TOTAL E&P PNG LIMITED

PAPUA LNG

Upstream Environmental Impact Statement

Volume 3: Technical Studies

Part 5
Greenhouse Gas and Climate Change for Impact Assessment

TOTAL
TOTAL E&P PNG LIMITED

PAPUA LNG PROJECT

Greenhouse Gas and Climate Change Impact Assessment

Prepared for:

Total E&P PNG Limited

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EXECUTIVE SUMMARY

Introduction

SLR Consulting Pty Ltd (SLR) has been commissioned by ERIAS Group on behalf of TEP PNG to undertake a greenhouse gas (GHG) assessment and climate change study for the Papua LNG Project. This report presents the method, inputs, assumptions, findings and conclusions of this assessment and study.

GHG Assessment

The main objectives of the GHG assessment are as follows:

- Identify the key Project-related GHG sources during Project construction and operations and estimate the quantities of GHG emissions generated from these sources over the design life of the Project.
- Broadly characterize the current level of GHG emissions within Papua New Guinea, and the Project's emissions in the context of these levels.
- Identify feasible options to reduce Project-related GHG emissions over the design life of the Project.

In compiling the inventory, GHG emission sources associated with the construction, operations and decommissioning phases of the Project were identified, and categorized as either Scope 1, 2 or 3 emissions as follows:

- The geographical boundary set for Scope 1 (direct) emissions covers the footprint of the wellpads, CPF, Logistics Base, the existing Herd Base, Purari Airstrip, onshore and offshore pipelines, and the Caution Bay landfall approach. GHG emissions associated with the transportation of materials and workforce from Port Moresby to the Project area have also been considered as Scope 1 emissions, as well as emissions associated with their movement within the Project area.
- Scope 2 emissions have not been included as the Project will not be externally sourcing any appreciable quantities of electricity hence any associated GHG emissions will be minimal.
- GHG emissions associated with the international transport of materials and workers to/from Port Moresby, transport of product gas to end users and combustion of the gas by end users have been included in the assessment as Scope 3 (indirect) emissions.
- It is understood that TEP PNG will be responsible for processing of the gas produced by the Project at a new liquefied natural gas facility to be co-located within the existing PNG LNG Facility as part of a multi-operator site arrangement. However, for the purposes of this assessment, GHG emissions associated with the downstream processing of the gas have been included as a Scope 3 emission source and not as a Scope 1 emission source as the downstream processing is beyond the scope of this EIS.

Relevant GHG emission factors were sourced from international guidelines and industry publications. In addition, annual GHG emission estimates calculated by the Project design team for fuel gas combustion, flaring venting/diffuse emissions at the CPF were adopted as part of this GHG assessment. The relevant activity data required for the calculations (land clearance areas, fuel consumption rates, barging activity data) were compiled based on the Project description and in consultation with TOTAL.

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Scope 1 (direct) and Scope 3 (indirect) GHG emissions have been calculated for each year of the Project life and are presented graphically in **Figure ES.1** (Scope 1 emissions only) and **Figure ES.2** (Scope 1 and Scope 3 emissions). The estimated annual and Life of Project emissions are summarized in **Table ES.1**.

Table ES.1 Summary of Estimated Project GHG Emissions

Project Year	Estimated Annual GHG Emissions (kt CO_2-e)		
	Scope 1	Scope 3	Scopes 1 + 3
Construction Year 1	152	22	173
Construction Year 2	233	41	274
Construction Year 3	330	184	514
Construction Year 4	309	287	596
Construction Year 5	103	46	149
Operations Year 1 – HP phase, acid gas venting via TO (start-up year)	399	6,726	7,124
Operations Years 2 to 5 – HP phase, acid gas venting via TO (average)	1,489	11,710	13,199
Operations Years 6 to 10 – HP phase, acid gas injection (average)	597	11,710	12,306
Operations Years 11 to 15 – MP phase, acid gas injection (average)	818	11,667	12,485
Operations Years 16 to 23 – LP phase, acid gas injection (average)	760	6,140	6,900
Decommissioning Year 1	25	68	93
Decommissioning Year 2	25	68	93
Total Life of Project GHG Emissions	**20,682**	**220,286**	**240,968**

Note: Columns may not add up exactly due to rounding

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Figure ES.1 Estimated Annual Scope 1 GHG Emissions for Each Year of the Project Life

