PAPUA LNG PROJECT - DOWNSTREAM

Greenhouse Gas Assessment

Prepared for:

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BASIS OF REPORT

This report has been prepared by SLR Consulting Australia Pty Ltd (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with Tetra Tech Coffey (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

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SLR disclaims any responsibility to the Client and others in respect of any matters outside the agreed scope of the work.

In this document a reference to "ExxonMobil" may be to ExxonMobil PNG Antelope Limited, or Niugini LNG Operating Company Limited, as the case requires. Nothing in this material is intended to override the corporate separateness of any entities.

DOCUMENT CONTROL

Reference	Date	Prepared	Checked	Authorised
620.31072.00000-R02-v1.0	24 May 2023	K Lawrence	IS, TW, AS, TC, KE, MS, NB, SJ, TV, MH, JM, CM-E	K Lawrence

EXECUTIVE SUMMARY

The proposed Papua LNG Project – Downstream (the Project) proposes to expand the capacity of the existing Liquefied Natural Gas Plant (LNG Plant) located in Caution Bay (Central Province), approximately 20 km northwest of Port Moresby. Currently there are two trains (Trains 1 and 2). New LNG processing trains are proposed, which will expand the capacity of the LNG Plant by an additional 4 million tonnes per annum (mtpa) Stream Day Capacity (SDC). Gas for the Project (Papua gas) will be supplied from the Elk and Antelope reservoirs in Gulf Province.

SLR Consulting Australia Pty Ltd (SLR) was commissioned by Tetra Tech Coffey PNG Ltd (Tetra Tech Coffey), on behalf of ExxonMobil PNG Antelope Limited (EMPNGA) to prepare a greenhouse gas (GHG) assessment to inform the Environmental Impact Statement (EIS) for the Project. The objectives of the GHG assessment were to:

- Compile an inventory of Scope 1 and 2 GHG emissions covering the construction and operational phase activities of the Project in accordance with PNG and/or international reporting standards.
- Assess the estimated annual GHG emissions for the Project against the emissions from EMPNG's current operations in PNG, as well as PNG's most recent available national GHG emissions inventory data.
- Review GHG abatement and energy efficiency measures proposed as part of the Papua LNG Project - Downstream.

It is noted that reporting of Scope 2 and 3 emissions is not required under UNFCCC methodologies as it can result in double-counting, and IPCC emission factors are not designed to allow the calculation of Scope 3 emissions. The estimation of Scope 3 emissions has therefore not been included as part of this assessment.

Scope 2 emissions were also not included, as the Project will not be sourcing any appreciable quantities of electricity from the grid or other third-party generators.

GHG emissions will also occur during decommissioning of the LNG Plant and other associated facilities at the end of their design life. Due to the uncertainty regarding the fate of the plant at that time, GHG emissions associated with the end-of-life phase of the LNG Plant and other infrastructure associated with the Project were not included.

Scope 1 emission estimates were provided by ExxonMobil for the proposed construction works as well as the following operational sources for 2023 to 2030:

- Existing and future LNG Plant Operations – Trains 1 and 2 (PNG LNG gas):
  - Operational GHG emissions associated with combustion of fuel gas in engines, heaters, boilers, reboilers, turbines and flaring
  - Fugitive emissions
  - Venting
  - Combustion of fuel in mobile equipment, vessels, and vehicles.
- Papua LNG Project – Downstream construction, commissioning, and operation (new trains):
  - Emissions associated with fuel use in stationary engines. mobile equipment, vessels, and vehicles
  - Emissions associated with flaring during commissioning and operations

EXECUTIVE SUMMARY

- Operational emissions associated with combustion of fuel gas in the Combined Cycle Power Plant (CCPP) providing power to both Papua LNG and PNG LNG Plant, which may allow PNG LNG Plant to shut down all of its less efficient utility gas turbine generators or be on standby, thereby reducing its emissions.
- Fugitive emissions

- The Project also includes processing up to 2 mtpa of Papua gas in Trains 1 and 2. In this estimate, the GHG emissions from the following LNG Plant Operations associated with processing this resource have been allocated to the Project:
  - Operational GHG emissions associated with combustion of fuel gas in engines, heaters, boilers, reboilers, turbines and flaring
  - Fugitive emissions
  - Combustion of fuel in mobile equipment, vessels, and vehicles.

As noted above, Scope 2 emissions were not included in the inventory, as the Project will not be sourcing any appreciable quantities of electricity from the grid or other third-party generators. The consumption of electricity produced by the Papua LNG CCPP will, however, mean that in relation to the current power produced by the less efficient utility gas turbine generators for the LNG Plant, there will be a reduction in Scope 1 emissions when the generators are shut down or on standby. In this estimate, allocations of GHG estimates from the CCPP between the two facilities is based on the design power needs of the two facilities. Future GHG allocation procedures will be identified as part of the commercial arrangements for sharing gas and utilities between the joint sites, with measurement facilities to be provided consistent with those agreements.

Annual Scope 1 GHG emissions estimated for the Project are summarised in **Table ES-1** and **Figure ES-1**. In **Figure ES-1**, estimated GHG emissions associated with gas processing in New Trains as well as processing of Papua gas in Trains 1 and 2 have been grouped together in plot (a) to provide the total estimated emissions associated with processing Papua LNG gas, while plot (b) presents the estimated GHG emissions associated with processing PNG LNG gas only in Trains 1 and 2 (i.e., excluding Papua gas processing). The breakdown between emissions from Trains 1 and 2 associated with processing PNG LNG gas versus Papua gas is provided in **Table ES-1**. These emission estimates contain a degree of uncertainty and are subject to change as detailed design of the Project moves forward.

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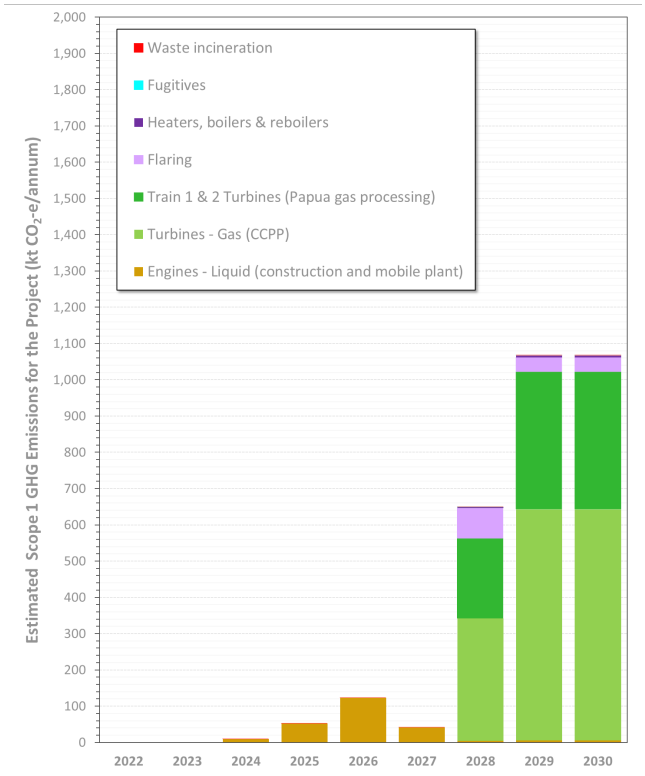
Table ES-1 Summary of Estimated Scope 1 Emissions

Source/Activity	2022	2023	2024	2025	2026	2027	2028	2029	2030
Existing PNG LNG Plant (Trains 1 and 2) – LNG Plant Only, Estimated Annual GHG Emissions in kt CO_2-e/annum									
Engines – Liquid	0.16	0.16	0.17	0.17	0.16	0.16	0.14	0.13	0.12
Flaring	19.99	19.99	19.99	20.03	24.62	51.98	16.56	14.66	12.75
Fugitives	0.49	0.49	0.59	0.62	0.63	0.63	0.61	0.59	0.60
Heaters/boilers/reboilers	15.49	14.34	15.29	14.93	14.30	12.42	10.57	10.13	10.23
Turbines – Gas	1,536.53	1,422.46	1,567.48	1,530.93	1,468.51	1,282.74	951.86	914.88	923.27
Vents	164.64	162.71	215.13	225.62	218.46	211.98	196.20	179.75	193.78
Mobile sources	4.66	4.53	4.81	4.81	4.73	4.52	4.20	3.90	3.59
Sub-Total	**1,741.9**	**1,624.7**	**1,823.4**	**1,797.1**	**1,731.4**	**1,564.4**	**1,180.1**	**1,124.0**	**1,144.3**
Papua LNG Project – Downstream, Estimated Annual GHG Emissions in kt CO_2-e/annum									
Papua LNG New Trains									
Turbines – Gas (CCPP)	-	-	-	-	-	-	337.26	637.50	637.50
Engines – Liquid	-	-	4.99	27.16	73.52	25.15	-	-	-
Flaring	-	-	-	-	-	-	77.27	30.00	30.00
Mobile sources	-	-	4.21	25.08	49.78	16.67	4.12	4.12	4.12
Waste incineration	-	-	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Sub-Total	**-**	**-**	**10.0**	**53.0**	**124.1**	**42.6**	**419.4**	**672.4**	**672.4**
PNG LNG Trains 1 and 2 – Papua Gas Processing									
Engines – Liquid	-	-	-	-	-	-	0.02	0.04	0.04
Flaring	-	-	-	-	-	-	6.74	11.55	11.55
Fugitives	-	-	-	-	-	-	0.07	0.13	0.13
Heaters/Boilers/Reboilers	-	-	-	-	-	-	2.22	3.81	3.81
Turbines – Gas	-	-	-	-	-	-	220.38	377.79	377.80
Mobile sources	-	-	-	-	-	-	0.66	1.12	1.12
Sub-Total	**-**	**-**	**-**	**-**	**-**	**-**	**230.1**	**394.4**	**394.4**
TOTAL Papua LNG Project*	**-**	**-**	**10.0**	**53.0**	**124.1**	**42.6**	**649.5**	**1,066.8**	**1,066.8**

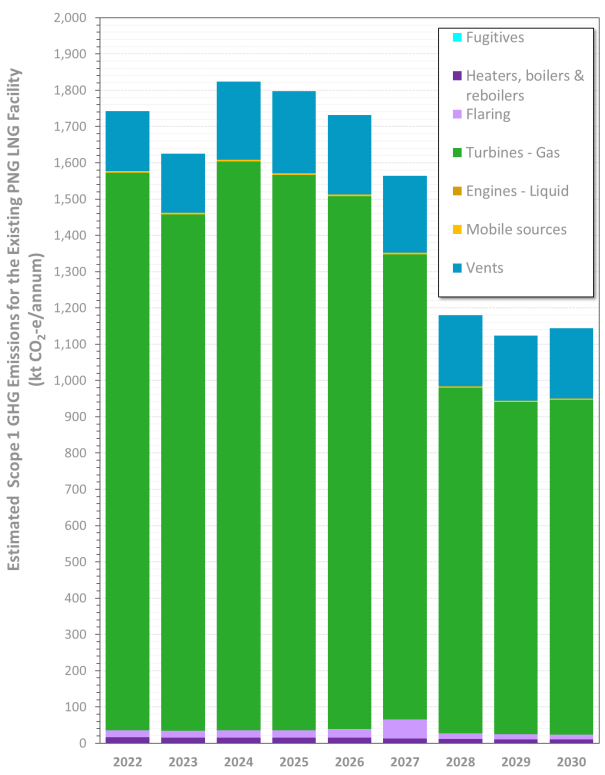
* Including Papua gas processing in Trains 1 and 2.

EXECUTIVE SUMMARY

Figure ES-1 Estimated Scope 1 Emissions



(a) **Project emissions associated with gas processing in New LNG Trains as well as processing of Papua LNG Upstream gas (2 MTA) in Trains 1 and 2**



(b) **Emissions associated with gas processing in PNG LNG Trains 1 and 2 – LNG Plant**

As shown in **Figure ES-1**, the estimated Scope 1 GHG emissions for the project construction phase (2024 to 2027) are minor compared to the current LNG Plant Operation emissions and are almost totally associated with fuel combustion in fixed and mobile construction sources. As would be expected, flaring emissions peak during 2028, associated with commissioning of the new trains.

Once commissioning is completed (2029 and 2030), the total Papua LNG Project – Downstream Scope 1 emissions are estimated to be approximately 1,060 kt CO_2-e per annum, with the main sources of these emissions being the combustion of fuel gas in the CCPP turbines (638 kt CO_2-e per annum) and in the Train 1 and 2 turbines associated with processing Papua gas (378 kt CO_2-e per annum).

The total annual Scope 1 emissions from the integrated LNG Plant are estimated to represent an approximate 27% increase on the current Scope 1 emissions estimated for the existing LNG Plant (see **Figure ES-2**). However, the Papua LNG Project – Downstream is forecasted to result in an improved emissions intensity for the combined expanded facility of around 17.1 tonnes CO_2-e per 100 tonnes of product available to market, compared to the current estimated emissions intensity of approximately 18.7 tonnes CO_2-e per 100 tonnes of product available for market for the LNG Plant Facility in 2022 (see **Figure ES-3**) (excluding emissions from the Hides Gas Processing Plant).

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Once the Papua LNG Project – Downstream is built and operating, the total integrated LNG Plant annual Scope 1 emissions in 2029 and 2030 are estimated to be approximately 27% higher than the forecast 2022 Scope 1 emissions estimated for the PNG LNG Plant. On this basis, the Project is projected to contribute an additional 470 kt CO_2-e/annum, representing an increase of around 5% for the energy sector, and would increase PNG's national emissions (excluding Land use, land-use change and forestry (LULUCF)) from 10,767 kt CO_2-e/annum reported for 2018 by around 4%.

