technologies, innovations and energy markets that may be applicable to the Revised Proposal;
- Effectiveness of existing GHG emission reduction measures;
- Changes to internal processes, policies and procedures to manage GHG emissions; and
- Changes in State or Commonwealth legislation or policy.

Worsley Alumina has a robust monitoring and reporting program (refer to Table 11) in place to quantify GHG emissions for compliance purposes. This information will also be used to monitor performance against the interim emissions reduction targets, review the effectiveness of GHG emission measures and adjust the approach to seek to achieve the objectives of this plan.

Outcomes of any reviews or updates to the management approach will be reported in the Worsley Alumina Annual Environment Report (see Section 6) and as part of the five yearly review and revision of this GHGMP (see Section 5.2).

5.2 REVIEW AND REVISION OF GHGMP

Within two years after an Environmental Approval is granted, Worsley will commits to provide an independent expert review to demonstrate that Worsley has, in its particular circumstances as a continuing brownfields operation in Western Australia, adopted best practice measures to avoid and reduce emissions, and that the approach described in this GHGMP is consistent with, or outperforming, relevant sector pathways and benchmarks or milestones (as outlined in the EPA Factor Guideline (EPA, 2023a). Worsley has commenced the process to engage an expert to undertake this review. The two-year post approval review also presents an opportunity to review the targets presented in this GHGMP.

Worsley Alumina also commits include in this initial review of the GHGMP within two years after approval any applicable updates in accordance with the Safeguard Mechanism, emissions associated with native vegetation clearing and sequestration associated with rehabilitation and restoration and to address outcomes from the independent expert third party review.

Following the initial review after 2 years, Worsley Alumina will also review and revise this GHGMP at least every five years to ensure the management actions outlined within the plan continue to support delivery of the interim emission reduction targets, with consideration given to completed studies and material advancements in emerging technology and energy markets. The revised GHGMP will be provided to DWER for approval. During a review of the GHGMP, Worsley Alumina will prepare a summary plan and progress statement, to be made publicly available. The document will outline key information from the GHGMP (and reports to that time), and compare the operations against other proposals, and against relative contributions to the achievement of EPA objectives for the State. The summary will include:

- a graphical comparison of emission reduction commitments in the GHGMP with 'actual' emissions for compliance periods;
- proposal performance against benchmarking for comparable facilities emissions intensity;

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- a summary of emission reduction measures undertaken by the proponent; and
- a clear statement as to whether interim targets have been achieved.

Any subsequent revisions of the GHGMP will remain aligned with South32's group-wide targets and goals, EPA objectives and State and/or Commonwealth legislation and policy.



6 REPORTING AND PUBLIC DISCLOSURE

This GHGMP will be made publicly available on the South32 website.

Worsley Alumina undertakes regular reporting of performance against its targets and management approach in accordance with a number of regulatory (e.g. NGER Act) and voluntary schemes (e.g. TCFD). A list of key reporting requirements associated with the GHGMP and Revised Proposal are summarised in Table 11.

In addition to the reporting process summarised in Table 11, South32 also produces an annual Sustainable Development Report. The reports are prepared in accordance with the recommendations of the Task Force on Climate-related Financial Disclosures and are released in September each year. These reports are publicly available on the South32 website (www.south32.net).

To verify the accuracy of reported emissions, internal and external environmental audits are undertaken. Worsley Alumina gains external assurance for the contents of NGER Act reporting submissions on an annual basis, by an auditor accredited under the NGER Act.