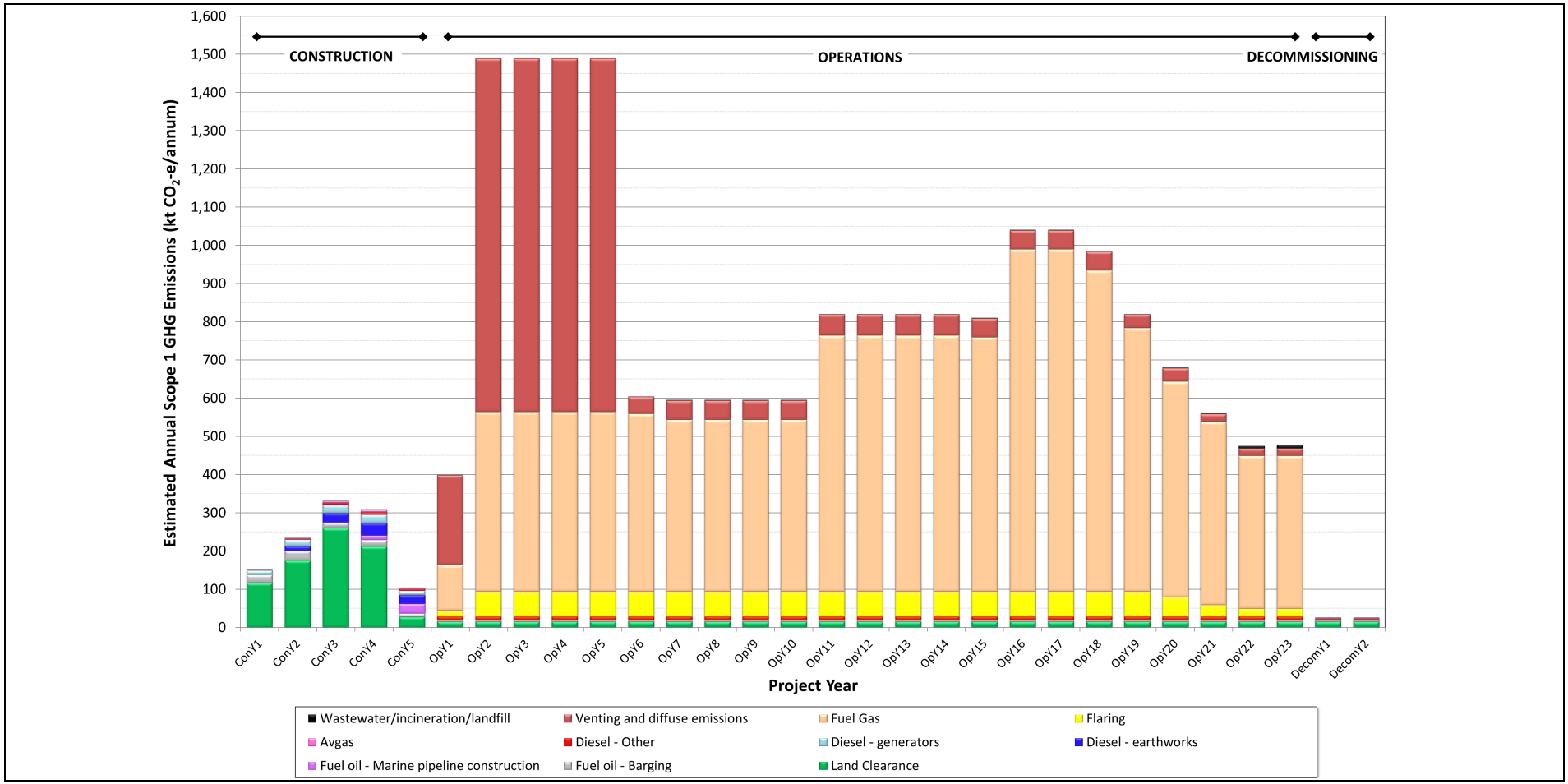

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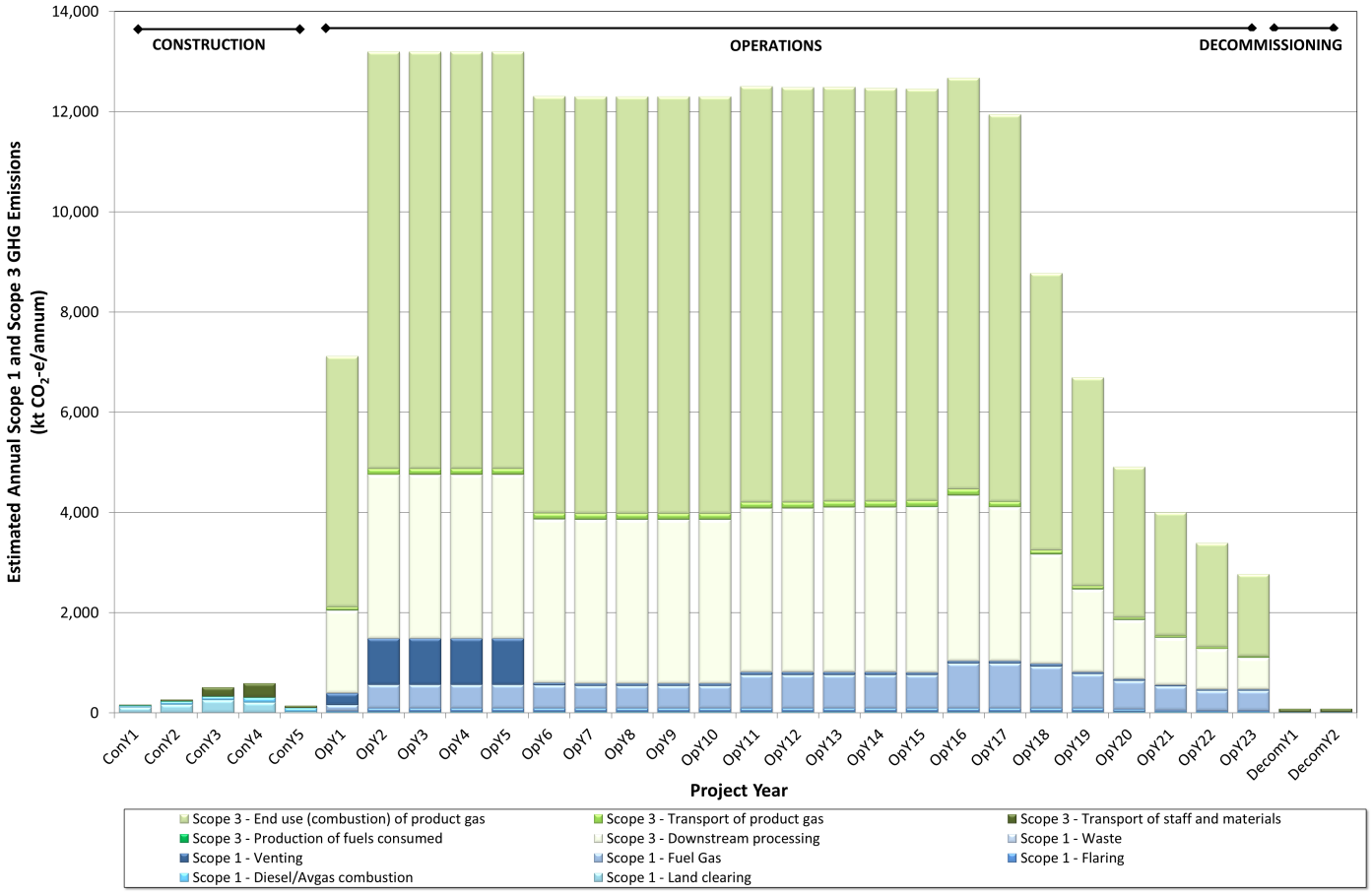
Figure ES.2 Estimated Annual Scope 1 and Scope 3 GHG Emissions for Each Year of the Project Life



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The annual and Life of Project emissions calculated for the Project indicate the following:

- The main contributor to the estimated Scope 1 emissions for the construction phase is the loss of carbon stocks due to land clearing, while the major Scope 1 emission source over the Project operational lifetime (61.8%) is the combustion of fuel gas.
- The Scope 1 emissions are shown to be highest during Years 2 to 5 of operation, which is due to the venting of acid gas (containing CO_2) via the thermal oxidizer. This reduces significantly after Year 5, when acid gas injection begins.
- Maximum calculated annual emissions of GHG (Scope 1 and 3) associated with Project operations are predicted to occur during Years 2 to 5 of operation, due to the Scope 1 emissions associated with the venting of acid gas via the thermal oxidizer. Over the Project life however, the most significant contributors to the estimated Scope 1 and 3 emissions are downstream processing of the gas (25.4%) and combustion of the product gas by the end user (64.8%).
- The indicative Scope 1 emission estimates compiled for the decommissioning phase are 25 kt CO_2-e per annum emitted for the assumed two year decommissioning period. These emissions represent a minor component of the Project in its entirety and are indicative only. 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 Project.
- The Scope 1 GHG emissions intensity (i.e. excluding downstream processing) is estimated to be 156.5 t GHG per thousand tonnes of hydrocarbon production. This emissions intensity value is slightly (4%) above the average value of 151 tonnes GHG per thousand tonnes of hydrocarbon production reported by the IOGP for Asia/Australia in 2017.
- Emissions from the Project would be included in PNG's national GHG emissions inventory as part of the Energy Sector emissions. The maximum annual Scope 1 GHG emissions estimated for the Project (i.e., during the acid gas venting phase in operations years 2 to 5) are 1,489 kt CO_2-e. This represents an additional 9.8% increase in the total reported national PNG GHG emissions (including LULUCF) for 2015 of 15,193 kt CO_2-e. The contribution during other years of the Project will be less than this (e.g. 3.9% during years 7 to 10).

Key design principles that have been adhered to during the pre-project phase to limit the Project's GHG emissions are as follows:

- No flaring during routine operations (flaring of natural gas strictly limited to minimum safety requirements such as start-up, maintenance, emergency situations and flare pilots).
- Injection of native acid gas (H_2S and CO_2) during Project life as soon as technically possible (acid gas venting (after removal of sulfur by the SRU) cannot be avoided during the first production years until sufficient depletion of the Elk reservoir).
- The Project will almost exclusively generate its own electricity from natural gas, minimizing the use of diesel fuel, which will also result in a lower GHG footprint.

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Climate Change Study

A climate change study has also been performed to assess the Project's vulnerability to the effects of climate change projected to occur within the region. The objectives of this study were to identify potential direct and indirect climate-related adverse effects that may affect the Project during its life-cycle and to identify opportunities for how the Project may improve its resilience to the effects of global climate change.

As part of this study, the existing climate features of Papua New Guinea and projections of the future climate were reviewed based on information contained within reports published by the Pacific Climate Change Science Program (PCCSP). Aspects of the Project that are potentially sensitive to climate changes projected to occur over the Project life cycle were then identified. These potential impacts were characterized as a function of the level of exposure to climate change (with consideration of factors such as duration, frequency and intensity of the change) and Project sensitivity (i.e., the degree to which the Project may be affected by the change). The adaptive capacity of the Project to the identified impacts was also assessed.

Based on the Project's potential exposure and sensitivity to the predicted climate change impacts, and the adaptive capacity of the Project in the design, construction and operations phases, its potential vulnerability to climate change was assessed. The main findings of this vulnerability assessment were as follows:

- There is an increased risk of flooding and landslides over the life of the Project associated with higher rainfalls and higher frequency of extreme rainfall events, and the potential for these events to result in damage to infrastructure and/or disruptions to logistics activities (barging, roads).
- The Project is concluded to have a low vulnerability to projected increased ambient temperatures due to its high adaptive capacity to the associated risks.
- Existing wave conditions in the nearshore zone and at river mouths have been identified as potentially being a restriction on vessel operations for the Project. While the PCCSP concludes that the climate models currently do not identify any significant changes in waves along the Coral Sea coast of Papua New Guinea in the future, this projection has a *low confidence*. Given that wave conditions already pose a risk for the Project, any unforeseen increases in wave heights, etc., due to climate change could exacerbate this. Relevant adaptation measures have therefore been included for implementation as required.

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1 Introduction

1.1 Project Overview

Joint venture partners are currently planning the development of the Elk-Antelope gas field, which is located within Petroleum Retention License 15 (PRL-15) in Gulf Province, Papua New Guinea (PNG). Total E&P PNG Limited (hereafter referred to as TEP PNG), a wholly owned subsidiary of TOTAL, has the largest interest in the Elk-Antelope gas field and is the operator of the Papua LNG Project (the Project) on behalf of the other joint venture partners.

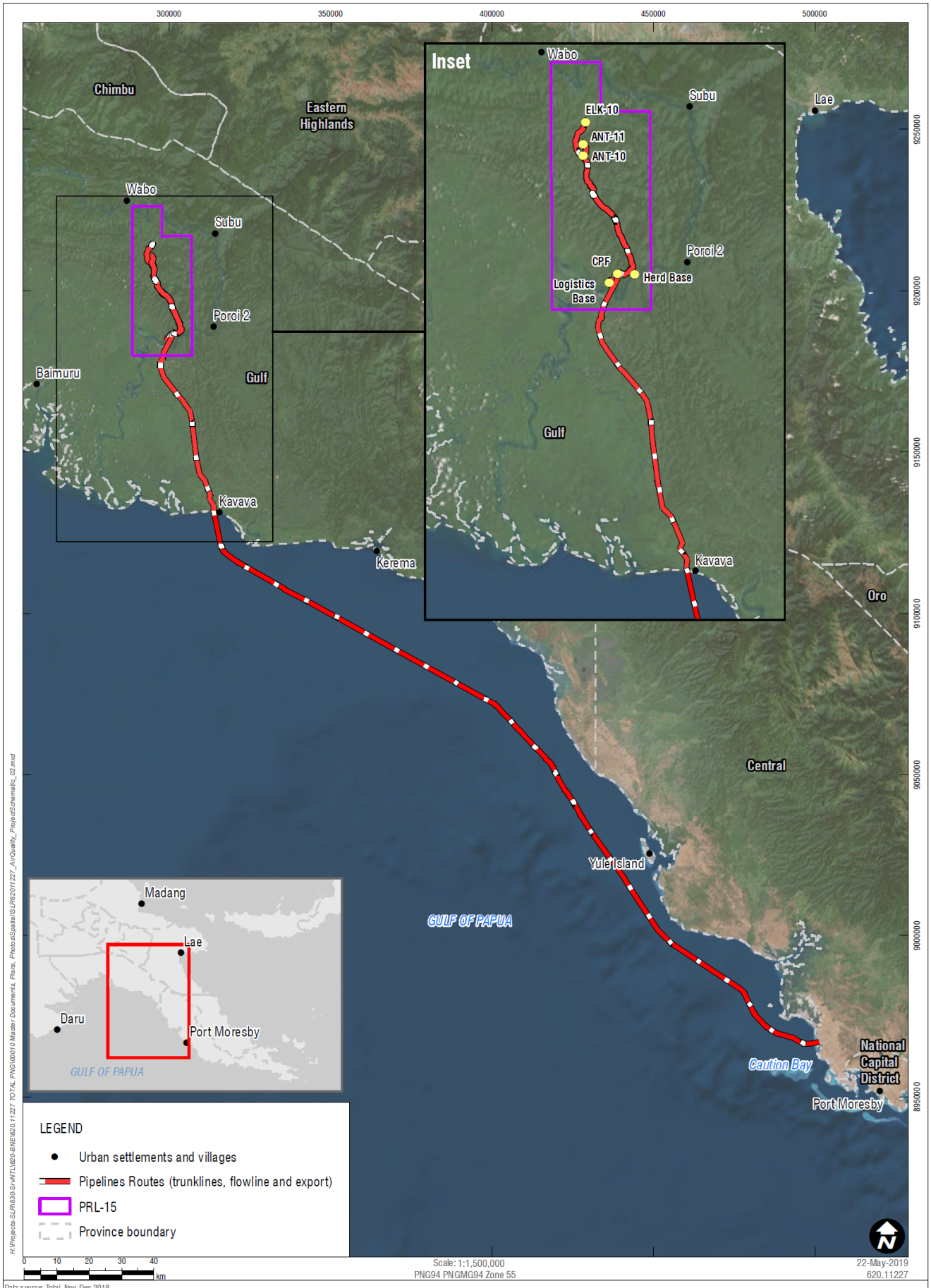
The Elk-Antelope gas field is a significant gas discovery in Papua New Guinea consisting of a gas reservoir with an estimated 7.2 trillion cubic feet (Tcf) of gas reserves and up to 100 million stock tank barrels (MMstb) of condensate, located approximately 120 km northwest from the provincial capital of Kerema, and 340 km northwest of Port Moresby (see **Figure 1**).