Figure ES-2 Total Estimated Scope 1 Emissions from the integrated LNG Plant (PNG LNG gas and the Papua gas)

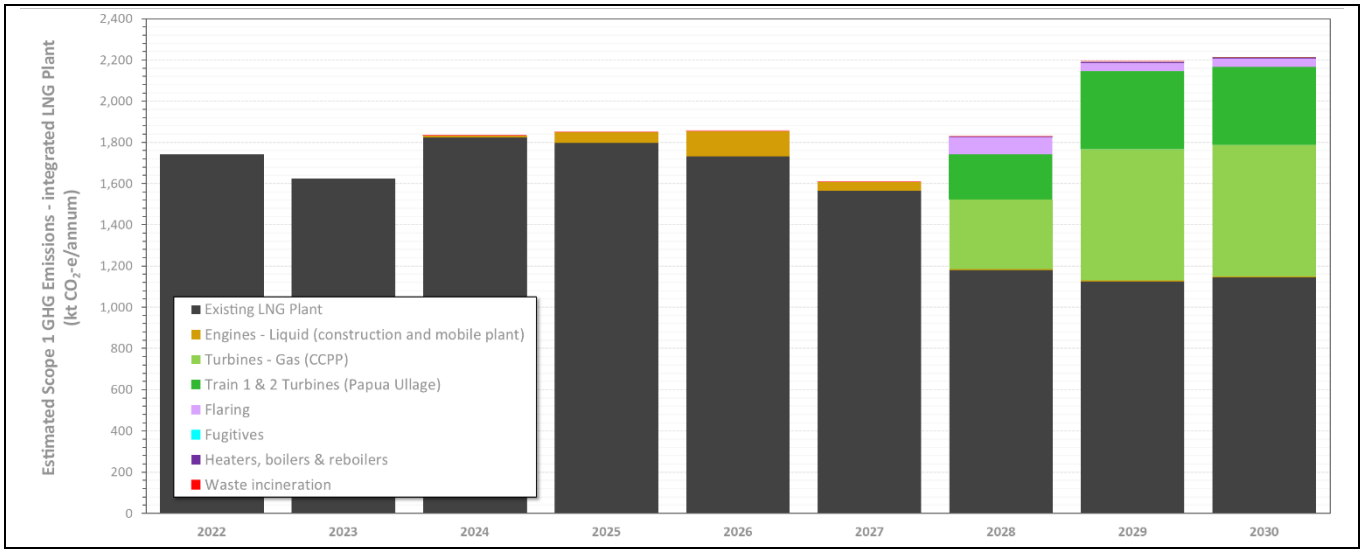
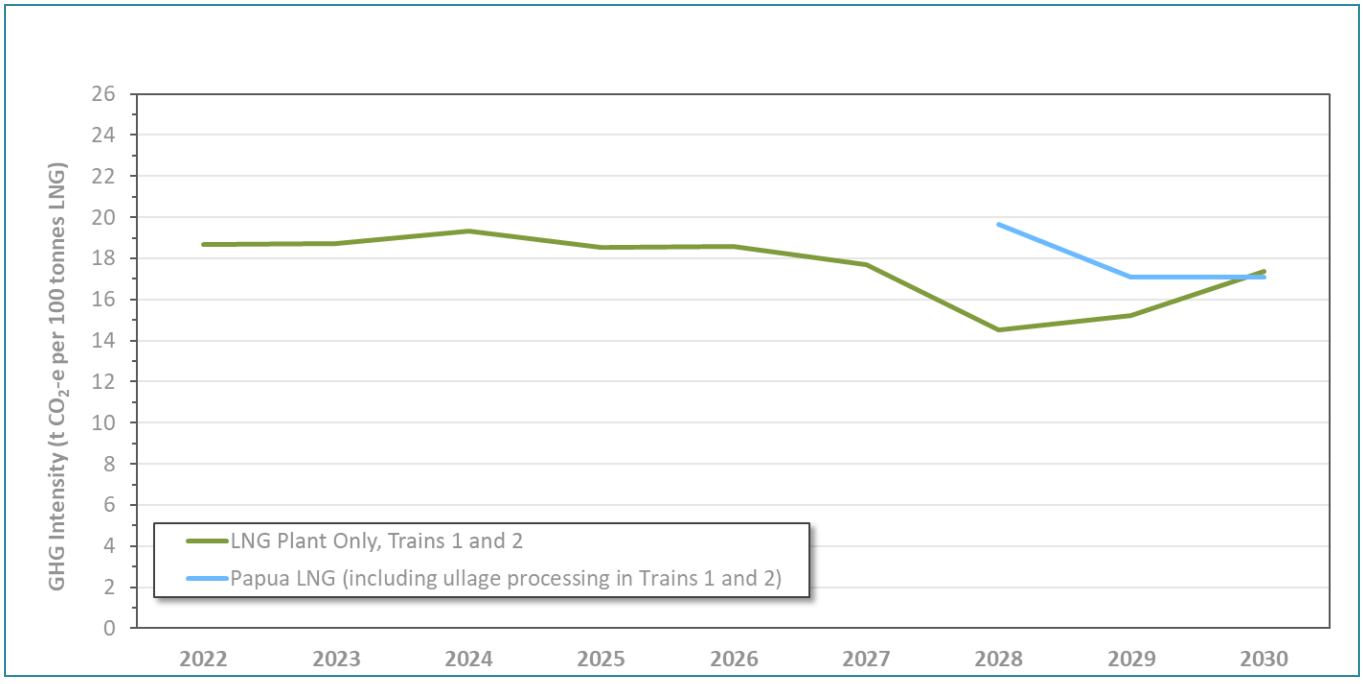


Figure ES-3 Forecasted Estimated Scope 1 Emissions Intensities



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The LNG Plant and associated facilities are relatively new, which means that most current energy efficiency measures have already been incorporated into the design of the facility. The minimisation of GHG emissions has also been a key consideration in the design of the Papua LNG Project – Downstream. Specifically, the following priorities were identified for the plant design in relation to GHG emissions mitigation:

- developing a plant design that is in line with ExxonMobil's corporate-wide 2030 & 2050 GHG emission reduction plans and ambitions (Scope 1 and 2) and methane and flaring plans;
- identifying design choices that have the potential to improve the GHG performance of the operating LNG Plant; and
- providing a plant design that does not preclude subsequent projects at the site that may reduce GHG emissions intensity.

Optimisation of energy use and minimisation of GHG emissions will be a key consideration throughout the detailed design phase of the project. As noted above, once commissioned, the Project will result in an improvement in the energy intensity of the LNG Plant Operations compared to current operations.

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Abbreviations

%	percent
°C	degrees Celsius
AGRU	acid gas recovery unit
BOG	boil-off gas
BUR	Biennial Update Report
CALM	catenary anchor leg mooring
CCDA	PNG Climate Change & Development Authority
CCPP	combined-cycle power plant
CFC	chlorofluorocarbons
CH_4	methane
COP	Conference of Parties
CPF	Central Processing Facility
CO_2	carbon dioxide
CO_2-e	carbon dioxide equivalents
DCPPS	Dirio Central Province Power Station
DNA	Designated National Authority
EHS	Environmental, Health, and Safety
EIS	Environmental Impact Statement
EMPNGA	ExxonMobil Papua New Guinea Antelope Limited
EMPNG	ExxonMobil Papua New Guinea Limited
g	gram
GHG	greenhouse gas(es)
GWP	Global Warming Potential
GTG	gas turbine generator
HRSG	heat recovery steam generator
IFC	International Finance Corporation
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Processes and Product Use
km	kilometre
kt	kilotonnes
LNG	liquefied natural gas
LULUCF	Land Use, Land-Use Change and Forestry
m^3	cubic metre
mtpa	million tonnes per annum
N_2O	nitrous oxide
NDC	Nationally Determined Contribution
OCCD	Office of Climate Change and Development (now CCDA)
PLEM	pipeline end manifold
PNG	Papua New Guinea
PNG LNG Project	Papua New Guinea Liquefied Natural Gas Project
PRL-15	Petroleum Retention License 15

REDD+	Reducing Emissions from Deforestation and forest Degradation in developing countries
SDC	Stream Day Capacity
SF_6	sulfur hexafluoride
t	tonne
UNFCCC	United Nations Framework Convention on Climate Change
WBG	World Bank Group
WRI/WBCSD	World Resources Institute/World Business Council for Sustainable Development

Glossary

atmosphere	A gaseous mass surrounding the planet that is retained by Earth's gravity. It is divided into five layers, with most of the weather and clouds found in the first layer.
biennial	(An event) lasting for two years or occurring every two years.
cogeneration	Electrical or shaft power production that also provides heat in a form useable for things other than additional power generation. Use of cogeneration improves energy efficiency.
combustion	The process of burning. A chemical change, especially oxidation, accompanied by the production of heat and light.
commissioning	The phase of a project when feed gas is introduced into new facilities and equipment to test the production of the sales products (LNG, condensate, etc)
downstream	Papua LNG facility, storage tanks and marine facilities
emissions intensity	A benchmarking tool defined as the tonnes of GHG emitted (in CO_2-e) per tonne of product available to market
flaring	The controlled burning of process gas when it cannot be processed for commercial use (e.g., during plant upsets, maintenance activities or commissioning)
fossil fuel	A natural fuel such as coal, diesel or gas, formed in the geological past from the remains of living organisms.
fugitive emissions	Emissions of gases or vapours from pressurised equipment due to leaks and other unintended or irregular releases of gases.
greenhouse gas	A gas that contributes to the greenhouse effect by absorbing infrared radiation, e.g., carbon dioxide.
guideline	A general rule, principle, or piece of advice. A statement or other indication of policy or procedure by which to determine a course of action.
Scope 1 emissions	Direct greenhouse gas (GHG) emissions produced from sources within the boundary of an organization and as a result of the organisation's activities.
Scope 2 emissions	Indirect GHG emissions produced during the generation of purchased electricity consumed in owned or controlled equipment or operations.
Scope 3 emissions	Indirect GHG emissions generated in the wider economy as a consequence of an organisation's activities but are physically produced by the activities of another organisation.
upstream	Gas production facilities, Central Processing Facility and pipelines connecting to the Papua downstream facility
venting	Discharge of unburned process gases into the atmosphere when it cannot be processed for commercial use (e.g. during plant upsets, maintenance activities or commissioning). In relation to this Project, also includes the reservoir-produced CO_2 that is vented from the Acid Gas Removal Unit (AGRU) at the LNG Plant.

1 Introduction

ExxonMobil PNG Limited (EMPNG) is the operator of the PNG LNG Project, an integrated development that is commercialising the gas resources of Papua New Guinea. The Papua LNG Project is a gas development project for the Papua LNG Project Joint Venture participants, which are:

- TotalEnergies EP PNG Limited (TotalEnergies, an affiliate of TotalEnergies SA)
- ExxonMobil PNG Antelope Limited (EMPNGA) and ExxonMobil PNG Elk Limited
- Pac LNG Assets Limited, Pac LNG International Limited, Pac LNG Investments Limited, Pac LNG Overseas Limited and Pac LNG Holdings Limited (affiliates of Santos Limited)
- JX Nippon Oil and Gas Exploration Pty Ltd.

EMPNGA is the Project proponent and the ExxonMobil affiliate responsible for the construction of the Project. Niugini LNG Operating Company Limited (NLOC) is the ExxonMobil affiliate responsible for the Project once it has been constructed and commissioned.

The Papua LNG Project will involve producing and processing the gas and condensate from the Elk and Antelope gas reserves in Petroleum Retention License 15 (PRL-15), located in Gulf Province, Papua New Guinea and piping them overland, then offshore in the Gulf of Papua, to the existing Papua New Guinea Liquefied Natural Gas Project (PNG LNG Project) producing and exporting facility (LNG Plant) located in Caution Bay (Central Province) approximately 20 km north-west of Port Moresby (see **Figure 1**).

The existing PNG LNG Project commercialises gas reserves in the Hela, Western and Southern Highlands provinces of Papua New Guinea. The gas is transported to the LNG Plant via pipeline, where it is liquefied and exported by ship to international gas markets. The LNG Plant also currently supplies gas to the NiuPower Port Moresby Power Station and the Dirio Central Province Power Station (DCPPS) for the domestic electricity market.

The Papua LNG Project involves two components:

- The Papua LNG Project – Upstream (referred to as the Upstream component)
- The Papua LNG Project – Downstream (referred to as the Downstream component, hereafter referred to as 'the Project' and the component addressed in this document).

Execution of the Upstream component and the Project is delimited in Caution Bay, with the approximate boundary (i.e., the scope break) between the components located near the fence of the LNG Plant, south of the existing jetty.

The new LNG processing trains will expand the capacity of the LNG Plant by approximately 4 million tonnes per annum (mtpa) stream day capacity (SDC), while also providing gas to utilise up to 2 mtpa of latent capacity of the existing trains. This expansion will bring the total capacity of the integrated LNG Plant to approximately 12.8 mtpa SDC.

Tetra Tech Coffey has been commissioned by ExxonMobil PNG Antelope Limited (EMPNGA) to undertake an EIS for the Project. SLR Consulting Australia Pty Ltd (SLR) was commissioned by Tetra Tech Coffey, on behalf of EMPNGA to prepare a greenhouse gas (GHG) assessment for the Project. The findings of this assessment will inform the EIS for the Project.

1.1 Assessment Objectives

The objectives of the GHG assessment were to:

- Compile an inventory of Scope 1 and 2 GHG emissions covering both the construction and operational phase activities of the Project in accordance with PNG and/or international reporting standards.
- Assess the estimated annual GHG emissions for the Project against the emissions from EMPNG's current operations in PNG, as well as PNG's most recent available national GHG emissions inventory data.
- Review GHG abatement and energy efficiency measures proposed as part of the Papua LNG Project – Downstream.

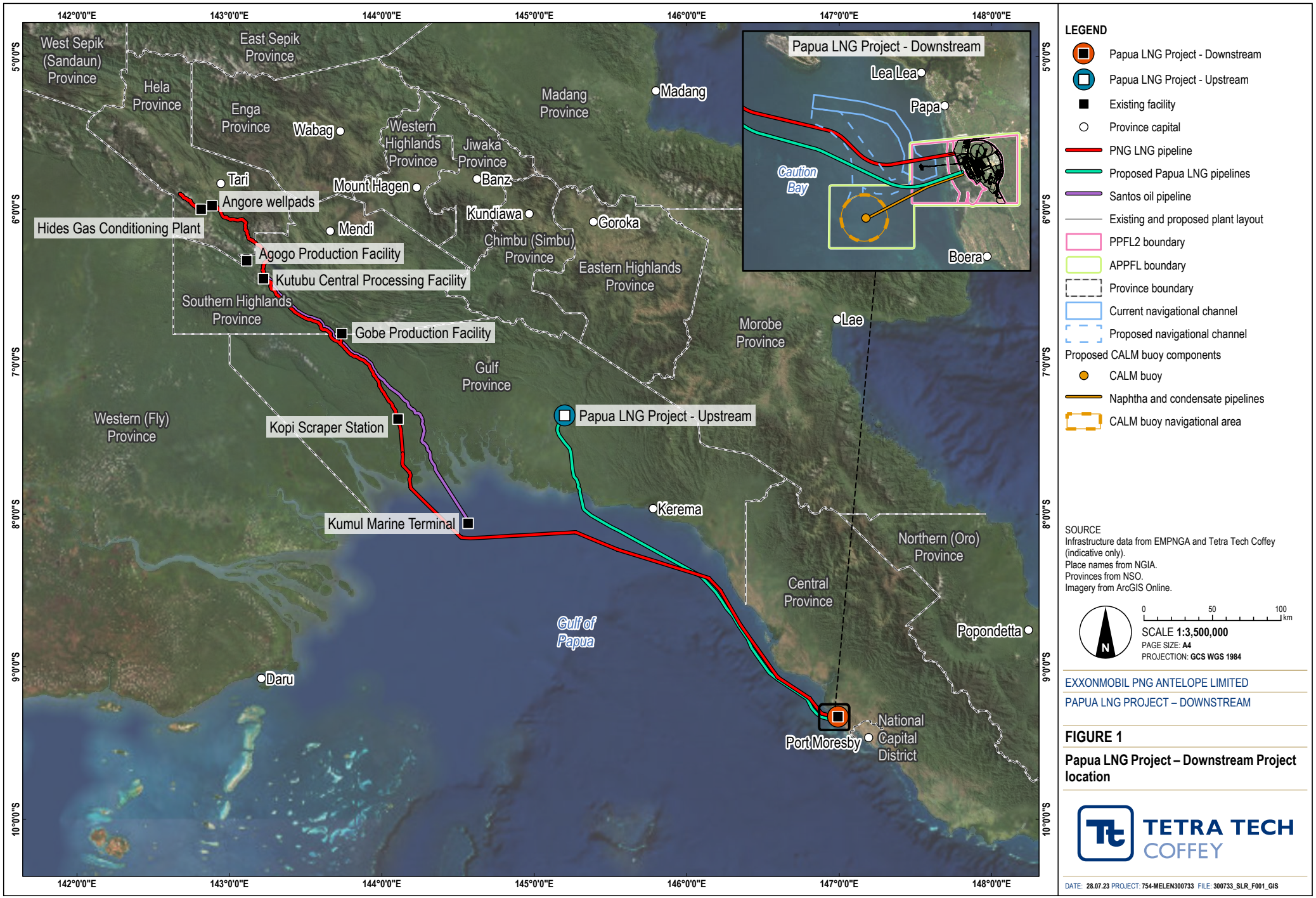
1.2 Assessment Approach

The overall approach used for the GHG assessment was as follows:

- identify relevant national and international statutory requirements and policies/ standards that may be relevant to the Project
- identify the key project-related GHG sources during project construction and operations
- estimate the quantities of GHG emissions generated from the identified sources
- assess the Project's contribution to PNG's national GHG emissions.

