Perdaman Urea Project

Environmental Management Plan

Greenhouse Gas Emissions

Final

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1 Overview

Perdaman Chemicals and Fertilisers Pty Ltd (Perdaman) plans to construct and operate a modern urea plant with a production capacity of approximately 2 million tonnes per annum (Mtpa). The plant would be located within the Burrup Strategic Industrial Area (Burrup SIA), on the Burrup Peninsula, approximately 10 kilometres (km) from Dampier and 20km north-west of Karratha in the north west region of Western Australia.

The project would source natural gas from the nearby Woodside operated gas facility. The natural gas would be converted to urea via a series of processing stages involving autothermal reforming (to produce syngas), gas treatment to adjust the syngas to hydrogen (H_2) and carbon dioxide (CO_2) followed by ammonia synthesis and conversion into urea in a granulated form. This final granulated product would be transported to local and international markets via Dampier Port.

Urea is a commonly used fertiliser, containing 46% nitrogen. Nitrogen is essential for crop growth as it is an element used by plants to produce protein as well as it being a component of their DNA. Urea is one of the most economical sources of nitrogen fertiliser, and globally, is the most popular nitrogen-based fertiliser in use. It is also used throughout Australia and is available from rural produce stores and nursery suppliers. In recent years, Australia has imported on average approximately 2 Mtpa of urea, mostly from the Middle East with smaller volumes imported from China and other countries. Urea imported from the Middle East is typically sourced from older plants (10 to 25 years old) which operate under a low-cost natural gas regime where economic efficiency drivers are less critical, resulting in higher GHG emissions. Similarly, urea imported from China is primarily produced using coal as feedstock, and is therefore also associated with higher GHG emissions (SNC-Lavalin, 2019).

The economic and social benefits of the project are discussed at length in the Environmental Review Document (ERD) documentation (Cardno, 2020). It is expected to include capital investment in Western Australia leading to company and government taxation revenue, more than 2000 construction phase linked jobs and subsequent direct and indirect employment opportunities during the long term operation of the project. The production and supply of urea to the global agricultural sector is expected to improve crop production where it is in use. Urea has a number of other uses albeit in significantly smaller usage quantities, including being an additive in fuels with Selective Catalytic Reduction (SCR) to reduce NOx emissions (Cardno, 2020).

This Greenhouse Gas Management Plan (GHGMP) has been prepared in accordance with relevant environmental impact assessment guidelines, including those relevant to the preparation of environmental management plans (EPA, 2020), and for greenhouse gases (EPA, 2015, EPA, 2019, EPA, 2020). This GHGMP has been prepared taking into account feedback received during the public consultation process associated with the ERD. The GHGMP therefore details the measures that Perdaman will implement to manage GHG emissions from the project. This is summarised in Table 1-1.

Table 1-1: Summary of GHGMP

Title of proposal	Perdaman Urea Project
Proponent name	Perdaman Chemicals and Fertilisers Pty Ltd (Perdaman)
Purpose of the Environmental Management Plan – Greenhouse Gas Emissions (GHGMP)	Environmental Scoping Document requirement - outline how Project greenhouse gas emissions will be minimised in accordance with EPA, 2020.
Key environmental factors	Greenhouse Gas (GHG) Emissions
Key environmental objectives[1]	To maintain air quality and minimise emissions so that environmental values are protected (EPA, 2016). To mitigate GHG emissions and consequently minimise the risk of contributing to climate change (EPA, 2019). To reduce net greenhouse gas emissions in order to minimise the risk of environmental harm associated with climate change (EPA, 2020).
Key provisions in the plan	• A description of the overall environmental management framework for the Project, and how this Greenhouse Gas Management Plan fits within this framework (Section 3). • A description of the urea manufacturing process and the sources of Scope 1 emissions (Section 4.1). • Estimation of greenhouse gas emissions from the project, an explanation of the limitations in providing complete and credible estimates of Scope 3 emissions at this point in time, and commitments and timing for providing a more complete Scope 3 emissions inventory ((Section 4.2) • Comparison of the project emissions against relevant international and overseas benchmarks (Section 4.3) • A description of how the project has incorporated best practice greenhouse gas emission reduction methods and technology (Section 5.2) • Commitments to continuous improvement and achieving net Scope 1 emission reductions through a combination of deploying technology and methods to avoid, reduce or offset emissions (Section 5.3). • Routine emissions monitoring and reporting in accordance with the *National Greenhouse and Energy Reporting Act 2007* (NGER Act) (Section 5.4)

[1] At the commencement of the assessment process, (2018) the Environmental Review Document (ERD) approved in 2019 was reflective of the EPA guidelines of the time (EPA, 2015). This “Air Quality” guideline addressed both air emissions and greenhouse gas emissions. The assessment documentation made available for Public Environmental Review (March 2020) was also consistent with this. In April 2020, EPA published a revised environmental factor guideline for greenhouse gas emissions (EPA, 2020). Where possible, the principles set out in the April 2020 guideline are accommodated and addressed in this GHGMP.

2 Scope

2.1 Proposal Assessed

Perdaman proposes to construct and operate a Urea Production Plant on the Burrup Peninsula, Western Australia. The Project will be located within the Burrup SIA approximately 10 km from Dampier and 20 km north-west of Karratha. The Urea Production Plant would be the sole urea production facility in Western Australia. The planned production capacity is approximately 2 Mtpa. Natural gas for feedstock to the urea plant will be sourced from a nearby domestic gas plant. The urea product will be transported via closed conveyor to the nearby Dampier Port for export. The life of the project is estimated to be 40-years (based on site access lease), with a possible extension of a further 40-years, making the possible life of project up to 80 years (i.e. decommissioning in 2100).

The Project is described in its entirety in the ERD (Cardno, 2020). Emission estimation is described in full in the ERD (Cardno, 2020) and the associated emission assessment, is summarised in Section 4.2 of the ERD. This GHGMP addresses feedback received during the ERD public consultation period.

This GHGMP will be implemented following receipt of approval under the provisions of the *Environmental Protection Act 1986* (WA) (EP Act), both Part IV and Part V approvals.

2.2 Purpose and scope of the GHGMP

This GHGMP outlines how Perdaman will reduce net greenhouse gas emissions in order to minimise the risk of environmental harm associated with climate change, consistent with EPA, 2020.

This GHGMP estimates the Scope 1 emissions from activities associated with the Perdaman Urea Project that are within the operational control of Perdaman (as defined under the NGER Act)), and sets out the commitments to avoid, reduce or offset these emissions.

Scope 2 emissions are indirect emissions from the generation of purchased energy to operate the project. There are no Scope 2 emissions from the Project, as all power for the project will be generated onsite. This means that emissions from the generation of onsite power are Scope 1 emissions.

This GHGMP also sets out an approach to quantifying Scope 3 emissions from the project. Our initial and conservative estimates are presented for upstream generation, transport and supply of gas, and the downstream transport of urea to markets and the application of urea in agriculture – see Table 4-2. This GHGMP also commits to the scoping and preparation of a more complete inventory of Scope 3 emissions during the first year of project operations.

2.3 Alignment of GHGMP to EPA, 2020

EPA, 2000 states that, as a minimum, a Greenhouse Management Plan should outline:

- intended reductions in Scope 1 emissions over the life of the proposal
- regular interim and long-term targets that reflect an incremental reduction in Scope 1 emissions over the life of the proposal
- strategies which demonstrate that all reasonable and practicable measures have been applied to avoid, reduce and offset a proposal's Scope 1 emissions over the life of the proposal.

These matters are addressed in Section 5 of this GHGMP.

2.4 Key environmental factors

GHG emissions are identified as a key environmental factor for the Project. As outlined in the EPA guideline (EPA, 2020) the EPA has the objective to use its best endeavours to protect the environment and to prevent, control and abate pollution and environmental harm. With the established link between GHG emissions and the risk of climate change, and the broad acknowledgement that the warming climate will impact the Western Australian environment, the EPA therefore considers the effects of proposals that would increase the State's emissions, and contribute to environmental harm. Generally, the geographic scope of the EPA's obligations is the State of Western Australia and its environment (EPA, 2020).

GHG emissions are classified by source and associated emission management responsibilities. Specifically:

- Scope 1 GHG emissions are the emissions released to the atmosphere as a direct result of an activity, or a series of activities, at a facility level.
- Scope 2 GHG emissions are the indirect emissions from purchased or acquired energy that is used in the project.
- Scope 3 emissions are all other indirect greenhouse gas emissions, other than Scope 2 emissions, that are generated as a consequence of the project. Scope 3 emissions can occur both upstream and downstream of the project.

As outlined in detail in Section 4 of this GHGMP, the project will be a source of:

- Scope 1 emissions of CO_2 from the combustion of natural gas for onsite power generation, process heating and steam generation, modest CO_2 emissions from the urea synthesis process, and minor leakage or loss of methane (CH_4) from the gas reforming and urea synthesis process circuits.
- Scope 3 emissions from upstream and downstream of urea production. The upstream Scope 3 emissions include natural gas supplied to the Project from sources not owned or controlled by Perdaman. Downstream Scope 3 emissions including the sale, export, distribution and use of urea to fertilise food crops, and the subsequent crop harvesting, distribution and consumption of crops as food source by end consumers, but from sources not owned or controlled by Perdaman's business.

2.5 Rationale and approach

This GHGMP describes how Perdaman will minimise net greenhouse emissions from the project in accordance with the EPA guidelines (EPA, 2020).

The project's greenhouse gas emissions are relatively small in comparison to Australia's existing emitters (CER[2], 2020). Nevertheless, Perdaman commits to achieving a net reduction of Scope 1 emissions from the project by undertaking the following steps in accordance with Section 5.3 of this GHGMP:

- it will seek to avoid and reduce the project's Scope 1 greenhouse gas emissions; and

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[2] Australian Government Clean Energy Regulator, available at http://www.cleanenergyregulator.gov.au/NGER/National%20greenhouse%20and%20energy%20reporting%20data/a-closer-look-at-emissions-and-energy-data/australias-highest-emitters-(scope-1)-and-cumulative-percentage-for-2014-15

- It will supplement these emissions avoidance and reduction measures with carbon-off-sets.

The relevant studies conducted by Perdaman in association with the environmental approvals for the Project have been used to inform the development of this GHGMP. This includes the following:

- *Perdaman Urea Project Greenhouse Gas Assessment* (ETA, 2019).
- *Perdaman Project Destiny Benchmarking of Technology BAT and Emissions* (SNC Lavalin, 2019)
- *Perdaman Project Destiny Review of the Technology Selections* (SNC-Lavalin, 2019).

In response to the environmental impact assessment consultation process, Perdaman has identified further opportunities to reduce greenhouse gas emissions over the life of the project. These opportunities are outlined in Section 5 of this GHGMP.

3 Management Framework

Perdaman maintains an environmental management system (EMS) that addresses activities with a potential to affect the environment. As described in the ERD, a key element of the EMS includes assessing risk to identify potential impacts early in the risk assessment process to enable sufficient planning for avoidance and/or mitigation (Cardno, 2020).

The overarching Project Environmental Management Plan (PEMP) documents the strategic environmental controls and Project specific procedures, management plans and protocols that will be used for the Project. It aims to provide an instrument to:

- Comply with permit and approval requirements for the Project granted under Part IV of the *Environmental Protection Act 1986* (WA) (EP Act) and the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act) and any other ancillary approvals;
- Address applicable legislative and regulatory requirements; and
- Provide a framework for continual improvement and application of best industry practice.