The Project will comprise upstream production well development and associated infrastructure at the gas field within PRL-15, construction of an upstream central processing facility (CPF) and delivery of gas and condensate via onshore and offshore export pipelines to new Liquefied Natural Gas (LNG) facilities to be co-located within existing PNG LNG facilities at Caution Bay, Central Province, 20 km northwest of Port Moresby. The new LNG facilities at Caution Bay are subject to a separate environment impact statement (EIS) and approvals process. The design life for the Project will be 25 years.

The Project area comprises the physical footprint of the various Project components and associated infrastructure as detailed below.

- Producing and processing the gas:
  - Wellpads and the associated gathering system (including flowlines and trunklines).
  - CPF.
- Transporting the gas:
  - Onshore export pipeline to landfall on the Gulf coast including valve stations.
  - Offshore section of the export pipeline to LNG plant site, Caution Bay.
- Infrastructure:
  - Camps.
  - Pipeyards.
  - New roads and upgrades.
  - Quarries.
  - Waste facilities including landfills.
  - A new logistics base and river offloading facilities.
  - Purari Airstrip extension.

River transport will be via the Purari and Ivo-Urika rivers.



Project Schematic

FIGURE 1

1.2 Study Objectives

SLR Consulting Pty Ltd (SLR) has been commissioned by ERIAS Group on behalf of TEP PNG to undertake a greenhouse gas (GHG) assessment and climate change study for the Papua LNG Project. This report presents the method, inputs, assumptions, findings and conclusions of this assessment and study.

The main objectives of the GHG assessment are as follows:

- Identify the key Project-related GHG sources during Project construction and operations and estimate the quantities of GHG emissions generated from these sources over the design life of the Project.
- Broadly characterize the current level of GHG emissions within Papua New Guinea, and the Project's emissions in the context of these levels.
- Identify feasible options to reduce Project-related GHG emissions over the design life of the Project.

The main objectives of the climate change study are as follows:

- Assess to what extent the Project is located in a 'climate change sensitive area'.
- Based on existing climate change predictions, identify changes to climatic conditions that may affect the Project facilities or exacerbate potential negative impacts from Project activities.
- Define a monitoring program, and mitigation and adaptation measures, as appropriate.
- Assess opportunities to mitigate risks associated with anticipated effects of climate change and support identifying adaptation needs for the Project.

The findings of the GHG assessment and climate change study will assist TEP PNG to reduce its exposure to increasing Project costs and potential schedule delays by proactively factoring in identified climate change risks, and to fulfill its obligations as a responsible oil and gas developer and producer.

2 Climate Change Science and GHG Emissions

2.1 Background

The greenhouse effect is a naturally-occurring process that warms the Earth's surface and atmosphere. It is the result of certain atmospheric gases, such as carbon dioxide, water vapor, and methane, influencing Earth's energy balance by absorbing longwave radiation emitted from the surface. Without the greenhouse effect, the average temperature on Earth would be around -18 degrees Celsius (°C) rather than the present 15°C (Pidwirny, 2006).

As energy from the Sun passes through Earth's atmosphere, approximately 26% is reflected or scattered back to space by clouds and other atmospheric particles. About 19% is absorbed by clouds, gases (such as ozone), and particles in the atmosphere. Of the remaining 55%, 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 then contributes to heating of the ground surface, melting of ice and snow and evaporation of water, and plant photosynthesis. Heating of the ground by sunlight causes Earth's surface to radiate energy in the longwave band (infrared radiation). A small portion of this infrared radiation is emitted back to space, while the majority is absorbed by GHGs. Absorption of longwave radiation by the atmosphere increases atmospheric temperature, and the warmer atmospheric GHG molecules radiate longwave energy. Over 90% of this longwave energy is directed back to, and absorbed by, Earth's surface. The heating of the ground by the longwave radiation causes the ground surface to once again radiate, repeating the cycle described above 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 (Pidwirny, 2006).

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 methane emissions from animal digestion processes. Emissions also occur as a result of human activities including burning of fossil fuels, use and leakage of refrigerants, clearing of forest and other vegetation, and use of fertilizers, amongst other sources. This separation of natural versus anthropogenic sources is complicated by the fact that natural processes may be influenced by humans, resulting in increased GHG emissions. There is strong consensus in the climate science research community that following the industrial revolution, GHG emissions from human activities have become the primary driver for an observed enhancement of the natural greenhouse effect, i.e., climate change (Parliament of Australia, 2010).

Gases involved in the enhancement of the greenhouse effect include:

- **Carbon dioxide** (CO_2): 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.
- **Methane** (CH_4): a hydrocarbon gas produced both through natural sources and human activities, including the decomposition of wastes in landfills, agriculture, ruminant digestion and manure management associated with domestic livestock.
- **Nitrous oxide** (N_2O): a GHG produced by soil cultivation practices, especially the use of commercial and organic fertilizers, fossil fuel combustion, nitric acid production, and biomass burning.
- **Chlorofluorocarbons** (CFCs): synthetic compounds 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.

Over the last century, the burning of fossil fuels (which are primarily comprised of carbon) has increased the concentration of atmospheric 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 CO_2 that is absorbed through photosynthesis. When vegetation is burnt or decomposes after land clearing, part of the stored CO_2 is emitted and re-enters the atmosphere.

2.2 Current Understanding of Climate Change Drivers and Effects

The Intergovernmental Panel on Climate Change (IPCC) is an international body established by the World Meteorological Organization and the United Nations Environment Programme, to provide governments with regular scientific assessments of climate change, its impacts and future risks, and mitigation and adaptation options. Since it was established in 1988, the IPCC has prepared five assessment reports, which have provided key inputs into international climate change negotiations. As part of the Fifth Assessment Report (AR5) process, the IPCC released a document titled: *Summary for Policy Makers - Climate Change 2013: The Physical Science Basis* (IPCC, 2013a). The following sections summarize the key findings presented in that document. The IPCC findings represent a consensus opinion of a wide range of scientific specialists. While a degree of uncertainty is associated with the predictions (as indicated in IPCC, 2013a) the estimates could still under-represent climate change consequences, and government policy should allow for potential exceedances.

2.2.1 Observed Changes in the Climate System

- Warming of the climate system is unequivocal. Since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of GHGs have increased.
- Each of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850. In the Northern Hemisphere, 1983 to 2012 was likely the warmest 30-year period of the last 1,400 years.
- Ocean warming dominates the increase in energy stored in the climate system, accounting for more than 90% of the energy accumulated between 1971 and 2010 (*high confidence*). It is virtually certain that the upper ocean (0 to 700 m) warmed from 1971 to 2010, and it likely warmed between the 1870s and 1971.
- Over the last two decades, the Greenland and Antarctic ice sheets have been losing mass, glaciers have continued to shrink almost worldwide, and Arctic sea ice and Northern Hemisphere spring snow cover have continued to decrease in extent (*high confidence*).
- The rate of sea level rise since the mid-19th century has been larger than the mean rate during the previous two millennia (*high confidence*). Over the period 1901 to 2010, global mean sea level rose by 0.19 (0.17 to 0.21) m.
- The atmospheric concentrations of CO_2, CH_4, and N_2O have increased to levels unprecedented in at least the last 800,000 years. Concentrations of CO_2 have increased by 40% since pre-industrial times, primarily from fossil fuel emissions and secondarily from net land use change emissions. The ocean has absorbed about 30% of the emitted anthropogenic CO_2, causing ocean acidification.

2.2.2 Drivers of Climate Change

- Natural and anthropogenic substances and processes that alter the Earth's energy budget are drivers of climate change. Radiative forcing (RF) quantifies the change in energy fluxes caused by changes in these drivers for 2011 relative to the year 1750. Positive RF leads to surface warming, negative RF leads to surface cooling.
- Total RF is positive, and has led to an uptake of energy by the climate system. The largest contribution to total RF is caused by the increase in the atmospheric concentration of CO_2 since 1750.

2.2.3 Understanding the Climate System and its Recent Changes

- The IPCC (2013a) states that climate models have improved since the IPCC's Fourth Assessment Report (AR4, (IPCC, 2007)) and that human influence has been detected in warming of the atmosphere and the ocean, in changes in the global water cycle, in reductions in snow and ice, in global mean sea level rise, and in changes in some climate extremes.
- The evidence for human influence has grown since AR4 and it is concluded to be extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century.

