

Project Halogen: Greenhouse Gas Assessment

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Glossary

Term	Definition
°	degrees
°C	degrees Celsius
GJ	gigajoules
GK/kL	gigajoules per kilolitre
ha	hectare
kg	kilograms
kL	kilolitres
kt	kilotonnes
kWh	kilowatt hours
m	metres
Mt	million tonnes
MtCO ₂ -e	million tonnes carbon dioxide equivalents
t	tonnes
TJ	terajoules
tpd	tonnes per day
Nomenclature	Definition
CH ₄	methane
CO ₂	carbon dioxide
CO ₂ -e	carbon dioxide equivalents
NH ₃	ammonia
NaOH	sodium hydroxide
Na ₂ CO ₃	sodium carbonate
HCl	hydrogen chloride, hydrochloric acid
H ₂ O ₂	hydrogen peroxide
H ₂ SO ₄	sulfuric acid
Abbreviation	Definition
ABS	Australian Bureau of Statistics
ATAP	Australian Transport Assessment and Planning
BAT	Best Available Technologies
BESS	Battery Energy Storage System
BOP	Balance of Plant
CC Act	Climate Change Act 2022 (Commonwealth)
CSIRO	The Commonwealth Scientific and Industrial Research Organisation
CQG	CQG Consulting (CQ Environmental Pty Ltd)
DA	Development Application
DCCEEW	Department of Climate Change, Energy, the Environment and Water
DETSI	Department of the Environment, Tourism, Science and Innovation
ECF	Energy Content Factors
EDQ	Economic Development Queensland
EF	Emission factor
EP Act	Environmental Protection Act 1994
EPA	Environment Protection Authority
ERA	Environmentally Relevant Activity
EV	Electric Vehicle
GSDA	Gladstone State Development Area
GHG	Greenhouse Gases
GWP	Global Warming Potential
IFC	International Finance Corporation
IPCC	Intergovernmental Panel on Climate Change

Term	Definition
LOP	Life of Project
LPG	Liquefied Petroleum Gas
LULUCF	Land Use, Land Use Change and Forestry
MCU	Material Change of Use
MoU	Memorandum of Understanding
NEM	National Electricity Market
NEPC	National Environment Protection Council
NGER	National Greenhouse and Energy Reporting
NPI	National Pollutant Inventory database
NVES	New Vehicle Efficiency Standard
OEM	Original Equipment Manufacturer
ODP	Ozone Depletion Potential
PPA	Power Purchase Agreement
QLD	Queensland
REC	Renewable Energy Certificates
SPP	State Planning Policy
ULP	Unleaded Petrol
UNFCCC	United Nations Framework Convention on Climate Change
ZEV	Zero Emission Vehicle

EXECUTIVE SUMMARY

Katestone Environmental Australia Pty Ltd (Katestone) was commissioned by CQG Consulting (CQG) on behalf of Grenof to complete a Greenhouse Gas (GHG) Assessment of Project Halogen (the Project). The GHG assessment is required to support a Development Application (DA) for an Environmentally Relevant Activity (ERA) 7(6d) regarding a material change of use (MCU) for chemical manufacturing.

The Project will support the Gladstone Region's Economic Transition Roadmap 2022-2032 through green chlor-alkali manufacture, minimising the need for these products to be imported. It is expected to have an operational asset life of 50 years (after 1 year of construction) and will produce caustic soda (NaOH), liquid chlorine (Cl₂), sodium hypochlorite (NaClO), and hydrochloric acid (HCl) for domestic customers.

The GHG assessment was conducted in accordance with the requirements of the *Guideline Greenhouse gas emissions ESR/2024/6819* (GHG Guideline) and classified the Project as a medium to high emitter with annual emissions >25,000 t CO₂-e, requiring a Scope 3 inventory and an abatement plan to support Queensland's emission reduction targets.

The GHG assessment estimated the total Life of Project (LOP) Scope 1 emissions at 201,778 tonnes of carbon dioxide equivalent (t CO₂-e) with average annual Scope 1 emissions of 3,956 t CO₂-e. Scope 2 emissions for the LOP are estimated at 2,820,667 t CO₂-e, with average annual Scope 2 emissions estimated at 55,307 t CO₂-e. LOP Scope 3 emissions are estimated at 778,499 t CO₂-e, with average annual Scope 3 emissions of 15,265 t CO₂-e.

The Project is expected to reduce emissions resulting from shipping of chemical imports from Asia by ~3,500 t CO₂-e – 22,000 t CO₂-e per annum. Grenof is committed to ensuring that the Project contributes to the transition to a low emissions global economy, whilst manufacturing essential chemicals for the region.

Decarbonisation actions categorised by the GHG hierarchy are:

Avoid

The Project cannot avoid GHG emissions and produce the required output of chemicals – however a conscious investment decision has been made to implement a best practice chemical production plant that is significantly more energy efficient than existing Australian plant with similar outputs. The GHG abatement plan focuses on mitigation and substitution, improving the electricity-to-work conversion efficiency to lower the production emission intensity and shifting to lower emissions energy sources.

Reduce

Scope 2 emissions will be reduced by 25% from the base case at the commencement of the Project through design and procurement of best practice and highest efficiency production technology.

Grenof will review and implement measures to further reduce Scope 2 emissions, where practicable and cost-effective, during future stages of the Project, including:

- Installation of onsite renewable energy generation
- Installation of a battery energy storage system (BESS)
- Renewable power purchase agreements (PPA)

Substitute

- Grenof will use a blend by-product hydrogen and liquid petroleum gas (LPG) generated in the production process at the commencement of the Project, to reduce LOP emissions by 33,425 t CO₂-e from the base case.
- Fossil fuelled transportation vehicles are substituted with electric vehicles (EVs) at the commencement of the Project, saving 139,025 t CO₂-e for the LOP.
- Hydrofluorocarbon (HFC) refrigerant R-507 used for chlorine liquification will be substituted with natural non- HFC refrigerants R-717 and R-744 (ammonia (NH₃) and carbon dioxide (CO₂)) where cost efficient and practicable, reducing LOP emissions from the base case by 31,820 t CO₂-e.

Offset

Residual emissions against Grenof's cooperate sustainability targets may be offset through the purchase and surrender of Renewable Energy Certificates (REC) and/or Australian Carbon Credit Units (ACCU) originating in Queensland, or other voluntary emissions reduction schemes.

Grenof will undertake periodic reviews of the technical readiness level (TRL) and commercial readiness level (CRL) of technology and process options that can improve the emissions intensity of production and/or provide new business models.

Feasibility studies will be conducted for options that have a TRL of 6 or greater and a CRL of 5 or greater and recommendations for further investment will be made to the Board as appropriate. Options may include:

- Higher efficiency production technologies
- Electrification of remaining Scope 1 GHG sources (boilers and forklifts)

The Project's emissions are expected to contribute 0.23%, 0.052% and 0.00072% to the remaining state, national and global carbon budgets for the 2025-2050 trajectory towards net zero

The Project will be required to report its emissions as a facility under the NGER system, but it will not be subject to the emissions reduction requirements of the Safeguard Mechanism. Annual recording and monitoring will be subject to internal validation and periodic independent auditing, and achievement of abatement key result areas (KRA) will be tied to executive key performance indicators (KPI) as appropriate to Grenof's delegation and operational control.

1. INTRODUCTION

Katestone Environmental Pty Ltd (Katestone) was commissioned by CQG Consulting (CQG) on behalf of Grenof to conduct a Greenhouse Gas (GHG) Assessment of a proposed chlor-alkali facility (the Project) to be located in the Gladstone State Development Area (GDSA). This assessment is to support a Development Application (DA) for a material change of use (MCU) for a concurrence environmentally relevant activity (ERA) 7(6d) *Chemical manufacturing: manufacturing in a year, more than 100,000 tonnes of inorganic chemicals*, for the Project.

Local production of chlor-alkali would support the Gladstone Region’s Economic Transition Roadmap 2022-2032, reducing GHG emissions and reducing the need for these products to be imported. Grenof has successfully secured Economic Development Queensland (EDQ) managed land in Yarwun for the Project.

This GHG assessment and abatement plan has been developed to meet the requirements of the *Guideline Greenhouse gas emissions ESR/2024/6819* (GHG Guideline) (section 2.3.1) in support of CQG’s application. The requirements in addition to the GHG abatement plan (Table 1) are to:

- Document the applicable State and Federal policy, legislation, standards, and guidelines applicable to GHG emissions from the Project (section 3)
- Describe the methodologies used to estimate GHG emissions, consistent with relevant standards and the GHG Guideline (section 4).