Table 11: GHG Reporting Requirements

| Aspect | Description | When | Recipient |
|---|--|---|---|
| Worsley Alumina Annual Environmental Report | Performance against commitments outlined in this GHGMP, as part of broader annual reporting against relevant environmental approvals conditions. This will include a summary of emissions performance for the corresponding financial year, and an update on progress against the interim emission reduction targets including any material advancements in the project and study portfolio outlined in Section 4.6. | Annually by 30 th Sept | Department of Water and Environmental Regulation (DWER) EMLG |
| Consolidated 5 Yearly Performance Report | Consolidated report on performance against commitments outlined in this GHGMP, and relevant environmental approvals conditions associated with GHG. This will include a summary of emissions performance for the corresponding 5-year period, and an update on progress against the interim emission reduction targets including any material advancements in the project and study portfolio outlined in Section 4.6. | 5 yearly (2025, 2030 etc) on approval of GHGMP | Department of Water and Environmental Regulation (DWER) |
| GHGMP | <p>Worsley Alumina will publish this GHGMP on the South32 website (www.south32.net) once finalised, and each subsequent revision as detailed in Section 5.2.</p> <p>The five yearly review and revision of the GHGMP is intended to ensure the management actions outlined within the GHGMP continue to:</p> <ul style="list-style-type: none"> • support delivery of emission reductions against the interim targets, and • consider material advancements in emerging technology and configuration of the SWIS network, and • align with South32’s group-wide targets and goals, EPA objectives and State and/or Commonwealth legislation and policy. <p>During a review of the GHGMP, Worsley Alumina will prepare and make publicly available a summary plan and progress statement as outlined in Section 5.2.</p> <p>The revisions will coincide with the commencement of the next interim emissions reduction target period and include a summary of progress of the preceding five years in an accessible form to be made available on the South32 website (www.south32.net).</p> | By 30 th Sept 2029 and within 5 years of EPA acceptance of each subsequent version of the GHGMP. | DWER |
| Emissions and Energy Reporting (Commonwealth) | <p>Annual reporting of Scope 1 and Scope 2 GHG emissions, energy production and energy consumption in line with <i>National Greenhouse and Energy Reporting Act 2007</i>, and associated measurement determination.</p> <p>The annual reporting under NGERs is also currently used to report performance against Safeguard Mechanism baseline established under the <i>National Greenhouse and Energy Reporting (Safeguard Mechanism) Rule 2015</i>. This applies to Scope 1 emissions at both the BBM and Refinery, which are treated as a single facility under the scheme.</p> <p>The data is published by the Clean Energy Regulator (CER) as part of the annual Safeguard Mechanism data tables. This occurs by 28th February the following calendar year (www.cleanenergyregulator.gov.au).</p> | Annually by 31 st Oct | CER |

7 STAKEHOLDER CONSULTATION

Worsley Alumina maintains ongoing consultation with key government agencies through the Environmental Management Liaison Group (EMLG). The EMLG consists of representatives from various State Government departments including the Department of Jobs, Tourism, Science and Innovation, the Department of Biodiversity, Conservation and Attractions, the Department of Water and Environmental Regulation, the Department of Primary Industries and Regional Development and the Department of Mines, Industry Regulation and Safety. Other interested parties (such as the Department of Agriculture, Water and the Environment) may be involved in the EMLG on an invitational basis. Worsley Alumina will continue to maintain consultation with these key government agencies throughout the implementation of the Revised Proposal

Stakeholder engagement occurs through the Community Liaison Committees (CLCs), which include representatives from local Shires, communities and conservation groups. Worsley Alumina will continue to utilise the CLCs throughout the life of the Revised Proposal.

A summary of stakeholder consultation undertaken in support of the Revised Proposal is provided in Appendix C of the Worsley Mine Expansion Environmental Review Document (South32, 2021). Any changes in relation to consultation processes (associated with GHG management) will be captured in subsequent revisions of this GHGMP.