2.2.4 Future Global and Regional Climate Change

- Continued emissions of GHGs will cause further warming and changes in all components of the climate system. Limiting climate change will require substantial and sustained reductions of GHG emissions.
- The global mean surface temperature change for the period 2016 to 2035 relative to 1986 to 2005 will likely be in the range of 0.3°C to 0.7°C (*medium confidence*). This assessment is based on multiple lines of evidence and assumes there will be no major volcanic eruptions to cause changes in total solar irradiance. Relative to natural internal variability, near-term increases in seasonal mean and annual mean temperatures are expected to be larger in the tropics and subtropics than in mid-latitudes (*high confidence*).
- It is *virtually certain* that there will be more frequent hot and fewer cold temperature extremes over most land areas on daily and seasonal timescales as global mean temperatures increase. It is very likely that heat waves will occur with a higher frequency and duration. Occasional cold winter extremes will continue to occur.
- Changes in the global water cycle in response to the warming over the 21st century will not be uniform. The contrast in precipitation between wet and dry regions and between wet and dry seasons will increase, although there may be regional exceptions.
- The global ocean will continue to warm during the 21st century. Heat will penetrate from the surface to the deep ocean and affect ocean circulation. The strongest ocean warming is projected for the surface in tropical and Northern Hemisphere subtropical regions. At greater depth the warming will be most pronounced in the Southern Ocean (*high confidence*).
- It is very likely that the Arctic sea ice cover will continue to shrink and thin and that Northern Hemisphere spring snow cover will decrease during the 21st century as global mean surface temperature rises. Global glacier volume will further decrease.
- Global mean sea level will continue to rise during the 21st century. Under all modeled scenarios, the rate of sea level rise will very likely exceed that observed during 1971 to 2010 due to increased ocean warming and increased loss of mass from glaciers and ice sheets.

2.3 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). The GWPs of potential relevance to the Project, as taken from the IPCC's Fourth and Fifth Assessment reports (AR4 and AR5) are presented in **Table 1**. The AR5 values (IPCC, 2013b) are the most recent, but the AR4 values (IPCC, 2007) are also listed because they are currently used in Australia for inventory and reporting purposes and have been used in this assessment.

Short-lived gases such as carbon monoxide (CO), nitrogen dioxide (NO_2), 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.

Table 1 Global Warming Potentials

Gas	Chemical Formula	IPCC GWP (100 year horizon)	
		Fourth Assessment Report [1]	Fifth Assessment Report [2]
Carbon dioxide	CO_2	1	1
Methane	CH_4	25	28
Nitrous oxide	N_2O	298	265

1: (IPCC, 2007)

2: (IPCC, 2013b)

3 Relevant Legislation, Guidelines and Policies

3.1 The Papua New Guinean Response to Climate Change

Papua New Guinea ratified the United Nations Framework Convention on Climate Change (UNFCCC) in 1993, the Kyoto Protocol in 2002 and the Paris Climate Change Agreement in 2016 (Paris Agreement).

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 (approximately 29 million hectares (ha)). The global mechanism on reduced Emissions from Deforestation, forest Degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries (REDD+) is also being used by PNG to help develop and implement a structured national approach to address the direct and indirect drivers of forest cover change. REDD+ seeks to reduce global GHG emissions from declines in global forest cover and quality by providing financial incentives to developing countries that successfully slow or reverse forest loss. In 2017, as part of the implementation of the REDD+ mechanism, the PNG Climate Change and Development Authority (CCDA), PNG's climate change and GHG regulating authority, published the *Papua New Guinea National REDD+ Strategy 2017 – 2027* (CCDA, 2017a), and submitted PNG's National REDD+ Forest Reference Level (FRL) to the UNFCCC (CCDA, 2017b).

PNG 2050 (NSPT, 2009) is a framework for a long-term strategy for the future direction of PNG, compiled by the National Planning Committee. It includes seven strategic focus areas, one of which relates to environmental sustainability and climate change. The focus of strategic objectives (and priority activities) in this area include sustainable development, conservation and use of natural resources, improvement in the understanding of environmental issues, and effective cooperation with the international community.

The PNG CCDA published the *National Climate Compatible Development Management Policy* (NCDMP) in August 2014 (CCDA, 2014). The policy aims to build a climate-resilient and carbon neutral pathway through sustainable economic development for PNG. The NCDMP is supported by the *Climate Change (Management) Act 2015* which provides a regulatory framework to:

- Promote and manage climate compatible development through climate change mitigation and adaptation activities (e.g. by developing energy policies that focus on renewable energy, improved energy transmission and storage systems, and carbon free energy sources).
- Implement relevant obligations of the State under applicable rules of international law and international agreements related to climate change.
- Establish PNG's Designated National Authority or equivalent for the purposes of the Kyoto Protocol and any other or subsequent arrangements or agreements made under the Kyoto Protocol.

In March 2016, PNG submitted its first Intended Nationally Determined Contribution (INDC) under the United Nations Framework Convention on Climate Change (PNG Parliament, 2016). This document notes:

> *PNG's current economic development is seeing a growth in fuel use therefore a big effort will be made to reduce fossil fuel emissions in the electricity generation sector by transitioning as far as possible to using renewable energy. The target in this respect will be 100% renewable energy by 2030, contingent on funding being made available. In addition PNG will improve energy efficiency sector wide and reduce emissions where possible in the transport and forestry sectors. The main forestry effort will be coordinated though the existing REDD+ initiative.*

3.2 Relevant GHG Performance Standards

3.2.1 The Equator Principles

The Equator Principles (Equator Principles Association, 2006) 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 nine principles, of which *Principle 3: Applicable Social and Environmental Standards* is of specific importance with regard to this Project.

Principle 3 requires that Social and Environmental Assessments refer to International Finance Corporation (IFC) Performance Standards and Industry Specific EHS Guidelines. All assessments are to be carried out to the EPFI's satisfaction of overall compliance, or with justified deviation from the respective Performance Standards and EHS Guidelines.

3.2.2 Performance Standard 3 – Resource Efficiency and Pollution Prevention

Performance Standard 3 - Resource Efficiency and Pollution Prevention (IFC, 2012), recognizes that increased economic activity and urbanization often generate increased levels of pollution to air, water, and land, and consume finite resources in a manner that may threaten people and the environment at the local, regional, and global levels.

In relation to GHG emissions, Performance Standard 3 requires that:

> *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 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.

3.2.3 IFC Environmental Health and Safety Guidelines – Thermal Power Plants

The International Finance Corporation (IFC) Environmental, Health, and Safety (EHS) Guidelines (IFC, 2019) 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.

The IFC EHS Guidelines for Thermal Power Plants (IFC, 2008), which is applicable to the power generation plant at the CPF, lists a number of recommendations to avoid, minimize, and offset emissions of CO_2 from new and existing thermal power plants, including:

> *Use of less carbon intensive fossil fuels (i.e., less carbon containing fuel per unit of calorific value -- gas is less than oil and oil is less than coal) or co-firing with carbon neutral fuels (i.e., biomass)*

It is noted that the second and final public consultation to revise the 2008 Thermal Power Plants EHS Guideline finished on 30 June 2017. In the proposed revised guidelines, the above statement is modified to (IFC, 2017):

> *Use of less carbon intensive fossil fuels (i.e., fuel that contains less carbon per unit of calorific value - gas is less than oil and oil is less than coal)*

The Project involves the combustion of fuel gas to meet the power demand of the CPF and other infrastructure (e.g., well pads, Logistics Base, accommodation camps), which aligns with the current and proposed IFC recommendations above.

The IFC EHS Guidelines for Thermal Power Plants (IFC, 2008) also requires that the Environmental Assessment for a new facility include estimation of GHG emissions associated with the Project. This GHG assessment has been prepared to meet the requirements of the IFC EHS Guidelines.

3.2.4 The Greenhouse Gas Protocol Initiative

The principles of GHG accounting and reporting outlined below are consistent with the World Resources Institute/World Business Council for Sustainable Development (WRI/WBCSD) GHG Protocol (a globally adopted and leading GHG accounting strategy) (WRI/WBCSD, 2004), and ISO 14064-1, 2, and 3 GHG guidelines (internationally accepted best practice). These principles[1] (of relevance, completeness, consistency, transparency and accuracy) are based on financial accounting and reporting standards. The following outlines the basic requirements of any GHG assessment, as defined by WRI/WBCSD (2004).

Relevance

The relevance of a company's GHG report reflects the information that it contains, which should allow stakeholders, both internal and external to the organization, to make informed decisions about GHG management. An important aspect of relevance is the selection of appropriate boundary conditions that reflect the reality of the company's operations. The operation of the company, the purpose of the information and the needs of users will all inform the choice of the inventory boundary. In choosing the inventory boundary, a number of factors should be considered:

- Organizational structure (control, ownership).
- Operational boundaries (on and off site activities, services, impacts).
- Business context (geographical locations, nature of activities, industry sector, purpose and users of information).

[1] Text on GHG Principles taken from the GHG Protocol documentation (WRI/WBCSD, 2004).

Completeness

All relevant emission sources within the chosen inventory boundary need to be accounted for so that a comprehensive and meaningful inventory is compiled. WRI/WBCSD (2004) states that no materiality threshold (or minimum emissions accounting threshold) should be defined, as this is not in line with the principle of completeness. However, if emissions cannot be estimated or estimated at a sufficient level of quality, then these should be transparently documented and justified.

Consistency

Consistency in an emissions inventory allows stakeholders to compare GHG emissions performance from year to year. This consistency also allows trends to be identified and performance against objectives and targets to be tracked. Any changes in the inventory (accounting approaches, boundaries, calculation methods) need to be transparently documented and justified.

Transparency

All processes, procedures, assumptions and limitations of an inventory should be presented clearly and accurately. Information needs to be recorded, compiled and analyzed in a way that enables internal reviewers and external auditors to verify the credibility of the inventory. Specific exclusions and inclusions are to be documented and justified, assumptions disclosed and appropriate references provided for the calculation methods applied and the data sources used. Transparency is essential in the production of a credible GHG inventory.

Accuracy

Accuracy describes how close the estimates of GHG emissions are to the 'true' value. The accuracy of a GHG inventory should be sufficient for stakeholders to make decisions with reasonable assurance of the integrity of the reported information. Quality management measures should be implemented to maximize inventory accuracy.