The PEMP outlines the requirements for identifying obligations, planning, auditing, monitoring, reviewing, reporting and managing environmental performance. This GHGMP is a sub-plan of the PEMP.

The company's Environmental Policy is the foundation for all of Perdaman's environmental management processes and includes a statement signed by the Chairman / Managing Director. This policy is communicated to all Project personnel and is freely available for all interested parties.

Perdaman's environmental management approach is risk-based, systematic and responsive to change. This is achieved by undertaking comprehensive risk assessments to ensure all hazards are identified, assessed and evaluated to effectively eliminate or control risk levels to an acceptable level. This includes:

- All work environments containing hazards will be assessed.
- Perdaman's risk assessment tools being utilised and associated documentation being retained.
- Risk assessments will be performed regularly and in a timely manner by qualified personnel and with sufficient management representation.
- Risk assessments will be conducted whenever changes occur to the scope of work, equipment or materials used, or in the organisation of the work team.
- Risk assessments will be reviewed at specified intervals with management involvement.
- Following the risk assessment, corrective actions will be taken to ensure that hazards are appropriately evaluated and controlled to levels as low as reasonably practicable (ALARP).
- A follow-up of the risk assessment action items will be performed to ensure corrective measures are effective and sustainable.

Perdaman is responsible for the preparation of overall Project related environment reports including compiling data from monitoring programs. Perdaman will compile monitoring data and relevant environmental information on a regular basis. Reporting to external stakeholders and regulators will be in strict accordance with the Project's approval conditions. In terms of greenhouse gas emissions, this reporting will include:

- reporting obligations under the *National Greenhouse and Energy Reporting Act 2007*, to undertake monitoring and publicly disclose emissions data
- Part IV and Part V annual environmental compliance reports
- 5-yearly report on technology innovations findings/update

4 Greenhouse Gas Emissions

The key information underpinning the GHGMP (i.e. emissions estimation, benchmarking), including revisions since the publication of the ERD, is summarised in this section. This section also summarises the project design elements to minimise greenhouse gas emission that Perdaman considered, evaluated and either excluded or adopted.

4.1 Process and emissions overview

Urea is an organic compound with the chemical formula $CO(NH_2)_2$, manufactured via the reaction of ammonia (NH_3) and carbon dioxide (CO_2) at high pressure and temperature as described in ERD section 2.3.3.3 (Cardno, 2020). Perdaman will use a latest commercially available technology to maximise urea production from natural gas feedstock. Natural gas from the nearby Woodside gas plant will be used as feedstock. The stages involved in ammonia synthesis and urea production are outlined below and depicted in the block flow diagram (Figure 4-1). Support utilities include onsite power generation and an air separation plant. The principal sources of GHG emissions from the process arise from each stage of the production cycle, are summarised below:

Gas reforming: Natural gas is catalytically reformed with oxygen and steam to form 'syngas', which is purified to a hydrogen rich and CO_2 stream. Catalytic reforming occurs at a high efficiency under pressure. However, the CO_2 stream is not emitted into the atmosphere at this stage, but is used as a reagent in the urea synthesis process described below

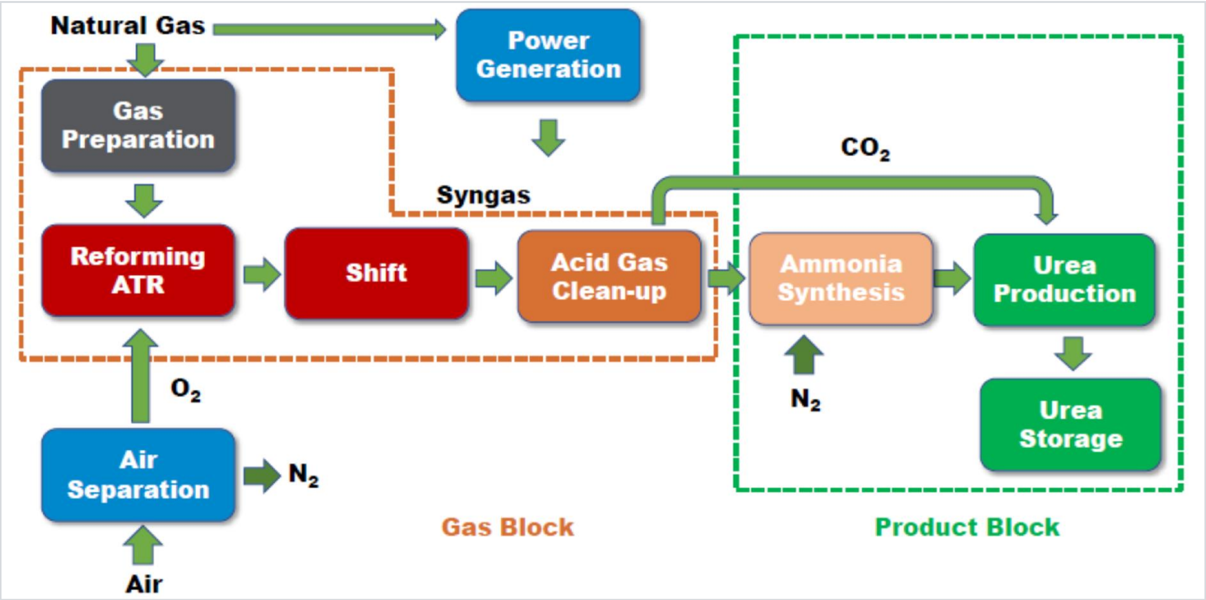
Ammonia synthesis: The hydrogen and nitrogen mixture are compressed and reacted (with help of a catalyst) to form ammonia. This chemical reaction releases heat (exothermic reaction) and is recovered as steam which improves the overall process thermal efficiency, and consequently lowers emissions. All ammonia requirements are produced at the plant.

Urea synthesis: Ammonia and CO_2 from the gas reforming stage are reacted to form urea (solution) in a two-stage process which involves an ammonium carbamate (NH_2COONH_4) intermediate. The urea solution is concentrated to over 95 per cent. Over 87 per cent of the CO_2 in the syngas is used during Urea synthesis, while the remaining portion is emitted by the Project as Scope 1. The CO_2 captured in the urea product (~1.5mpta) is not emitted by the Project but may be emitted when the urea acts as a fertiliser i.e. as Scope 3. Water is recovered and cleaned by a stripping process for internal re-use.

Urea granulation: The concentrated urea solution is dried and granulated, suitable for storage before being conveyed to Dampier Port for export to market.

Power generation: Process power requirements will be met with a high efficiency combined cycle gas turbine (CCGT) that includes cogeneration of steam, and a steam turbine for excess steam. The gas turbine will be operated on natural gas under normal conditions, and is another source of greenhouse gas emissions. The gas turbine will achieve low nitrogen oxides (NOx) emissions by using a DLN (dry-low NOx) burner. Power supply demand will be supplemented with solar power generation, there is no grid connection for third party power supply to the project.

Air separation: Air is compressed and separated into nitrogen (N_2) and oxygen (O_2) in a conventional cryogenic air separation unit.



[3]

Figure 4-1 Block flow diagram of urea production

During the preliminary design stages of the Project, a number of design features have been embedded into the project that will deliver an emission reduction compared to alterative designs options considered. The options considered and incorporated into the project design are summarised in Table 4-1. Importantly, the technologies are equivalent to leading industry practice for the specific applications and are successfully operate elsewhere in the world. The selected technology recovers much of the energy generated at various stages of the manufacturing process for reuse.

[3] Note: Figure 4-1

- Orange box Gas Block captures all processing upstream of product manufacture
- Green box Product Block captures all processing downstream before product transport to market

Table 4-1: Technology design considerations and greenhouse gas emissions

Design Selected	Alternatives Considered	GHG Benefits of Design Selected compared to Alternatives Considered
Natural gas feedstock	Coal gasification as feedstock	Gas has a lower thermal consumption rate than coal, to produce urea. The process is simpler, resulting in reduced solids handling. Lower SO_2, NOx and dust emissions. Eliminated H_2S emissions and need for additional emissions controls. Significantly less net CO_2 is produced. Reduced power consumption. Reduced waste handling.
Gas to Urea Technology • Water system – seawater cooled system	Freshwater cooled system Air cooled system	Mainly seawater cooled system minimises reliance on fresh water, desalination and power costs associated with running desalination. Condensing temperature of water is more effective compared to ambient air temperatures.
Gas to Urea Technology • Reforming process – catalytic	Conventional steam reforming	Catalytic reforming estimated to have 3% lower overall energy usage, compared to conventional steam reforming. Catalytic reforming estimated to have substantial reduction in the steam and water make-up flows. Catalytic reforming approach uses oxygen, with an air separation unit (ASU), and the autothermal reforming allows a higher carbon retention in the syngas compared to conventional ammonia plants – enabling full conversion of all ammonia produced to urea, rather than some ammonia exports, and additional equipment to increase CO_2 capture.
Gas to Urea Technology • Power generation using combined cycle gas turbine with cogeneration	Third party power supply Other than combined cycle gas turbine	Combined cycle gas turbine balances plant steam requirements and is a material efficiency improvement over a steam raising boiler and condensing steam turbine approach for plant power requirements i.e. converts excess process steam into power. Natural gas in line at start-up of the plant reduces dependence on a diesel fired mode and its higher emissions intensity.

Perdaman acknowledges that technologies and technology packages will continue to evolve. As described in Section 5 of this GHGMP, Perdaman will continue to evaluate the practicability and merits of implementing alternative technologies that reduce or avoid GHG emissions and also deliver overall performance outcomes as good as or better than described in the ERD (Cardno, 2020).

4.2 Estimation of Greenhouse Gas Emissions

4.2.1 Overview and summary

The Greenhouse Gas Assessment (ETA, 2019), included in ERD Appendix E, applied accepted methods to estimate the net greenhouse gas emissions from the Project to assess the contribution to state and national GHG emissions, and benchmark the Project's energy efficiency and GHG intensity compared to international best practice for the relevant industry sector.

The focus of the emissions at this pre-approval stage has been on the calculation of Scope 1 emissions that will be within the management control of Perdaman. During the public consultation period, feedback was received to the effect that Perdaman should estimate Scope 3 emissions. This is addressed in Section 4.2.4 of this revised GHGMP.

The components that make up the boundaries and delineation of a greenhouse gas emissions inventory spanning Scope 1, 2 and 3 emissions are summarised in the reporting protocols and guidance of the World Resources Institute Greenhouse Gas Protocol. The overlap and inter-relationship of the three Scopes is shown in Figure 4-2.