Table 1 Sections of GHG Abatement Plan addressing the GHG Guideline

Requirement	Section
a. Project details	Section 2
b. Emissions projections and commencing abatement measures:	Section 5
i. Emission inventory and estimates as developed in section 3.1 of the GHG Guideline	Section 6
ii. Management practices proposed to be implemented at commencement to reduce GHG emissions as per section 3.3 of the GHG Guideline	Table 8
c. GHG emissions reference point:	Section 6.2
i. Outline the level of emissions against which ongoing reduction of GHG emissions will be assessed throughout the life of the Project (reference point) (based on projected GHG emissions prior to implementation of the GHG abatement plan)	
ii. Provide justification for the reference points proposed	
d. Emission reduction targets:	Section 6
i. Identify interim Scope 1 and Scope 2 GHG emission reduction targets to be applied throughout the life of the Project	
ii. Identify long-term overall Scope 1 and Scope 2 GHG emission reduction targets.	
iii. Provide justification for the emission reduction trajectory and targets proposed and how they support the Queensland Government’s GHG emission reduction targets	

<p>e. GHG emission reduction program (as detailed in section 3.3 and Appendix A (Part B) of the GHG guideline), including:</p> <ul style="list-style-type: none"> i. Implementation details including timeframes for implementation and estimated reduction of emissions expected ii. Risk assessment details including cost, practicality, effectiveness, and risks of each measure iii. Justification for each measure including a comparison of each proposed measure with relevant best practice environmental management standards iv. Estimates of emissions expected to be abated by each measure v. Any ongoing monitoring proposed to be undertaken to ensure the success of emission reduction measures 	<p>Section 6, 6.8, 6.10 Table 10</p>
<p>f. Advancing technologies and opportunities:</p> <ul style="list-style-type: none"> i. Include provisions for regularly reviewing new technologies to identify opportunities to further reduce emissions and energy efficiency 	<p>Section 6.7</p>
<p>g. Monitoring and auditing program</p>	<p>Section 6.10</p>
<p>h. Reporting:</p> <ul style="list-style-type: none"> i. A program for periodic public reporting on progress towards the GHG emission reduction targets outlined in the GHG abatement plan, including details about how public reporting will be undertaken 	<p>Section 6.11</p>

2. PROJECT DESCRIPTION

2.1 Process Summary

Grenof is seeking to develop a modular chlor-alkali production facility located in the GDSA. The plant will have a product capacity of 160,000 tonnes per annum (tpa), with product outputs consisting of sodium hydroxide (NaOH) (caustic soda), liquid chlorine (Cl₂), hydrogen chloride (HCl), and sodium hypochlorite (NaOCl). The chlor-alkali production facility will also produce derivative chemicals from the primary products, which include sodium hypochlorite (NaOCl) and hydrochloric acid (HCl).

The electrolytic process uses electricity to convert high-purity brine into Cl₂ gas, H₂ gas, and NaOH, with a membrane separating the resulting products (Figure 2). The entire facility will have a closed loop design and consequently will not have any fugitive releases. A potential fugitive source based on facilities elsewhere is the electrolyser room. In the case of the Project, the electrolyser room will be designed so that any leaks will be immediately identified by the control system due to the monitoring of pressure on either side of each electrolyser. The control system will have the capability to detect leaks as small as a pinhole. There are no GHG emissions resulting from the chemical reactions.

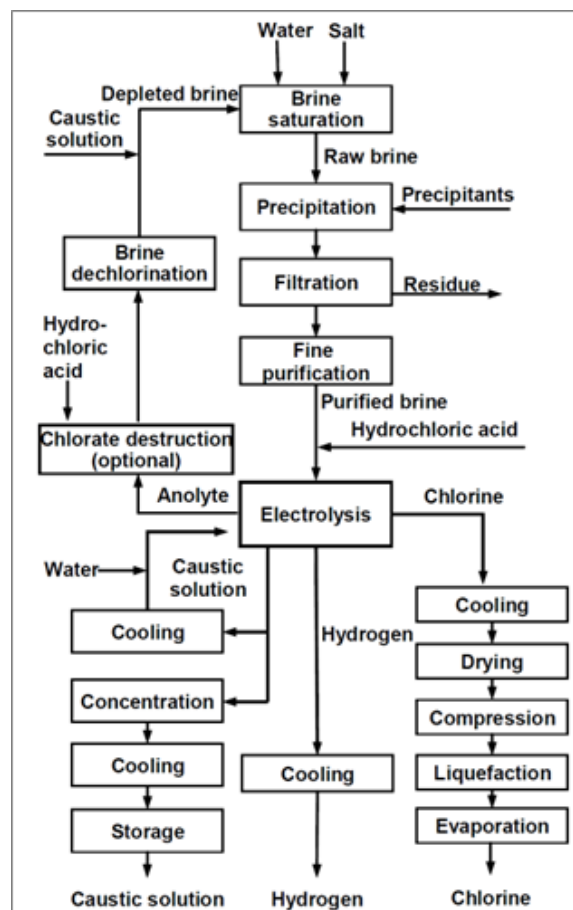


Figure 1 Typical flow diagram of the membrane cell technique (source: European Commission, 2014, Best Available Techniques (BAT) Reference Document for the Production of Chlor-alkali)

A schematic view of the chlorine electrolysis cells is provided in Figure 3. In comparison to the alternative electrolysis techniques (diaphragm cell process and the mercury cell process), the membrane cell process has the following benefits:

- Low total energy consumption
- Low investment and operating costs
- Does not use mercury or asbestos
- High-purity caustic production

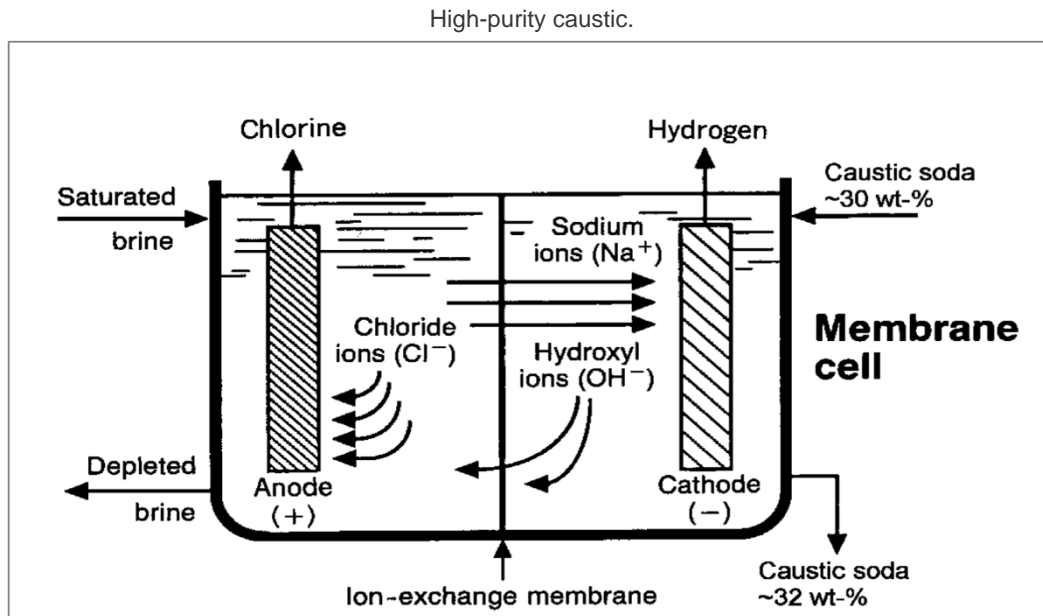


Figure 2 Schematic view of chlorine electrolysis cells for membrane cell technique (source: European Commission, 2014, Best Available Techniques (BAT) Reference Document for the Production of Chlor-alkali)

2.2 Project overview

Construction

The construction phase is estimated to occur across the first year of the LOP. The key activities and sources of Scope 1 GHG emissions are:

- Vegetation clearing
- Heavy machinery earthworks
- Onsite concrete batching
- Onsite generators
- Miscellaneous ancillary equipment
- Light vehicles and logistics

Transport of steel and skid mounted modules to site during construction was omitted from the assessment due to total fuel usage less than 1 kiloliter (kL) and emissions less than 1 tonne of carbon dioxide equivalent (t CO₂-e).