This GHG assessment has been prepared to meet the above requirements of the GHG Protocol.

3.2.5 TOTAL Policies and Guidelines

Relevant GHG mitigation and assessment requirements set out in TOTAL policy documents and general specification documents have been reviewed. Relevant requirements are set out in *General Specification – Exploration and Production - Environment*, Revision 5, January 2011 (GS-EP-ENV-001) (TOTAL, 2011). Section 5.2 of GS-EP-ENV-001 includes the following requirements in relation to GHG emissions:

The design of new developments shall comply with the following:

- *Elimination of continuous flaring and venting in accordance with Company's commitment to adhere to what is stated in the Global Gas Flaring and Venting Reduction Voluntary standard (World Bank Group, 2004).*
- *To keep as low as possible GHG emissions. This includes temporary flaring and venting minimization, and optimization of fuel gas and energy efficiency.*
- *To monitor directly or indirectly the flows and characteristics of significant GHG emission sources.*

- *GHG emission sources and associated emissions shall be identified according to the Company-approved methodology.*
- *Minimization of GHG emissions and optimization of energy efficiency shall be considered in the selection of the development scheme and main equipment. The accordance with Company's objectives with respect to energy efficiency and GHG emissions reductions shall be considered.*

Section 5.2.1 sets out additional requirements in relation to flaring and venting minimization:

Facilities shall be designed to comply with the following:

- *No continuous flaring of associated gas, including Low Pressure and Low Low Pressure gas streams, during normal operation, unless there is no feasible alternative. To be noted that safety flaring (gas purging of flare headers) is not covered by this requirement.*
- *If gas cannot be marketed or used as fuel gas, reinjection either into the producing reservoirs or other adequate reservoirs shall be the base case.*
- *No continuous venting of associated gas, unless there is no feasible alternative. If venting is to be considered, its replacement by flaring shall be evaluated wherever it represents an environmental benefit in terms of GHG emissions and complies with Company's safety requirements.*
- *No continuous venting of CO_2 from decarbonation units (amines, membranes), unless there is no feasible alternative or the native CO_2 vented is not significant when compared to the CO_2 from the combustion.*
- *Flaring during new field's start-up shall be minimized. The project team shall set a strategy and a detailed technical plan (available for internal review) to demonstrate how flaring shall be minimized: schedule of commissioning, flaring and venting profiles including well drilling, testing and workovers and mitigation measures.*
- *Temporary flaring related to operational upsets shall be minimized by ensuring the targeted availability of the critical systems. Adequate redundancy and/or adequate spare parts philosophy, preventive and curative maintenance strategy and means shall be implemented.*
- *Flare headers metering systems should cover all the range of gas flow to flare with a good accuracy.*
- *Instrumentation technologies powered by instrument gas should be avoided whenever feasible, or vented volumes should be minimized.*

Section 5.2.2 requires that the design of a new facility ensures an optimized use of energy, including (but not limited to) the minimization of fuel gas consumption, as follows:

- *Optimization of energy use shall be considered not only for the oil and gas plateau, but also for the entire life of the facility.*
- *Where justified by the process heat requirements, the installation of a waste heat recovery unit on gas turbines shall be the base case.*
- *A system for quantifying the energy consumption (fuel gas, electricity, mechanical power) of each key component of the system (gas turbine, compressor, pump, and heater), shall be installed in order to enable the monitoring and optimization of the energy efficiency of that component.*

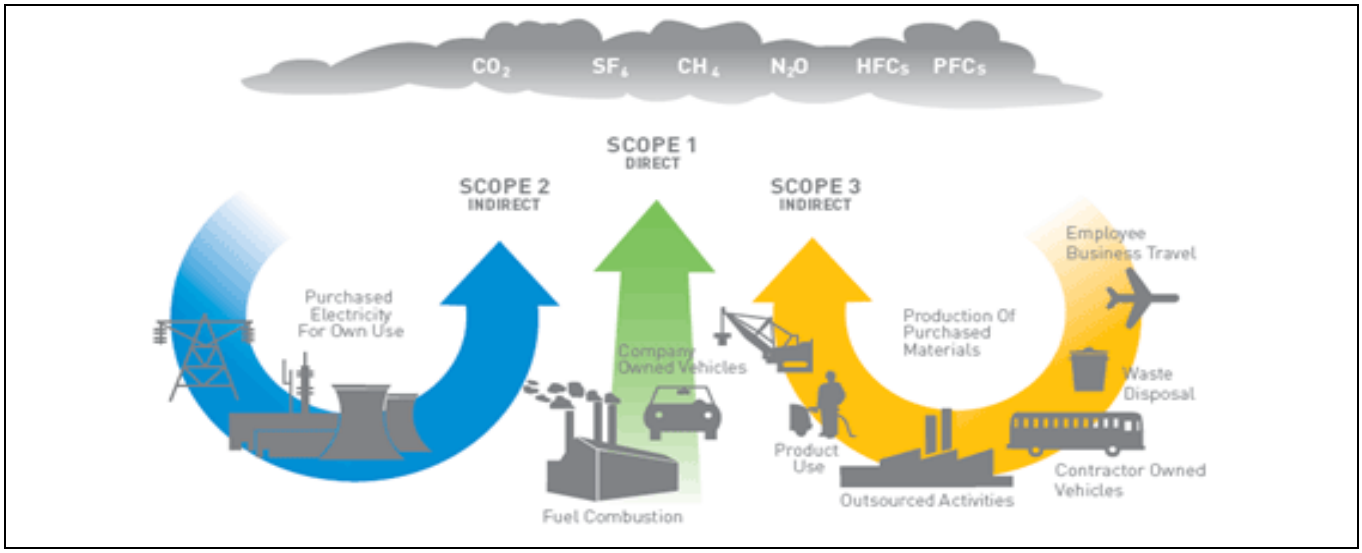
- *If possible, the main energy consuming machines should include a system to perform the on-line monitoring of the energy efficiency and to compare it to the expected energy efficiency, in order to be optimized by the operation's team.*
- *Sampling points shall be installed to characterize the composition of LP and HP fuel gases.*

Section 4.8 outlines how the proposed Project addresses TOTAL's company GHG mitigation and management requirements as listed above.

3.3 Scope Definition

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

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



Source: WRI/WBCSD (2004)

The definitions below are derived from the WRI/WBCSD GHG Protocol (WRI/WBCSD, 2004). These documents provide detailed information on the activities that 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 TEP PNG (Scope 1 and Scope 2), and those that TEP PNG will have some, but limited control over (Scope 3).

3.3.1 Direct Emissions (Scope 1)

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

- Transport of materials, products, waste or people (e.g., the combustion of diesel in on-road and off-road vehicles, fly-in and fly-out of workers from Port Moresby, barging of fill, plant modules and other materials and equipment to site).
- Generation of electricity, heat and/or steam (e.g., the combustion of fuel gas in the power generation turbines and the combustion of diesel in portable generators).

- Flaring during commissioning activities, start-up, maintenance and plant upsets.
- Fugitive emissions, both intentional and unintentional (e.g., venting during maintenance activities and plant upsets, leakage of sulfur hexafluoride (SF_6) from switchgear, and land clearing).
- On-site waste management, e.g., solid and liquid waste management through landfilling, incineration and sewage treatment plant(s).

3.3.2 Indirect Emissions (Scope 2 and Scope 3)

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

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 in owned or controlled equipment or operations. As the Project will not be sourcing any appreciable quantities of electricity (i.e., only for offices, etc., in Port Moresby), Scope 2 emissions have not been considered further.

Scope 3 Emissions

An organization wishing to undertake a full life cycle analysis of their product would also include all other indirect emissions that are generated outside of their own organization as a consequence of their activities. The following activities are examples of potential Scope 3 emissions:

- Extraction and production of purchased materials and fuels.
- Transport related activities:
  - Transport of purchased materials, goods and fuels.
  - Employee business travel and commuting to and from work.
  - Transport of products.
  - Transport 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 by third parties:
  - Disposal of waste generated in operations.
  - Disposal of waste generated in the production of purchased materials and fuels.
  - Disposal of products at the end of their life.

4 GHG Assessment

4.1 Study Method

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. The overall approach used for this GHG assessment was as follows:

- Assess the current regime within PNG in terms of baseline conditions, commitments to the reduction of GHG emissions and any other obligations under international conventions to which PNG is a signatory.
- Identify the key (significant) Project-related GHG sources during Project construction and operations.
- Estimate the quantities of GHG emissions generated from these sources over the life of the Project and compile an annual GHG emissions inventory in terms of tonnes (t) of carbon dioxide equivalent (CO_2-e) for the Project.
- Based on the above information, assess the Project's contribution to PNG's national GHG emissions.

Calculation of GHG emissions from the Project has been performed in a five-stage process:

1. Definition of the Project boundary (**Section 4.2**).
2. Identification of emission sources within the Project boundary (**Section 4.3**).
3. Identification of emission calculation methods for each source (**Section 4.4**).
4. Identification of activity data for each emission source (**Section 4.5**).
5. Calculation of GHG emissions (**Section 4.6**).

Further details are provided in the following sections.

4.2 Definition of the Project Boundary

The geographical boundary set for Scope 1 emissions considered in this GHG assessment covers the Project area comprising the footprint of the wellpads, CPF, Logistics Base, the existing Herd Base, Purari Airstrip, onshore and offshore pipelines, and the Caution Bay landfall approach. GHG emissions associated with construction, operations and decommissioning of all these infrastructure areas are considered to be within the geographical boundary of this assessment.

GHG emissions associated with the transportation of materials and workforce from Port Moresby to the Project area by air and by barge have also been considered as Scope 1 emissions, as well as emissions associated with their movement within the Project area. For these activities, the geographical boundary therefore extends to Port Moresby, including the Gulf of Papua and the two distributaries of the Purari River that will be used to barge materials and equipment up to site.