Calculation of GHG emissions from the Papua LNG Project – Downstream has been performed in a five stage process:

1. Definition of the Project boundary (**Section 5.1**)
2. Identification of emission sources within the Project boundary (**Section 5.2**)
3. Identification of emission calculation methods for each source (**Section 6.1**)
4. Identification of activity data for each emission source (**Section 6.2**)
5. Calculation of GHG emissions (**Section 6.3**)



LEGEND

- Papua LNG Project - Downstream
- Papua LNG Project - Upstream
- Existing facility
- Province capital
- PNG LNG pipeline
- Proposed Papua LNG pipelines
- Santos oil pipeline
- Existing and proposed plant layout
- PPFL2 boundary
- APPFL boundary
- Province boundary
- Current navigational channel
- Proposed navigational channel

Proposed CALM buoy components

- CALM buoy
- Naphtha and condensate pipelines
- CALM buoy navigational area

SOURCE
Infrastructure data from EMPNGA and Tetra Tech Coffey (indicative only).
Place names from NGIA.
Provinces from NSO.
Imagery from ArcGIS Online.

0 50 100 km

SCALE **1:3,500,000**
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PROJECTION: **GCS WGS 1984**

EXXONMOBIL PNG ANTELOPE LIMITED

PAPUA LNG PROJECT – DOWNSTREAM

FIGURE 1

Papua LNG Project – Downstream Project location

TETRA TECH COFFEY

DATE: **28.07.23** PROJECT: **754-MELEN300733** FILE: **300733_SLR_F001_GIS**

2 Project Description

The PNG LNG Project's existing facilities for liquefaction of natural gas are called the LNG Plant, located in Caution Bay (Central Province), approximately 20 km north-west of Port Moresby, between the coastal settlements of Boera and Papa. The Project will build on and increase the current capacity of the existing LNG Plant. Gas will be supplied from the Elk and Antelope reservoirs being developed for the Upstream component of the Papua LNG Project. The LNG Plant occupies three separate lease areas: Portion 2456, Portion 2457 (coastal strip) and Portion 2458 (offshore).

2.1 Project Overview

The Project incorporates the expansion of the LNG Plant's existing onshore and marine facilities in Caution Bay, including the installation of new LNG processing trains (SMR technology).

A Combined Cycle Power Plant (CCPP) will be utilised to provide electric power for the LNG plant. The CCPP will consist of four gas turbine generators (GTGs), four Heat Recovery Steam Generators (HRSGs) and two steam turbine generators. The CCPP will provide sufficient power to the integrated LNG Plant, therefore three of the seven PNG LNG Plant GTGs will be repurposed as cold standby for the integrated LNG Plant.

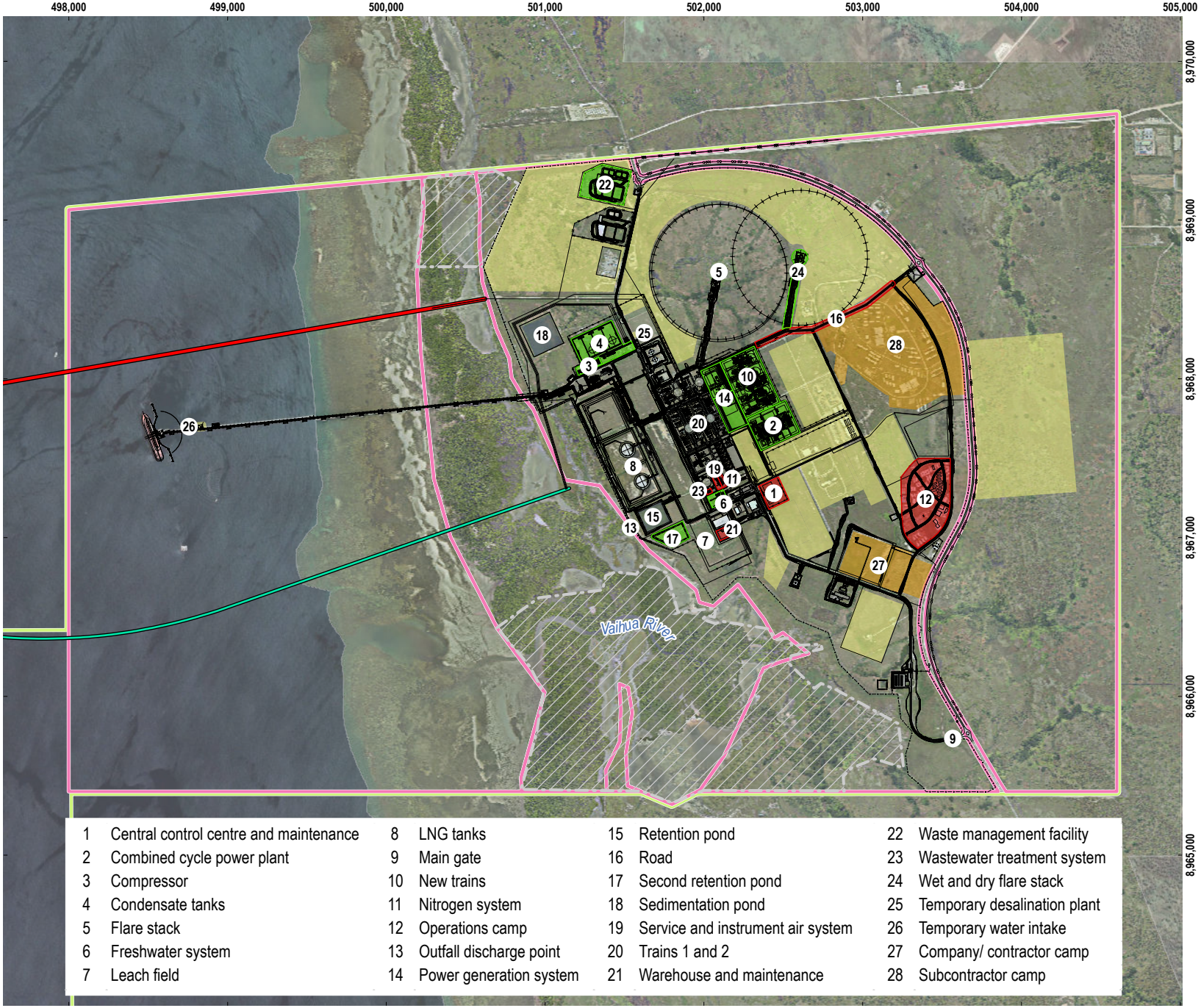
Figure 2 shows the proposed areas within the existing LNG Plant lease area where the new onshore facilities will be developed. The proposed marine facilities associated with the Project are shown in **Figure 3**.

A summary of the components of the Project is provided in **Table 1**.

Table 1 Project Components at the LNG Plant

Component	Description
Additional LNG trains	New LNG processing trains and supporting systems including: • Inlet gas receiving and treatment • Dehydration/mercaptan removal • Mercury removal • Heavy-hydrocarbon separation (which contains benzene, toluene, ethylbenzene, and xylenes (BTEX)) • Liquefaction • Stabilisation • Refrigeration system • Fractionation system (naphtha)
Expansion of existing utilities	Existing PNG LNG shared utilities to be expanded include: • Hot oil system • Service and instrument air system • Nitrogen system • Freshwater system • Desalinated water system • Potable water system • Diesel oil storage and distribution system • Open and closed drain systems

Component	Description
	• Sanitary wastewater treatment systems
New utilities	Options for new separate utilities may include: • Integrated fuel gas system • Power generation system • Tempered water system • Highly demineralised water system for the Heat Recovery Steam Generators (HRSGs) • Flare system (wet and dry gas) • Thermal oxidiser
Product storage	Product storage will include: • New condensate storage tanks with a total storage capacity of up to 110,000 m^3
New marine facilities	Options for new or expanded marine facilities may include: • Catenary Anchor Leg Mooring (CALM) buoy and associated exclusion zones • Pipeline end manifold (Upstream construction component, Project operations component) • Naphtha and condensate pipelines (Upstream construction component, Project operations component) • New FEED pipelines including a gas pipeline and a condensate pipeline (Upstream construction component and Project operations component), with landfall and tie-in to the pipelines at the LNG Plant. The pipelines will be located south of the existing LNG Plant jetty. • Alternate shipping channel • Navigation and monitoring systems
Temporary facilities	Temporary construction facilities will be located within the PNG LNG Project's lease boundaries and will include laydown areas, offices, workshops and concrete batching plants.
Waste	Options being reviewed for waste facilities and management being assessed may include: • Temporary onsite storage and segregation of waste, with transport to and disposal at third party waste management facility • New engineered solid waste landfill within existing LNG Plant security fence for disposal of non-restricted waste, with limited disposal of restricted waste by specialised service.
Logistics route	Most construction materials will be transported by truck from Motukea Port in Port Moresby to the LNG Plant site via the Lea Lea Road. Repairs or upgrades to the road, or relocation of overhead cables may be required to allow transport of large, heavy loads.
Workforce	Construction: Approximately 5,000 to 7,000 personnel at peak. Operation: Increase of approximately 50 operations and maintenance technicians with support staff anticipated to increase.
Accommodation	Construction: Up to 6,000 bed construction camps. Operation: Up to 500 beds at the existing operations camp.



1	Central control centre and maintenance	8	LNG tanks	15	Retention pond	22	Waste management facility
2	Combined cycle power plant	9	Main gate	16	Road	23	Wastewater treatment system
3	Compressor	10	New trains	17	Second retention pond	24	Wet and dry flare stack
4	Condensate tanks	11	Nitrogen system	18	Sedimentation pond	25	Temporary desalination plant
5	Flare stack	12	Operations camp	19	Service and instrument air system	26	Temporary water intake
6	Freshwater system	13	Outfall discharge point	20	Trains 1 and 2	27	Company/ contractor camp
7	Leach field	14	Power generation system	21	Warehouse and maintenance	28	Subcontractor camp

LEGEND

- PNG LNG pipeline
- Proposed Papua LNG pipelines route
- Existing and proposed plant layout
- Proposed new facility
- Proposed expanded/upgraded facility
- Temporary construction area
- Temporary camp
- PPFL2 boundary
- APPFL boundary
- Cultural heritage restricted area

SOURCE
Infrastructure, cultural heritage and lease boundary from EMPNGA.
Imagery from EMPNGA and Google Earth.

0 0.5 1 km

SCALE **1:35,000**
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PROJECTION: **WGS 1984 UTM Zone 55S**

EXXONMOBIL PNG ANTELOPE LIMITED

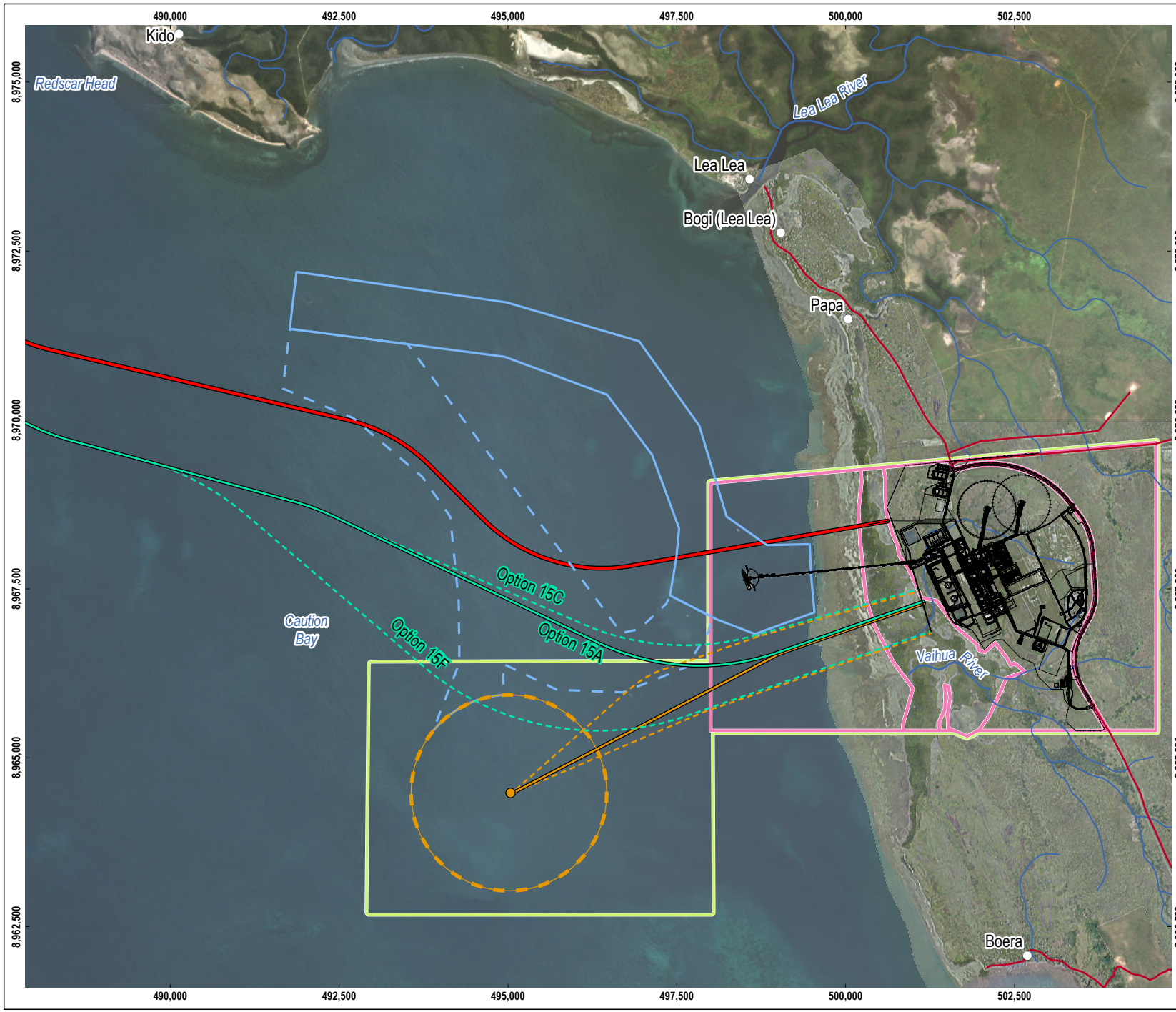
PAPUA LNG PROJECT – DOWNSTREAM

FIGURE 2

Proposed onshore facilities for the Project

TETRA TECH COFFEY

DATE: **28.07.23** PROJECT: **754-MELEN300733** FILE: **300733_SLR_F002_GIS**



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LEGEND

- Village
- Road
- Watercourse
- PNG LNG pipeline
- Proposed Papua LNG pipelines route
- Proposed Papua LNG pipelines route alternate
- Existing and proposed plant layout
- PPFL2 boundary
- APPFL boundary
- Current navigational channel
- Proposed navigational channel

Proposed CALM buoy components

- CALM buoy
- Naphtha and condensate pipelines
- Naphtha and condensate pipelines alternate
- CALM buoy navigational area

SOURCE
Infrastructure, roads, watercourses and lease boundary from EMPNGA.
Imagery from EMPNGA and Planet Labs.

0 1 2 km

SCALE **1:80,000**
PAGE SIZE: **A4**
PROJECTION: **WGS 1984 UTM Zone 55S**

EXXONMOBIL PNG ANTELOPE LIMITED

PAPUA LNG PROJECT – DOWNSTREAM

FIGURE 3

Proposed marine facilities for the Project

TETRA TECH COFFEY

DATE: **28.07.23** PROJECT: **754-MELEN300733** FILE: **300733_SLR_F003_GIS**

2.2 Onshore Production Facilities

New liquefaction trains will be located adjacent to the existing trains 1 and 2 (**Figure 2**). As with the existing trains 1 and 2, processing of the gas into LNG requires removal of impurities and hydrocarbons that are heavier than methane, followed by super cooling to form a liquid. The new trains will utilise single mixed refrigerant (SMR) technology to process the gas.