Operation

The operational phase period is expected to last for 50 years. Key activities and sources resulting in Scope 1 and 2 emissions include:

- Electricity used in the chlor-alkali process, balance of plant and charging of electric vehicles (EVs)
- Combustion of liquid petroleum gas (LPG) and H₂ gas blend (80:20) in boilers to generate steam
- Leakage from refrigerants used in chlorine liquefaction
- LPG used in forklifts

The combustion of hydrogen was omitted from the assessment as 40 tonnes combusted over the LOP will result in less than 0.3 t CO₂-e.

3. POLICY CONTEXT AND REGULATORY FRAMEWORK

3.1 Policy, Guidelines, and Strategy

3.1.1 State Planning Policy

Queensland's State Planning Policy (SPP)¹ expresses the State's interests in land use planning and development. The SPP notes that Queensland's largest source of GHG emissions comes from energy generation and that planning to enable the development of renewable energy will play a key role in reducing emissions.

3.1.2 Environmentally Relevant Activities (ERA) Guidelines

Environmentally relevant activities (ERAs) are prescribed activities with the potential to release emissions which can impact on the environment and surrounding land uses. The Project will require assessment by the Department of the Environment, Tourism, Science and Innovation (DETSI) for a concurrence environmentally relevant activity (ERA) 7(6d) Chemical manufacturing: manufacturing in a year, more than 100,000 tonnes of inorganic chemicals (for the Project).

3.1.3 Gladstone Region Economic Transition Roadmap 2022-2032

The Gladstone Region Economic Transition Roadmap 2022–2032 strategy supports the *Climate Change Act 2022 (Cwlth)* by helping Australia and Queensland reduce greenhouse gas emissions and reach net zero by 2050. It outlines a shift away from carbon-intensive industries, such as coal power and liquefied natural gas (LNG) towards low-emission alternatives like renewable energy, green hydrogen, and sustainable manufacturing.

3.1.4 National Hydrogen Strategy 2024

The National Hydrogen Strategy 2024 outlines a coordinated vision and roadmap for developing Australia's hydrogen industry. It sets strategic priorities, goals, and actions to support investment, innovation, and market development. It serves as a framework to guide government and industry efforts towards a low-emissions hydrogen economy.

3.1.5 Zero Emission Vehicle Strategy 2022-2032 (Qld)

Queensland's Zero Emission Vehicle Strategy 2022–2032 sets a strategic direction for reducing transport emissions by accelerating the uptake of zero emission vehicles (ZEVs). Released with an action plan in March 2022, it supports the state's broader climate goals: 50% renewable energy by 2030, a 30% emissions reduction from 2005 levels by 2030, and net zero emissions by 2050, while ensuring the energy network can support this transition.

3.1.6 National Electric Vehicle Strategy 2023

Australia's National Electric Vehicle Strategy, launched in April 2023, is a comprehensive policy framework aimed at accelerating the adoption of EVs across the country. The strategy focuses on reducing emissions, enhancing public health, and improving the well-being of Australians through increased EV uptake.

¹ <https://dsdmipprd.blob.core.windows.net/general/spp-july-2017.pdf>

3.2 International Agreements

3.2.1 Paris Agreement

The Australian Government signed the legally binding Paris Agreement² to take actions to keep global warming to 'well below' 2°C and strive to limit warming to 1.5°C. The current Australian target (Nationally Determined Contribution) is to reduce emissions to 43% below 2005 levels by 2030, and 62 - 70% by 2035, including land use, land use change, and forestry (LULUCF) and using Global Warming Potential (GWP) values from the IPCC's Fifth Assessment Report (AR5). The intention is to have net zero GHG emissions by 2050.

3.3 Legislation and Regulation

3.3.1 Climate Change Act 2022 (Cwlth)

The *Climate Change Act 2022* (CC Act) provides the legislative framework to implement Australia's net-zero commitments and codifies Australia's 2030, 2035 and 2050 net GHG emissions reductions targets under the Paris Agreement. The legislated targets are to reduce net GHG emissions to 43% below 2005 levels by 2030, and 62 - 70% by 2035, and to reduce net GHG emissions to zero by 2050. The CC Act establishes that 2030 GHG emissions reduction target as a national point target and an emissions budget. The CC Act does not impose obligations directly on companies, but it does signal sector-based reforms to achieve the GHG emissions reduction targets.

3.3.2 Climate Change (Consequential Amendments) Act 2022 (Cwlth)

The *Climate Change (Consequential Amendments) Act 2022* (CCCA Act) embeds the GHG emissions reduction targets into fourteen Commonwealth Acts, including the *Clean Energy Regulator Act 2011*, *Infrastructure Australia Act 2008*, *National Greenhouse and Energy Reporting Act 2007*, and the *Renewable Energy (Electricity) Act 2000*.

3.3.3 National Greenhouse and Energy Reporting Act 2007 (Cwlth)

The *National Greenhouse and Energy Reporting Act 2007* (NGER Act) established a national framework for corporations to report GHG emissions and energy consumption.

NGER registration and emissions reporting are mandatory for corporations or facilities that have energy production, energy use, or GHG emissions that exceed specified thresholds (Table 2). These entities are required to report on their Scope 1 and Scope 2 emissions, where:

- Scope 1 emissions – the release of GHG into the atmosphere from a facility as a direct result of an activity or series of activities (including ancillary activities) that constitute the facility. GHG emissions associated with land clearing are effectively a Scope 1 emission but are not included in the NGER scheme.
- Scope 2 emissions – the release of GHG into the atmosphere as a direct result of one or more activities that generate electricity, heating, cooling, or steam at another facility and that is consumed by the facility.

Scope 3 emissions are defined as indirect GHG emissions, other than Scope 2 emissions, that are generated in the wider economy by a facility's supply chain or value chain. They occur because of the activities of a facility, but from sources not owned or controlled by that facility's business. They are not included in NGER reporting due to the potential for double counting.

² <https://unfccc.int/process-and-meetings/the-paris-agreement>

Table 2 NGER annual reporting thresholds – greenhouse gas emissions and energy use

Threshold level	Threshold type	
	GHG (ktCO ₂ -e)	Energy production and/or consumption (TJ)
Facility	25	100
Corporate	50	200

Table Notes: kt CO₂-e = kilotonnes of carbon dioxide equivalent. TJ = terajoules.

3.3.4 Safeguard Mechanism (Crediting) Amendment Act 2023 (Cwth)

The Safeguard Mechanism provides a framework for Australia’s largest emitters to measure, report and manage their emissions. It does this by requiring large facilities, whose net emissions exceed the Safeguard threshold of 100,000 t CO₂-e per year, to keep their emissions at or below emissions baselines set by the Clean Energy Regulator. The Clean Energy Regulator is the government body responsible for accelerating carbon abatement for Australia through the administration of the National Greenhouse and Energy Reporting scheme, Renewable Energy Target, and the Emissions Reduction Fund.

3.3.5 Clean Economy Jobs Act 2024 (Qld)

The purpose of the *Clean Economy Jobs Act 2024* (CEJ Act)³ is to reduce GHG emissions in Queensland by legislating emissions reduction targets. The CEJ Act sets a target of net zero emissions by 2050, with an emissions reduction target of 62 - 70% below 2005 emissions by 2035. The initial target of a reduction by 30% of 2005 levels by 2030 has already been achieved. Queensland’s emissions in 2005 were 197.3 mega tonnes of carbon dioxide equivalents (MtCO₂-e) meaning that annual emissions will need to be reduced to 49.3 MtCO₂-e or below by 2035.

3.3.6 Environmental Protection Act 1994 (Qld)

The *Environmental Protection Act 1994* (EP Act)⁴ seeks to protect Queensland’s environment while allowing for development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends.

The EP Act does not explicitly regulate the emission of GHG, other than with reference to the storage of GHG regulated under the *Greenhouse Gas Storage Act 2009*. However:

- Regarding air emissions, a contaminant can be a gas (11(a))
- GHG emissions may constitute an environmental harm (14(1)(2)), i.e., “... any adverse effect, or potential adverse effect (whether temporary or permanent and of whatever magnitude, duration or frequency) on an environmental value ...” “whether the harm is a direct or indirect result of the activity; or whether the harm results from the activity alone or from the combined effects of the activity and other activities or factors”.

3.3.7 Environmental Protection Regulation 2019 (Qld)

The *Environmental Protection Regulation 2019* prescribes the detail for processes contained in the EP Act.