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9 DEFINITIONS, TERMS AND ABBREVIATIONS

| Term | Description |
|--------------------|--|
| AAC | Australian Aluminium Council |
| ACCUs | Australian Carbon Credit Units |
| ARENA | Australian Renewable Energy Agency |
| BBM | Boddington Bauxite Mine |
| BTC | Bauxite Transport Corridor |
| CBME | Contingency Bauxite Mining Envelope |
| CER | Clean Energy Regulator |
| CO ₂ | Carbon dioxide |
| CO ₂ -e | Carbon dioxide equivalent |
| CLC | Community Liaison Committee |
| CSIRO | Commonwealth Scientific and Industrial Research Organisation |
| CST | Concentrated solar thermal |
| DCCEEW | Department of Climate Change, Energy, the Environment and Water |
| DWER | Department of Water and Environmental Regulation |
| EMC | Electric Mine Consortium |
| EMLG | Environmental Management Liaison Group |
| EPA | Environmental Protection Authority |
| EP Act | <i>Environmental Protection Act 1986 (WA)</i> |
| FY | Financial Year (End of) |
| GHG | Greenhouse Gas |
| GHGMP | Greenhouse Gas Management Plan |
| Goal | 'Goal' is defined as an ambition to seek an outcome for which there is no current pathway(s), but for which efforts will be pursued towards addressing that challenge, subject to certain assumptions or conditions. |
| GWPs | Global Warming Potentials |
| HFC | Hydrofluorocarbons |
| HILT | Heavy Industry Low-carbon Transition |
| HILT CRC | Heavy Industry Low-Carbon Transition Cooperative Research Centre |
| IAI | International Aluminium Institute |
| ICMM | International Council on Mining and Metals |
| ICSV | Innovation for Cleaner, Safer Vehicles |
| kt | Kilotonne |
| LDES | Long Duration Energy Storage |
| LDESC | Long Duration Energy Storage Council |
| LoOP | Life of Operations Plan |
| MA | Management action |
| MFC | Multi Fuel Cogeneration Power Plant |
| ML/a | Megalitres per annum |

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| Term | Description |
|-----------------|---|
| MS719 | Ministerial Statement No. 719 |
| Mt | Million tonnes |
| Mtpa | Million tonnes per annum |
| MW | Megawatt |
| NGER | National Greenhouse and Energy Reporting |
| NGER Act | <i>National Greenhouse and Energy Reporting Act 2007 (Cth)</i> |
| RLA | Refinery Lease Area |
| SF ₆ | Sulfur hexafluoride |
| SWIS | South West Interconnected System |
| Target | 'Target' is defined as an intended outcome in relation to identified one or more pathways for delivery of that outcome, subject to certain assumptions or conditions. |
| TES | Thermal Energy Storage |
| TCFD | Taskforce for Climate Change Financial Disclosure |
| tpa | tonnes per annum |
| WMDE | Worsley Mining Development Envelope |
| Worsley Alumina | South32 Worsley Alumina Pty Ltd |

10 DOCUMENT CONTROL

Version Control

| Version | Change | Date |
|---------|--|------------|
| 1.0 | Initial version prepared for submission with Worsley Mine Expansion Revised Proposal ERD EPA Assessment #2216 and EPBC Reference #2019/8437 | 27/10/2021 |
| 1.1 | Amended to address comments received in public submissions | 15/03/2023 |
| 1.2 | Amended to reflect progress in studies to end of FY23 and address the requirements of the new <i>Greenhouse Gas Emissions Environmental Factor Guideline</i> (EPA, 2023) and <i>Template: Greenhouse Gas Environmental Management Plan</i> (EPA, 2023b). | 06/11/2023 |
| 1.3 | Amended to bring forward emissions reductions in the first five years of the plan and apply as much as possible a linear trajectory to the reductions | 27/02/2024 |

Reviewer Circulation

| Role | Name | Endorsed | Date |
|--|-------------|----------|------------|
| Principal – Sustainability | Lee Butcher | ✓ | 27/2/2024 |
| Manager Environment Heritage and Approvals | Claire Reid | ✓ | 27/02/2024 |

Approval Circulation

| Role | Name | Approved | Date |
|---------------------------|-----------------|----------|------------|
| Manager Technical | Ashley Royston | ✓ | 08/03/2024 |
| Vice President Operations | Erwin Schaufler | ✓ | 08/03/2024 |

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11 APPENDICES

Appendix A Worsley Bauxite-Alumina Operation Greenhouse Gas Benchmarking Study (Ramboll, 2020)