The main steps in LNG processing are shown in **Figure 4** and include the following systems:

- Inlet receiving and treatment
  - These systems receive gas from the pipelines, heat it to prevent hydrate (water) formation, and separate out liquids from the gas.
- Dehydration and mercury removal
  - Gas from the inlet and treatment systems is processed to remove moisture and mercury.
- Heavy Hydrocarbon removal
  - The sweet, dry gas stream is fed to the Heavy Hydrocarbon Removal system, which includes the heavy hydrocarbon removal cold box, scrub column feed separator and scrub column. Heavier hydrocarbons (such as ethane, propane and butane) are separated off at this stage to avoid freezing in the liquification step.
- Liquefaction
  - The gas is cooled to below the methane boiling point of around -161^{o}C. At this temperature, it liquefies to 1/600th of its original volume.
- Refrigeration
  - These systems cool and pressurise the refrigerants used in the liquefaction systems.
- Fractionation
  - The heavier hydrocarbons removed prior to cooling the gas are processed to produce sour naphtha.

The main products produced by the existing LNG Plant include LNG and naphtha. The LNG Plant also supplies gas to the Port Moresby Power Station for the domestic electricity market.

Sour naphtha recovered from the fractionation system will be blended with the Papua LNG field condensate and stored in new storage tanks with a total capacity of up to 110,000 m^3. The blended product is then pumped from the new condensate storage tanks to the CALM buoy, to be loaded onto tankers for shipping.

2.3 Supporting Utilities and Offsites

The LNG Plant facilities and infrastructure comprise various systems that support the operation of the plant, such as those for power generation, freshwater supply and wastewater treatment. The existing systems were analysed during the preliminary design process to determine if they had capacity available to support the Project.

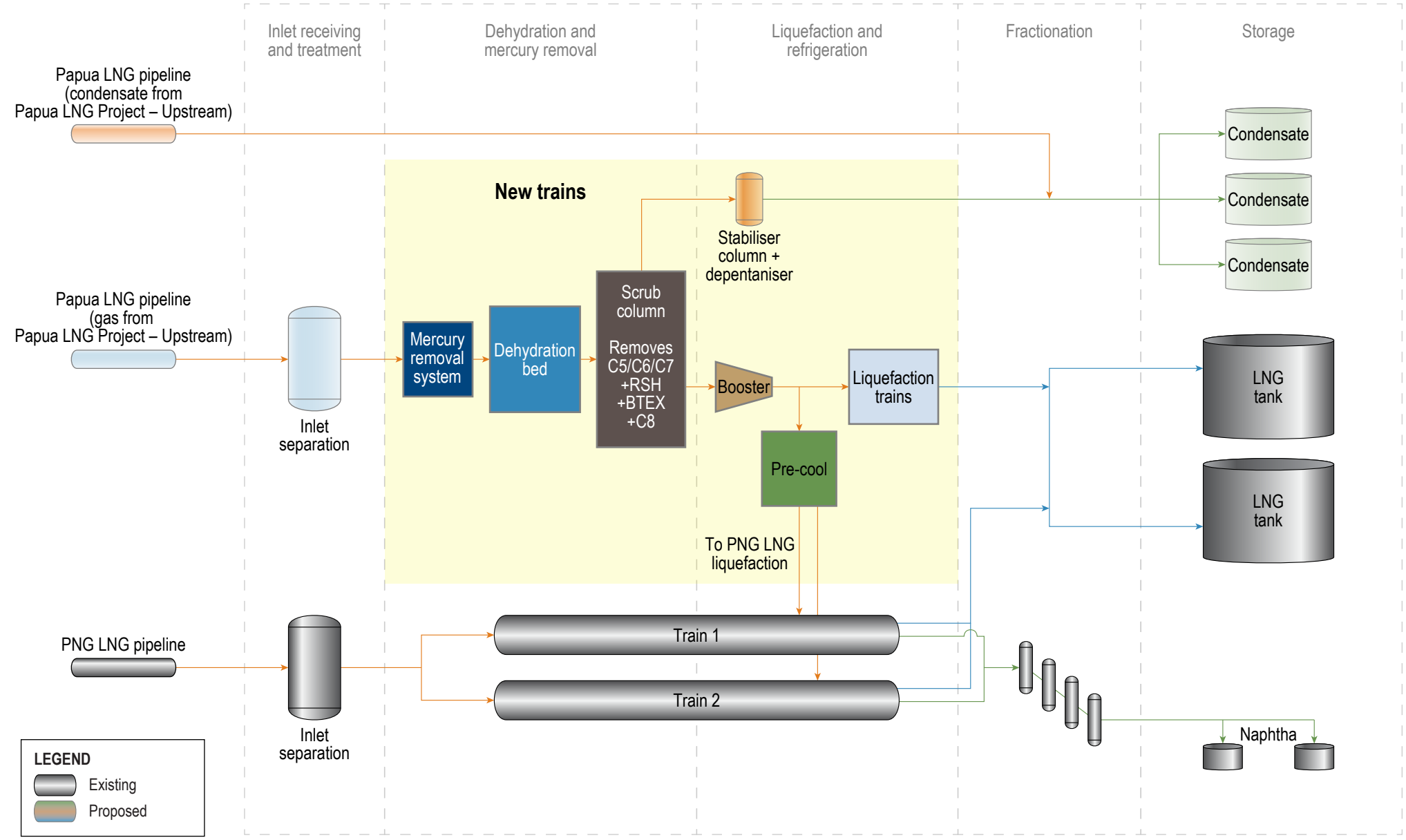
Facilities and infrastructure required to support the operation of the new LNG trains are distinguished by those that are shared facilities and those that are new facilities. The shared facilities will be common to existing and new trains and will utilise the available capacity of the existing LNG Plant systems with some modifications and upgrades to provide expanded capacity where required. New facilities will be for the operation of the new LNG trains.

The existing LNG Plant shared facilities and infrastructure that the Project will tie into, modify or expand include:

- Hot oil system
- Power generation system
- Service and instrument air system
- Nitrogen system
- Fresh water system
- Desalinated water system
- Fire water supply system
- Potable water system
- Diesel oil storage and distribution system
- Open and closed drain systems
- Sanitary wastewater treatment systems (sewage treatment plant, STP)

New facilities and infrastructure to be constructed include:

- Integrated fuel gas system
- Tempered water system
- Highly demineralised water system for the HRSGs
- Wet and dry flare systems
- Thermal oxidizer



EXXONMOBIL PNG ANTELOPE LIMITED

PAPUA LNG PROJECT – DOWNSTREAM

FIGURE 4

Overview of proposed LNG processing systems

SOURCE
EMPNGA

TETRA TECH COFFEY

DATE: 19.07.23 PROJECT: 754-MELEN300733 FILE: 300733_SLR_F004_GRA DOC REFERENCE: \\ETSS772GISFS1\DATA$\GIS\300733_EMPNG_PAPUALNGDOWNSTREAM\2_GRAPHICS\SLR300733_SLR_GRA001.AI_7

2.4 Temporary Facilities

Temporary facilities will be required during construction and include laydown areas, offices, workshops, a temporary desalination facility and concrete batching plants. These facilities will be located within the existing LNG Plant lease boundaries.

2.5 Marine Facilities

A catenary anchor leg mooring (CALM) buoy will be installed to expand the existing marine offloading facilities to accommodate the increased LNG and non-LNG liquids production rates and subsequent increase in the number of vessels. The CALM buoy will delink the non-LNG liquids (naphtha and condensate) from LNG offloading at the existing berth. The concept includes a second shipping channel, additional navigational and monitoring systems, and approximately 7 km of subsea pipelines for the naphtha and condensate. Additional upgrades to the existing berth are being considered to improve maintainability such as the installation of a maintenance crane and replacement of the existing condensate loading arm with an LNG loading arm.

2.6 Offshore Pipelines

Two new pipelines, one for feed gas (40-inch diameter pipe) and one for field condensate (10-inch diameter pipe), and including a fibre optic cable line, will be constructed, and operated as part of the Upstream component to deliver product to the LNG Plant. Combined, this pipeline infrastructure is referred to as the 'Papua LNG pipelines'. The Papua LNG pipelines are to be located on the southern side of the existing LNG Plant jetty and traverse the existing LNG Plant PPFL2 boundaries (see Figure 3).

The Papua LNG pipelines will be laid on the sea floor by a pipelaying vessel and pulled ashore by equipment located on land. Depending on seabed conditions, the pipe will be placed in an excavated trench, or laid by ploughing or jetting. The Papua LNG pipelines will be concrete-coated to weigh them down and for protection from external influences.

The offshore pipelines will connect to a short section of onshore pipeline that will then 'tie-in' to the LNG Plant.

2.7 Workforce and Accommodation

An estimated peak construction workforce of between 5,000 and 7,000 people will be needed to construct the Project over the planned four-year period. Construction camps for company and contractor personnel will be established to cater for the workforce and staff requiring accommodation, numbering between approximately 4,000 to 6,000.

A construction camp will be established within the LNG Plant site, to the west of the existing operations camp (Camp A). Camp A has approximately operational 500 beds, of which approximately 300 personnel represent the steady state requirement on site. This provides approximately 200 beds for overflow capacity for events such as major maintenance programs and unplanned events.

The permanent operations and maintenance workforce is expected to increase by approximately 50 technicians to support the integrated LNG Plant. Support staff is anticipated to increase and will be evaluated throughout FEED. The staffing change from a 28/28 rotation to a walk-in/out strategy for local workers decreases the overall camp requirement during operations from 300 to 200 by 2026.

Camp A will not be expanded and is sufficient to meet increased capacity from the Project, and that of the integrated LNG Plant.

2.8 Logistics Route

Most construction material will be imported by ship via Motukea Port and trucked to site along the Lea Lea Road. If materials are shipped to Motukea Port then the Road may require repairs or upgrade, including relocation of overhead cables, to accommodate heavy and/or overweight vehicles and transport of large modules. Transport of construction and operations personnel from Port Moresby will also occur along this road.

Smaller sensitive equipment and time constrained shipments may be transported by air to Jacksons International Airport in Port Moresby and trucked to the LNG Plant.

2.9 Commissioning and Operation

Commissioning activities will be required to test the modified shared facilities and new facilities at the LNG Plant. These activities are expected to include testing the operation of individual components and systems, including flaring during start-up.

The operational and maintenance procedures are expected to be similar to those in place at the existing LNG Plant.

2.10 Project Schedule

Timeframes for key project development milestones are shown in **Table 2**.

Table 2 Project Timeframe

Key Milestone	Timeframe
Environment surveys and approval process	2022 to 2023
Front-end engineering design	2023
Detailed engineering design	2024 to 2026
Construction	2023 to 2027
Commissioning and start-up	2027 to 2028

3 The Greenhouse Effect

The greenhouse effect is a naturally occurring process that aids in heating the Earth's surface and atmosphere. It results from the fact that certain atmospheric gases, such as carbon dioxide, water vapor, and methane, are able to change the energy balance of the planet by absorbing longwave radiation emitted from the Earth's surface. Without the greenhouse effect, life on this planet would probably not exist as the average temperature of the Earth would be around -18 degrees Celsius (°C), rather than the present 15°C.

As energy from the Sun passes through the atmosphere a number of things take place. A portion of the energy (26% globally) is reflected or scattered back to space by clouds and other atmospheric particles. About 19% of the energy available is absorbed by clouds, gases (like ozone), and particles in the atmosphere. Of the remaining 55% of the solar energy passing through the Earth's atmosphere, about 4% is reflected from the surface back into space. Thus, on average, about 51% of the Sun's radiation reaches the Earth's surface. This energy is then used in a number of processes, including the heating of the ground surface; the melting of ice and snow and the evaporation of water; and plant photosynthesis.

The heating of the ground by sunlight causes the Earth's surface to become a radiator of energy in the longwave band (infrared radiation). This emission of energy is generally directed to space. However, only a small portion of this energy actually makes it back to space. The majority of the outgoing infrared radiation is absorbed by GHGs.

Absorption of longwave radiation by the atmosphere causes additional heat energy to be added to the Earth's atmospheric system. The now warmer atmospheric GHG molecules begin radiating longwave energy in all directions. Over 90% of this emission of longwave energy is directed back to the Earth's surface where it once again is absorbed by the surface. The heating of the ground by the longwave radiation causes the ground surface to once again radiate, repeating the cycle described above, again and again, until no more longwave radiation is available for absorption.

The amount of heat energy added to the atmosphere by the greenhouse effect is controlled by the concentration of GHGs in the Earth's atmosphere.

Emissions of GHGs can result from natural or man-made (anthropogenic) sources. Examples of natural sources include the decomposition or burning of plant material and emissions of methane from animal digestion processes. Emissions also occur as a result of human activities and such sources include the burning of fossil fuels, the use and leakage of refrigerants, the clearing of forest and other vegetation, and the use of fertilisers, amongst other sources. This separation of natural versus anthropogenic sources is complicated by the fact that natural processes may be manipulated by humans, resulting in increased emissions of GHGs.

On Earth, human activities are changing the natural greenhouse effect. A number of gases are involved in the human-caused enhancement of the greenhouse effect including (NASA, 2019):

- **Carbon dioxide** (CO_2): A minor but very important component of the atmosphere, CO_2 is released through natural processes such as respiration and volcanic eruptions and through human activities such as deforestation, land use changes, and burning fossil fuels. Humans have increased the atmospheric CO_2 concentration by more than a third since the Industrial Revolution began.

- **Methane** (CH_4): A hydrocarbon gas produced both through natural sources and human activities, including the decomposition of wastes in landfills, agriculture (especially rice cultivation), as well as ruminant digestion and manure management associated with domestic livestock. On a molecule-for-molecule basis, CH_4 has a higher GHG warming potential than CO_2, but is also one which is much less abundant in the atmosphere.
- **Nitrous oxide** (N_2O): A powerful GHG produced by soil cultivation practices, especially the use of commercial and organic fertilisers, but also (in lesser amounts) from fossil fuel combustion, nitric acid production, and biomass burning.
- **Chlorofluorocarbons** (CFCs): Synthetic compounds, entirely of industrial origin, used in a number of applications, but now largely regulated in production and release to the atmosphere by international agreement for their ability to contribute to destruction of the ozone layer. They are also GHGs.

Over the last century, the burning of fossil fuels such as coal and oil has increased the concentration of atmospheric CO_2. This happens because the coal or oil burning process combines carbon with oxygen in the air to make CO_2. To a lesser extent, the clearing of land for agriculture, industry, and other human activities has also increased concentrations of GHGs. Vegetation and soils typically act as a carbon sink, storing carbon dioxide that is absorbed through photosynthesis. When the land is disturbed, part of the stored carbon dioxide is emitted through mechanisms such as burning or decomposition of vegetation etc., re-entering the atmosphere. Land disturbance will often also remove the associated carbon sink decreasing the potential for future CO_2 removal.

Quantifying linkages between emissions of GHGs from an individual project to resulting global GHG concentrations and climate warming is not possible due to a host of uncertainties and a lag in the climate system. Action by national governments aimed at reducing GHG emissions by sector and national totals will result in mitigation of climate change. Hence, accurate quantification of GHG emissions will aid the ongoing assessment of climate impacts and the development of targeted and effective policies and strategies to reduce the impact of global climate warming.

4 Relevant Legislation, Guidelines and Policies

4.1 International Framework

Several mechanisms are in place to encourage international cooperation in the management and minimisation of GHG emissions, including the Intergovernmental Panel on Climate Change (IPCC), United Nations Framework Convention on Climate Change (UNFCCC), the Equator Principles, the Kyoto Protocol and the Paris Agreement. The function of each of these is outlined below.