³ <https://www.legislation.qld.gov.au/view/pdf/inforce/current/act-2024-016>

⁴ <https://www.legislation.qld.gov.au/view/pdf/inforce/current/act-1994-062>

3.3.8 Environmental Protection (Air) Policy 2019 (Qld)

The purpose of *Environmental Protection (Air) Policy 2019* is to achieve the object of the EP Act in relation to the air environment by:

- Identifying environmental values to be enhanced or protected
- Stating indicators and air quality objectives for enhancing or protecting the environmental values
- Providing a framework for making consistent, equitable and informed decisions about the air environment.

3.3.9 DETSI Guideline Greenhouse Gas Emissions

The DETSI *Guideline Greenhouse gas emissions ESR/2024/6819* (GHG Guideline) describes requirements under the EP Act and provides information about how to meet these requirements in relation to GHG emissions for new and amended environmental authority (EA) applications.

The GHG Guideline sets out the minimum expectations for GHG emissions information to be provided with applications and supports rigorous, defensible, and transparent decision making in relation to these emissions. The required information includes:

- An inventory of expected GHG emissions resulting from the Project including the stage at which the emissions will occur and a breakdown by source (Section 5)
- An estimate of projected Scope 1 and Scope 2 CO₂-e emissions over the Life of Project (LOP), including an unabated and abated emissions scenario (Section 6.8)
- An estimate of annual Scope 3 emissions and total Scope 3 emissions over the LOP (Section 5.3)
- A description of the method used for estimating GHG emissions (Section 4)
- A GHG abatement (decarbonisation) plan in alignment with recommendations made in Appendix A of the GHG Guideline (Section 6)
- A description of risks and the likely magnitude of impacts on environmental values resulting from the Project, including qualitatively describing the impacts of climate change on environmental values and the likely magnitude of such impacts based on the relative scale of the Project's net GHG emissions (Section 7) .

The GHG Guideline identifies expected GHG emission rates for activities as:

- Low emitters if expected annual GHG emissions are less than 25,000 t CO₂-e.
- Medium to high emitters if expected annual GHG emissions are 25,000 t CO₂-e or more at any time during the LOP.

3.3.10 New Vehicle Efficiency Standard Bill 2024 and New Vehicle Efficiency Standard (Consequential Amendments) Bill 2024

The *New Vehicle Efficiency Standard Bill (and consequential amendments) 2024* (NVES) turn Australia's vehicle emissions targets into law. From 2025, car manufacturers must ensure their new vehicle fleets meet average CO₂ emissions limits, or face penalties. Manufacturers can trade credits with others or bank unused credits, with oversight by the Clean Energy Regulator. This legislation is the core mechanism for cutting transport emissions under the National Electric Vehicle Strategy.

3.3.11 Australia's HFC phase-down

Australia has committed to an international phase-down of hydrofluorocarbons (HFC) under the Montreal Protocol (2016). The HFC phase-down contributes to Australia's 2030 greenhouse gas emissions reduction target and encourages industry to move to alternative technologies using lower or zero global warming potential gases. The phase-down is being managed through an annual import quota that will gradually reduce over 18 years. The end point of the phase-down, 15% of the baseline level, will be reached on 1 January 2036.

4. METHOD

4.1 Definitions

The following gases are considered to be GHGs (section 7A NGER Act):

- Carbon dioxide (CO₂)
- Methane (CH₄)
- Nitrous oxide (N₂O)
- Hydrofluorocarbons (HFC)

4.2 Scope 1, Scope 2, and Scope 3 Emissions

GHG emissions are calculated and reported according to the Scope in which they occur.

Scope 1 GHG emissions are those emissions released to the atmosphere as a direct result of the activity conducted at a facility and that are under the direct control of the facility or operation. The emissions value is obtained by multiplying, for example, the total volume of diesel used during the reporting period with its emission factor (EF).

Scope 2 GHG emissions are those associated with the production of electricity that is purchased and used by the facility. The emissions value is obtained from the total electricity used, in kilowatt hours (kWh), during the reporting period, or that projected to be used in future, multiplied by the EF of the state in which the facility operates.

Scope 3 GHG emissions are those associated with the provision of goods and services purchased by the facility or operation but that are not owned or controlled by the entity responsible for the facility or operation. Emissions are categorised according to Scope 3 Standard. The Scope 3 emissions categories relevant to the Project include:

- Category 1: Purchased goods and services
- Category 2: Capital goods
- Category 3: Fuel and energy related emissions
- Category 4: Upstream transportation and distribution
- Category 5: Waste generated in operations
- Category 7: Employee commuting

4.3 Method for Calculation of GHG emissions

4.3.1 Project Scope 1, Scope 2 and Scope 3 Emissions

This desktop assessment has been prepared by Katestone based on information, data, and assumptions provided by Grenof. Katestone has not independently verified the accuracy, completeness, or validity of the data supplied and makes no representation or warranty regarding its accuracy. The findings and conclusions presented in this assessment are based on the information available at the time of reporting.

Projected Scope 1, Scope 2, and Scope 3 GHG emissions for the Project during construction and operation have been calculated using the methods described in the following resources and through using energy content factors (ECF) and EFs outlined in Table 3:

- The National Greenhouse Accounts Factors 2025 (DCCEEW, 2025)
- National Greenhouse and Energy Reporting (Measurement) Determination 2008, (Compilation 19)

- The Greenhouse Gas Protocol (WRI/WBCSD, 2004)
- Australian Transport Assessment and Planning (ATAP, 2020) Guidelines.

Katestone employs Method 1 as outlined in the NGER Determination for all emissions calculations as this method is adequate to perform a rigorous GHG assessment of the Project. The Method 1 formula is:

$$E = \frac{Q \times ECF \times EF}{1000},$$

where E represents the total emissions in tCO₂-e, Q is the quantity of the emission source (e.g., with units kL), ECF is the energy content factor of the emission source (e.g., with units GJ/kL), EF is the emission factor that describes the total amount of equivalent carbon dioxide emissions associated with the emission source (i.e., with units kg CO₂-e/GJ), and the 1000 returns the correct units for the emissions.

4.3.2 Emissions from Vegetation clearance

The Full Carbon Accounting Model (FullCAM) (Richards, 2001) is used to assess the carbon stock (tonnes carbon per hectare (t C / ha)) of vegetation within the proposed areas for land clearing resulting from the Project. FullCAM estimates the carbon stock change in ecosystems at a grid scale of 25 m x 25 m including:

- above and belowground biomass
- standing and decomposing debris
- soil carbon resulting from land use and management activities.

FullCAM is the standard method for measuring change in carbon stocks due to land use change and is used to assess the effects of LULUCF in Australia's National Greenhouse Gas Accounts. The carbon stock is multiplied by an emissions factor to give the t CO₂-e that would be emitted if all the carbon stock was converted to carbon dioxide at a single point in time.

The clearing footprint (~6.9 ha), supplied by the Grenof as a shapefile, was classified as *Eucalyptus* open woodlands based on aerial mapping. The assessment quantified the total carbon stock loss over the 50-year LOP following clearing.

Emissions were calculated by running FullCAM simulations of 100% clearing for each FullCAM vegetation type. FullCAM returns the total tonnes of carbon per hectare (t C / ha) for the vegetation type (Table 3). The t C values are converted to t CO₂-e by multiplying by the ratio of the molecular weight of carbon dioxide to that of carbon (44/12). The t CO₂-e is then multiplied by the vegetation type area (in hectares) cleared. Land clearing is assumed and modelled as occurring entirely in Year 1, with all pre-clearing carbon stock accounted as emitted in the same calendar or financial year.

4.3.3 Emissions from Hydrofluorocarbons and natural refrigerants

Emissions from hydrofluorocarbons (HFCs) were determined in accordance with Part 4.5, subsection 4.102, Method 1 of the NGER determination. Method 1 is”

$$E_{jk} = Stock_{jk} \times L_{jk}$$

Where, E_{jk} is the emissions of gas (t CO₂-e)

$Stock_{jk}$ is the stock of the gas type determined by the GWP × Mass (t) of gas

L_{jk} is the default leakage rate assumed as 0.16 (industrial refrigeration)

GWP for R-507A was determined using IPCC's fifth assessment report and the composition denoted by DCCEEW (2024). Ammonia (R-717) and carbon dioxide (R-744) were modelled to have GWP's of 5 and 1 respectively (DCCEEW, 2024).