As outlined in **Section 1.1**, downstream processing of the gas and condensate produced by the Project will be undertaken at new LNG facilities to be co-located within ExxonMobil's existing PNG LNG facilities at Caution Bay. Construction of the extra gas processing trains and marine facilities will be undertaken and permitted separately by ExxonMobil and is subject to a separate EIS and approvals process. For the purposes of this assessment, GHG emissions associated with the downstream processing of the gas have been included in this assessment as a Scope 3 emission source and not as a Scope 1 emission source as the downstream processing is beyond the scope of this EIS.

GHG emissions associated with the international transport of materials and workers to/from Port Moresby, transport of product gas to end users, and consumption of the gas by end users have been included in this assessment as Scope 3 emissions.

As noted in **Section 3.3.2**, Scope 2 emissions have not been included as the Project will not be externally sourcing any appreciable quantities of electricity, hence any associated GHG emissions will be minimal.

4.3 Identification of Emission Sources

GHG emission sources have been identified by review of the Project description. GHG emissions will arise from the construction, operations and decommissioning phases of the Project. The emissions associated with each phase that were included in the GHG emissions inventory are outlined in **Table 2**.

Emissions identified for the decommissioning phase of the Project are indicative only. Options for the plant will vary between life extension, upgrading or decommissioning. Due to the uncertainty regarding the fate of the plant at that time, the estimation of emissions associated with the end of life phase of the Project has been calculated based on a range of broad assumptions. 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 Project.

There are several emissions sources that will be associated with the Project that have not been included in the emissions inventory, including:

- Scope 1 emissions from the leakage of any SF_6 (if used) from switchgear associated with the on site power generation and distribution systems.
- Scope 1 emissions from the leakage of hydrofluorocarbons (HFC) used in refrigeration equipment.
- Scope 3 emissions associated with the manufacture of plant and equipment installed as part of the Project.
- Scope 1 emissions from the burning of diesel in generators during decommissioning once power becomes unavailable from the CPF.
- GHG sequestration associated with rehabilitation and revegetation of decommissioned infrastructure sites.

There is no information currently available on the stocks of SF_6 and HCF (if any) required in switchgear and refrigeration equipment during the construction and operations phases of the Project. Based on SLR's experience in preparing GHG assessments for similar projects, the emissions associated with the leakage of SF_6 and HCF are expected to be a very minor contributor to the overall Project GHG emissions inventory and have not been considered further.

Similarly, there is no detailed information available on countries that the plant and equipment installed during the construction phase will be sourced from, or the composition of those materials, to enable an estimation of the likely embedded energy associated with their manufacture. Any estimation of Scope 3 emissions associated with the manufacture of plant and equipment installed as part of the Project would therefore be unreliable and has not been included.

As noted above, the emission estimates for the decommissioning phase are indicative only, and are intended to only capture key potential sources based on broad assumptions. The identification of potential GHG sources and the estimation of emissions will need to be reviewed using updated factors and activity data once details regarding the preferred decommissioning option(s) are known.

Table 2 GHG Emission Sources Associated with the Project Included in the Emissions Inventory

Project Activity	Scope 1	Scope 3
CONSTRUCTION		
Vegetation clearing	• Initial loss of carbon stock and material decomposition from clearing • Ongoing annual losses due to cleared vegetation no longer sequestering carbon	-
Site establishment and earthworks	• Emissions from diesel combustion in earthworks machinery	• Emissions associated with extraction and processing of diesel consumed
Construction (CPF, onshore pipelines, camp, Logistics Base, etc.)	• Emissions from diesel combustion in construction equipment, including drill rigs, forklifts, cranes, concrete batch plants, etc.	• Emissions associated with extraction and processing of diesel consumed
Offshore export pipeline construction	• Emissions from diesel combustion in the pipe-laying vessel, pipe and general supply vessels, bulk carriers, accommodation vessel, crew boats and survey vessel	• Emissions associated with extraction and processing of diesel consumed
Transport of workers from Port Moresby to site and between Project infrastructure	• Emissions from diesel combustion in light vehicles, buses, ferries used to transport staff • Emissions from aviation gasoline ('Avgas') combustion in aircraft flying between Port Moresby and Purari Airstrip.	• Emissions associated with extraction and processing of diesel consumed • Emissions associated with extraction and processing of Avgas consumed • Emissions associated with international flights for workers between Port Moresby and their home country
Power generation	• Emissions from diesel combustion in portable power generators (gensets)	• Emissions associated with extraction and processing of diesel consumed
Barging	• Emissions from diesel combustion in barges delivering aggregate, plant modules, equipment and supplies from Port Moresby and between Purari Airstrip and Herd Base/Logistics Base	• Emissions associated with extraction and processing of diesel consumed *
Management of solid waste and wastewater	• Emissions from organic material decomposition in landfill, sewage treatment and solid waste incineration	-

Project Activity	Scope 1	Scope 3
Shipping of plant modules to PNG from country of origin	-	• Emissions associated with shipping of equipment from country of origin to Port Moresby
OPERATIONS		
Fuel gas combustion	• Emissions from fuel gas combustion at the CPF in compressors, boilers and power generation units	-
Venting	• Emissions of CO_2 from venting of acid gas at CPF during first four years of the Project	-
Flaring	• Emissions from gas flaring at the CPF and well pads	-
Transport of workers from Port Moresby to site and between Project infrastructure	• Emissions from diesel combustion in light vehicles, buses, ferries used to transport staff • Emissions from Avgas combustion in aircraft flying between Port Moresby and Purari Airstrip	• Emissions associated with extraction and processing of diesel consumed • Emissions associated with extraction and processing of Avgas consumed • Emissions associated with international flights for workers between Port Moresby and their home country
Barging	• Emissions from fuel combustion in barges delivering equipment and supplies from Port Moresby to Herd Base/Logistics Base	• Emissions associated with extraction and processing of fuel consumed *
Management of solid waste and wastewater	• Emissions from organic material decomposition in landfill, sewage treatment and solid waste incineration	-
Downstream processing of gas and condensate	-	• Emissions associated with downstream processing of gas
Transport of product gas to end user	-	• Emissions associated with shipping of gas to customers in China, Japan, etc.
Consumption of product gas by end user	-	• Emissions associated with combustion of gas by customers
DECOMMISSIONING		
Earthworks and rehabilitation	• Emissions from diesel combustion in trucks, earthworks machinery, forklifts, cranes, etc.	• Emissions associated with extraction and processing of diesel consumed
Transport of workers from Port Moresby to site and between Project infrastructure	• Emissions from diesel combustion in light vehicles, buses, ferries used to transport staff • Emissions from Avgas combustion in aircraft flying between Port Moresby and Purari Airstrip	• Emissions associated with extraction and processing of diesel consumed • Emissions associated with extraction and processing of Avgas consumed • Emissions associated with international flights for workers between Port Moresby and their home country

Project Activity	Scope 1	Scope 3
Barging	• Emissions from diesel combustion in barges delivering equipment and supplies from Port Moresby and transporting demolition materials from site	• Emissions associated with extraction and processing of diesel consumed *
Management of solid waste and wastewater	• Emissions from organic material decomposition in landfill, sewage treatment and solid waste incineration	-

* Note: Fuel consumption estimates are not available for the Project for the barging activities; hence Scope 1 emissions associated with this source were estimated using published emission factors that require an estimate of the tonnes-km transported (i.e. tonnes transported multiplied by the distance travelled, see **Section 4.4** and **Appendix A**). As fuel volumes have not been estimated, Scope 3 emissions from the production of this fuel cannot be calculated and have not been included in this assessment. This will not have a material impact on the calculated total Project emissions.

4.4 Emission Calculation Methods

Emission factors allow the quantity of GHG emitted by a source to be calculated from the units of activity (see **Section 4.5**). Within this assessment, emission factors have been sourced using the following hierarchy:

- IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006).
- Australian National Greenhouse Accounts (NGA) Factors Workbook (DEE, 2018).
- Published industry guidelines for GHG emission inventory development.

Other IPCC publications have also been referenced in this document, including '*Good Practice Guidance for Land Use, Land-Use Change and Forestry*' (IPCC, 2003).

IPCC and NGA emission factors are designed to allow countries to calculate Scope 1 emissions. IPCC emission factors are not designed to allow the calculation of Scope 3 emissions, as reporting of Scope 2 and 3 emissions is not required under UNFCCC methods as it can result in double-counting. One example would be two entities who report emissions associated with diesel combustion and diesel production. The entity reporting emissions associated with diesel combustion would report the emissions related to the combustion of that fuel (Scope 1) and the production of the fuel (Scope 3). The entity that produces the fuel would report emissions associated with production of the fuel under Scope 1. Therefore, both entities are reporting emissions associated with the production, and thus double-counting the emissions if they were to be included in the national GHG budget.

Indirect (Scope 3) emissions can be reported under non-UNFCCC programs, and for project-specific requirements. Reporting of Scope 3 emissions allows a more complete picture of the GHG impact of the Project to be identified and allows more direct comparison with other projects. Emission factors used for reporting of Scope 3 GHG emissions associated with the Project have been sourced from the NGA Factors. Scope 3 emission factors are provided in the NGA Factors for organizations that burn fossil fuels.

A summary of the relevant GHG emission factors used is presented in **Table 3**. Further details regarding the derivation of the emission factors used are provided in **Appendix A**.

Because fuel consumption estimates are not available for the Project for the barging activities, emissions associated with this source (as well as Scope 3 emissions associated with international shipping of plant modules and product gas) were estimated using emission factors published by the European Chemical Industry Council in *Guidelines for Measuring and Managing CO_2 Emission from Freight Transport Operations* (Cefic, 2011). Emissions from the offshore pipeline construction activities were estimated using the IPCC emission factor for fuel oil combustion in waterborne navigation (IPCC, 2006).

The emission factor shown in **Table 3** for the downstream processing of the gas at the Caution Bay facility was derived by SLR based on publicly available GHG reports prepared by Oil Search.