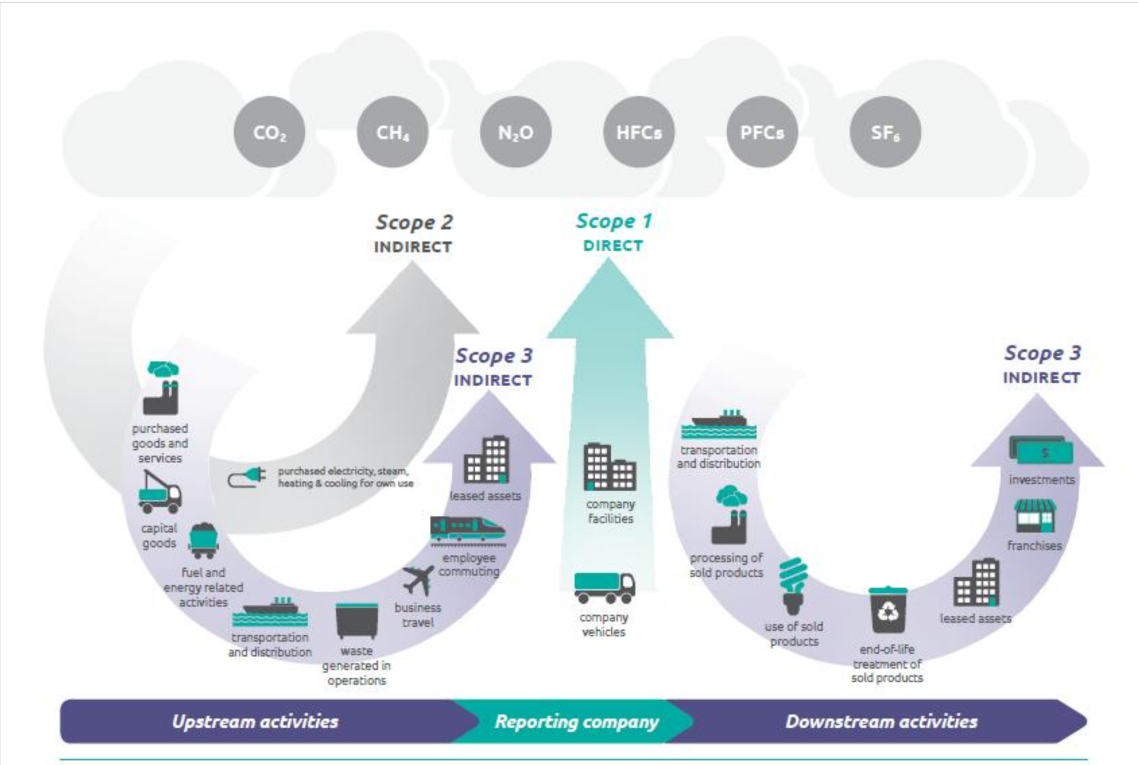


Figure 4-2: Overview of GHG Protocol Scopes and emissions across the value chain (WRI et al, 2013[4])

[4] Greenhouse Gas Protocol – Corporate Value Chain (Scope 3) Accounting and Reporting Standard – Supplement to the GHG Protocol Corporate Accounting and Reporting Standard. World Resources Institute (WRI) and World Business Council for Sustainable Development (WBCSD).

Indicative estimates of greenhouse gas emissions for key project elements have been made according to the methodology published by the International Fertiliser Society (IFS, 2019). These estimates do not capture all Scope 3 emissions, primarily because there is insufficient data and information to enable a complete and credible estimate of all Scope 3 emissions at this stage of the design process. More information about this, as well as the steps which Perdaman will take to quantify Scope 3 emissions, is set out in Section 4.2.4.

The preliminary indicative total carbon footprint for project based on estimates shown later in this GHGMP are:

- Scope 1: 0.65 Mtpa CO_2-e direct emissions from urea manufacturing operations under Perdaman's control;
- Scope 3 Upstream: 0.17 Mtpa CO_2-e associated with the supply of natural gas to the project from a 3rd party and not under Perdaman's control; and
- Scope 3 Downstream: About 1.50 Mtpa CO_2-e from the assumed release of CO_{2-e} when urea is applied in agriculture by a third party and not under Perdaman's control. For illustrative purposes only, it estimated that the transport of urea by ship to east coast Australia would be about 0.16Mtpa.

The above indicative estimate is based on regional emissions factors rather than project specific factors (see Table 4-3), where energy intensity is reduced through the applied project Best Applicable Technology (BAT) initiatives (see Table 5-2) including;

- Autothermal reforming layout to reduce steam (energy) demand,
- Maximised waste heat steam recovery systems,
- Hydraulic turbine to recover process energy in the Acid Gas Recovery (AGR) unit,
- High efficiency pump selection,
- Fuel gas containing streams are collected and reused for fired heater duty (steam raising) rather than flared and reducing additional natural gas for steam raising,
- Integrated project dedicated Combined Cycle Gas Turbines (100MW) where waste heat is recovered to raise steam, and
- Low energy reverse osmosis desalination plant.

On this basis it is important to note that Figure 4-3 (above) is a conservative estimate, and should be viewed as an indicative (over) estimation of the project's likely carbon footprint.

More information about the estimates of project GHG emissions are set out below.

4.2.2 Scope 1

Scope 1 GHG emissions are the emissions released to the atmosphere as a direct result of an activity, or a series of activities, at a facility level. In this GHGMP, this is the estimated direct emission of greenhouse gases into the atmosphere from the 80-year operating life of the Perdaman Urea Project on the Burrup Peninsula.

About 67% of Scope 1 emissions, or 0.43 Mtpa CO_{2-e}, are CO_2 formed from the combustion of natural gas for onsite power generation, process heating and steam generation. This onsite generated power is also used for the project conveyors to the Dampier Port as well as the Project ship loader at the Port.

The project also generates about 1.72 Mtpa CO_2-e of CO_2 as a by-product of gas reforming. However, 1.5Mtpa CO_2-e of this amount will be used as a reagent in the urea synthesis process, and hence will not be emitted to the atmosphere by Perdaman. An important feature of the Project design is that the production of ammonia is fully balanced to urea, so that no ammonia is produced for export as with typical plants, resulting in the consumption of CO_2 generated from gas reforming within the urea synthesis process. Consequently, only 0.22Mtpa CO_2-e will be emitted into the atmosphere from the gas reforming.

Although minor, the leakage or loss of methane (CH_4) from the gas reforming and urea synthesis process circuits is also a direct source of GHG emissions. Fugitive methane is considered around 23 tpa (mainly from the Urea Granulator stack) (SNC-Lavalin, 2019).

Total Scope 1 emissions for the Project are therefore estimated to be equal to 0.65 Mtpa CO_2-e.

As a proportion of national and state GHG emissions, the contribution of the Project is low[5], but still of significance within the context of an increasing trend in Western Australia's emissions of GHGs, and in view of the State Government's aspirational target of zero net emission increase by 2050. The comparison is shown contextually in Figure 4-3.

It is expected that once the annual urea production achieves nameplate production, then the Scope 1 emissions over the life of the project will likely remain relatively consistent year to year.

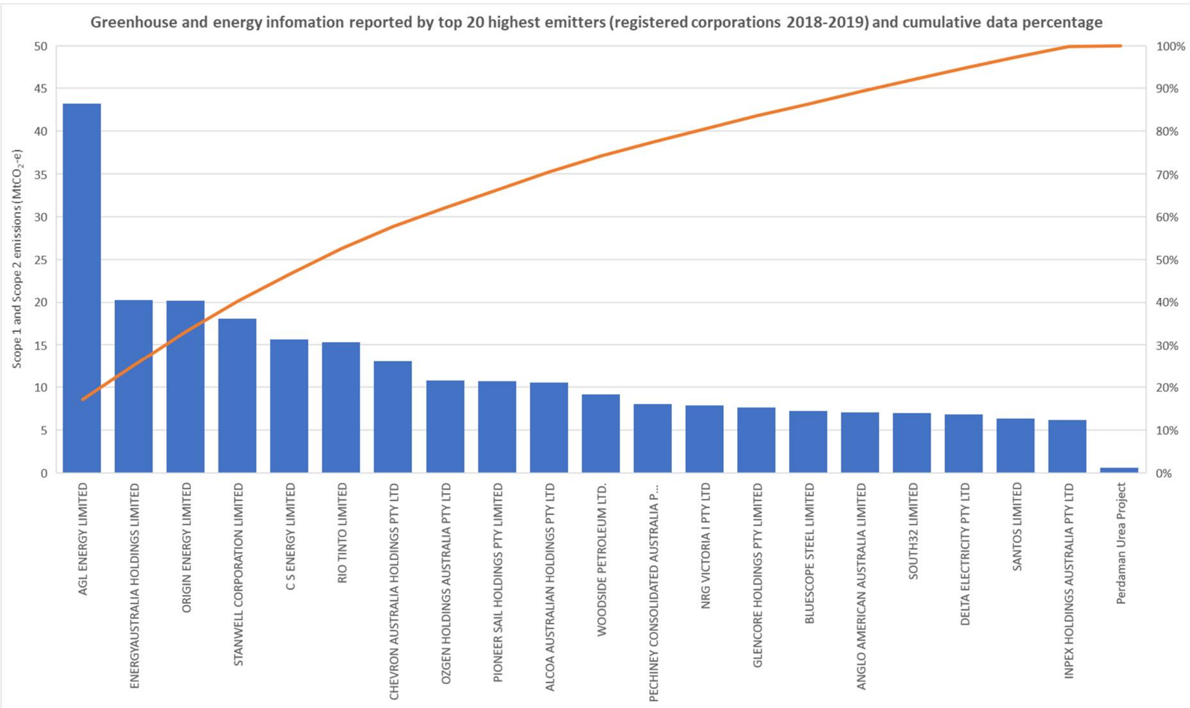


Figure 4-3: Perdaman's estimated emission in comparison to 2018-2019[6] reported emissions (highest 20 reported registered corporations, Australia)

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[5] The Quarterly Update of Australia's National Greenhouse Gas Inventory (March 2020), estimates the emissions for the industrial processes and product use" to be 34.6 Mpta CO_2-e.

[6] Data reported at 28/02/2020, published as part of the 2018-19 National Greenhouse and Energy Reporting dataset.

4.2.3 Scope 2

Scope 2 greenhouse gas emissions are indirect emissions from the generation of energy, heating, cooling or steam that is purchased and consumed at the project facility, but is not generated at the facility. There are no Scope 2 emissions associated with the project, as energy is generated onsite, and emissions associated with onsite energy generation is accounted for as a Scope 1 emission (see Section 4.2.2 above).

4.2.4 Scope 3

This section explains the limits on presenting a complete and credible estimate of Scope 3 emissions at the present time, and Perdaman's commitments to prepare a Scope 3 emissions inventory once its supply chains have matured. Following this discussion, the preliminary estimates of Upstream Scope 3 emissions from natural gas supply and the Downstream Scope 3 emissions from the transportation of urea and the use of urea in agriculture.

4.2.4.1 Limits on presenting complete and credible Scope 3 estimates

Scope 3 emissions are all the indirect GHG emissions, other than Scope 2 emissions, that are generated in the wider community (i.e., not at the project facility) across the Perdaman value chain. In this context, Scope 3 emissions occur as a consequence of activities upstream and downstream of urea production. Unlike Scope 1 and Scope 2, the Scope 3 emissions are not reported under the NGER Act.

EPA, 2020 does mandate or recommend protocols to be used in estimating Scope 3 emissions, so reference has been made to the protocols and emission estimation set out by the international protocols (WRI, 2013). Either the GHG Protocol Scope 3 Standard or the GHG Protocol Product Standard could potentially be used to estimate Scope 3 emissions for the project, and could result in one of the following two methods being used

- project level quantification – development of a GHG inventory based on upstream and downstream emissions; or
- product level quantification – development of a GHG emissions inventory for the entire life cycle impacts of the urea product manufactured, from raw material extraction to product disposal.

Figure 4-4 shows the relationship between a Scope 3 GHG emission inventory, and a product GHG emission inventory as it would be applicable to the Perdaman Urea Project and the production of the urea fertiliser for the export market.