4.4 Emission Factors

This section outlines key emissions factors associated with the Project across Scope 1, Scope 2, and Scope 3, based on commonly accepted values and published emissions inventories (NGER, DCCEEW). These factors are used to estimate GHG emissions from relevant energy and material sources.

Table 3 Energy content factors (ECF) and emission factors (EF) used to calculate Scope 1, Scope 2, and Scope 3 emissions

Emission source	ECF	Units	EF			Units
			Scope 1	Scope 2	Scope 3	
Diesel (transport) ^{1,3}	38.6	GJ/kL	70.4	-	17.3	kgCO ₂ -e/GJ
Diesel (stationary) ^{1,2,3}	38.6	GJ/kL	70.2	-	17.3	kg CO ₂ -e/GJ
Gasoline (ULP) ^{1,3}	34.2	GJ/kL	67.62	-	17.2	kg CO ₂ -e/GJ
Queensland Electricity ¹	0.0036	GJ/kWh	-	0.67	0.09	kgCO ₂ -e/kWh
LPG ³	25.7	GJ/kL	60.6	-	20.2 ¹⁰	kgCO ₂ -e/GJ
Vegetation clearing- Eucalyptus open woodlands ⁴	-	-	75.05	-	-	t C /ha
NaOH sodium hydroxide ⁵	-	-	-	-	2.18	kgCO ₂ -e/ kg
HCl hydrochloric acid ⁶	-	-	-	-	0.51	kgCO ₂ -e/ kg
H ₂ O ₂ hydrogen peroxide ⁵	-	-	-	-	2.38	kgCO ₂ -e/ kg
Na ₂ CO ₃ sodium carbonate ⁷	-	-	-	-	0.138	kgCO ₂ -e/ kg
H ₂ SO ₄ sulphuric acid ⁷	-	-	-	-	0.14	kgCO ₂ -e/ kg
Active carbon ⁸	-	-	-	-	9.5	kgCO ₂ -e/ kg
Concrete 32 – 40 MPa ⁹	-	-	-	-	305	kgCO ₂ -e/m ³
Concrete 25 – 32 MPa ⁹	-	-	-	-	747	kgCO ₂ -e/m ³
Concrete 20 – 25 MPa ⁹	-	-	-	-	222	kgCO ₂ -e/m ³

Structural steel (galvanised structural sections) ⁸	-	-	-	-	2,400	kgCO ₂ -e/kg
Commercial and industrial waste	-	-	-	-	1.3	t CO ₂ -e / t
General Cargo Ship Average ¹¹					0.0132	t.km / kgCO ₂ -e
Container Ship Average ¹¹					0.0161	t.km / kgCO ₂ -e
Bulk Carrier Average ¹¹					0.00353	t.km / kgCO ₂ -e
Table notes: ¹ DCCEEW, 2025 ² Includes non-road-registered-vehicles ³ National Greenhouse and Energy Reporting (Measurement) Determination 2008, Compilation 19 ⁴ Full Carbon Accounting Model (FullCAM) (Richards, 2001) ⁵ U.S EPA, 2016 ⁶ Federal Ministry for Economic Affairs and Climate Action. (2024). ⁷ CarbonCloud, 2025 ⁸ Vilén et al., 2022 ⁹ NABERS, 2025 ¹⁰ Natural gas EF ¹¹ Department for Energy Security and Net Zero, 2025						

4.4.1 Emissions from Purchase of Construction Materials

A variation of Method 1 is used to calculate Scope 3 emissions (t CO₂-e) of construction materials, i.e.:

$$\frac{Q \times EF}{1000}$$

where Q is the volume (metres cubed, m³) or mass (tonnes) of the materials and EF is the published emissions factor (Table 3).

4.4.2 Emissions from Upstream Processing of Chemicals, Fuels, and Energy

Chemicals (Category 2), diesel, and LPG will be consumed throughout the LOP for construction and operation activities. Scope 3 GHG emissions associated with the upstream extraction, processing, and distribution of these fuels were calculated using EFs denoted in Table 3. GHG emissions from transmission and distribution losses associated with purchased electricity were calculated using the same method.

4.4.3 Emissions from Upstream Transportation and Distribution

Emissions from upstream transportation and distribution (Category 4) includes all third-party transportation and distribution services purchased by Grenof which includes inbound and outbound (sold products) logistics. Data relating annual trips, vehicle classes, gross vehicle mass (GVM), and trip distances was provided by Grenof (Table 4). The transportation of products mainly relate to outbound logistics.

Table 4 Summary of inputs for emission from upstream transportation and distribution

Product	Truck type	GVM Loaded (t)	Distance (one way) km	Trips per Year	Total Annual Distance (km)	Fuel Consumption (L/ 100 km)
Salt ¹	B Double	62	75	1351	101,325	79
Caustic Soda Bulk	B Double	62	3	606	1,818	1
Caustic Soda Bulk & IBC	Heavy Rigid	27.5	600	497	298,200	134
Chlorine Gas drums	Semi-Trailer	42.5	600	983	589,800	367
Sodium Hypochlorite - Bulk	B Double	62	600	31	18,600	15
Sodium Hypochlorite - IBC	Heavy Rigid	27.5	600	408	244,800	110
Hydrochloric Acid - Bulk	Heavy Rigid	27.5	600	590	354,000	159
Hydrochloric Acid - IBC	Heavy Rigid	27.5	600	913	547,800	246
Miscellaneous ¹	Passenger	4.5	15	260	3,900	0
Waste	Heavy Rigid	15	15	104	1,560	1

Table Notes:
¹ Inbound
² Accounted in waste (Category 5)

Fuel consumption for each vehicle was derived using the ATAP uninterrupted fuel consumption model, with coefficients and base fuel values specified for a road alignment of rise and fall = 0 and curvature of 20°/km (ATAP, 2020). The model accounts for GVM (tare weight plus payload) and incorporates parameters for speed, road roughness (IRI), curvature, and rise and fall to represent uninterrupted flow conditions at an assumed 100 km/h. The respective fuel consumption of each vehicle was multiplied by the distance and number of movements and the respective emissions factor for diesel (transport) (Table 3).

Notes: Transport of steel and skid mounted modules to site during construction was omitted from the assessment due to total fuel usage less than 1 kL and emissions less than 1 t CO₂-e concerning the Transport from Gladstone centre (15 km trip). Further, the combustion of hydrogen was omitted from the assessment as 40 tonnes combusted over the LOP will result in less than 0.3 t CO₂-e.

4.4.4 Waste Generated in operations

In assessing the emissions resulting from waste in operations, Grenof's total waste tonnage disposed by third parties was multiplied by the commercial and industrial waste EF (Table 3).

Emissions arising from transportation to the processing facility is optionally included for completeness as determined in section 4.4.3.

4.4.5 Emissions from Worker Commute

The road travel commute covers the construction-phase workforce and operations staff.

- During construction, an estimated 50 workers drive personal vehicles 15 km from Gladstone township to site, totalling 260 return trips or 390,000 km
- During operation, 10 workers operating 12-hour shifts (5 workers each shift) drive a personal vehicle 15 km from Gladstone township to site 7 days a week, totalling 364 return trips or 109,200 km per year. An additional 14 workers, travel the same total distance commuting 5 days a week.

All employee vehicles were assumed to be passenger vehicles, averaging 11.1 L/100 km, based on the Australian Bureau of Statistics (ABS) survey of motor vehicle use (2020). For this analysis, all personal vehicles were assumed and equally divided between diesel and unleaded. Emissions factors in Schedule 1, NGER Determination (Table 3) were then applied to the relative fuel consumptions to evaluate total GHG emissions per year.

4.4.6 Avoided Emissions

- LPG Boilers: 3.6 t LPG/day (base case) vs 3.0 t LPG/day (abated case)
- Road transport: Using the EV charging electricity consumption (kWh) and the equivalent travel distance, emissions avoided are estimated by applying an average 11.1 L/100 km passenger-vehicle intensity (ABS, 2020) to the same distance, with a 50:50 diesel:gasoline split
- International shipping: Avoided emissions estimated using tonne.kilometre (t.km) EFs for general cargo, container, and bulk carrier vessels (Table 3), applied to routes from Tianjin (China) and Jurong (Singapore) to Gladstone Port.