In addition to the calculations outlined in **Table 3**, annual emission estimates calculated by the Project design team for the following operations phase sources were adopted as part of this GHG assessment:

- Combustion of fuel gas.
- Flaring.
- Venting/diffuse emissions.

GHG emissions associated with waste management will be a very minor contributor to the total Project emissions. GHG emissions from waste incineration, landfilling and sewage treatment were estimated by scaling the emission estimates for the P'nyang Project (CNS, 2015) as follows:

- Emissions from waste incineration, landfilling and sewage treatment associated with construction of the pipeline were scaled based on the length of the pipeline.
- Emissions from waste incineration, landfilling and sewage treatment associated with construction and operation of the CPF and other non-pipeline infrastructure were scaled from the P'nyang Project estimates based on the estimated number of workers for each year of the Project.

For further details, refer to **Appendix A**.

Table 3 GHG Emission Factors Used in this Assessment

Activity	Emission Factor and Source
SCOPE 1	
Land clearing – Initial loss during clearing	826 t CO_2-e/ha (Chapter 2 and Chapter 4 of (IPCC, 2006))
Land clearing – Ongoing annual loss due to permanently cleared vegetation no longer sequestering carbon	31 t CO_2-e/ha (Chapter 2 and Chapter 4 of (IPCC, 2006))
Combustion of diesel in mobile off-road equipment and vehicles	3.56 t CO_2-e/kL (Chapter 1 and Chapter 3 of (IPCC, 2006))
Combustion of diesel in portable generators	3.20 t CO_2-e/kL (Chapter 1 and Chapter 2 of (IPCC, 2006))
Combustion of Avgas in fixed wing aircraft and helicopters	3.13 t CO_2-e/kL (Chapter 1 and Chapter 3 of (IPCC, 2006))
Combustion of fuel oil in offshore pipeline construction vessels	3.16 t CO_2-e/kL (Chapter 1 and Chapter 3 of (IPCC, 2006))
Combustion of fuel in 700 t barges	49.1 x 10^{-6} t CO_2-e/t-km * for river transport 70.8 x 10^{-6} t CO_2-e/t-km for open water (Cefic, 2011)
Combustion of fuel in 1,600 t barges	40.0 x 10^{-6} t CO_2-e/t-km for river transport 57.7 x 10^{-6} t CO_2-e/t-km for open water (Cefic, 2011)
Combustion of fuel in 2,300 t barges	32.1 x 10^{-6} t CO_2-e/t-km for river transport 46.0 x 10^{-6} t CO_2-e/t-km for open water (Cefic, 2011)
SCOPE 3	
Extraction and processing of diesel consumed	0.155 t CO_2-e/kL (DEE, 2018)
Extraction and processing of fuel oil consumed	0.145 t CO_2-e/kL (DEE, 2018)
Extraction and processing of Avgas consumed	0.159 t CO_2-e/kL (DEE, 2018)
Shipping of plant modules from country of origin to PNG	8.4 x 10^{-6} t CO_2-e/t-km (Cefic, 2011)
International flights for workers to/from PNG	0.25 x 10^{-6} t CO_2-e/hr (Carbon Independent, 2015)
Downstream processing of gas at Caution Bay facility	512,960 t CO2-e/MTPA (see **Appendix A**)
Shipping of gas to end users	5.0 x 10^{-6} t CO_2-e/t-km (Cefic, 2011)
Combustion of gas by end users	0.06315 t CO_2-e/GJ (Chapter 2 of (IPCC, 2006))

* t-km refers to the tonnes of material transported multiplied by the travel distance in kilometers.

4.5 Summary of Activity Data for Each Emission Source

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

4.5.1 Land Clearance

The total areas of disturbance for each project component were provided by TOTAL, spread over the five-year construction period as shown in **Table 4**. The area cleared for pipeline construction will be allowed to revegetate, albeit to a limited extent (vegetation will be cut to low levels and trees with extensive root systems will not be allowed to grow), and this has been accounted for in the GHG emission estimates (see **Appendix A**). In addition to the areas shown in **Table 4**, there will also be some clearance associated with quarries. These areas will not have a material impact on the estimated GHG emissions for the Project.

Table 4 Land Disturbance Areas Assumed over the Construction Phase

Area	Area Cleared During Construction (ha)					
	Year 1	Year 2	Year 3	Year 4	Year 5	Total
CPF and accommodation	-	98.4	-	-	-	**98.4**
Logistics Base	-	6.9	-	-	-	**6.9**
Wellpads	-	-	8.2	-	-	**8.2**
Roads	38.7	58.10	58.10	-	-	**154.9**
Purari Airstrip	101.4	-	-	-	-	**101.4**
Spoil disposal areas	-	39.9	39.9	39.9	-	**119.7**
General waste landfill	-	2.4	2.4	-	-	**4.8**
Pipelines*	-	-	191.7	191.7	-	**383.4**
TOTAL	**140.1**	**205.7**	**300.3**	**231.6**	**0.0**	**877.6**

* The area cleared for pipeline construction will be allowed to revegetate to a limited extent (vegetation will be cut to low levels and trees with extensive root systems will not be allowed to grow).

Note: Columns/rows may not add up exactly due to rounding

4.5.2 Fuel Consumption

Diesel - Earthworks Activities

Estimated monthly fuel consumption rates associated with earthworks activities during the construction phase were provided by TOTAL. These monthly values were consolidated into annual consumption figures by SLR as shown in **Table 5**.

Table 5 Estimated Diesel Consumption - Earthworks

Activity	Diesel Consumption During Construction (kL)					
	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Earthworks	0	3,464	6,830	9,093	6,561	**25,948**

Diesel - Generators

Portable generators are expected to be required at a number of locations during the construction and operations phases of the Project, including camps and construction sites (i.e., the CPF, Logistics Base, Purari Airstrip, pipeline/road construction sites).

For the construction phase, annual diesel consumption rates for the portable generators were calculated based on the number and size of generators likely to be required, as estimated in consultation with TOTAL. All generators were assumed to be 150 kW and the fuel consumption rate per generator in liters per hour (L/hour) was sourced from a literature review.

For the operations phase, TOTAL provided a fuel consumption estimate of 110 kL/annum.

A summary of the assumptions is provided in **Table 6**.

Table 6 Estimated Diesel Consumption – Generators

Project Year	Number of Generators Assumed	Assumed Average Power (kW)	Estimated Fuel Consumption Rate* (L/hour)	Annual Average Load	Calculated Fuel Consumption (kL/annum)
Construction Year 1	10	150	50	80%	**3,504**
Construction Year 2	15	150	50	80%	**5,256**
Construction Year 3	20	150	50	80%	**7,008**
Construction Year 4	20	150	50	80%	**7,008**
Construction Year 5	10	150	50	80%	**3,504**
Operations	-	-	-	-	**110**
Decommissioning	10	150	50	80%	**3,504**

* From: (Gan, Shek, & Mueller, 2015)

Diesel – Other Mobile Plant and Equipment

In addition to the earthmoving equipment and portable generators, diesel will also be consumed by the Project in drill rigs, forklifts, cranes, concrete batch plants, as well as vehicles, buses, ferries used to transport staff. No fuel consumption estimates are available at the time of writing this report for these activities. Estimates were therefore made by SLR based on the following assumptions and confirmed with TOTAL:

- Construction Phase: Assumed the annual diesel consumption is 20% of the earthmoving consumption rate estimated for that year.
- Operations Phase: Assumed that 2,750 kL/annum of diesel is combusted. This is based on the operational diesel use estimated for the P'nyang Project (1,700 kL for pipeline and 2,360 kL for the gas processing facility) and taking into account the shorter onshore export pipeline (60 km versus 260 km) (CNS, 2015).
- Decommissioning Phase: Assumed the annual diesel consumption is 50% of the average annual earthmoving consumption rate for the construction years.

Avgas – Fly In/Fly Out from Port Moresby

Annual Avgas consumption rates associated with flying workers between Purari Airstrip and Port Moresby were calculated based on estimated numbers of flights per year, a 1.25 hour flight time (one way) and the following assumed fuel consumption rates:

- Twin Otter: 263.1 kg/hour (NOAA, 2017).
- ATR 42-500: 731.0 kg/hour (ATR, 2009).

The numbers of flights per annum between Purari Airstrip and Port Moresby during the construction phase were estimated based on Project information provided to SLR. For the operations phase, it was assumed there will be one flight per day (Twin Otter). For the decommissioning phase it was assumed that the annual Avgas consumption will be 50% of the peak annual consumption rate for the construction years (i.e., 50% of Construction Year 4).

Table 7 Estimated Avgas Consumption

Project Year	Flights per Annum		Estimated Avgas Consumption Rate (kL/annum)		
	Twin Otter	ATR 42	Twin Otter	ATR 42	Total
Construction Year 1	434	-	206	-	**206**
Construction Year 2	868	-	411	-	**411**
Construction Year 3	-	1,065	-	1,404	**1,404**
Construction Year 4	-	1,583	-	2,086	**2,086**
Construction Year 5	396	183	188	241	**428**
Operations	365	-	173	-	**173**
Decommissioning	-	-	-	-	**1,043**

4.5.3 Barging

The emission factors (in t CO_2-e/t-km) used to estimate the GHG emissions associated with the barging operations, vary depending on the size of the barge and whether it is operating in the river system or open water. For this study, the upstream emission factor for river transportation was adopted for travel along the coastline. It is therefore necessary to estimate the total distance travelled by each sized barge in the river, and between Port Moresby and the river mouth.

Information on the anticipated number of barge trips for each construction year and during operations was provided by TOTAL for the construction and operational years of the Project. Based on this information, the number of barge movements per annum for each barge type has been estimated as shown in **Table 8**. The travel distances shown in **Table 8** were estimated from aerial imagery (Google Australia, 2019) based on use of the Lower Purari River Route.