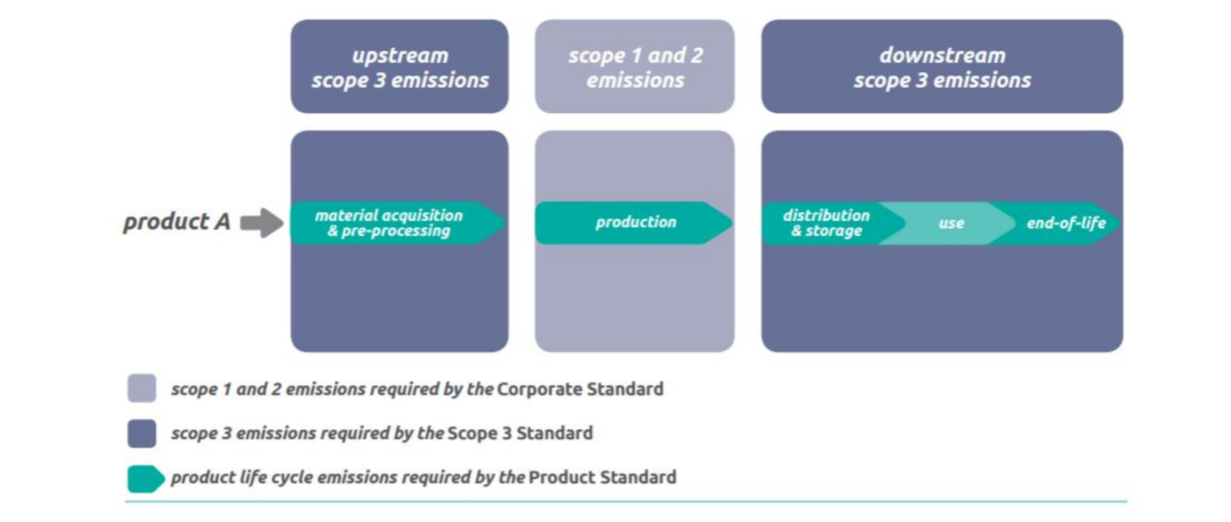


Figure 4-4: Relationship between a possible Scope 3 GHG emission inventory for the Perdaman Urea Project, and a product GHG emission inventory for Urea produced by Perdaman

The GHG Protocol Scope 3 Standard and GHG Protocol Product Standard both take a value chain or life cycle approach to GHG accounting. The Scope 3 Standard accounts for value chain emissions at the corporate level, and the Product Standard accounts for life cycle emissions at the individual product level.

These standards are designed to account for the emissions generated during the reporting period (usually a period of one year), and covers the six main greenhouse gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF_6). The standards do not address the quantification of avoided emissions or GHG reductions from actions taken to compensate for or offset emissions, noting these types of reductions are addressed by the GHG Protocol for Project Accounting.

Based on the WRI (2013), there are 15 categories of Scope 3 areas that would require investigation. The categories are summarised in Table 4-2. The 15 distinct reporting categories are intended to cover all indirect emissions that occur along a company's value chain, and are intended to provide a systematic framework to measure, manage and reduce emissions across the corporate value chain. The categories are designed to be mutually exclusive to avoid double counting emissions among categories.

The upstream and downstream supply chains for the Perdaman's project is still being developed and will continue to evolve during the project's detailed design phase. Accordingly, and as illustrated in Table 4-2, there is presently insufficient data or information to prepare a complete and credible estimate of Scope 3 emissions associated with the project.

Perdaman acknowledges the importance of understanding and reliably quantifying Scope 3 emissions, and appreciates the community interest in this issue. However, any attempt to quantify Scope 3 emissions now would rely on multiple assumptions and speculations about potential supply chains that are not yet sufficiently mature in their planning to be considered a likely or representative description. Perdaman considers that presenting such information prematurely is inappropriate, and in due course may be perceived as misleading rather than being a product of early supply chain assumptions.

In the interim, Table 4-2 provides an overview of the likely extent of the inventory to be developed. The upstream emissions are indirect greenhouse emissions related to Perdaman's purchased or acquired goods and services. The downstream emissions are the indirect greenhouse emission related to Perdaman's sale of urea, which would extend to the agricultural use of the urea in crop production carried out by third parties.

In reviewing these categories, it is anticipated that the majority of Scope 3 emissions would likely be attributable to following three categories:

- third party supplied fuel and energy;
- downstream transportation and distribution of product; and
- the use of urea products by third parties in agriculture, assuming that the project operates at its full nameplate capacity for its 80 year life. The estimate of Scope 3 emissions in Table 4-2 assume that all of the 1.5Mt of purified CO_2 from the reforming process that is used in the manufacture of and included in the urea product is released as part of the uptake of nitrogen from the fertiliser usage.

It is important to note that Scope 3 emissions from two of these three significant sources have been estimated and presented in Table 4-2. The estimate of emissions from the use of urea products in agriculture is considered to be the largest source of Scope 3 emissions associated with the Project

While transport emissions at present are impossible to meaningfully estimate as the markets and customers for the product are yet to be resolved, for illustrative purposes assuming all Perdaman production substitutes for Australia's current imported urea demand, an estimate of Scope 3 emissions has been included in Table 4-2.

As urea is assumed to be applied as fertiliser with total release of any entrained CO_2, this is considered to be the "end of product life." Consequently, Scope 3 emissions related to Category 10 - downstream processing of sold products and Category 12 - end of life treatment of sold products, are both assumed not to arise and are therefore reasonably estimated as Nil (Table 4-2).

Table 4-2: The likely calculation boundaries for Scope 3 emissions for Perdaman Urea Project

	Scope 3 category	Relevance to Perdaman Urea Project	Emission Estimate (CO_{2-e})
Scope 3 Upstream Emission Category	1. Purchased goods and services	Extraction, production, and transportation of goods and services expected to be purchased or acquired by Perdaman in the reporting year – Supply chain still to be resolved, so all upstream (cradle to grave) emissions of likely purchased goods and services cannot be reliably estimated at this time.	Not estimated - Reasonable/credible estimate not possible at this time as these supply chain matters are not yet finalised, and to attempt an estimate would be speculative
	2. Capital goods	Extraction, production, and transportation of capital goods purchased or acquired by Perdaman in the reporting year – Detailed design for capital goods is pending finalisation so all upstream (cradle to grave) emissions of likely capital goods cannot be reliably estimated at this time.	Not estimated - Reasonable/credible estimate not possible at this time these capital goods matters are not yet finalised, and to attempt an estimate would be speculative
	3. Fuel and energy-related activities (not included in Scope 1 or Scope 2)	Natural gas supply to Project, relevant to Perdaman. Note that this is expected to be supplied from the Scarborough gas field development, which is a low CO_2 field (SNV-Lavalin, 2019). The estimate of Scope 3 emissions in this category is therefore considered conservative. If the Scarborough project was required to avoid, reduce and offset its Scope 1 emissions, this would also progressively reduce the Scope 3 emissions associated with the supply of energy from Scarborough to the project.	0.17 Mtpa - see 4.2.4.3 below and based on generic industry emission factors
	4. Upstream transportation and distribution	Supply chain still to be resolved – The Scope 1 and Scope 2 emissions of transportation and distribution providers that occur during use of vehicles and facilities (e.g. from energy use) cannot be reliably estimated at this time.	Not estimated - Reasonable/credible estimate not possible at this time as these supply chain matters are not yet finalised, and to attempt an estimate would be speculative
	5. Waste generated in operations	Waste services contracts are not resolved. The Scope 1 and Scope 2 emissions of waste management suppliers that would occur during disposal or treatment of Perdaman generated	Not estimated - Reasonable/credible estimate not possible at this time as waste

	Scope 3 category	Relevance to Perdaman Urea Project	Emission Estimate (CO_{2-e})
		waste cannot be reliably determined at this time.	service matters are not yet finalised, and to attempt an estimate would be speculative
	6. Business Travel	Transportation of employees for business-related activities during the reporting year (in vehicles not owned or operated by Perdaman) may be relevant in future however transportation carriers are to be confirmed. This estimate cannot be reliably determined until post detailed design.	Not estimated - Reasonable/credible estimate not possible at this time as business transport matters could only be calculated on the basis of speculation
	7. Employee commuting	Transportation of employees between their homes and their worksites during the reporting year cannot be reliably determined at this point in time. Perdaman is firmly committed to develop a non-FIFO operational workforce of about 150 full time employees. Contributing to GHG avoidance for this category, the Project will offer its operational employees a home during the life of the Project and intends to develop a residential housing village and associated services to cater for 150 homes within the Karratha region. The Project expects to develop a joint venture with MAC in developing homes for its employees. Perdaman is committed to employing and training local indigenous people, and the focus will be predominantly on local hires, with no FIFO during operations.	Not estimated - Reasonable/credible estimate not possible at this time – see comment re contribution to avoidance.
	8. Upstream leased assets	Operation of assets leased by the Perdaman in the reporting year is not possible pending completion of detailed design and project procurement options being finalised.	Not estimated - Reasonable/credible estimate not possible at this time, as Perdaman does not yet know what assets it will lease, if any.
Scope 3 Downstream Emission Category	9. Downstream transportation and distribution	Distribution and marketing still to be negotiated and resolved. Conveyor transfer of urea product from production facility to port for storage prior to export via shipping, approximately 2 ships (Panamax) per week anticipated, and ship loader are powered by the Project CCGT power station	Reliable estimate not possible until there is greater clarity about destination markets. For example, there would likely be a big difference between

	Scope 3 category	Relevance to Perdaman Urea Project	Emission Estimate (CO_{2-e})
		and thus is part of the Scope 1 estimates. Markets for the urea product may include east coast Australia, overseas markets, or a combination of both. At this stage however, it is assumed that the primary market for the urea product will be overseas.	Scope 3 emissions for shipping urea product to east coast Australia compared to markets in China or the Middle East. For illustrative purposes, assuming 100% product sales as import substitution to the Australian market, it is estimated that Scope 3 emissions would be about 0.16 Mpta see Section 4.2.4.4 below.
	10. Processing of sold products	Not relevant as urea sold by Perdaman will be in final product form. Additional CO_2 capture through enhanced biomass production as a result of biological processing of the applied urea fertiliser is highlighted in Section 4.2.4.4 below.	Nil to negative.
	11. Use of sold products	Urea is the final product sold to market, for use in agriculture. The estimate needs to extend to cover the end use of Urea sold by Perdaman in the reporting year. Sales targets can be estimated in lead up to commissioning, but at this stage for estimation purposes it is assumed that all CO_2 entrained in the urea is released to the atmosphere when used in agriculture.	1.5 Mtpa - see 4.2.4.4 below
	12. End of life treatment of sold products	Not relevant to urea product, as covered by Category 11 when urea acts as a fertiliser is end of product life.	Nil
	13. Downstream leased assets	Operation of assets leased by Perdaman and leased to others in the reporting year pending completion of detailed design cannot be reliably determined at this point in time.	Not estimated - Reasonable/credible estimate not possible at this time, as there is no information about what downstream assets will be leased by Perdaman, if any.

	Scope 3 category	Relevance to Perdaman Urea Project	Emission Estimate (CO_{2-e})
	14. Franchises	It can be noted that Perdaman's currently envisaged Project business model does not anticipate franchise arrangements being entered into as part of the value chain for the urea product manufactured by the Project.	No franchises are contemplated – Nil.
	15. Investments	Operation of investments (including equity and debt investments and project finance) cannot be reliably determined at this point in time.	Not estimated - Reasonable/credible estimate not possible at this time, as the financing model for the project has not been determined.
	TOTAL	Preliminary estimate based on reliable, quantifiable information available at this time	1.83 Mtpa.

Note:
Based on Table 5.4 of the Scope 3 Standard (WRI, 2013)

4.2.4.2 Commitments to develop a Scope 3 emissions inventory

Prior to commissioning of the project, Perdaman will screen and estimate Scope 3 emissions in each of the 15 categories outlined in Table 4-2. The screening would be based on generic or preliminary information that would enable a more reliable estimate of Scope 3 emissions than is presently possible. Through this screening process, each category would be examined to determine whether to further refine the emission estimates on an ongoing basis.