4.1.1 Intergovernmental Panel on Climate Change

The IPCC was established in 1988 and operates to provide decision makers and others interested in climate change with an objective source of information. The IPCC prepares assessment reports based on available scientific evidence and produce guidance documents and recommended methodologies for GHG emission inventories.

4.1.2 United Nations Framework Convention on Climate Change

The UNFCCC was established in 1994 following the release of the first technical report written by the IPCC. It comprises 172 countries (parties) that have ratified the Kyoto Protocol (see **Section 4.1.4**). The UNFCCC sets the overall framework for efforts to manage climate change on an international scale.

4.1.3 The Equator Principles

The Equator Principles is a risk management framework adopted by financial institutions for determining, assessing and managing environmental and social risk in project finance. It is primarily intended to provide a minimum standard for due diligence to support responsible risk decision-making.

Formally launched in Washington DC in June 2003, The Equator Principles were based on existing environmental and social policy frameworks established by the International Finance Corporation (IFC). Since then, the standards have been periodically updated to build upon implementation expertise and ongoing learnings, as well as to reflect changes in the evolving operating environment and good practices. The reviewed fourth iteration of the Equator Principles were published in July 2020 (Equator Principles Association, 2020).

4.1.4 The Kyoto Protocol

The Kyoto Protocol was in force as of 16 February 2005 and commits member states to individual, legally binding targets to limit or reduce GHG emissions. PNG, amongst a number of other developing countries, forms part of the Non-Annex I Parties. Non-Annex I countries do not have legally binding emissions reductions targets.

4.1.5 The Paris Agreement

The Paris Agreement was established in 2015 and sets in place a durable and dynamic framework for all countries to take action on climate change from 2020. The key objectives of the Paris Agreement include:

- a goal to limit the increase in global temperatures to well below 2 degrees and pursue efforts to limit the rise to 1.5 degrees
- a commitment to achieve net-zero emissions, globally, by the second half of the century

- differentiated expectations for developed nations, that they will reduce their emissions sooner than developing nations
- a five-year review and ratchet process designed to lead to more ambitious commitments from countries in the future.

4.1.6 26th UN Climate Change Conference

The United Kingdom hosted the 26th UN Climate Change Conference of the Parties (referred to as COP26) in Glasgow in October-November 2021. This was the first meeting after the initial five-year period, which meant that countries needed to submit or update their plans for reducing emissions.

Nations adopted the Glasgow Climate Pact, aiming to turn the 2020s into a decade of climate action and support. The Glasgow Pact refers to a package of decisions agreed to at COP26 covering a range of items, including strengthened efforts to build resilience to climate change, to curb greenhouse gas emissions and to provide the necessary finance for both. Nations reaffirmed their duty to fulfill the pledge of providing $100 billion annually from developed to developing countries. They collectively agreed to work to reduce the gap between existing emission reduction plans and what is required to reduce emissions, so that the rise in the global average temperature can be limited to 1.5°C. For the first time, nations are called upon to phase down unabated coal power and inefficient subsidies for fossil fuels.

4.2 The Papua New Guinean Response to Climate Change

PNG ratified the UNFCCC in 1993, the Kyoto Protocol in 2002 and the Paris Climate Change Agreement in 2016.

In March 2008, PNG entered into a cooperative agreement with Australia to reduce GHG emissions from deforestation and forest degradation: the '*Papua New Guinea-Australia Forest Carbon Partnership'*. Nearly two-thirds of PNG's land area is forested (more than 29 million hectares in area). Additionally, PNG's tropical forests are being targeted for carbon emission reduction schemes under the REDD+ (reducing emissions from deforestation and forest degradation in developing countries) mechanism (OCCD, 2014). The REDD+ mechanism is aimed at offsetting carbon emissions by protection of forest that would otherwise have been degraded by logging or other means.

In May 2018, the governments of PNG and Australia signed the Papua New Guinea – Australia Climate Change Action Plan, affirming their joint commitment to work together to advance effective actions on climate change. Under this action plan, a commitment has been made to:

- establish an annual Climate Change Dialogue
- develop the capacity of PNG national, provincial and local governments to address the impact of climate change
- support PNG to access international and private climate finance opportunities
- cooperate on direct programs for climate change action
- support the development of clean energy markets and continue to focus on climate smart infrastructure.

PNG 2050 is a framework for a long-term strategy for the future direction of PNG and has been compiled by the National Planning Committee (NSPT, 2009). It includes seven strategic focus areas (referred to as pillars) with one of these pillars related to environmental sustainability and climate change. The focus of strategic objectives (and priority activities) in this area relate to sustainable development, conservation and use of natural resources, improvement in the understanding of environmental issues, conservation of language and cultural diversity and effective partnerships and cooperation with the international community.

The PNG Climate Change & Development Authority (CCDA, formerly the Office of Climate Change and Development (OCCD)) coordinates the Climate Change efforts of the Government of Papua New Guinea and is the designated National Authority under the UNFCCC. The CCDA aims to ensure that PNG's future development is climate compatible and achieved in accordance with the country's GHG emissions targets. In addition, the CCDA aims to build the resilience of socio-economic and ecological systems and reduce vulnerability to climate change at the local level, and at the same time deliver on its international obligations.

The CCDA is mandated under the *Climate Change (Management) Act 2015* (PNG Parliament, 2015), amended in 2021 (PNG Parliament, 2021), with the responsibility to contribute toward global efforts in mitigating GHG emissions, through low carbon development that fosters economic growth and social welfare for the people's wellbeing and prosperity. Pursuant to Part II Section 10 of the *Climate Change (Management) Act 2015*, the CCDA's Corporate Plan 2018-2022 (the most recent available) states that its purpose is to (CCDA, 2018):

- promote and manage climate compatible development through climate change mitigation and adaptation activities
- implement relevant obligations of the State under applicable rules of international law and international agreements related to climate change
- act as PNG's Designated National Authority (DNA) for the purposes of the Paris Agreement and any such other or subsequent arrangements or agreements made under the Paris Agreement, and related purposes. Under these arrangements, CCDA is the DNA for the issuance of Host Country Letter of Approval for all projects and activities related to Carbon Trading or any form of Carbon Offset Projects
- establish and administer trust funds that facilitate the control and distribution of the received benefits and levies
- implement the *United Nations Paris Agreement (Implementation) Act 2016* pursuant to Section 7.

The CCDA Corporate Plan 2018-2022 is understood to be in the process of being reviewed and updated, however it is not known when an update is expected to be released. Strategy 3.1 within the CCDA Corporate Plan 2018-2022 relating to GHG emissions reporting and reduction targets, and the associated objectives and key performance indicators, are reproduced in **Table 3**.

Table 3 PNG CCDA Objectives and KPIs relating to GHG Emission Targets

Objectives	Key Performance Indicators (KPI)
1. Establish and maintain an effective and comprehensive GHG data inventory system	i. Carbon dioxide emissions from all sectors monitored, reported and verified
	ii. Enabling environment for REDD+ results based payment (RBP) created
2. Improve and maintain an effective system of reporting greenhouse gas emissions and carbon neutral development	iii. Reduction in GHG emissions against 2018 baseline of 14,251 Gg and 2022 target of 12,000 Gg
	iv. Progressive reporting against 50% GHG emissions reduction by 2030 target per Nationally Determined Contribution (NDC)
	v. Progressive reporting against carbon neutral target before 2050 per Copenhagen Accord under the UNFCCC

In March 2016, PNG submitted its first NDC under the United Nations Framework Convention on Climate Change (PNG Parliament, 2016). In December 2020, an updated NDC was submitted, which states:

> *As part of PNG's energy transition, the country is targeting a transition in its energy mix in the energy industries for the share of installed capacity of renewables from 30 percent in 2015 to 78 percent in 2030 for on-grid connection managed by PNG Power Limited. This target is conditional and based on the availability and timing of international support. The National Electricity Roll-Out Plan and PNG Power Limited's 15-year power development plan were used to establish this target and will also be used to monitor the progress of this target.*
>
> *This target represents a decrease from PNG's original target of 100 percent renewable by 2030. This revision is based on:*
>
> - *Enhanced information on existing and planned projects and the time lag to operationalize larger generation projects.*
> - *The expansion of PNG's LNG sector and its increased role in electricity generation - which, while allowing for removal of or avoidance of higher emission energy sources from the grid, do not present a renewable energy resource.*

4.3 Relevant GHG Performance Standards

In the absence of PNG-specific guidance published by the PNG CCDA, this GHG assessment has been prepared with reference to the following international guidelines and reporting standards.

4.3.1 The Equator Principles

The Equator Principles (Equator Principles Association, 2013) are applied by financial institutions globally across all industry sectors to all new project financings with project capital costs of US$10 million or more. For a project to be eligible for a loan through an Equator Principle Financial Institution (EPFI) it must conform to a set of ten principles, of which *Principle 3: Applicable Social and Environmental Standards* is of specific importance with regard to this Project.

Principle 3 requires that for projects located in a Non-Designated Country (such as PNG), a Project's compliance with the applicable International Finance Corporation (IFC) Performance Standards on Social and Environmental Assessments, and the World Bank Group (WBG) Environmental, Health, and Safety (EHS) Guidelines. All assessments are to be carried out to the EPFI's satisfaction of overall compliance, or with justified deviation from the respective IFC Performance Standards and WBG EHS Guidelines.

In relation to GHG emissions, IFC Performance Standard 3, *Resource Efficiency and Pollution Prevention*, requires that:

> *"In addition to the resource efficiency measures described above, the client will consider alternatives and implement technically and financially feasible and cost-effective options to reduce project-related GHG emissions during the design and operation of the project. These options may include, but are not limited to, alternative project locations, adoption of renewable or low carbon energy sources, sustainable agricultural, forestry and livestock management practices, the reduction of fugitive emissions and the reduction of gas flaring.*
>
> *For projects that are expected to or currently produce more than 25,000 tonnes of CO_2-equivalent annually, the client will quantify direct emissions from the facilities owned or controlled within the physical project boundary, as well as indirect emissions associated with the off-site production of energy[1] used by the project. Quantification of GHG emissions will be conducted by the client annually in accordance with internationally recognized methodologies and good practice.*

This GHG assessment has been prepared to meet the requirements of Performance Standard 3.

4.3.2 IFC Environmental Health and Safety Guidelines for Liquified Natural Gas Facilities

The IFC EHS Guidelines are technical reference documents with general and industry-specific examples of Good International Industry Practice. These guidelines include industry sector EHS guidelines that are designed to be used together with the General EHS Guidelines document, which provides guidance to users on common EHS issues potentially applicable to all industry sectors.

4.3.3 The Greenhouse Gas Protocol

The GHG Protocol Initiative is a multi-stakeholder partnership of businesses, non-governmental organisations (NGOs), governments and others, convened by the World Resources Institute (WRI) (a US-based environmental NGO), and the World Business Council for Sustainable Development (WBCSD) (a Geneva-based coalition of 170 international companies). The objective of the GHG Protocol Initiative is to develop internationally accepted GHG accounting and reporting standards for business.

The GHG Protocol comprises two separate but linked standards:

- **GHG Protocol Corporate Accounting and Reporting Standard**–- This document provides a step-by-step guide for companies to use in quantifying and reporting their GHG emissions.
- **GHG Protocol for Project Accounting**–- A guide for quantifying reductions from GHG mitigation projects.

[1] *Refers to the off-site generation by others of electricity, and heating and cooling energy used in the project*.

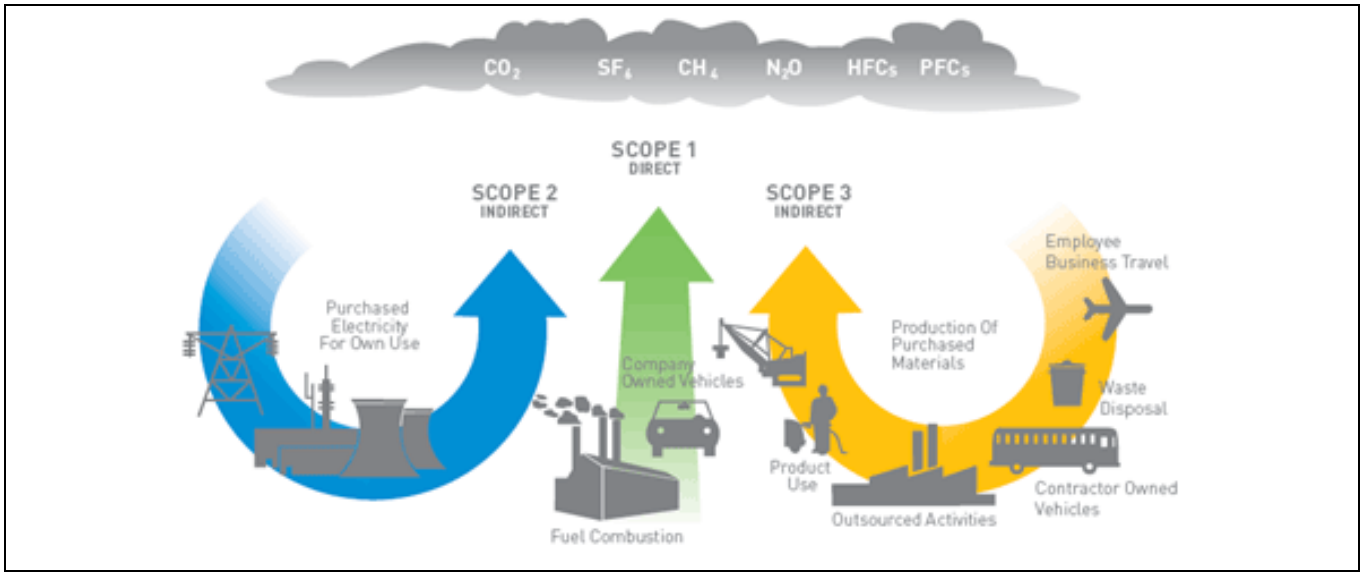
The first edition of the GHG Protocol Corporate Accounting and Reporting Standard was published in September 2001, covered the accounting and reporting of the six GHGs covered by the Kyoto Protocol and has been widely adopted by industry, NGO and government organisations as a basis for GHG accounting and reporting systems. The latest edition of the GHG Protocol Corporate Standard (WRI, 2004), has been referred to in preparing this assessment.

4.4 Scope Definition

Emissions of GHG can be termed as being *Scope 1, Scope 2* or *Scope 3*, and '*direct*' or '*indirect*' emissions (**Figure 5**).

The definitions below for each Scope have been taken from the WRI and WBCSD GHG Protocol (WRI, 2004). These documents provide detailed information on the activities which should be included in each of the Scope 1, 2 and 3 boundaries. The definition of these boundaries allows the determination of those sources of GHG emissions that can be directly controlled by the Project (Scope 1 and Scope 2), or those that the Project will have some, but limited control over (Scope 3).

Figure 5 Scope 1, 2 and 3 GHG Emissions as Defined in the GHG Protocol Initiative



Source: WRI (2004)

4.4.1 Direct Emissions (Scope 1)

Direct emissions of GHG are termed Scope 1 emissions and are produced from sources within the boundary of the Project and as a result of the Project's activities. These direct emissions will arise from the following sources associated with proposed Project activities and may include:

- transportation of materials, products, waste or people
- generation of electricity, heat and/or steam
- flaring during commissioning activities, maintenance activities and plant upsets
- fugitive emissions

- On-site waste management, e.g., solid and liquid waste management through landfilling, incineration and sewage treatment plant(s).

Once the Project is operational, the electricity produced by the CCPP will be shared with the LNG Plant. This new power source will enable the LNG Plant to shut down all of its less efficient gas turbine generators or put them on standby. In this estimate, allocations of GHG estimates from the CCPP between the two facilities is based on the design power needs of the two facilities. Future GHG allocation procedures will be identified as part of the commercial arrangements for sharing gas and utilities between the joint sites, with measurement facilities to be provided consistent with those agreements.