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Appendix B Summary of Proposed Management Actions

Deployed XX XXX XXXX
Revalidate XX XXX XXXX
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Owner Supervisor Environment
[Subject]
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| Management Action | Description | Timing | Monitoring and Reporting |
|--|---|-----------------------|--|
| MA1 – Establish Interim Emission Reduction Targets (Section 0) | <p>To establish interim reduction targets over five yearly increments to drive performance over the indicative duration of the proposal:</p> <ul style="list-style-type: none"> • 9.1% reduction by EOFY29 • 21.9% reduction by EOFY34 • 40% reduction by EOFY39. <p>The targets will apply to the net operational emissions (Scope 1 and Scope 2) inclusive of both the BBM and Refinery, with 3.74 Mt CO2e used as the baseline (FY21 emissions). They will be adjusted to account for the net emissions balance between import and export electricity between the Refinery and the SWIS.</p> | Commencement of GHGMP | <p>Emissions are monitored and reported internally on a monthly basis and reported annually under regulatory (e.g. NGER Act) and voluntary schemes (e.g. TCFD), and in accordance with the requirements set out in Section 6 of the GHGMP.</p> <p>The GHG emissions and associated reductions will be independently verified by an auditor accredited under the NGER Act.</p> <p>Performance against the goals and targets, and the details of the next interim reduction target will be documented as part of the five-yearly review of the GHGMP outlined in Section 6 of the GHGMP.</p> |
| MA2 – Mitigation Measures (Section 4.4) | <p>Build on existing studies and emission reduction activities to develop and implement reasonable and practicable decarbonisation initiatives that are intended to achieve the interim reduction targets.</p> <p>Evaluation of new and existing projects against a number of criteria including safety, technical performance, operability, emissions reduction, maturity, scale, economic return and time required to adapt to changes in process or energy efficiency technologies (including technology commercialisation).</p> | Ongoing | <p>Annual update on the status and maturity of studies and emission reduction activities included in the Worsley Alumina Annual Environmental Report, and as part of the five-yearly review of the GHGMP.</p> <p>This will include reporting on expected changes to the abatement potential of projects as they move through their respective study phases to confirm whether they are reasonable and practicable.</p> |
| | <p>Energy Efficiency (Section 4.4.1.1)</p> <ul style="list-style-type: none"> • Mud Washing Study – new, high efficiency washers to reduce the amount of water and evaporation required, and associated consumption of coal generated steam. • Waste Heat to Digestion Study – modifications and upgrades to the Refinery to allow re-use of waste heat to pre-heat incoming process streams and reduce the amount of required direct steam and associated consumption of coal. • Other – Facility 50 dilution reduction, calciner flue gas heat recovery, replacing steam ejectors with vacuum pumps. | Ongoing | <p>Summary of study outcomes and progress through internal tollgates to be reported annually in the Worsley Alumina Annual Environmental Report.</p> |

| Management Action | Description | Timing | Monitoring and Reporting |
|-------------------|--|---------|---|
| | <p>Fuel Switching (Section 4.4.1.2)</p> <ul style="list-style-type: none"> • Coal to Gas Conversion Study – displacing coal with natural gas (as a transitional fuel) as the primary fuel source to the coal and multi-fuel cogeneration boilers on site. • Steam Electrification – long term study to achieve final state energy supply for steam generation. • Biomass Execution– short-term complementary activity that utilises timber waste product (biomass) as a fuel source to reduce coal consumption. • Other – investigate and progress studies to achieve final state energy supply requirements (i.e. gas to lower carbon energy source). | Ongoing | Summary of study outcomes and progress through internal tollgates to be reported annually in the Worsley Alumina Annual Environmental Report. |
| | <p>Long-term Studies and Future Technology (Section 4.4.1.3)</p> <ul style="list-style-type: none"> • Renewables – studying renewable technologies that could support commercial deployment of renewable energy alternatives, such as hydrogen or electrification. • Next Generation Calcination – monitor development in technology to decarbonise the Calcination process. • Industry Partnerships – leverage and accelerate our efforts by collaborating with other companies, industry groups and research organisations • Other – support low-carbon energy markets and policy to underpin decarbonisation of the south-west energy grid | Ongoing | Summary of study outcomes and progress through internal tollgates to be reported annually in the Worsley Alumina Annual Environmental Report. |
| | <p>Carbon Offsets (Section 4.9)</p> <ul style="list-style-type: none"> • As described in Section 4.9 of the GHGMP, and following application of the mitigation hierarchy, Worsley may seek to acquire and retire carbon offsets to meet the proposed interim targets and offset against residual and ‘hard to abate’ emissions where decarbonisation alternatives remain undeveloped, or not technically or economically feasible. • Options to acquire offsets include procurement, partnership and self-generation strategies and may provide additional co-benefits (e.g. environment or local communities). | Ongoing | Carbon offset acquisition strategies and retirement of offsets (if required) to be reported in Worsley Alumina Annual Environmental Report, and as part of the five-yearly review of the GHGMP. |