As part of this screening exercise, Perdaman commits to prioritising the estimation of Category 11 – Direct use-phase emission (i.e. GHG and products that contain or form GHG that are emitted during use, and is relevant to fertilizer use), as soon as reasonably practicable. This is currently considered the highest priority because this category likely represents by far the largest amount of potential Scope 3 greenhouse gas emissions associated with the project. The updated estimates will be based on projected market distribution of urea product. Calculating emissions from Category 11 typically requires product design specifications and assumptions about how consumers use products (e.g. use profiles, assumed product lifetimes).

Following the commencement of operations, Perdaman commits to update the Scope 3 emissions inventory and include the inventory in its first post-operational annual report. Perdaman will also liaise with Murujuga Aboriginal Corporation (MAC) during the development and mapping out of the detailed Scope 3 emission inventory.

4.2.4.3 Upstream Fuel and Energy

The estimate of Category 3 Scope 3 emissions from the supply of fuel and energy for the project is based on data collected under the NGER Act covering the period 1 July 2008 to 30 June 2009. The estimate includes natural gas exploration, production or processing, transmission and distribution (4.0 kgCO_2-e/GJ) (DoISER, 2020), As shown in Figure 4-3 above, this equates to 0.17 Mtpa CO_2-e for this source based on 130TJ/d gas usage, as indicated in ERD Table ES2, operating for 320d/a.

While the above estimate is based on generic industry wide emissions factors, as the gas supply for the Project is based on Perdaman being a foundation domestic gas customer for the Scarborough field development, the estimate based on these emission factors is considered a conservative indicative quantity. Gas from the Scarborough field is recognised as very low CO_2, with typically 50ppm CO_2 compared to the 3% mol CO_2 reflected in the current allowable maximum inert gas levels in the Dampier Bunbury Natural Gas Pipeline (SNC-Lavalin, 2019) which would be used to transport gas from Woodside to Perdaman. Thus the generic emission factors used are demonstrably conservative for the Project but have been used at this time due to the lack of any more precise applicable or credible factors.

4.2.4.4 Transportation, Distribution and Use of Sold Product

It is recognised that the production, distribution and use of fertilisers generally (and urea specifically) contribute directly and indirectly to emissions of GHGs. At the same time, fertilisers help increase agricultural productivity, reducing GHG emissions per unit of agricultural output. Enhanced yields are particularly important in helping to prevent deforestation, which is the most important contribution of GHGs related to agriculture on a global scale (IFIA, 2009).

The life-cycle assessment of GHG emissions associated with urea needs to weigh emissions against the energy and carbon capture that fertiliser use promotes. When fertilisers are used properly, they assist plants to produce more energy than is consumed during the production, transport and application of fertilisers. They also encourage the conversion of CO_2 in biomass through photosynthesis, although the length of time during which the carbon is bound will depend on whether the biomass is used immediately, ploughed into the soil, part of a perennial plant or used for bioenergy/biomaterials (IFIA, 2009).

This opportunity for reduced GHG emissions through downstream urea product use is relatively unique for petrochemical and gas products, as most such products result in additional carbon emissions in their processing and use (SNC-Lavalin, 2019).

Table 4.2 estimates the Category 11 emissions from the use of urea in agriculture by assuming that all of the 1.5Mt of purified CO_2 from the reforming process that is used in the manufacture of and inclusion in the urea product is released as part of the uptake of nitrogen from the fertiliser usage.

It should be noted that this illustrative estimate of Scope 3 emissions takes no account of the following consideration which, in future when the project is operational, can be reasonably expected to modify or moderate the ultimate fate and impact of the CO_2 within the urea product:

- The primary purpose of fertiliser application is to enhance the growth of biomass that through photosynthesis uses CO_2, including potentially part of the CO_2 released from the urea.
- As application of urea enhances productivity of pasture crops intended to feed people, this increased productivity may reduce the need for land clearing that would otherwise be undertaken to feed the equivalent number of people, therefore offsetting the loss of sequestration that additional land clearing would potentially lead to.
- While the most likely application of urea is to enhance biomass generation in perennial crops, which is not regarded as a permanent sequestration, where crop stubble is ploughed back in, a significant portion of the CO_2 captured in the enhanced biomass is captured in the soil (Lal, 2010).
- As an alternative to enhanced soil capture by ploughing back in, the biomass may potentially be used as an alternative energy source reducing the reliance on alternative fossil fuels. This could extend to the potential

for the biomass to be used as an input to biodiesel or a similar fuel, or in processes such as Alphakat™ technology (refer to https://alphakatholdings.com/).

The GHG benchmarking study (SNC-Lavalin, 2019) was described in the ERD (Cardno, 2020). This report discusses in detail the GHG remissions related to distribution to Australian markets and the positive GHG ramifications this has due to import substitution

Category 9 relates to the Downstream transportation and distribution of the sold product. The typical urea import to Australia has been 1.9-2.3 Mtpa in recent years, which is an average of approximately 2.04Mtpa i.e. equivalent of Perdaman production (SNC-Lavalin, 2019).

The imports are taken to main ports across Australia including Melbourne, Sydney, Newcastle, Adelaide and Perth (SNC-Lavalin, 2019). Using the shipping GHG emissions factor from SNC-Lavalin Table 7-2 for Perdaman Urea supplied to Australian markets, ie 0.08 t $CO_{2\text{-}e}$/t urea (SNC-Lavalin, 2019), Scope 3 category 9 emissions related to Transport and distribution of sold urea product to east coast Australian markets is estimated to be 0.16 Mtpa $CO_{2\text{-}e}$. For comparison, this is lower than the 0.41 Mtpa $CO_{2\text{-}e}$ if the Australian market is supplied from alternative international sources and the Perdaman product is sold to international market. As:

- the import supply locations are not expected to be the same as potential overseas markets if Perdaman product is exported; and
- indicative potential export markets are not yet identified at this point in the projects development cycle.

No illustrative estimate of the Scope 3 down stream transportation and distribution are included at this time for this potential scenario, but indicatively may potentially be expected to be of a similar order of magnitude

4.2.4.5 Scope 3 Life-cycle assessment summary

Because of the limitations and uncertainties outlined (above), it is not possible to reliably estimate all of the Scope 3 emissions associated with the Project at this point in time. However, estimates of three largest sources of Scope 3 emissions have been calculated to derive the estimate of 1.83 Mtpa $CO_{2\text{-}e}$. Where usual Scope 3 categories are currently not expected to be applicable given the nature of the Project or the urea product, for additional clarity, it is reasonable to include "Nil" estimates as shown also (Table 4-2). Furthermore, the estimate of Scope 3 emissions from the end-use of the urea product (1.5 Mtpa $CO_{2\text{-}e}$) is very conservative and is currently understood to represent by far the highest source of estimated Scope 3 emissions associated with the Project.

Nevertheless, the Scope 3 estimates illustrate the type of considerations that will be relevant when undertaking future estimations when the Project is being commissioned and operating for 12 months.

4.3 Greenhouse Gas Emissions Benchmarking – Updated

The GHG benchmarking study (SNC-Lavalin, 2019) was described in the ERD (Cardno, 2020). It was completed using a tiered approach, through comparison of feedstock, international performance benchmarks, Australian ammonia production and approved Western Australian projects. Energy efficiency and GHG emission considerations have been taken into account iteratively throughout the project design stages to date, recognising that the most significant opportunities to avoid and reduce emissions is associated with technology selection and choice of feedstock material for the production of urea.

The integrated design of the Perdaman urea project has meant that there is a lack of publicly available GHG emissions data for similar or directly comparable plants operating either locally or globally. A subsequent literature review in response to the public comment period for the ERD indicates there to be little change in the availability of published material for comparison. This has restricted the extent of the benchmark analysis of the emissions intensity of the Project. Therefore, the application of the tiered approach continues to support a reasonable benchmark comparison.

In addition, it is important to note the study for the Inter-America Development Bank (2013). This independent study found the estimated GHG emission of urea production plant could range from 300 to 400 CO_2-e per year. As the urea production process consumes carbon, it was noted that emission reduction potential from these types of facilities is small (Suding, 2013). This must be understood in the context of identifying reasonable and practicable measures to mitigate emissions from within the Perdaman Urea Project itself.

It is also important to note that the most recent benchmarking study undertaken by the International Fertilizer Industry Association (IFIA) found that modern plants are rapidly approaching the theoretical minimum energy consumption (thermodynamic limit) for ammonia production of 20 GJ/Mt of NH_3 (IFIA, 2009). This must be understood in the context of identifying reasonable and practicable measures to mitigate emissions from within the Perdaman Urea Project itself.

The GHG intensity of the Project has been assessed

- for the ammonia sub-plant alone, as if it were not integrated and exporting ammonia as a product, based on ammonia production (t CO_2-e/t of NH_3),
- as well as for the Project as an integrated whole based on urea production (CO_2-e/t of urea).

This approach has been adopted so the GHG intensity of the project can be compared to a more conventional urea plant that also manufactures and sells ammonia product.

The GHG intensity estimated for ammonia production is based on Scope 1 GHG emissions - ie, it is calculated on the basis that CO_2 from gas reforming is used in the urea production process rather than emitted to atmosphere. Similarly, the energy efficiency of the Project has been assessed based on ammonia production alone, as well as for the Project as a whole based on urea production. The estimated energy efficiency and GHG intensity of the Project are presented in Table 4-3.

Table 4-3: Estimated Project energy efficiency and GHG intensity (Cardno, 2020)

Parameter	Units	Ammonia Plant (alone)	Urea Project (1)
Production	Tpa	1,157,310 (ammonia)	2,046,000 (urea)
Energy (2)	GJ_{LHV}/y	30,887,969	39,599,960
Energy efficiency	GJ_{LHV}/t NH_3 or urea	26.7	19.4
GHG emissions (3)	Mtpa CO_2-e	0.51	0.65
GHG intensity	tCO_2-e/t NH_3 or urea	0.44	0.32

(1) Refers to Project as a whole (includes ammonia and urea synthesis).
(2) Natural gas consumption present on LHV basis. LHV:HHV ratio of 0.945 applied (*Pers comm* J De Boer (SNC-Lavalin), 11 September 2019).
(3) Stationary energy demands of the Project apportioned as 78% required for ammonia synthesis and 22% for urea synthesis (*Pers comm* J De Boer (SNC-Lavalin), 11 September 2019).

4.3.1 Feedstock

The type of feedstock used in ammonia (and urea) production plays a significant role in the amount of energy that is consumed and GHG emissions produced. The type of process technology used for gas reforming is another key factor. The selection of natural gas as feedstock for the Project is considered the most energy efficient and least GHG intensive option. Approximately 70% of all ammonia is produced from natural gas, about 25% from coal and petroleum coke (mainly in China), and the remaining plants from other sources such as naphtha or fuel oil (mainly in India) (SNC-Lavalin, 2019).

Data published by the International Fertiliser Industry Association (IFIA) (2009) indicates that the energy requirement in coal-based ammonia production plants is significantly higher, producing some 2.4 times more CO_2 per tonne of ammonia than natural gas plants. Therefore, the selection of natural gas as feedstock for the Project is considered the most energy efficient and least GHG intensive option.