4.4.2 Indirect Emissions (Scope 2 and Scope 3)

Indirect emissions are generated in the wider economy as a consequence of an organisation's activities but are physically produced by the activities of another organisation.

Scope 2 Emissions

The most important category of indirect emissions is from the consumption of purchased electricity (Scope 2 emissions). Scope 2 emissions relate to the GHG emissions from the generation of purchased electricity consumed within the boundary of the organisation and as a result of the organisation's activities.

As the Project will not be sourcing any appreciable quantities of electricity from the PNG grid (i.e., only for offices etc in Port Moresby), Scope 2 emissions have not been considered further in this assessment.

Scope 3 Emissions

An organisation wishing to undertake a full life cycle analysis of their product would include all of the following activities within their emissions inventory as Scope 3 emissions:

- extraction and production of purchased materials and fuels
- transport-related activities, including:
  - transportation of purchased materials or goods
  - transportation of purchased fuels
  - employee business travel
  - employees commuting to and from work
  - transportation of sold products
  - transportation of waste
- electricity related activities not included under Scope 2 emissions, including:
  - extraction, production and transportation of fuels consumed in the generation of electricity
  - purchase of electricity that is sold to an end user
  - generation of electricity that is consumed in a transport and distribution system
- leased assets, franchises and outsourced activities
- use of sold products and services
- waste disposal

- disposal of waste generated in operations
- disposal of waste generated in the production of purchased materials and fuels
- disposal of sold products at the end of their life

The Equator Principles do not require the assessment and reporting of Scope 3 emissions, other than emissions associated with off-site generation of heating and cooling energy used in the project (in addition to Scope 2 emissions associated with the use of electricity from the grid) if the project's Scope 1 emissions are more than 25,000 tonnes CO_2-e/annum.

4.5 Global Warming Potentials

For comparative purposes, non-CO_2 GHGs are awarded a "CO_2-equivalence" (CO_2-e) based on their contribution to the enhancement of the greenhouse effect. The CO_2-equivalence of a gas is calculated using an index called the Global Warming Potential (GWP). GWPs are periodically updated by the IPCC in line with improvements to the underlying science. The 100-year GWPs of potential relevance to the Project, as taken from the IPCC's Fourth (IPCC, 2007), Fifth (IPCC, 2013) and Sixth (IPCC, 2021) Assessment Reports (AR4, AR5 and AR6 respectively) are presented in **Table 4**. The AR6 values (IPCC, 2021) have been used in this assessment.

Short-lived gases such as carbon monoxide, nitrogen dioxide, and non-methane volatile organic compounds (NMVOCs) vary spatially and it is consequently difficult to quantify their contribution to project GHG emissions. For this reason, GWP values are generally not attributed to these gases, nor have they been considered further as part of this assessment.

No significant sources of other GHGs (such as hydrofluorocarbons or perfluorocarbons) have been identified as part of the project, therefore they have not been considered further as part of this assessment.

Table 4 Global Warming Potentials

Gas	Chemical Formula	IPCC Global Warming Potentials (100-year horizon)		
		Fourth Assessment Report [1]	Fifth Assessment Report [2]	Sixth Assessment Report [3]
Carbon dioxide	CO_2	1	1	1
Methane	CH_4	25	28	29.8
Nitrous oxide	N_2O	298	265	273
Sulfur hexafluoride	SF_6	22,800	23,500	25,200

1: (IPCC, 2007); 2: (IPCC, 2013); 3: (IPCC, 2021)

5 Identification of GHG Emissions

5.1 Definition of the Project Boundary

The geographical boundary set for Scope 1 emissions considered in the GHG assessment covers the Project area comprising the LNG Plant and facilities located within the fence of the LNG Plant, south of the existing jetty (see **Figure 2**). GHG emissions associated with construction and operation of these infrastructure areas are considered to be within the geographical boundary of this assessment.

As noted in **Section 4.4.2**, Scope 2 emissions have not been included as the Project will not be sourcing any appreciable quantities of electricity from the grid or other third-party generators, and any associated GHG emissions will be negligible.

Scope 1 GHG emissions will also occur during decommissioning of the Papua LNG plant and associated facilities at the end of their design life. Future options for the LNG Plant will vary between life extension, upgrading or decommissioning. Due to the uncertainty regarding the fate of the plant at that time, the GHG emissions associated with the end-of-life phase of the LNG Plant and other infrastructure associated with the Project have not been estimated as part of this study. These emissions will need to be evaluated in detail in the future, once the potential options are understood, and should be factored into the decisions regarding the ongoing operation or decommissioning of the facilities.

5.2 Identification of Emission Sources

Construction and operational phase emission sources have been identified by a review of the Project description and GHG emissions projections provided by EMPNGA. The emissions associated with the construction and operational phases that were considered in preparing this GHG assessment are listed in **Table 5**.

The new plant will be installed within the existing site footprint, hence no clearing will be required during the construction phase beyond slashing of grass at the proposed laydown area adjacent to the site. No emissions associated with vegetation clearance or land use change have therefore been identified for the Project.

GHG emissions from the vessel loading of condensate and naphtha from the export lines are anticipated to be negligible. Both product streams must be stabilised for transportation, which means their Reid vapor pressure must be less than 12, and there would be no material emissions of methane.

No appreciable quantities of sulfur hexafluoride (SF_6) are currently used on site, nor would there be significant quantities required for the project. Scope 1 emissions associated with the leakage of SF_6 from switchgear have therefore not been considered in this assessment.

Table 5 Identified Potential GHG Emission Sources for the Project Construction and Operation

Project Activity	Scope 1 Emission Source
CONSTRUCTION	
Construction (LNG Plant, pipelines, camps, etc.)	• Emissions from diesel combustion in construction equipment, including drill rigs, forklifts, cranes, concrete batch plants, etc. *Note: Fuel consumption data for construction of the CALM buoy was not available and has therefore not been included in the inventory*
Vehicle movements transporting staff and equipment	• Emissions from diesel combustion in light vehicles, buses and trucks, etc.
Power generation	• Emissions from diesel combustion in portable power generators (gensets) used during pipeline construction.
Flaring	• Emissions from flaring of gas during commissioning.
Management of solid waste and wastewater	• Emissions from organic material decomposition in landfill, sewage treatment
OPERATION	
Fuel gas combustion – LNG Plant	• Emissions from fuel gas combustion in compressors, power generation units and furnaces.
Flaring – LNG Plant	• Emissions from gas flaring at the LNG Plant
Fugitive emissions – LNG Plant and pipelines	• Fugitive leakage of methane from sources such as unintentional equipment leaks from valves, flanges, pump seals, compressor seals, relief valves, sampling connections, process drains, open-ended lines and tanks.
Vehicle movements transporting staff and equipment	• Emissions from diesel combustion in light vehicles, buses and trucks, etc.
Management of solid waste and wastewater	• Emissions from organic material decomposition in landfill, sewage treatment
	• Emissions from liquid waste incineration.

Note: Shaded cells denote emission sources excluded from the emissions inventory as they are minor sources and not material to the assessment.

In relation to potential GHG emission sources associated with the treatment and disposal of waste generated by the Project:

- Emissions from sewage and wastewater treatment will be negligible compared to the other operational and construction-related emissions. Given this, these emissions are not considered to be material to the assessment and have not been considered further.
- Information provided by the Project design team on waste stream compositions showed that the types of wastes to be landfilled are mostly inert and do not have any significant biodegradable content. As a result, any emissions of GHGs generated within the landfill from this waste will be very minor and have also not been considered further in this assessment.
- Annual GHG emissions from waste incineration at the LNG Plant for proposed operations (noting that the existing on-site incinerator is no longer operational) were included in the emission inventory.

6 Emission Estimation

6.1 Emission Calculation Methodologies

6.1.1 Scope 1 Emissions

Operational phase annual emission estimates calculated by the Project design team for the following Scope 1 emission sources for 2023 to 2030 were adopted as part of this GHG assessment:

- Existing and future LNG Plant Operations – Trains 1 and 2:
  - Operational GHG emissions associated with combustion of fuel gas in engines, heaters, boilers, reboilers, turbines and flaring
  - Fugitive emissions
  - Venting
  - Combustion of fuel in mobile equipment, vessels, and vehicles.
- Papua LNG Project New Trains – Downstream construction, commissioning, and operation:
  - Emissions associated with fuel use in stationary engines, mobile equipment, vessels, and vehicles
  - Emissions associated with flaring during commissioning and operations
  - Operational emissions associated with combustion of fuel gas in the CCPP turbines providing power to both Papua LNG and PNG LNG facilities, which may allow PNG LNG to shut down all of its less efficient gas turbine generators or put on standby, thereby reducing its emissions
  - Fugitive emissions
- The Project also includes processing of up to 2 mtpa gas from the Papua LNG Upstream Project in Trains 1 and 2. The GHG emissions from the following LNG Plant Operations associated with the processing of this resource will be responsibility of the Project:
  - Operational GHG emissions associated with combustion of fuel gas in engines, heaters, boilers, reboilers, turbines and flaring
  - Fugitive emissions
  - Combustion of fuel in mobile equipment, vessels, and vehicles.

Emissions from the incineration of waste were estimated according to the following formula (DISER, 2021):

$$E_i = Q_i \times CC_i \times FCC_i \times OF_i \times 3.664$$

where:

E_i is the emissions of carbon dioxide released from the incineration of waste type ‘i’ by the plant during the year measured in CO_2-e tonnes.

Q_i is the quantity of waste type ‘i’ incinerated by the plant during the year measured in tonnes of wet weight value

CC_i is the carbon content of waste type ‘i’ (default is 0.60 for clinical waste).

FCC_i is the proportion of carbon in waste type ‘i’ that is of fossil origin (default 0.40)

OF_i is the oxidation factor for waste type ‘i’ (default 1).

Using the default values for CC_i, FCC_i and OF_i, the factor is 0.88 t CO_2-e per t waste.

6.1.2 Scope 2 Emissions

As noted above, Scope 2 emissions were not included in the inventory, as the Project will not be sourcing any appreciable quantities of electricity from the grid or other third-party generators.

6.2 Activity Data

A summary of the activity data and assumptions used in the calculations for each source is provided below.

The existing LNG Plant waste incinerator is currently not functional, and a new incinerator will be designed and installed that will be able to cater to the requirements of the waste from the existing and expansion facilities. A summary of the estimated waste quantities requiring incineration from the expanded facility operations is provided in **Table 6**. It was assumed that the incinerator would start operations during construction year two.

Table 6 Annual Waste Incineration Estimates for the integrated LNG Plant

Waste Type	Quantity (kg/annum)	Percentage of Waste Stream
Paper and cardboard	257,123	30%
Domestic/camp waste or trash (refuse / food)	250,060	29%
Grease trap waste / sludges	129,000	15%
Organic waste (trees, leaves, grass, dead animals etc.)	54,825	6%
Medical waste	54,083	6%
Filters (water, air)	44,590	5%
Styrofoam	41,084	5%
Other	25,761	3%
Total	**856,526**	**100%**

6.3 Estimated GHG Emissions

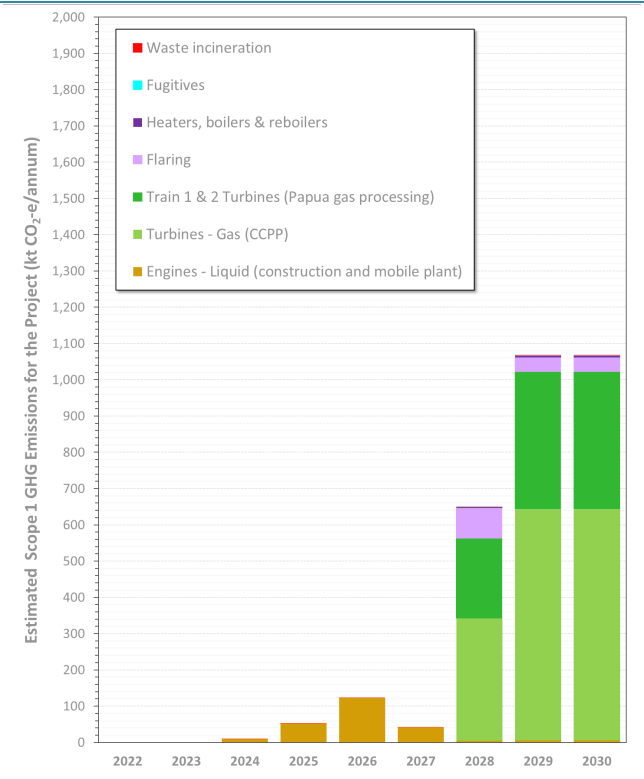
The annual Scope 1 (direct) GHG emissions estimated for the Project using the approach outlined above are summarised in **Figure 6** and **Table 7**. These emission estimates contain a degree of uncertainty and are subject to change as detailed design of the Project moves forward.

In **Figure 6**, estimated GHG emissions associated with gas processing in New Trains as well as processing of Papua gas in Trains 1 and 2 have been grouped together in plot (a) to provide the total estimated emissions associated with processing LNG Plant gas, while plot (b) presents the estimated GHG emissions associated with processing LNGP gas only in Trains 1 and 2 (i.e. excluding Papua gas processing). The breakdown between emissions from Trains 1 and 2 associated with processing LNG Plant gas versus Papua gas is provided in **Table 7**.

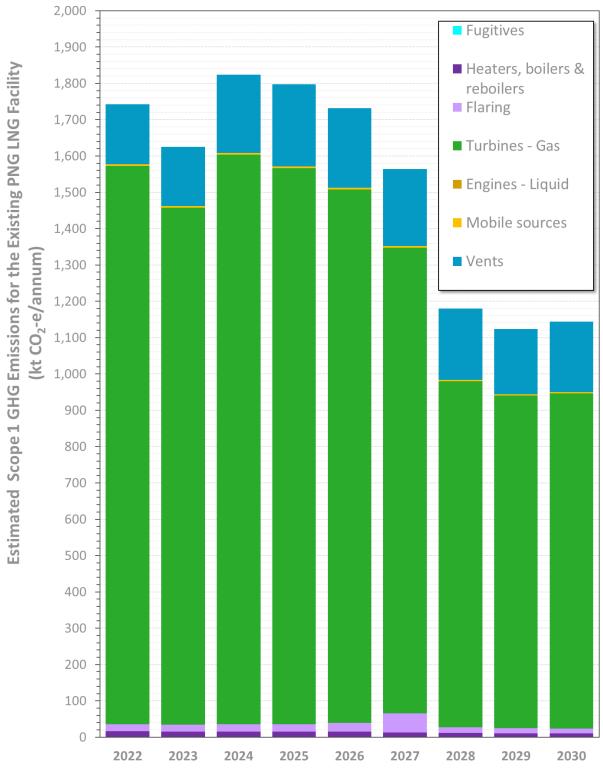
As shown in **Figure 6** and **Table 7**, the estimated Scope 1 GHG emissions for the project construction phase (2024 to 2027) are minor compared to the current LNG Plant operation emissions, and are almost totally associated with fuel combustion in fixed and mobile construction sources. As would be expected, flaring emissions peak during 2028, associated with commissioning of the new trains.

Once commissioning is completed (2029 and 2030), the total Papua LNG Project - Downstream Scope 1 emissions are estimated at approximately 1,060 kt CO_2-e per annum, with the main sources being the combustion of fuel gas in the CCPP turbines (638 kt CO_2-e per annum) and in the Train 1 and 2 turbines associated with processing Papua gas (378 kt CO_2- e per annum).