5. GREENHOUSE GAS EMISSIONS INVENTORY

5.1 Summary

The total GHG emissions over the LOP (including construction and operations phases) are estimated to be 3,800,943 t CO₂-e (Table 5). The total LOP Scope 1 and 2 emissions are estimated at 201,778 t CO₂-e and 2,820,667 t CO₂-e respectively. The average annual Scope 1 and 2 emissions are estimated at 3,956 t CO₂-e and 55,307 t CO₂-e respectively. LOP Scope 3 emissions are estimated at 778,499 t CO₂-e, with annual average emissions of 15,265 t CO₂-e.

Table 5 Summary of LOP and average annual GHG emissions (t CO₂-e) rounded to nearest t

Scope	Metric	Emissions (t CO ₂ -e)
Scope 1	Average annual	3,956
	Total	201,778
Scope 2	Average annual	55,307
	Total	2,820,667
Scope 3	Average annual	15,265
	Total	778,499
Total GHG Emissions		3,800,943
Average Annual Total Emissions		74,528

5.2 Scope 1 and Scope 2 Emissions

5.2.1 Construction

Construction is expected to occur across the first year of the Project and contribute a total of 2,533 t CO₂-e including vegetation clearing. The largest contribution to emissions apart from vegetation clearing will arise from heavy machinery and plant equipment, excluding vehicles transporting modules (559 t CO₂-e), followed by light vehicles used on site (75 t CO₂-e). There are no Scope 2 emissions during construction as no electricity is purchased from the National Electricity Market (NEM).

5.2.2 Operation

At maximum operation, annual Scope 1 and 2 emissions are estimated to be 3,985 t CO₂-e and 56,413 t CO₂-e respectively (Table 6). Electricity used for the main chlor-alkali process is the largest contributing emission source (81%) to the operation Scope 1 and 2 inventory, followed by electricity usage for the Balance of Plant (BOP) (12%).

The emissions resulting from electricity usage for the main process and BOP are estimated at 49,032 t CO₂-e and 7,370 t CO₂-e respectively, per annum. LPG gas usage by boilers for steam generation is the third highest contributing source (6%), estimated at 3,343 t CO₂-e.

Table 6 Total Scope 1 and Scope 2 emissions (t CO₂-e rounded to nearest t) from year 1 (construction) to end of operation (50-year life)

Phase		Construction Year 1	Annual Operation Years 2 - 51	Total LOP Emissions (construction & operation)
Source		GHG Emissions (tCO ₂ -e)		
Scope 1	Diesel Stationary	559	-	559
	Diesel Transport	75	-	75
	Boilers – LPG	-	3,343	167,127
	Forklifts – LPG ¹	-	5	238
	Refrigerant - R507	-	638	31,880
	Land Clearing	1,899	-	1,899
Scope 2	Main Process	-	49,032	2,451,597
	Balance of Plant	-	7,370	368,500
	Charging of EVs	-	11	570
Total Scope 1		2,533	3,985	201,778
Total Scope 2		-	56,413	2,820,667
Total Scope 1 + 2		2,533	60,398	3,022,444

5.3 Scope 3 Emissions

Across the LOP, the largest Scope 3 category is upstream fuel and energy related activities 434,840 t CO₂-e, followed by upstream transport and distribution (150,866 CO₂-e) and purchased goods and services (118,462 t CO₂-e; Table 7).

The Scope 3 emissions of the construction phase are estimated at 6,624 t CO₂-e. Capital goods contribute the largest share of Scope 3 construction emissions, with upstream manufacture of steel and concrete accounting for 6,359 t CO₂-e. The upstream production of diesel used on site, and the commute of construction workers is estimated to result in 156 t CO₂-e, and 109 t CO₂-e respectively.

At maximum operation, purchased fuel and energy related activities are the largest Scope 3 category, estimated at 8,694 t CO₂-e per annum, driven primarily by upstream electricity transmission and distribution losses (7,578 t CO₂-e per annum). The upstream transportation and distribution concerning both inbound and outbound logistic services purchased by Grenof is the second largest Scope 3 category estimated at 3,018 t CO₂-e per annum. The purchasing of goods and services, specifically chemicals required for the chlor-alkali process is the third largest category, estimated at 2,369 t CO₂-e per annum. The processing and transportation of waste and employee commuting are estimated at 1,218 t CO₂-e and 138 t CO₂-e per annum respectively.

Table 7 Scope 3 GHG emissions (t CO₂-e rounded to nearest t): Construction and Operation (annual) by Category and Source, with LOP Category Totals

Category	Source	Construction Year 1	Annual Max Operation Years 2 – 51	Category Total LOP
		Emissions t CO ₂ -e		
1. Goods and services	NaOH	-	1,353	118,462
	HCl	-	633	
	H ₂ O ₂	-	269	
	NA ₂ CO ₃	-	34	
	H ₂ SO ₄	-	77	
	Active Carbon	-	3	
2. Capital goods	Steel	3,600	-	6,359
	Concrete	2,759	-	
3. Fuel and Energy related emissions	LPG	-	1,116	434,840
	Electricity	-	7,578	
	Diesel	156	-	
4. Upstream Transportation and Distribution	Inbound	-	215	150,886
	Outbound	-	2,803	
5. Waste	Processing	-	1,217	60,923
	Transportation	-	2	
7. Employee Commute	Passenger Vehicles	109	138	7,029
Total		6,624	15,437	778,499

6. GREENHOUSE GAS ABATEMENT PLAN

6.1 Introduction

This GHG Abatement and Mitigation Plan addresses the requirements of the GHG guideline in line with Queensland's emission reduction targets, supporting Grenof in their application for Development Approval. The Project is considered a medium to high emitter, with Scope 1 and Scope 2 GHG emissions predicted to be 60,398 t CO₂-e annually, during the operational phase.

Grenof adheres to the GHG abatement hierarchy, prioritising emission avoidance and reduction through renewable energy, vehicle electrification, and proactive operational measures. Where feasible, lower-emission alternatives are adopted, while offsets may be considered for residual emissions against the company's sustainability targets that cannot be eliminated. Recognised as a leader in clean technology and recipient of the Sunshine Coast Business Award for Clean Technology (Large Business), Grenof embeds sustainability and innovation across its operations. Environmental management aligns with the Equator Principles, IFC Performance Standards, and the Project will be ISO 14001 accredited.

6.2 Reference Point

The GHG emissions reference point for the Project represents the level of emissions against which ongoing reduction of GHG emissions will be assessed throughout the life of the Project, based on projected GHG emissions (excluding land clearing – not NGER reportable) at the commencement of the Project and prior to any future abatements.

The projected operational Scope 1 GHG emissions for the Project is estimated at 3,985 t CO₂-e annually. Operational Scope 2 emissions are estimated at 56,413 t CO₂-e annually. These serve as the baseline against which all GHG abatement and mitigation measures will be assessed.

Additionally, the emission intensity may serve as an additional reference to the efficiency of operations, estimated at 0.37 t CO₂-e / t of gross product (160,000 tpa).

6.3 Management Controls to Reduce GHG Emissions

The following management controls will be applied for the Project (Table 8), where practicable and cost-effective, to achieve the objectives and key result areas. Following the GHG Guideline hierarchy, details of the abatement measures that will be implemented to mitigate GHG emissions over the lifetime of the Project include:

- Reducing GHG emissions through planning, appropriate technology, energy efficient processes, upgrading equipment, introducing control technologies, and entering arrangements with third parties
- Substituting remaining GHG emissions processes to low emission processes
- Offsetting mechanisms and carbon crediting as a last resort, after all reasonable avoidance, reduction and substitution measures have been taken.

6.3.1 Avoid

The Project cannot avoid GHG emissions and produce the required output of chemicals – however a conscious investment decision has been made to implement a best practice chemical production plant that is significantly more energy efficient than existing Australian plant with similar chemical outputs.

6.3.2 Reduce

Grenof has committed to reducing GHG emissions through resource use efficiency and implementation of leading-edge technology (KRA 1, Table 8). The production technology (oxygen-depolarized cathode electrolysis technology) that will be installed at the commencement of the Project requires 25% less electricity than current chlor-alkali facilities in Australia, reducing Scope 2 emissions proportionally. Thus, the Project is expected to reduce emissions by 16,344 t CO₂-e annually against a typical facility base case. Local production of chemicals will further reduce emissions within chemical procurement supply chains, via reducing the required shipping imports as outlined in section 6.5.