4.3.2 International performance benchmarks

The Fertilisers Europe, formerly the European Fertiliser Manufacturers Association (EFMA), publication series on Best Available Techniques (BAT) in the European fertiliser industry (Fertilisers Europe, 2000) is adopted as the relevant international environmental performance benchmark for ammonia production (Table 4-4), used to evaluate the energy efficiency of the Project in terms of world's best practice. The energy efficiency benchmark for ammonia production (28.4 GJ_{LHV}/t NH_3) is comparable to theoretical design efficiencies and the optimum efficiency level for new plant of approximately 28-29 GJ_{LHV}/t NH_3 (IFIA, 2009).

Comparison of the Project metric to this international performance benchmark demonstrates that the Project meets international best practice for energy efficiency in ammonia production.

Table 4-4: International performance benchmark (Cardno, 2020)

Parameter	Product	Units	Benchmark (1)	Project
Energy efficiency (2)	Ammonia	GJ_{LHV}/t NH_3	28.4 (3)	26.7

Notes:

(1) Sourced from Fertilisers Europe (2000).
(2) Natural gas consumption reported on Lower Heating Value (LHV) basis.
(3) Sum of 24.8 GJ_{LHV}/t NH_3 (typical feedstock requirement for modern plants using autothermal reforming) and 3.6 GJ_{LHV}/t NH_3 (low end range given for fuel requirements for autothermal reforming).

The International Fertiliser Industry Association (IFIA) periodically conducts an industry-wide benchmarking survey that is used to estimate energy efficiency in the ammonia sector. The most recent survey conducted in 2008 included participation by 93 plants located in 33 countries, representing approximately one quarter (40 million tonnes) of total world ammonia production (IFIA, 2009). This benchmarking survey found that the Best Practice Technology (BPT) energy requirement for the top ten percentile natural gas-based ammonia production facilities is 32 GJ per tonne of NH_3 (net energy consumption). The top quartile performed in the range of 28 to 33 32 GJ per tonne of NH_3. Comparison of the Project metric to these more recent international benchmarking survey results demonstrates that the Project meets international best practice for energy efficiency in ammonia production.

The energy demands of urea production are small compared to those of ammonia production and no efficiency benchmark is provided in the relevant the EFMA BAT publication series for urea production (Fertilisers Europe, 2000a).

An evaluation of the energy consumption in the production of urea, using life cycle energy consumption analysis, was reported on by Shi *et al* (2020). The study assessed a “cradle-to-grave” or “gate-to-gate” evaluation of the environmental costs associated with urea production in China. Notably, China is the world’s largest producer and consumer of urea, producing 61.9 million tons of urea and consuming over 55% of total urea produced along with the Southwest Asian region in 2016 (Shi *et al*, 2020). The lifecycle analysis (LCA) approach provides a holistic view of environmental interactions that covers a range of activities from the extraction of raw materials to the production and distribution of energy, through the use, reuse, and final disposal of the product.

The study by Shi et al (2020) found that the average life cycle of energy consumption (LCEC) is about 30.1 GJ/t urea, based on an evaluation of seven operating urea plants. The energy consumption of the materials preparation stage, synthesis stage, and waste-treatment stage is about 0.388 GJ/t urea, 24.8 GJ/t urea, and 4.92 GJ/t urea, accounting for 1.3%, 82.4%, and 16.3% of LCEC, respectively (Shi *et al*, 2020). Notably the analysis was based on coal consumption, as is the norm in China where this most recent study was based. The Perdaman project excludes coal, replacing the feedstock with natural gas, and as such can be considered a higher performing benchmark than these international operations. The energy efficiency metric for the Project as a whole (incudes ammonia and urea synthesis) is 19.4 GJ_{LHV}/ t of urea, which is a significant improvement in comparison.

4.3.3 Australian ammonia production

The latest available data published in the Australian National Greenhouse Accounts (Department of the Environment and Energy, 2019) provides production and emissions information from the manufacture of ammonia in Australia reported from 2009 onwards under the NGER Act. This data has been used to derive an average GHG intensity for ammonia production in Australia over this time period (Figure 4-23).

The GHG intensity of the Project is a significant improvement on the national average for ammonia production in Australia and will further enhance the reduction in the national average GHG intensity that can be seen in the longer-term trend.

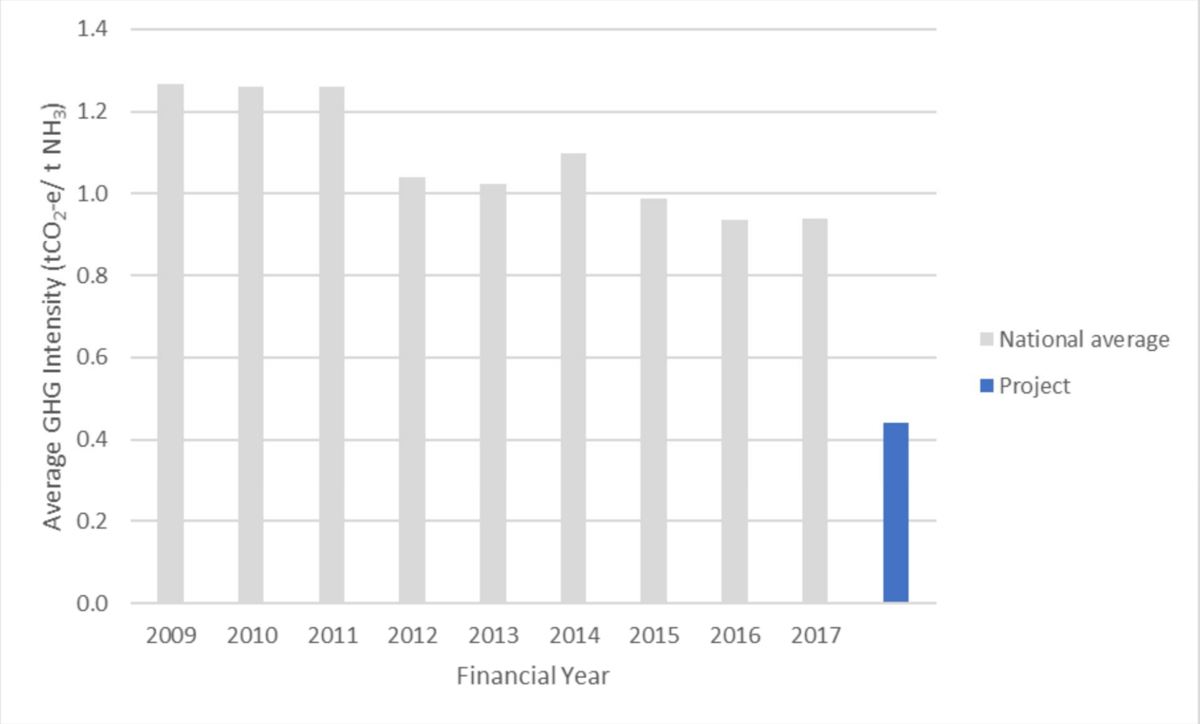


Figure 4-5: National average GHG intensity for ammonia production (Cardno, 2020)

4.3.4 Approved Western Australian projects

The GHG intensity of the Project has been compared to other comparative ammonia and urea projects in Western Australia that have been granted environmental regulatory approval, summarised in Table 4-4.

The enhanced energy efficiency of the Project is indicated by the lower energy requirement estimated for the Project compared to other projects that have been approved in Western Australia, when considered both on an ammonia production basis and on a urea production basis. Furthermore, there is a more significant improvement in GHG intensity for the Project compared to the Dampier Nitrogen project, also an ammonia urea plant and hence most suitable for comparison, attributable to the increased net reduction (offset) of CO_2 emissions in the urea synthesis process from 'balanced' ammonia to urea production.

Table 4-5: Comparison to approved Western Australia projects (Cardno, 2020)

Project	Proponent	Location	Products	Energy efficiency	GHG Intensity	Reference
Ammonia-Urea Plant	Dampier Nitrogen Pty Ltd (1)	Burrup Peninsula	Ammonia urea	29.3 GJ_{LHV}/t NH_3 26.6 GJ_{LHV}/t urea (2)	0.67 t CO_2-e/t urea (2)	EPA (2002)
Ammonia Plant	Yara Pilbara Fertilisers Pty Ltd (3)	Burrup Peninsula	Ammonia	29.7 – 29.9 GJ_{LHV}/t NH_3	-	EPA (2001)
Kwinana Ammonia Project	Wesfarmers CSBP Ltd	Kwinana	Ammonia	33 – 35 GJ_{LHV}/t NH_3	-	EPA (1998)

Project	Proponent	Location	Products	Energy efficiency	GHG Intensity	Reference
Perdaman	Perdaman	Burrup Peninsula	Ammonia urea	26.7 GJ_{LHV}/t NH_3 19.4 GJ_{LHV}/t urea (2)	0.32 t CO_2-e/t urea	Cardno (2020)

Notes:

(1) Formerly known as Plenty River Corporation Ltd.
(2) Calculated from available information. Urea Plant 3,500 tpd nominal capacity. Natural gas 93 TJ/day (max). estimated total CO_2-e emissions 841,055 tpa.
(3) Formerly known as Burrup Fertilises Pty Ltd.

The benchmarking of GHG emissions from the Project demonstrates the following:

- Selection of natural gas as feedstock for the Project is considered the most energy efficient and least GHG intensive option of the alternative feedstocks (e.g. coal based) used for ammonia production.
- The Project meets the international best practice benchmark established by the EFMA (2000) for energy efficiency in ammonia production.
- The GHG intensity of the Project is a significant improvement on the national average for ammonia production in Australia and will further enhance the reduction in the national average GHG intensity that can be seen in the longer-term trends in data published in the Australian National Greenhouse Accounts.
- The enhanced energy efficiency of the Project is indicated by the lower energy requirement estimated for the Project compared to other projects that have been approved in Western Australia.

5 Environmental Management Measures

5.1 Overview

This section describes the management-based measures that, when implemented, are intended to achieve the environmental objective of minimising GHG emissions from the project over its operating lifetime. The management measures have been developed in alignment with the EPA guidelines (EPA, 2020).

The GHG mitigation and management framework for the Project has been developed in accordance with the mitigation hierarchy (avoid, reduced, offset):

- avoiding emissions through best practice design and benchmarking
- continuous improvement to reduce emissions over the project life
- offsetting emissions.

The opportunities to avoid, reduce and offset Scope 1 greenhouse gas emissions from the project will be reviewed every five years. Based on the outcomes of those five-yearly reviews, and by using a combination of the above three mechanisms in accordance with this GHGMP, the project will achieve a net 20% reduction of the initial forecast Scope 1 emissions at 5 yearly intervals from practical completion (assumed from 2025) to achieve zero net Scope 1 GHG emissions by 2050.

5.2 Best practice design

In designing the project, Perdaman considered a suite of alternatives designs and abatement measure options. Those that were considered, but determined to be unsuitable and therefore not taken are summarised in Table 5-2:

Table 5-1: Considered reduction options excluded from design

Option considered	Basis for exclusion
Solar power	The output from a solar source is electricity only, with no capability to deliver the project steam requirements for reforming. An additional or larger fired heater would be required (increase in fuel combustion and CO_2 emission). There is no currently available "off the shelf" 3rd party source with available capacity to deliver 100MW solar power. Would require additional necessary planning, development and financial approval to meet project timeframes. As a conceptual greenfields potential initiative, Horizon's suggestion [7]has no guarantee of being able to provide the suggested alternative within a feasible time frame that aligns with the Proponent's requirements. CCGTGs where exhaust heat is recovered to provide essential process steam as well as supplemental steam turbine generation, to enhance the process energy efficiency

[7] "Horizon's suggestion" refers to the ERD submission by Horizon Power to substitute solar generation for the Project's proposed CCGT power generation.