Figure 6 Estimated Scope 1 Emissions



(a) Projet emissions associated with gas processing in New Trains as well as processing of Papua LNG Upstream gas (2 Mtpa) in Trains 1 and 2



(b) Emissions associated with gas processing in PNG LNG Trains 1 and 2 – LNG Plant gas processing only

Table 7 Summary of Estimated Scope 1 Emissions

Source/Activity	2022	2023	2024	2025	2026	2027	2028	2029	2030
Existing LNG Plant (Trains 1 and 2) – LNG Plant Only, Estimated Annual GHG Emissions in kt CO_2-e/annum									
Engines – Liquid	0.16	0.16	0.17	0.17	0.16	0.16	0.14	0.13	0.12
Flaring	19.99	19.99	19.99	20.03	24.62	51.98	16.56	14.66	12.75
Fugitives	0.49	0.49	0.59	0.62	0.63	0.63	0.61	0.59	0.60
Heaters/boilers/reboilers	15.49	14.34	15.29	14.93	14.30	12.42	10.57	10.13	10.23
Turbines – Gas	1,536.53	1,422.46	1,567.48	1,530.93	1,468.51	1,282.74	951.86	914.88	923.27
Vents	164.64	162.71	215.13	225.62	218.46	211.98	196.20	179.75	193.78
Mobile sources	4.66	4.53	4.81	4.81	4.73	4.52	4.20	3.90	3.59
Sub-Total	**1,741.9**	**1,624.7**	**1,823.4**	**1,797.1**	**1,731.4**	**1,564.4**	**1,180.1**	**1,124.0**	**1,144.3**
Papua LNG Project – Downstream, Estimated Annual GHG Emissions in kt CO_2-e/annum									
Papua LNG New Trains									
Turbines – Gas	-	-	-	-	-	-	337.26	637.50	637.50
Engines – Liquid	-	-	4.99	27.16	73.52	25.15	-	-	-
Flaring	-	-	-	-	-	-	77.27	30.00	30.00
Mobile sources	-	-	4.21	25.08	49.78	16.67	4.12	4.12	4.12
Waste incineration	-	-	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Sub-Total	**-**	**-**	**10.0**	**53.0**	**124.1**	**42.6**	**419.4**	**672.4**	**672.4**
LNG Plant Trains 1 and 2 - Papua Gas Processing									
Engines	-	-	-	-	-	-	0.02	0.04	0.04
Flaring	-	-	-	-	-	-	6.74	11.55	11.55
Fugitives	-	-	-	-	-	-	0.07	0.13	0.13
Heaters/Boilers/Reboilers	-	-	-	-	-	-	2.22	3.81	3.81
Turbines	-	-	-	-	-	-	220.38	377.79	377.80
Mobile sources	-	-	-	-	-	-	0.66	1.12	1.12
Sub-Total	**-**	**-**	**-**	**-**	**-**	**-**	**230.1**	**394.4**	**394.4**
TOTAL *	**-**	**-**	**10.0**	**53.0**	**124.1**	**42.6**	**649.5**	**1,066.8**	**1,066.8**

* Including Papua gas processing in Trains 1 and 2.

Figure 7 combines the separate plots presented in **Figure 6** and shows that once the Papua LNG Project is commissioned, total annual Scope 1 emissions from the integrated LNG Plant and Papua LNG Facility in 2029 and 2030 are estimated to represent an approximate 27% increase on the forecast 2022 Scope 1 emissions estimated for the LNG Plant.

Figure 7 Total Estimated Scope 1 Emissions from the integrated LNG Plant

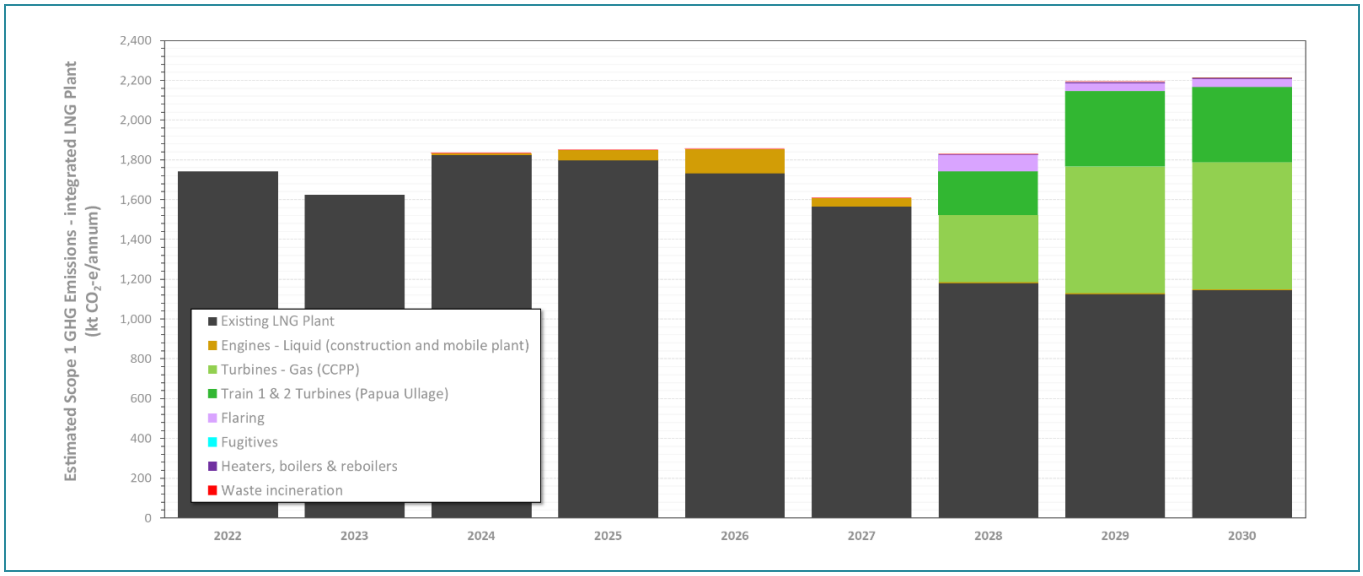


Figure 8 shows that the Papua LNG Project – Downstream is forecasted to result in an improved emissions intensity for the combined expanded facility, of around 17.1 tonnes CO_2-e per 100 tonnes of product available to market, compared to the current estimated emissions intensity of approximately 18.7 tonnes CO_2-e per 100 tonnes of product available to market for the LNG Plant in 2022 (excluding emissions from the Hides Gas Processing Plant).

Figure 8 Forecasted Estimated Scope 1 Emissions Intensities

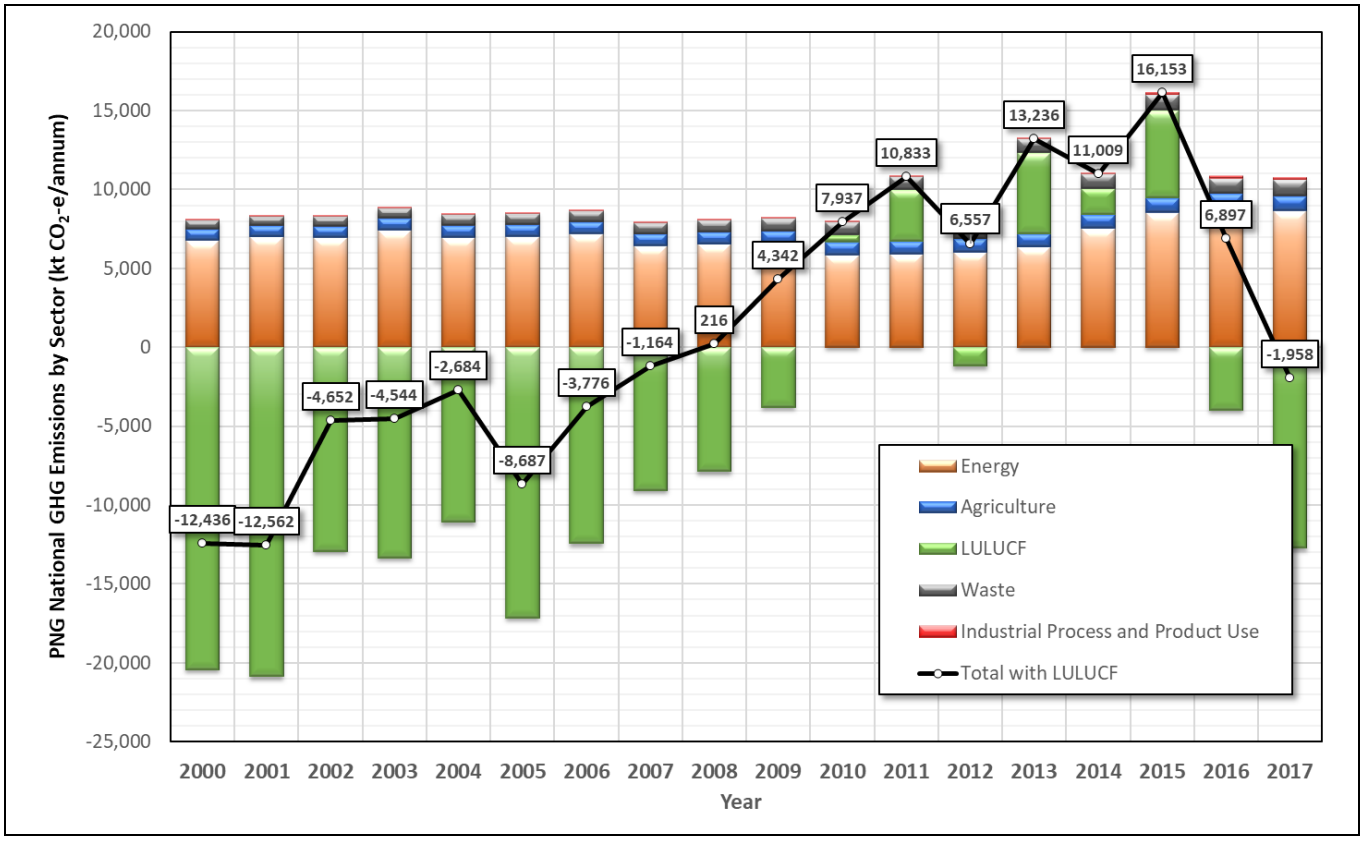
7 Comparison with National Emissions

7.1 PNG Current GHG Emissions Inventory

In April 2019, the PNG Government released *Papua New Guinea's First Biennial Update Report to the United Nations Framework on Climate Change* (CCDA, 2018). This first Biennial Update Report (BUR1) presented an overview of PNG's national circumstances relevant to climate change along with an inventory of anthropogenic GHG emissions by sources and removals by sinks for years 2000 through to 2015. It also presented information on identified mitigation actions and associated constraints and gaps, including information on the results achieved by Papua New Guinea from reducing emissions from deforestation, forest degradation and enhancement of forest carbon stocks.

In May 2022, an updated National Inventory Report (NIR) 2000 – 2017 (CCDA, 2022) was submitted to the UNFCCC. A summary of the PNG GHG emission inventory data presented in the NIR 2000 – 2017 report is presented in **Figure 9**.

Figure 9 Estimated National GHG Emissions for PNG (2000 to 2017)



Source: (CCDA, 2022)

The emissions and removals presented in the NIR 2000 – 2017 report are split between the following five sectors:

- Energy
- Industrial processes and product use (IPPU)
- Agriculture, forestry and other land use
- Land use, land-use change and forestry (LULUCF)
- Waste

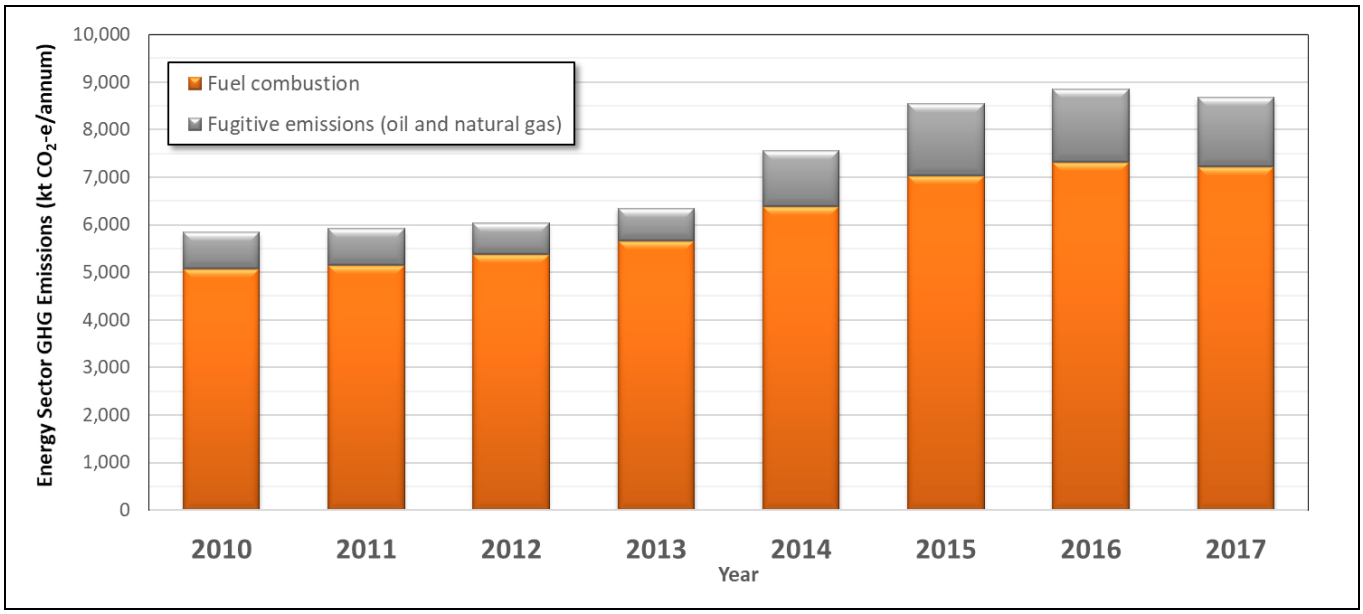
It is stated in the report that the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC, 2006) were used to estimate emissions and removals for the inventory. It is noted that the global warming potentials used in the emissions estimation were taken from the IPCC Second Assessment Report (see **Table 4**).

Further information on the estimated national emission inventory data for each sector is summarised below.

7.1.1 Energy

A breakdown of the estimated emissions for the energy sector is presented in **Figure 10**. Emissions from the energy sector were estimated at 8,673 kt CO_2-e in 2017, an increase of 1,913 kt CO_2-e (28%) when compared to 2010. CO_2 emissions from liquid fuel combustion contributed 68% of the total GHG emissions in 2017, followed by CH_4 from fugitives (16%), CO_2 from gaseous fuel combustion (12%), N_2O from fuel combustion (2%), CH_4 from fuel combustion (1%) and CO_2 from fugitive emissions (1 %). Approximately 81% of total sector emissions are CO_2, while CH_4 contributed 17%, and N_2O the remaining 2%.

Figure 10 Estimated GHG Emissions from the Energy Sector (2010 to 2017)



Source: (CCDA, 2022)

7.1.2 Agriculture, Forestry and Other Land Use

GHG emissions from the agricultural sector are generally linked to the management of agricultural soils, livestock, rice production and biomass burning. The main agricultural sources of GHG emissions in PNG are the following:

- enteric fermentation, part of the digestive process for many ruminants such as cattle, sheep and goats, which produces methane (CH_4) emissions
- nitrification and denitrification of the nitrogen present in soils, which produces nitrous oxide (N_2O) emissions
- manure decomposition under anaerobic condition, which produces methane emissions)

Biomass burning in forest lands is captured under the Land Use Land-Use Change and Forest (LULUCF) sector. Biomass burning of other land use, liming, urea application and rice cultivation are not estimated due to limited or unavailability of data.