Grenof will periodically review and implement opportunities to reduce electricity related emissions by shifting supply to lower emissions sources, subject to technical feasibility and cost effectiveness (KRA 2). Potential abatement measures include:

- On site photovoltaic electricity generation and hydrogen generation
- Power Purchase Agreements
- Battery energy storage systems to support renewable generation
- Electrified boilers and forklift fleet

6.3.3 Substitute

Grenof will substitute ~15% of its LPG by mass with hydrogen generated within the chlor-alkali process at the commencement of the Project (KRA 3). The abatement strategy is expected to reduce annual emissions by 669 t CO₂-e and support industry efforts towards a low emission hydrogen economy (The National Hydrogen Strategy 2024).

Grenof will further substitute all site vehicles with EVs (KRA 4) which will reduce transport emissions by 2,780 t CO₂-e annually against a base case using vehicles with internal combustion engines. This supports Queensland's Zero Emission Vehicle Strategy 2022–2032 and Australia's National Electric Vehicle Strategy 2023 and will reduce the Scope 3 emissions that would have been associated with production and transport of the liquid fuel.

HFC R-507 used in process cooling will be substituted with natural refrigerants R-717 (ammonia) and R-744 (CO₂) in a closed loop system where technically practical and safe (KRA 5). R-717 and R-744 are intended to be used at the commencement of the Project within a closed loop process resulting in minimal leakage and reducing emissions by 636 t CO₂-e annually. The natural non-HFCs have global warming potentials (GWP) of less than 5 in contrast to R-507 which has a GWP of 3,300 (DCCEEW, 2024).

6.3.4 Offset

The Project will not be required to offset its emissions, however, may voluntarily engage in offsets as part of its sustainability strategy. Grenof will consider purchasing renewable energy certificates (RECs), Australian Carbon Credit Units, or credits from other voluntary schemes to offset their carbon footprint, where it cannot practically be achieved through other measures (KRA 6).

6.4 Scope 3 emission management and abatement

Grenof will investigate and implement the following measures to address Scope 3 emissions where economically viable and technically feasible:

- Contract transport and logistics providers based on their verified emissions intensity; select the lowest emission mode per task

- Procure goods and capital goods with lowest verified embodied emissions
- Reduce commuting emissions via car-pooling incentives, public transport support, and flexible work policies

Additionally, Grenof intends to investigate the feasibility of construction of a caustic soda pipeline to a large customer, with the potential to displace emissions from diesel fueled freight carriers.

Risks to effective Scope 3 mitigation may include inconsistent supplier compliance with emissions standards, dependency on third-party reliability with limited control over maintenance standards and disruptions in certified waste disposal logistics.

6.5 Enabled Avoided Emissions

The Project is expected to contribute to the economic abatement of shipping related emissions of chemical imports from Asia. The Project is expected to reduce shipping emissions by ~3,500 t CO₂-e – 22,000 t CO₂-e per annum depending on the shipping method considered.

6.6 Monitoring, Evaluation, and Reporting

Grenof will annually report its GHG emissions and energy production in accordance with requirement of the NGER scheme. It will use this reporting to monitor GHG emissions, and the effectiveness of any conditional GHG emissions management measures implemented for the Project.

6.7 Advancing technologies and opportunities

Grenof will undertake periodic reviews of the technical readiness level (TRL) and commercial readiness level (CRL) of technology and process options that can improve the emissions intensity of production and/or provide new business models. Advancing technologies and opportunities include:

- Lower emission production technologies
- Electrification of remaining Scope 1 GHG sources (boilers and forklifts)

Table 8 Key result areas and management controls for the Project by GHG abatement hierarchy

Priority	Key Result Area	Management Controls and Timing
Reduce	KRA 1: Reduce production technology electricity use by 25% against the base case	Implement highest efficiency Thyssen Krupp Nucera membrane technology in Project
	KRA 2: Reduce Scope 2 emissions with investment in renewable energy technology where feasible and cost-effective	Evaluate cost-effectiveness and feasibility of onsite solar PV and BESS Evaluate cost-effectiveness of PPAs for renewably generated electricity
Substitute	KRA 3: Reduce emissions from onsite LPG combustion in boilers by <15% from the base case	Substitute a proportion of LPG used in boilers for hydrogen at the commencement of the Project
	KRA 4: Reduce GHG emissions due to transport fuel combustion by <95% through use of EVs	Replace fossil-fuel transport vehicles with EVs at commencement of the Project's operational phase
	KRA 5: Reduce potential fugitive refrigerant leakage emissions by > 600 t CO ₂ -e per annum	Substitute R-507 with R-717 (ammonia) and R-744 (carbon dioxide) for closed loop chlorine liquefaction on commissioning
Offset	KRA 6: Offset residual emissions where necessary and cost-effective	Annual review of emissions inventory and regulatory requirements for emission offsetting

6.8 Projected GHG Emissions

The Project's projected GHG emissions without decarbonisation are 4,012,094 t CO₂-e. Implementing KRAs 1 and 3-5 from commencement of the Project will reduce emissions by 1,021,469 t CO₂-e (25.5%) over the LOP to 2,990,624 t CO₂-e.

Table 9 Base case and abated case GHG emissions and reductions

Scope	Phase	Source	Base	Abated	LOP Emissions Reductions (t CO ₂ -e)
Scope 1	Construction	Diesel Stationary	559	559	-
		Diesel Transport	75	75	-
		Land Clearing	1,899	1,899	-
	Operation	Operational Vehicles	139,594	570 ¹	139,025
		Boilers LPG	200,552	167,127	33,425
		Forklifts LPG	238	238	-
Refrigerants		31,880	60	31,820	
Scope 2	Main Process	3,268,796	2,451,597	817,199	
	Balance of Plant	368,500	368,500	-	
Total Scope 1			374,798	169,958	204,840
Total Scope 2			3,637,296	2,820,667	816,630
Total			4,012,094	2,990,624	1,021,469
Tables note: ¹ Scope 2 EV charging					

6.9 Assessment of proposed GHG mitigation measures

An assessment of proposed GHG abatement measures for the Project is provided in Table 10 and considers the timeframe for implementation, key risks, a comparison with relevant best practice environmental management standards, an estimate of emissions reductions resulting from the abatement measure, and consideration of whether the inclusion of an ongoing monitoring program for the abatement measure is necessary.

The timeframes for implementation are presented as Immediate, Near, Medium, and Long-term. These timeframes are relative to the number of Project years. Immediate represents the commencement of the Project (pre or during construction); Near-term represents the first 25% of all Project years; Medium-term represents the middle 25–75% of all Project years; Long term represents the final 25% of Project years and decommissioning.

'Approaching best practice' indicates the abatement measure is dependent on the degree of implementation. An 'embedded' monitoring program requirement indicates the abatement measure should become standard operating procedure once implemented.

6.10 Monitoring and Audit

Grenof will monitor and record all energy use and production within the facility boundary consistent with NGER requirements and methods. This data and the methods for monitoring will be available and subject to periodic internal validation and independent audit.

Grenof will tie the success of the KRAs (Table 8) to executive key performance indicators (KPI) as appropriate to their level of delegation and operational control.

6.11 Reporting

Grenof is required to provide annual reports of its emissions and energy usage through the Commonwealth NGER system. The Project forms a facility for the purposes of NGER and its emissions and energy production will be included in the company reporting.

Table 10 Assessment of proposed GHG mitigation measures

KRA	Mitigation measure	Timeframe	Risks	Opportunities	Industry Standard	Emissions reduction estimate for the LOP (t CO ₂ -e)
KRA 1	Reduce production technology electricity use by 25% against the base case	Immediate	<ul style="list-style-type: none"> High capital costs lead to procurement of less efficient production technologies 	<ul style="list-style-type: none"> Installation of highest efficiency production technologies provides best return on investment through optimal chemical production and reduced emission intensity of production 	Best	817,199
KRA 2	Reduce Scope 2 emissions with investment in renewable energy technology where feasible and cost-effective	Immediate	<ul style="list-style-type: none"> Inadequate capacity to support electricity demand if not correctly sized in design leading to higher emission intensity of production Cost overruns, due to high consumption or underestimation of initial costs, delays causing extra labour or equipment costs Increased maintenance demands or poorly integrated backup systems 	<ul style="list-style-type: none"> Greater self-reliance through on-site generation and storage enabling new revenue streams (e.g. selling of electricity) and reduces exposures to future grid price volatility Eligibility of incentives and green financing, strengthening tender competitiveness and stakeholder confidence against climate risks 	Best	TBD
KRA 3	Reduce emissions from onsite LPG combustion for boiler by <15% from the base case	Immediate	<ul style="list-style-type: none"> Cost overruns from workforce training, lead times in procurement and design and construction requirements 	<ul style="list-style-type: none"> Greater energy self - reliance (when paired with KRA 4) improves margins 	Best	33,425