Option considered	Basis for exclusion
	in line with the application of BAT. Supplementary solar generation also being pursued.
Hydrogen produced by electrolysis	Technology is currently unproven and uncommercial, therefore excluded. Noted that may become a potential option in the long term, so developments will be tracked in the 5-year reviews.
Conventional reformer	Conventional reforming requires large land area, more site disturbance than autothermal reform (ATR). ATR is more efficient. Conventional reform was considered but not implemented.

Design features incorporated into the Project design to improve energy efficiency and produce lower GHG emissions are summarised in Table 5-3, noting that this is not an extensive list and does not exclude the possibility of further improvements during the detailed design of the project.

Table 5-2: Considered reduction options included in the design

Area considered	Design feature included
Process Input	Switch from coal-based urea production approved for Collie location to natural gas Reduces Scope 1 GHG from 1.8Mtpa for Coal-based Collie urea production to 0.65Mtpa Burrup natural gas-based urea production.
Process energy demands	Autothermal reforming layout to reduce steam demand
	Maximised waste heat steam recovery systems
	Hydraulic turbine to recover process energy in the Acid Gas Recovery (AGR) unit
	High efficiency pump selection
	Fuel gas containing streams are collected and reused for fired heater duty
Water supply	Low energy reverse osmosis desalination plant
On-site power generation	Modern combined cycle power plant with cogeneration mode for start-up using BAT ca. 0.45t CO2/MWh compared to open cycle gas turbine 0.7t/MWh (ERD Section 4.8.4.2) Compared to 0.87t/MWh for approved Collie Coal-based urea plant.
Process cooling	Water cooling rather than air cooling to achieve a better condensing approach temperature and greater stability during hot days
Once-through sea water cooling system	Fresh water-cooling system required a greater input of power, natural gas than a once-through sea water cooling system. Fresh

Area considered	Design feature included
	water-cooling system was not pursued further in favour of the more GHG effective once-through sea water cooling system .
Waste gas flare	No continuous flare purging required

5.3 Continuous improvement and applying the Mitigation Hierarchy

5.3.1 Net Scope 1 reduction targets

The Project commits to achieving the Scope 1 emission reduction targets in Table 5-4, in accordance with (and subject to) the procedures and guidelines set out in Sections 5.3.2 - 5.3.4 below:

Table 5-4 – Committed reductions in Net Scope 1 emissions (Annual and each 5 year period Total)

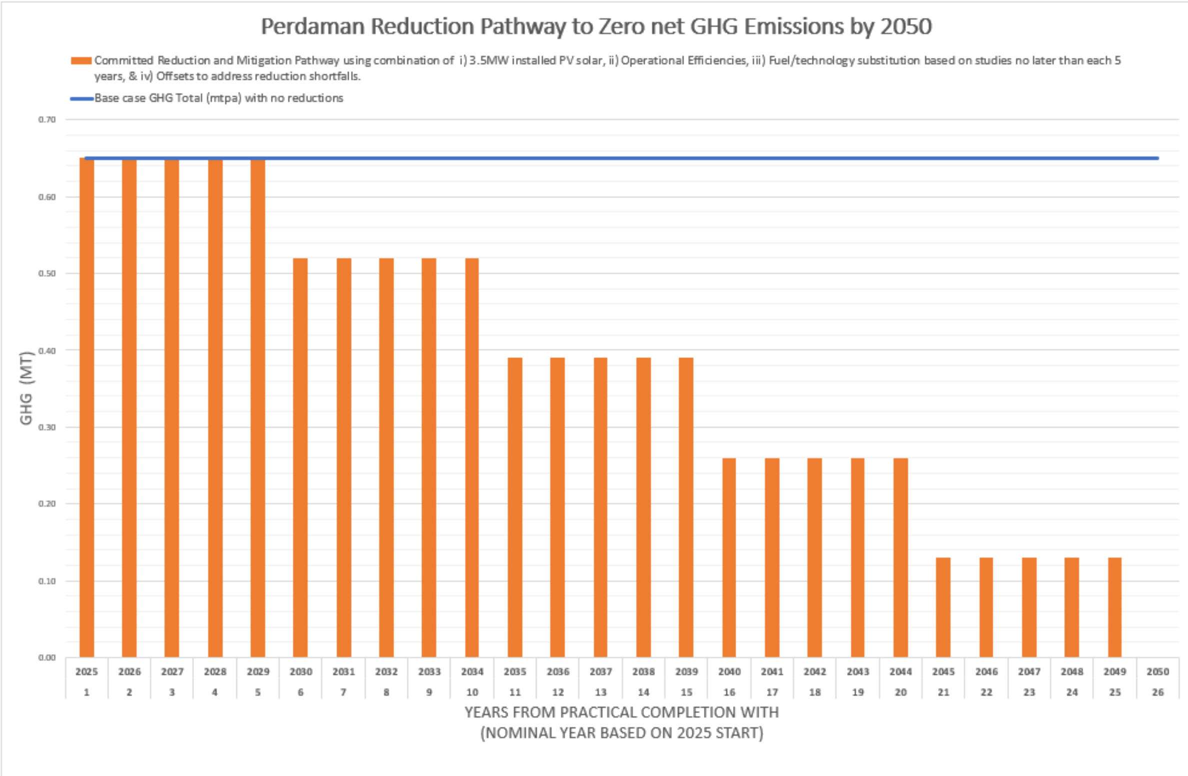
Year from practical completion	0	5	10	15	20	25+[8]
	Committed target			Aspirational target		
Net Scope 1 emission Base case without reductions (CO_{2-e} Mtpa)	0.65	0.65	0.65	0.65	0.65	0.65
Net Scope 1 emissions with emission targets (CO_{2-e} Mtpa)	0.65	0.52	0.39	0.26	0.13	0
Periodic reduction aggregate from Base case	0%	20%	40%	60%	80%	100%
5yr period Total Net Scope 1 Base case emissions (CO_{2-e} Mt)	3.25	3.25	3.25	3.25	3.25	3.25
5yr period Total Net Scope 1 emissions with emission targets (CO_{2-e} Mt)	3.25	2.60	1.95	1.30	0.65	0
Cumulative Net Scope 1 emissions Base case (CO_{2-e} Mt)	3.25	6.5	9.75	13.0	16.25	16.9[9]
Cumulative Net Scope 1 emissions with emission targets (CO_{2-e} Mt)	3.25	5.85	7.80	9.10	9.75	9.8

[8] Beyond 25 years for the remainder of the Project lifecycle, Net Scope 1 aspirational emissions annually and each 5 year total is then Zero till end of Project life out to 40, then potentially, 80 years duration of the Project lease.

[9] Cumulative Net Scope 1 emissions Base case shown at 25 years for comparative purposes at the point in the project lifecycle when zero Net Scope 1 GHG emissions is targeted.

The glidepath to achieving zero net emissions by 2050, assuming practical completion for the project is achieved in 2025, is depicted in Figure 5-1 below:

Figure 5-1: Glidepath to achieving zero net emissions by 2050



To achieve these committed reductions in net Scope 1 emissions, opportunities to avoid, reduce and offset Scope 1 greenhouse gas emissions from the project will be reviewed every five years. Based on the outcomes of those five-yearly reviews, actions to avoid, reduce or offset the emissions will be taken in accordance with the measures outlined below.

5.3.2 Avoidance of Scope 1 emissions

The first of the 5-year period studies will examine available processes and technologies that could potentially be retrofitted to the power generation and fired heating elements of the project. The intent will be to identify options capable of achieving a minimum reduction of 10% in greenhouse gas intensity for those specific process areas and move towards achieving a zero net GHG emissions aspirational target. The study would examine the availability, cost (including the relative costs of offsetting Scope 1 emissions), applicability, the feasibility and the environmental consequence to other key environmental factors of the identified processes and technologies addressed in the review.

If the study demonstrates that the process and technology can be practicably and cost effectively implemented to provide a minimum GHG performance enhancement of at least 10% and that the processes and technology do not harm other key environmental values, in particular maintaining the integrity of rock art, the review report will set out an indicative timetable for implementation. Perdaman will seek approvals from EPA and other relevant government agencies for the process/technology. If the process/technology is approved in a timely manner, Perdman will use reasonable endeavours to implement the process/technology in accordance with the review timetable

For each review, Perdaman will also explore opportunities to foster and support the development of potential collaborative government and industry GHG offset initiatives. Such initiatives could include:

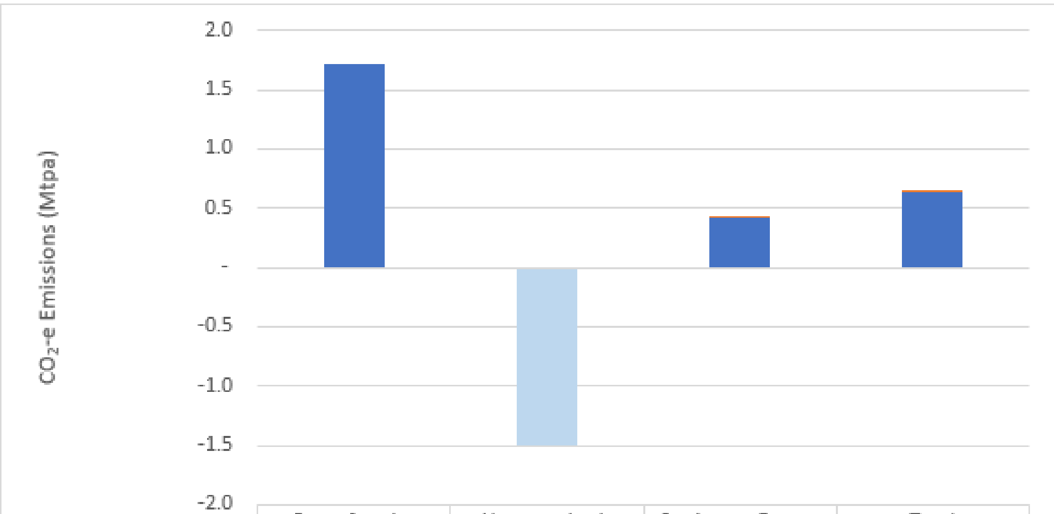
- local tertiary industry that makes use of any surplus high-grade purity CO_2 produced as a by-product of the Gas Reforming plant;
- a common-user sequestration site for GHG emissions produced by regional industries, such as potential use of depleted oil and gas reservoirs; and
- fuel replacement for stationary energy production that may arise if large scale hydrogen production proves feasible in the Karratha region.

Subsequent 5 – yearly reviews will explore and, where feasible and practicable, implement other opportunities to avoid Scope 1 emissions from the project. When assessing whether an opportunity is feasible and practicable to avoid Scope 1 emissions, regard will be had to the availability, cost (including the relative cost of offsetting Scope 1 emissions), efficiency, feasibility and environmental consequence of the opportunity.

5.3.3 Reduction of Scope 1 emissions

Following its considerations of submissions on the ERD, Perdaman has decided to install 3.5MW solar generating capacity. The intent is to integrate this power generating capacity with the planned 100MW combine cycle gas turbine (CCGT) power generation system, with the inclusion of a solar power feeder line to the power station. The purpose of the solar generating capacity is to supplement peak energy demand without increasing demand on the CCGT.

During detailed design, the opportunity to place the solar project on previously cleared project areas (ie. within Site C or Site F) will be confirmed. This would avoid the necessity to clear additional land and vegetation, and the inherent GHG emissions associated with land clearing. The recalculation of the project's GHG contribution will be confirmed following the detailed design stage, with preliminary estimates summarised in Figure 5-.