GHG emissions from this sector amounted to 934.7 kt CO_2-e in 2017, which is about 9% of the national emission in that year (excluding LULUCF). Total GHG emissions increased by 203 kt CO_2-e (28%) when compared with the year 2000. The highest emitting category in 2017 was direct N_2O emissions from managed soils, which contributed 57% of the total sector emissions. After this, the enteric fermentation category contributed 18%, followed by manure management with 17%, and indirect N_2O emissions from managed soils with about 7%.

The BUR1 report stated that the increasing trend in emissions from agriculture since 2000 has been mainly driven by national economic growth and the increased demand for agricultural commodities, which has led to a large number of agriculture and livestock development initiatives in the country.

7.1.3 Land use, Land-Use Change and Forestry (LULUCF)

The LULUCF sector covers the emissions and removals from carbon stock changes due to land use and forest management. Non-CO_2 emissions from biomass burning are also included under this sector.

The LULUCF sector is one of the biggest sectors in the PNG GHG emission inventory, and historically acted as a sink. As shown in **Figure 9**, this sector has become an increasingly smaller sink over time due to a decrease in forest lands, and in 2010, 2011, 2013, 2014 and 2015 the LULUCF sector was a net source. The increase in emissions in 2015 was caused by an increase in the area of land affected by forest fire. The decrease in the net emissions for the years 2016 and 2017 shown for the LULUCF sector in **Figure 9** is due to decreases in deforestation and forest degradation areas.

The NIR 2000-2017 report states that in PNG, the majority of the population undertakes family agriculture, which is one of the main causes of deforestation. Oil palm, cocoa and coconut are the major crops responsible for deforestation due to commercial agriculture.

Commercial (selective) logging was identified as the major driver of forest degradation, responsible for 90% of the degradation occurring during the reporting period. Commercial and subsistence agriculture are also major drivers of forest degradation, which contributes to most of the emissions in the LULUCF sector.

7.1.4 Waste

Estimated emissions from the waste sector increased from 2000 to 2015 due to population growth, development, consumer consumption rate increases and rural-to-urban drift. The emissions from this sector were estimated to be 1,006 kt CO_2-e in 2017. Wastewater treatment and discharge was estimated to contribute 67% to total sector emissions in 2015, followed by solid waste disposal (27%), incineration and open burning (6%), and biological treatment of solid waste (0.7%).

The NIR 2000 – 2017 report states that limited activity data were available to carry out GHG emission estimations for the waste sector and most of the GHG emission estimates were performed based on population-based emission factors, assumptions and expert judgement. At present, industrial waste is not considered in the GHG estimates for the waste sector.

7.1.5 Industrial Processes and Product Use (IPPU)

PNG's economy is dominated by resources, agriculture, forestry, and fishing, and also includes a small import-substituting manufacturing sector. A number of these activities involve an industrial process or a product use that results in GHG emissions, including lubricant use, refrigeration and air-conditioning. A number of import-substituting manufacturing industries also result in the emission of non-GHGs (CO, NOx (oxides of nitrogen), NMVOC) and include food, beverage, and tobacco manufacturing. The import of N_2O used in products also gives rise to GHG emissions. The estimated emissions from this sector cover two categories:

- Non-energy products from fuels and fossil fuels: Accounts for application of lubricants used in transportation and industry in the form of oil types
- Product used as substitutes for ozone depleting substances (included from 2015 onwards): Based on bulk hydrofluorocarbon (HFC) import data
- Other product manufacture and use: Accounts for emissions from use of N_2O for anaesthetic, analgesic and veterinary use

Emissions from other categories within the IPPU sector were not included, either because they do not occur in PNG or have not been estimated due to data limitations. This includes emissions from the Mineral Industry, Chemical Industry and Metal Industry, as well as emissions associated with stocks of SF_6 in the country, which are all reported as 'not occurring' until confirmed otherwise via the GHG Inventory Improvement Plan

The total estimated emissions for the IPPU sector was 153.3 kt CO_2-e in 2017. Approximately 98% of this relates to hydrofluorocarbon emissions.

The NIR 2000 – 2017 report acknowledges that the IPPU inventory remains largely incomplete.

7.2 Assessment of Project Contribution

Emissions from the Project will be included in PNG's future national GHG emissions inventory as part of the Energy Sector emissions. As outlined in **Section 7.1.1**, emissions from PNG's energy sector in 2017 were reported to be 8,673 kt CO_2-e in 2017. The Scope 1 2022 GHG emissions estimated for the existing LNG Plant is 1,742 kt CO_2-e (20% of the reported total sector emissions).

Once the Papua LNG Project - Downstream is built and operating, the total annual Scope 1 emissions from the integrated LNG Plant in 2029 and 2030 are estimated to be approximately 27% higher than the forecast 2022 Scope 1 emissions estimated for the LNG Plant. On this basis, the Project is projected to contribute an additional 470 kt CO_2-e/annum, representing an increase of around 5% for the energy sector, and would increase PNG's national emissions (excluding LULUCF) from 10,767 kt CO_2-e/annum reported for 2018 by around 4%.

8 Mitigation and Monitoring

8.1 ExxonMobil GHG Emissions Management and Monitoring

Total GHG emissions are calculated and reported on an annual basis. In 2021, LNG Plant facilities generated approximately 2,132 kt CO_2-e, which was primarily from gas turbine fuel consumption at the LNG Plant and Hides Gas Conditioning Plant (EMPNG, 2022).

8.1.1 Project Design

EMPNG's *Environmental Management Plan: LNG Plant and Marine Facilities* (the EMP) notes that minimising GHG emissions was considered during engineering, design and procurement of equipment for the existing LNG Plant. Aero-derivative turbine technology was selected due to its high fuel efficiency and subsequent lower GHG emissions, when compared to traditional frame turbine technology. In addition, the waste heat recovery units utilise heat from the gas turbine refrigerant compressor exhausts to provide the main source of heat to the hot oil system.

The minimisation of GHG emissions has also been a key consideration in the design of the Papua LNG Project - Downstream. Specifically, the following priorities were identified for the plant design in relation to GHG emissions mitigation:

- identifying design choices that have the potential to improve the GHG performance of the operating LNG Plant, with any design choices that change the projected GHG emissions by 5 kt CO_2-e/annum or greater to be communicated to management for further investigation; and
- providing a plant design that does not preclude subsequent projects at the site that may reduce GHG emissions intensity.

Optimisation of energy use and minimisation of GHG emissions will be a key consideration throughout the detailed design phase of the project. An overview of the key GHG considerations incorporated into the current design of the Project is provided below.

Native CO_2

CO_2 in gas reservoirs (i.e., native CO_2) is expected to be removed at the Central Processing Facility (CPF) and sent directly from the CPF to a sequestration site. Therefore, no native CO_2 is to be received at the downstream facility and there are no significant or continuous CO_2 vents in the plant design.

Power Generation

Power for the new Papua LNG trains will be supplied by an on-site centralized power plant featuring gas and steam turbines used together to generate more electricity from the same fuel than either could do alone. The gas turbine drives an electrical generator, and the exhaust gas is used to produce steam. The steam then drives another turbine to create additional electricity. Such a configuration is called a combined cycle power plant (CCPP). With this CCPP, the Project will benefit by requiring less fuel and in creating fewer GHG emissions when compared to previous power solutions.

The CCPP configuration also seeks to maximise the gas turbine generators' normal operating efficiency, and consideration has been given to design options that preserve the flexibility to convert the site to a fuel gas supply of up to 100% hydrogen in the future. To this end, the plant design considers the future addition of a hydrogen generation facility to replace the existing fuel gas system. Electric LNG (eLNG) trains were also selected as the design basis to enable the potential for power supply from renewable generation in the future.

The CCPP may allow PNG LNG's less efficient Solar Titans to be on standby or shut down, supplying power to both plants to optimise fuel gas and reducing GHG emissions under normal operations (power share mode).

Other options for self-generation of power were investigated, but solar, wind and hydro power generation options were all deemed inadequate for the Project at this time. The connection to the external power grid will be maintained to facilitate the possibility of power import in the future, should suitable renewable or other low GHG-intensity electrical power become available through the external power grid.

Flaring

The design is expected to minimise flaring at the facility via a Flare Gas Recovery System (FGRS). This system is expected to achieve a reduction in GHG emissions from the Papua LNG flare system of approximately 13 kt CO_2- /year.

As the plant design is refined, further options to minimise flaring (i.e., during initial plant start up, plant restart and abnormal operating conditions) will be assessed and considered. Flare flow rate measurement will be provided to support flare GHG emissions tracking and reporting.

LNG Tank Boil-off Gas (BOG) Recovery System

Given the high methane content of the LNG Product, GHG emissions from its storage will be minimised via a boil-off gas (BOG) recovery system. If there is a short-term outage of the BOG system, BOG will be sent to the flare for destruction (i.e., conversion of the methane to CO_2) rather than vented, to minimise GHG emissions.

Process Regeneration Gas Heaters

Process regeneration gas heating is currently proposed to be provided by a steam or electrical heating source. As steam and electric heating has not previously been used for this service, if technical issues arise with that option a fired heater would be used instead, which would be designed for compatibility with a possible future fuel gas of up to 100% hydrogen.

Mobile Emissions Sources

Material handling studies for the Project will prioritise the use of electrically powered material handling equipment over diesel or petrol powered equipment as much as feasible.

Energy Efficiency in Design

Most of the energy used in the plant operation will be provided by combustion of fuel gas, so efficient use of energy throughout the plant is aimed at reducing the GHG intensity of the facility and conserving fuel gas. Energy efficient practices incorporated into the plant design include:

- use of feed/effluent and other heat recovery heat exchangers
- selection of rotating equipment that operates close to the best efficiency point for normal operation
- addition of one or more process hydraulic turbines to increase overall plant efficiency
- fuel gas flow rate measurement on all combustion equipment or devices to support flare GHG emissions tracking and reporting through an automated data management system

8.1.2 Construction

An Air Quality and GHG Management Plan will be prepared as part of the project's Construction Environmental and Social Management Plan. Construction-related GHG mitigation measures that will be adopted during the detailed design and construction of the project are as follows:

- consider the GHG implications of modularisation during the construction planning process
- minimise the use of temporary diesel power generator units by connecting to the existing gas turbine generators for electrical power supply or leverage grid power (which is natural gas sourced from PNG LNG), where possible
- where possible, schedule deliveries and activities to minimise distances travelled
- maintain equipment and vehicles in good working order to maximise fuel efficiency
- minimise waste to minimise GHG emissions from treatment/disposal and transport of waste
- sort waste as much as possible to minimise quantities landfilled and to maximise recycling and reuse
- track and report on GHG emissions and associated activity data (i.e. fuel consumption) to assist in identifying key emission sources and appropriate targeting of mitigation measures.

8.1.3 Operations

GHG emissions are tracked and reported to internal and external stakeholders as part of EMPNG's environmental performance reporting requirements. Site emission sources are accounted for, including generators, turbine compressors, flares, process vents and mobile sources such as vehicles and tugboats. Direct process fuel usage is used with approved emission factors to calculate the final GHG emissions.

A fugitive emissions monitoring program will also be implemented at the site (ExxonMobil, 2022).

Year-on-year trends in the estimated GHG emissions are reviewed and any differences noted are used to understand any potential changes in operations.

The management and monitoring measures included in the PNG LNG EMP would also be leveraged and, and updated where necessary, for the integrated LNG Plant operated by Niugini LNG Operating Company Limited to undertake as part of its operational responsibilities once the Project has been constructed and commissioned. GHG allocation procedures will be identified as part of the commercial arrangements for sharing gas and utilities between the joint sites, with measurement facilities to be provided consistent with those agreements.

9 Conclusions

A GHG emissions inventory has been compiled for the Papua LNG Project – Downstream and the significance of the estimated annual emissions has been assessed against the emissions from EMPNG's current operations in PNG as well as PNG's most recent available national GHG emissions inventory.

The inventory included Scope 1 emissions covering the construction and operational phases of the Project. Scope 2 emissions were not included as the Project will not be sourcing any appreciable quantities of electricity from the PNG grid or other third-party generators.

GHG emissions will also occur during decommissioning of the LNG Plant and other associated facilities at the end of their design life. Due to the uncertainty regarding the fate of the plant at that time, GHG emissions associated with the end-of-life phase of the LNG Plant and other infrastructure associated with the Project were not included.

Construction phase Scope 1 emissions were provided by ExxonMobil, along with operational phase annual emission estimates for the following Scope 1 emission sources for 2023 to 2030:

- Existing and future LNG Plant Operations – Trains 1 and 2:
  - Operational GHG emissions associated with combustion of fuel gas in engines, heaters, boilers, reboilers, turbines and flaring
  - Fugitive emissions
  - Venting
  - Combustion of fuel in mobile equipment, vessels and vehicles.
- Papua LNG Project – Downstream construction, commissioning, and operation (New Trains):
  - Emissions associated with fuel use in stationary engines, mobile equipment, vessels and vehicles
  - Emissions associated with flaring during commissioning and operations
  - Operational emissions associated with combustion of fuel gas in the CCPP turbines providing power to both Papua LNG and PNG LNG facilities, which may allow PNG LNG to shut down all of its less efficient gas turbine generators or put them on standby, thereby reducing its emissions
  - Fugitive emissions.
- Project-related emissions associated with up to 2 mtpa Papua gas processing in Trains 1 and 2 to utilise latent capacity:
  - Operational GHG emissions associated with combustion of fuel gas in engines, heaters, boilers, reboilers, turbines and flaring
  - Fugitive emissions
  - Combustion of fuel in mobile equipment, vessels, and vehicles.

A review of the emission estimates shows the following:

- The estimated Scope 1 GHG emissions for the project construction phase (2024 to 2027) are minor compared to the current LNG Plant Operation emissions and are almost totally associated with fuel combustion in fixed and mobile construction sources. Flaring emissions peak during 2028, associated with commissioning of the new trains.

- Once commissioning is completed, the total Papua LNG Project – Downstream Scope 1 emissions are estimated to be approximately 1,060 kt CO_2-e per annum, with the main sources of these emissions being the combustion of fuel gas in the CCPP turbines (638 kt CO_2-e per annum) and in the Train 1 and 2 turbines associated with processing Papua gas (378 kt CO_2-e per annum).
- The total annual Scope 1 emissions from the integrated LNG Plant are estimated to represent an approximate 27% increase compared to the forecast 2022 Scope 1 emissions estimated for the LNG Plant.
- On this basis, the Project is projected to contribute an additional 470 kt CO_2-e/annum, representing an increase of around 5% for the energy sector, and would increase PNG's national emissions (excluding LULUCF) from 10,767 kt CO_2-e/annum reported for 2018 by around 4%.
- The expansion is forecasted to result in an improved emissions intensity for the combined expanded LNG Plant of around 17.1 tonnes CO_2-e per 100 tonnes of product available to market, compared to the current estimated emissions intensity of approximately 18.7 tonnes CO_2-e per 100 tonnes of product available to market for the LNG Plant in 2022.

The LNG Plant and associated facilities are relatively new, which means that most current energy efficiency measures have already been incorporated into the design of the facility. The minimisation of GHG emissions has also been a key consideration in the design of the Papua LNG Project - Downstream. Specifically, the following priorities were identified for the plant design in relation to GHG emissions mitigation:

- developing a plant design that is in line with ExxonMobil's corporate-wide 2050 GHG emission reduction plans (Scope 1 and 2) as well as goals to reduce methane emissions;
- identifying design choices that have the potential to improve the GHG performance of the operating LNG Plant, with any design choices that change the projected GHG emissions by 5 kt CO_2-e/annum or greater to be communicated to management for further investigation; and
- providing a plant design that does not preclude subsequent projects at the site that may reduce GHG emissions intensity.

Optimisation of energy use and minimisation of GHG emissions will be a key consideration throughout the detailed design phase of the project. As noted above, once commissioned, the Project will result in an improvement in the greenhouse gas intensity of ExxonMobil's operations compared to current operations.

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