| Management Action | Description | Timing | Monitoring and Reporting |
|--|--|---|---|
| MA3 – Addressing Value Chain Emissions (Section 4.6.1) | <p>Studying and implementing energy efficiency projects (e.g. upgrade of potlines with AP3XLE technology) and low-carbon electricity options at Hillside Aluminium and Mozal Aluminium.</p> <p>Engaging with the South African Government, Eskom and other potential partners to identify options for renewable energy infrastructure to support the decarbonisation of the South African grid.</p> <p>Building partnerships with customers and suppliers, participating in industry groups and product stewardship initiatives, and supporting innovative technology solutions to reduce Scope 3 emissions.</p> | Ongoing as part of South32 group-wide decarbonisation program | <p>Worsley Alumina will report on these value chain studies and initiatives, and potential impact on Worsley Alumina’s Scope 3 emissions as part of Worsley Alumina’s Annual Environmental Report, and as part of the five-yearly review of the GHGMP.</p> <p>Scope 3 emissions are calculated in accordance with the methodologies in the GHG Protocol Technical Guidance for Calculating Scope 3 Emissions (World Resources Institute, 2013).</p> |
| MA4 – Just Transition Planning (Section 4.8.1) | <p>Undertake a Just Transition Risk Assessment to better understand the potential risks and opportunities to people and communities through the energy transition.</p> <p>The outcomes of this work will inform South32’s ongoing participation in the Collie Just Transition Working Group (CJTWG) and implementation of the Just Transition Plan for Collie.</p> | <p>Risk Assessment commenced in FY22.</p> <p>Ongoing implementation in collaboration with CJTWG</p> | <p>Findings of the Just Transition Risk Assessment and relevant activities of the Collie Just Transition Working Group to be reported in the Worsley Alumina Annual Environmental Report, and as part of the five-yearly review of the GHGMP.</p> |
| MA5 – Adaptive Management, Monitoring and Review (Section 5.1) | <p>Apply an adaptive management approach to enable Worsley Alumina to adapt and respond to changing circumstances, optimise the delivery of the proposed and future management actions, with an aspiration, where reasonable and practical, to out-perform and not just meet the interim reduction targets.</p> <p>Commit to annual reporting and five yearly reviews to monitor and review effectiveness of emission reduction measures.</p> | <p>Annually, with formal review of GHGMP every five years</p> | <p>Emissions are monitored and reported internally on a monthly basis and reported annually under regulatory (e.g. NGER Act) and voluntary schemes (e.g. TCFD), and in accordance with the requirements set out in Section 6 of the GHGMP.</p> <p>The emissions performance will be reviewed to monitor performance against the interim emissions reduction targets, review the effectiveness of GHG emission measures and adjust the approach to achieve the objectives of this plan. Outcomes of any reviews or updates to the management approach will be reported in the Worsley Alumina Annual Environment Report, and as part of the five-yearly review of the GHGMP.</p> |