	Gas reforming	Urea synthesis	Stationary Energy	Total
100 MW CCGT	1.72	-1.50	0.43	0.65
3.5 MW Solar option	1.72	-1.50	0.42	0.64

Figure 5-2: Estimated GHG emissions – with and without 3.5MW solar power generation

The feasibility of installing greater than 3.5MW of solar generation will be reviewed every 5 years, in accordance with this GHGMP. When assessing the feasibility of expanding the solar generation capacity of the project, regard will be had to land availability, cost (including the relative cost of offsetting Scope 1 emissions), efficiency, feasibility and the environmental consequence of installing extra solar generation capacity.

Perdaman has also agreed to collaborate with Woodside on exploring the opportunity for a hydrogen and gas technology park that is to be powered by renewable energy ("green energy"). The park would support the Western Australian government's aspirational CO_2 reduction targets as well as the development of a broader renewable energy economy in Western Australia during the transition to a lower-carbon economy. This provides opportunities that target both the domestic and export markets. The park would be used for trials and field testing to progress the investigation of technology enhancements. If successful, this could facilitate the opportunity to explore substitution of hydrogen for natural gas as a fuel source in the Project power supply. The renewable (also referred to as "green") hydrogen industry is beginning to display signs of future potential in the Pilbara. The feasibility of commercial scale renewable hydrogen production has not yet been demonstrated, and will necessarily involve a staged development approach over an extended period of perhaps a decade.

A recent feasibility study for a renewable hydrogen plant in the Pilbara (Engie, 2020) has indicated a demonstration scale project (10MW) as technically feasible, on the basis of power from solar PV generation used to feed an electrochemical technology-based hydrogen plant (using alkaline or Proton Exchange Membrane (PEM) electrolyser). While this is very encouraging, to be commercially feasible, in the immediate future, the reference demonstration project (Engie, 2020) would require government grant support and other key commercial assumptions would need to be confirmed.

An offtake market willing to pay the premium for low-carbon fertiliser products does not presently exist, therefore the timeline for transition to the use of renewable hydrogen is difficult to predict and is subject to a high level of risk and uncertainty. Consequently, no commitment can be made to using renewable hydrogen. Nevertheless, Perdaman will review the feasibility of using renewable hydrogen for the Project as part of the 5-yearly reviews under this GHGMP.

When reviewing the feasibility of using renewable hydrogen, regard will be had to the availability, cost, efficiency, feasibility and environmental consequence of the supply and use of renewable hydrogen for the project.

5.3.4 Off-setting of Scope 1 emissions

Because there is no certainty that the introduction and use of new technology and processes will achieve the net Scope 1 emission reduction targets in Table 5-4, Perdaman commits to the development, and implementation of offsets to make-up any shortfall in achieving the net Scope 1 emission reduction targets through avoidance and reduction actions. The offsets proposed must meet the WA Government applicable criteria for accredited offsets.

The key aspects or principles on which Perdaman propose as the basis for providing offsets are as follows:

- During each 5 yearly review, Perdaman will form a 'worst case view' on the proportion of its Scope 1 emissions after planned avoidance and reduction measures under Sections 5.3.2 and 5.3.3 have been implemented. This will represent the maximum possible Scope 1 emissions that will need to be met by offsets. It should be noted that a conservative approach will be adopted, noting that Perdaman is optimistic that the implementation of avoidance and reduction measures will reduce this maximum offset figure.
- From the maximum offset figure, Perdaman will identify and secure a portfolio of potential off-sets mechanisms and off-set acquisition methods, to minimise price risk and maximise quality and yield, including:

  - A proportion acquired through projects of which Perdaman is a proponent. It is anticipated that this may include pursuing regional co-benefits (e.g. support Indigenous Land Management businesses and the Western Australian Blue Carbon economy).
  - A proportion acquired through projects underwritten by Perdaman.
  - A proportion acquired through the forward market (both domestic and international).
  - A proportion acquired and banked from the existing secondary market (both Australian Carbon Credit Units (ACCUs) and non-ACCUs).
  - Perdaman will also consider this off-set portfolio yield against the forecast lifetime emissions profile of the project to confirm maximum alignment.
  - Perdaman will also consider the thresholds within the necessary glide path to net zero at which point it becomes clear that Perdaman will need to increase the number of offsets relative to internal abatement.

  Perdaman will also consider using, at a minimum, recognised off-set certifications and align with any WA climate change laws relating to offsets.

5.4 Monitoring and Public Reporting of Greenhouse Gas Emissions

Perdaman commits to developing and implementing a comprehensive energy efficiency and GHG emissions monitoring and reporting system to track relevant performance metrics over the life of the Project, and to inform decisions on opportunities to implement practicable measures to improve energy efficiency. This reporting will include the baselining and tracking of Scope 1 emissions, and is intended to meet both State and National reporting requirements.

Scope 1 GHG emissions will be measured or estimated and reported in accordance with the NGER Act.

In addition, progress against implementation of this plan will be provided in the annual report relating to the Project and will be made to the public as required (e.g. in accordance with the EPA's Post Assessment Guideline for Making Information Publicly Available)

Table 5-3: Greenhouse Gas Management Measures

EPA factor and objective: Greenhouse Gas Emissions – To mitigate greenhouse gas emissions and consequently minimise the risk of contributing to climate change.			
Outcome: To avoid, reduce and offset emissions of Greenhouse Gases (GHG) over the project life.			
Key environmental values: Global climatic conditions (beneficial use and ecosystem health)			
Key impacts and risks: Global warming and climate change			
[redacted]			
Management actions	Management targets	Monitoring	Reporting
Incorporate Project design features to optimise energy efficiency and minimise GHG emissions intensity.	Ammonia Plant Target: Energy efficiency of 26.7 GJ_{LHV}/t NH_3 GHG intensity of 0.44 t CO_2-e/t NH_3. Urea Plant Target: Energy efficiency of 19.4 GJ_{LHV}/t urea GHG intensity of 0.32 t CO_2-e/t urea. Solar Power Generation Detailed Design Target minimum 3.5MW solar generating capacity.	In accordance with obligations under the *National Greenhouse and Energy Reporting Act 2007.*	In accordance with obligations under the *National Greenhouse and Energy Reporting Act 2007.* Findings of periodic review (every five years) of technologies and process for reduction of Scope 1 GHG emissions reported in accordance with Section 6 of this GHGMP.
Establish interim and long-term targets to avoid, reduce or offset Scope 1 GHG emissions from the Project – with solar, continuous improvement in operational efficiencies and green energy options being considered as part of the 5-yearly reviews.	Net Scope 1 emission reduction target at each 5 year interval after Practical Completion (nominally 2025) - see Figure 5-1 and Table 5-1. 20% after Year 5 - nominally from 2030 20% after Year 10 – nominally from 2035 (ie 40% aggregate reduction) 20% after Year 15 – nominally from 2040, (ie. 60% aggregate reduction)	In accordance with obligations under the *National Greenhouse and Energy Reporting Act 2007* and in conjunction with the 5-yearly review.	See Section 6 of this GHGMP.
Continue to review and identify emission reduction management and mitigation measures, including equipment and			

EPA factor and objective: Greenhouse Gas Emissions – To mitigate greenhouse gas emissions and consequently minimise the risk of contributing to climate change.			
technologies, that could be demonstrated to reduce GHG emissions with a view to obtaining approval to adopt practicable options in future.	20% after Year 20 – nominally from 2045 (ie. 80% aggregate reduction) 20% after Year 25 – nominally from 2050 (ie. 100% aggregate reduction achieving goal of zero net emission by 2050 with continued performance at this level for remainder of Project life).		
Establish and implement off-sets to supplement project technology and processes to avoid and reduce Scope 1 emissions.	The size and type of off-sets will be determined in accordance with Sections 5.3.3 and 5.3.4 of this GHGMP, and be based on the 5-yearly review and implementation of technology and processes to avoid and reduce Scope 1 emissions, and projections for the next 5-year review period.	In conjunction with the 5-yearly technology and process review.	See Section 6 of this GHGMP.
Routine emissions monitoring and reporting in accordance with the National Greenhouse and Energy Reporting Act.	Scope 1 emissions will be measured and reported in accordance with the NGER Act. In addition greenhouse gas emissions and progress against implementation of this plan will be provided in the annual report relating to the Project and will be made to the public as required (eg in accordance with the EPA's Post Assessment Guideline for Making Information Publicly Available).	In accordance with obligations under the *National Greenhouse and Energy Reporting Act 2007* and as necessary to inform the implementation of this plan.	In accordance with obligations under the *National Greenhouse and Energy Reporting Act 2007.* Progress against implementation of this plan will be provided in the annual report relating to the Project and will be made to the public as required (eg in accordance with the EPA's Post Assessment Guideline for Making Information Publicly Available).
Establish credible Scope 3 emission for upstream and downstream emission	An inventory of Scope 3 emissions will be developed within the first year of operations.	NA.	The Scope 3 emissions inventory will be included within the first post-

EPA factor and objective: Greenhouse Gas Emissions – To mitigate greenhouse gas emissions and consequently minimise the risk of contributing to climate change.			
contributions associated with urea production plant.			operational annual report provided to EPA.

6 Review of this Plan

This GHGMP will be periodically reviewed and amended as required during the design, construction and commissioning phases of the project to provide a framework for GHG management requirements that are consistent with EPA, 2020.

Once operational, Perdaman commits to reviewing the GHGMP every five years and report to EPA on progress in achieving the net Scope 1 emission reduction targets, provide explanations if the targets are not achieved or are exceeded, and summarise the outcome of reviews of technologies and processes carried out under Sections 5.3.2 and 5.3.3. A copy of this report will be put on the project website.

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8 Acronyms

Acronym	Definition
ACCU	Australian Carbon Credit Units
AGR	Acid Gas Recovery
ALARP	As low as reasonably practicable
ATR	Autothermal reform
BAT	Best Available Techniques
BPT	Best Practice Technology
CCGT	Combined cycle gas turbine
CER	Clean Energy Regulator
CH3	Methane
CO2	Carbon Dioxide
CO2-e	Carbon dioxide equivalent
DLN	Dry low NOx
EFMA	European Fertiliser Manufacturers Association
EMP	Environmental Management Plan
ERD	Environmental Review Document
EMS	Environmental Management System
EPA	Environmental Protection Authority
EP Act	*Environmental Protection Act 1986* (Western Australia)
EY	Ernst & Young
FIFO	Fly In Fly Out
GJ	Giga Joules

Acronym	Definition
HHV	Higher Heating Value
IFIA	International Fertiliser Industry Association
IFS	International Fertiliser Society
GHG	Greenhouse Gas
GHGMP	Greenhouse Gas Management Plan
LCA	Life Cycle Analysis
LCEC	Life cycle of energy consumption
LHV	Lower Heating Value
MAC	Murujuga Aboriginal Corporation
Mt	Million tonnes
Mtpa	Million tonnes per annum
MW	Mega Watt
N_2	Nitrogen
N_2O	nitrous oxide
NGER Act	National Greenhouse and Energy Reporting Act 2007
NH_2COONH_4	Ammonium carbamate
NH_3	Ammonia
NO_x	Nitrogen oxides
O_2	Oxygen
PEMP	Project Environmental Management Plan

Acronym	Definition
Perdaman	Perdaman Chemicals and Fertilisers Pty Ltd
SF_6	sulphur hexafluoride
SIA	Strategic Industrial Area
SO_2	Sulfur dioxide

Acronym	Definition
T	Tonnes
Tpd	Tonnes per day
WRI	World Resources Institute
Y	year

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