KRA	Mitigation measure	Timeframe	Risks	Opportunities	Industry Standard	Emissions reduction estimate for the LOP (t CO ₂ -e)
			<ul style="list-style-type: none"> Complete electrification and hydrogen fueled options may have low TRLs and CRLs 			
KRA 4	Reduce GHG emissions due to transport fuel combustion by <95% through use of EVs	Immediate	<ul style="list-style-type: none"> Additional charging and electrical-upgrade requirements can drive cost overruns and added labour Reduced overall fire incidence, however fire from misuse or damage can be more intense and harder to extinguish 	<ul style="list-style-type: none"> Lower reliance on fossil fuels and less exposure to volatile fuel supply chains Lower operating cost from higher drivetrain efficiency 	Best	139,025
KRA 5	Reduce potential fugitive refrigerant leakage emissions by > 600 t CO ₂ -e per annum	Immediate	<ul style="list-style-type: none"> Additional system requirements and workforce training can drive cost overruns 	<ul style="list-style-type: none"> Improved low temperature energy performance, increasing production efficiency Natural refrigerants support lower emission production, increasing green investment opportunities and lowers supply chain risks associated with HFC phase down 	Best	31,820
KRA 6	Investigate offsetting residual emissions where necessary and cost-effective	As practicable	<ul style="list-style-type: none"> Current technical and economic feasibility inadequate 	<ul style="list-style-type: none"> Building sustainability strategy and goals 	Emerging	TBD

7. RISKS AND LIKELY MAGNITUDE OF IMPACTS ON ENVIRONMENTAL VALUES

7.1 Impacts of GHG Emissions on Environmental Values

The increasing concentration of greenhouse gases in the atmosphere, primarily due to the combustion of fossil fuels and deforestation, is leading to the warming of oceans, land, and atmosphere. This warming increases the heat energy available in the climate system leading to changed weather patterns including more frequent and intense extreme weather events. Australia is required to provide the UNFCCC with National Inventory Reports annually, biennial reports every 2 years, and National Communications every 4 years. These reports include details on total and sectoral GHG emissions, progress against reduction targets, and mitigation actions.

The Project is located in Central Queensland. It is projected that by 2050, under a high emissions scenario., the key climate risks for the region include (Queensland Government, Department of Energy and Climate, 2024):

- increased frequency of hot days (>35 °C)
- Increased rainfall variability and a general decrease of annual rainfall
- Increased likelihood of bushfire weather and greater severity when fires occur
- increased pan evaporation rates
- increased frequency and severity of drought
- less frequent but more intense tropical cyclones
- warmer and more acidic ocean
- rising sea levels and more frequent coastal and open ocean extreme events.

Consequently, there is a need to reduce emissions at a state, national, and global level. The Project will be a contributor to Queensland's net emissions reduction whilst guaranteeing supply.

7.2 Contribution of Project to State, Commonwealth and Global GHG Emission Budgets

The state, national, and global carbon budgets remaining to achieve net zero GHG emissions by 2050 are presented in Table 11. The expected LOP GHG emissions are estimated to account for 0.23%, 0.052% and 0.00072 % of the remaining emissions budgets for Queensland, Australia, and the global total respectively.

Table 11 Contribution of expected LOP emissions at maximum production capacity to current GHG

Contributions to Emission Budgets						
Expected LOP Emissions	Queensland		Australia		Global	
	Emissions (MtCO ₂ -e)	Project %	Emissions (MtCO ₂ -e)	Project %	Emissions (MtCO ₂ -e)	Project %
3.8	1,679.77	0.23%	7,248.62	0.052%	531,000.00	0.00072%

8. SUMMARY

Katestone Environmental Australia Pty Ltd (Katestone) was commissioned by CQG Consulting (CQG) on behalf of Grenof to complete a Greenhouse Gas (GHG) Assessment of Project Halogen (the Project). The GHG assessment is required to support a Development Application (DA) for an Environmentally Relevant Activity (ERA) 7(6d) regarding a material change of use (MCU) for chemical manufacturing.

The Project will support the Gladstone Region's Economic Transition Roadmap 2022-2032 through green chlor-alkali manufacture, minimising the need for these products to be imported. It is expected to have an operational asset life of 50 years (after 1 year of construction) and will produce caustic soda (NaOH), liquid chlorine (Cl₂), sodium hypochlorite (NaClO), and hydrochloric acid (HCl) for domestic customers.

The GHG assessment was conducted in accordance with the requirements of the *Guideline Greenhouse gas emissions ESR/2024/6819* (GHG Guideline) and classified the Project as a medium to high emitter with annual emissions >25,000 t CO₂-e, requiring a Scope 3 inventory and abatement plan to support Queensland's emission reduction targets.

The GHG assessment estimated the total Life of Project (LOP) Scope 1 emissions at 201,778 tonnes of carbon dioxide equivalent (t CO₂-e) with average annual Scope 1 emissions of 3,956 t CO₂-e. Scope 2 emissions for the LOP are estimated at 2,820,667 t CO₂-e, with average annual Scope 2 emissions estimated at 55,307 t CO₂-e. LOP Scope 3 emissions are estimated at 778,499 t CO₂-e, with average annual Scope 3 emissions of 15,265 t CO₂-e.

The Project is expected to reduce emissions resulting from shipping of Asian chemical imports by ~3,500 t CO₂-e – 22,000 t CO₂-e per annum. Grenof is committed to ensuring that the Project contributes to the transition to a low emissions global economy, whilst manufacturing essential chemicals for the region.

Decarbonisation actions categorised by the GHG hierarchy are:

Avoid

The Project cannot avoid GHG emissions and produce the required output of chemicals – however a conscious investment decision has been made to implement a best practice chemical production plant that is significantly more energy efficient than existing Australian plant with similar outputs. The GHG abatement plan focuses on mitigation and substitution, improving the electricity-to-work conversion efficiency to lower the production emission intensity and shifting to lower emissions energy sources.

Reduce

Scope 2 emissions will be reduced by 25% from the base case at the commencement of the Project through design and procurement of best practice and highest efficiency production technology.

Grenof will review and implement measures to further reduce Scope 2 emissions, where practicable and cost-effective, during future stages of the Project, including:

- Installation of onsite renewable energy generation
- Installation of a battery energy storage system (BESS)
- Renewable power purchase agreements (PPA)

Substitute

- Grenof will use a blend by-product hydrogen and liquid petroleum gas (LPG) generated in the production process at the commencement of the Project, to reduce LOP emissions by 33,425 t CO₂-e from the base case.

- Fossil fuelled transportation vehicles are substituted with electric vehicles (EVs) at the commencement of the Project, saving 139,025 t CO₂-e for the LOP.
- Hydrofluorocarbon (HFC) refrigerant R-507 used for chlorine liquification will be substituted with natural non- HFC refrigerants R-717 and R-744 (ammonia (NH₃) and carbon dioxide (CO₂)) where cost efficient and practicable, reducing LOP emissions from the base case by 31,820 t CO₂-e.

Offset

Residual emissions against Grenof's cooperate sustainability targets may be offset through the purchase and surrender of Renewable Energy Certificates (REC) and/or Australian Carbon Credit Units (ACCU) originating in Queensland, or other voluntary emissions reduction schemes.

Grenof will undertake periodic reviews of the technical readiness level (TRL) and commercial readiness level (CRL) of technology and process options that can improve the emissions intensity of production and/or provide new business models. Feasibility studies will be conducted for options that have a TRL of 6 or greater and a CRL of 5 or greater and recommendations for further investment will be made to the Board as appropriate. Options may include:

- Higher efficiency production technologies
- Electrification of remaining Scope 1 GHG sources (boilers and forklifts)

The Project's emissions are expected to contribute 0.23%, 0.052% and 0.00072% to the remaining state, national and global carbon budgets for the 2025-2050 trajectory towards net zero

The Project will be required to report its emissions as a facility under the NGER system, but it will not be subject to the emissions reduction requirements of the Safeguard Mechanism. Annual recording and monitoring will be subject to internal validation and periodic independent auditing, and achievement of abatement key result areas (KRA) will be tied to executive key performance indicators (KPI) as appropriate to Grenof's delegation and operational control.

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