Table 8 Estimated Barge Movements

Project Year	Port Moresby – Herd Base [a,b,c]			Port Moresby – Logistics Base [d,e,f,g,h,i]			Herd Base – Purari Airstrip [j]		
	Barge Size (t)			Barge Size (t)			Barge Size (t)		
	700	1,600	2,300	700	1,600	2,300	700	1,600	2,300
Construction Year 1	417	-	-	-	121.67	-	-	-	-
Construction Year 2	235	-	-	26	273.75	-	120	-	-
Construction Year 3	52	-	-	52	182.5	-	-	-	-
Construction Year 4	52	-	-	52	182.5	24	-	-	-
Construction Year 5	52	-	-	52	91.25	-	-	-	-
Operations	26	-	-	-	26	-	-	-	-
Travel Distance (one way)									
Lower Purari River Route (km)	110			100			2.5		
Open Water (km)	300			300			-		

Estimated barge movements based on the following:

a. For the first 18 months (prior to the Logistics Base becoming operational), there will be one 700 t barge per day transporting aggregate from Port Moresby to Herd Base.
b. For the entire construction phase, there will be one 700 t barge per week transporting supplies from Port Moresby to Herd Base.
c. During the operations phase, there will be one 700 t barge every two weeks transporting supplies from Port Moresby to Herd Base.
d. From 18 months onwards during the construction phase, there will be one 700 t barge per week transporting supplies from Port Moresby to the Logistics Base.
e. In construction Year 1, for a four month period, there will be one 1,600 t barge per day transporting aggregate from Port Moresby to the Logistics Base site.
f. In construction Year 2, there will be six months of daily 1,600 t barge movements transporting aggregate from Port Moresby to the Logistics Base site, then 6 months of 1,600 t supply barges every two days that will continue to the end of Construction Year 4.
g. In Construction Year 4, for six months, 2,300 t barges will be delivering the plant modules from Port Moresby to the Logistics Base at a rate of one per week.
h. In construction Year 5, the 1,600 t supply barges travelling from Port Moresby to the Logistics Base will reduce to every four days.
i. During the operations phase, there will be one 1,600 t barge every two weeks transporting supplies from Port Moresby to the Logistics Base.
j. In construction Year 2, there will be one 700 t barge per day transporting fill from Herd Base to the Purari Airstrip site for a four-month period.

Using the data shown in **Table 8**, the activity data in tonnes-km required for the Scope 1 GHG emission estimates were calculated as shown in **Table 9**. These calculations account for the two-way travel of the barge movements estimated in Table 8. For the purposes of estimating approximate GHG emissions for the decommissioning stage of the Project, the emission estimates for the operational years was multiplied by a factor of two.

Also shown in **Table 9** are estimated fuel oil consumption rates for the barging activities. These volumes have been estimated to enable Scope 3 emissions associated with the production and supply of fuel oil to the Project to be estimated. The hourly fuel consumption rates for each barge type (see footnote to **Table 9**) used to estimate the annual fuel consumption rates have been assumed by SLR based on a review of publicly available information from various manufacturers and suppliers of different sized barges, and are indicative estimates only.

Table 9 Barging Activity Data used in Calculations

Project Year	Estimated '000 tonnes-km						Estimated Fuel Oil Consumption (kL/annum) *
	700 t Barge		1,600 t Barge		2,300 t Barge		
	River	Open Water	River	Open Water	River	Open Water	
Construction Year 1	58,258	158,884	35,320	105,959	-	-	15,827
Construction Year 2	36,444	99,255	79,469	238,408	-	-	17,742
Construction Year 3	13,869	39,626	52,980	158,939	-	-	9,973
Construction Year 4	13,869	39,626	52,980	158,939	10,850	32,550	11,174
Construction Year 5	13,869	39,626	26,490	79,469	-	-	6,359
Operations	3,632	9,906	7,548	22,643	-	-	1,716
Decommissioning	7,265	19,813	15,096	45,287	-	-	3,432

* Estimated using assumed fuel oil consumption rates of 100 L/hour (700 t barge), 150 L/hour (1,600 t barge) and 175 L/hour (2,300 t barge) to enable Scope 3 emissions for production of the fuel oil to be estimated.

4.5.4 Offshore Pipeline Construction

GHG emissions from the offshore pipeline construction activities were calculated based on an estimated fuel oil consumption rate for the vessels involved, which are:

- A pipe-laying vessel.
- A general supply vessel.
- Pipe supply vessels to continuously supply pipe to the pipe-laying vessel.
- Bulk carriers to transport pipe to a location from which it can be loaded onto the pipe supply vessels.
- An accommodation vessel.
- Crew boats to transfer personnel to and from shore bases.

The duration of the works for the offshore LNG pipeline installation works is six months, after which the offshore condensate pipeline with require 3 months. The emissions were assumed to occur in Construction Year 3.

The fuel consumption rate was estimated based on the following assumptions:

- One pipe-laying vessel consuming 15 m^3 diesel per day (reported consumption rate for a DP3 pipelay construction vessel, equivalent to 625 L/hour (Sea Trucks Group, 2016) operating for 9 months.
- Four supply vessels consuming 400 L/hour diesel operating 12 hours per day for 9 months
- One bulk carrier consuming 600 L/hour diesel operating 12 hours per day, 2 days per week, for 9 months.
- One accommodation vessel consuming 100 L/hour operating 24 hours per day for 9 months.

4.5.5 Waste Management

As noted in **Section 4.4**, GHG emissions from waste incineration, landfilling and sewage treatment were calculated by scaling the emission estimates for the P'nyang Project (CNS, 2015) as follows:

- Emissions from waste incineration, landfilling and sewage treatment associated with construction of the pipeline were scaled based on the length of the pipeline.
- Emissions from waste incineration, landfilling and sewage treatment associated with construction and operation of the CPF and other non-pipeline infrastructure were scaled from the P'nyang Project estimates based on the estimated number of workers for each year of the Project.

A summary of the activity data used in these calculations is provided in **Table 10**.

Table 10 Data used to Scale Estimated Emissions for Waste Management Activities from P'nyang Project

Project Year	Units	Activity Data		
		P'nyang Project	Papua LNG Project	
Workforce - Construction	People	4,360 (all years)	Construction Year 1	200
			Construction Year 2	440
			Construction Year 3	2,195
			Construction Year 4	2,870
			Construction Year 5	470
Workforce - Operations	People	110	230	
Workforce - Decommissioning	People	10	400	
Pipeline Length	km	250	60	

4.5.6 Other Scope 3 Activity Data

Scope 3 emissions associated with the production and supply of fuels used were calculated using the relevant emission factor from **Table 3** and the fuel consumption rates estimated as part of the Scope 1 emission calculations for diesel, Avgas and fuel oil combustion as described above.

Other activity data used to estimate the Scope 3 emissions was as follows:

- Scope 3 emissions from shipping of plant modules from the country of manufacture were calculated using the relevant emission factor from **Table 3**, a total weight of 28,000 t and an assumed travel distance of 3,698 km (reported shipping distance between Port Moresby and Port of Shanghai as a nominal estimate).
- Scope 3 emissions associated with flying workers from their country of origin were calculated using the relevant emission factor from **Table 3**, and a nominal average flight duration of 5 hours (each way). The numbers of international flights per year were estimated based on the following assumptions:
  - The numbers of flights per day between Port Moresby and Purari Airstrip, the passenger capacity of each plane type (Twin Otter and ATR42) and an assumed average 90% occupancy rate.

- A conservative assumption that during the construction and decommissioning phases all workers will be Other Country Nationals (OCNs) requiring international flights, while during the operations phase 25% of workers will be OCNs.

- Scope 3 emissions from the downstream processing of gas were calculated using the relevant emission factor from **Table 3** and the production profile (produced (raw) gas quantities) shown in **Figure A3.2** in **Appendix A**.
- Scope 3 emissions from the shipping of product gas from PNG to the end users were calculated using the relevant emission factor from **Table 3,** the production profile (export gas quantities) shown in **Figure A3.2** in **Appendix A** and an assumed travel distance of 3,565 km (reported shipping distance between Port Moresby and Port of Tokyo as a nominal estimate).
- Scope 3 emissions from the combustion of product gas from PNG by end users were calculated using the relevant emission factor from **Table 3** and the production profile (export gas quantities) shown in **Figure A3.2** in **Appendix A**.

4.6 Papua LNG Project GHG Emissions Inventory

4.6.1 Estimated Emissions

Based on the activity data for each source summarized in **Section 4.5**, and the emission factors presented in **Table 3** and detailed in **Appendix A**, estimated Scope 1 (direct) and Scope 3 (indirect) GHG emissions have been calculated for each year of the Project life and are presented graphically in **Figure 3** (Scope 1 emissions only) and **Figure 4** (Scope 1 and Scope 3 emissions). The estimated annual and Life of Project emissions are summarized in **Table 11**, with further details provided in **Appendix B**.

A review of the emission estimates shows the following:

- The main contributor to the estimated Scope 1 emissions for the construction phase is the loss of carbon stocks due to land clearing. As shown in **Figure 4**, the emission inventory also accounts for the ongoing annual losses of carbon during the operations and decommissioning phases, due to cleared vegetation not being available to assimilate any further CO_2. These estimates do not include the areas cleared for the pipelines however, as they will be allowed to revegetate, albeit to a limited extent (vegetation will be cut to low levels and trees with extensive root systems will not be allowed to grow).
- The Scope 1 emissions are shown to be highest during Years 2 to 5 of operation, which is due to the venting of acid gas (containing CO_2) via the thermal oxidizer. This reduces significantly after Year 5, when acid gas injection begins.
- For the combined Scope 1 and 3 emission estimates, the maximum calculated annual emissions of GHG associated with Project operations are still predicted to occur during Years 2 to 5 of operations, due to the Scope 1 emissions associated with the venting of acid gas via the thermal oxidizer.
- The indicative Scope 1 emission estimates compiled for the decommissioning phase are 25 kt CO_2-e per annum emitted for the assumed two year decommissioning period. These emissions represent a minor component of the Project in its entirety.

Figure 3 Estimated Annual Scope 1 GHG Emissions for Each Year of the Project Life

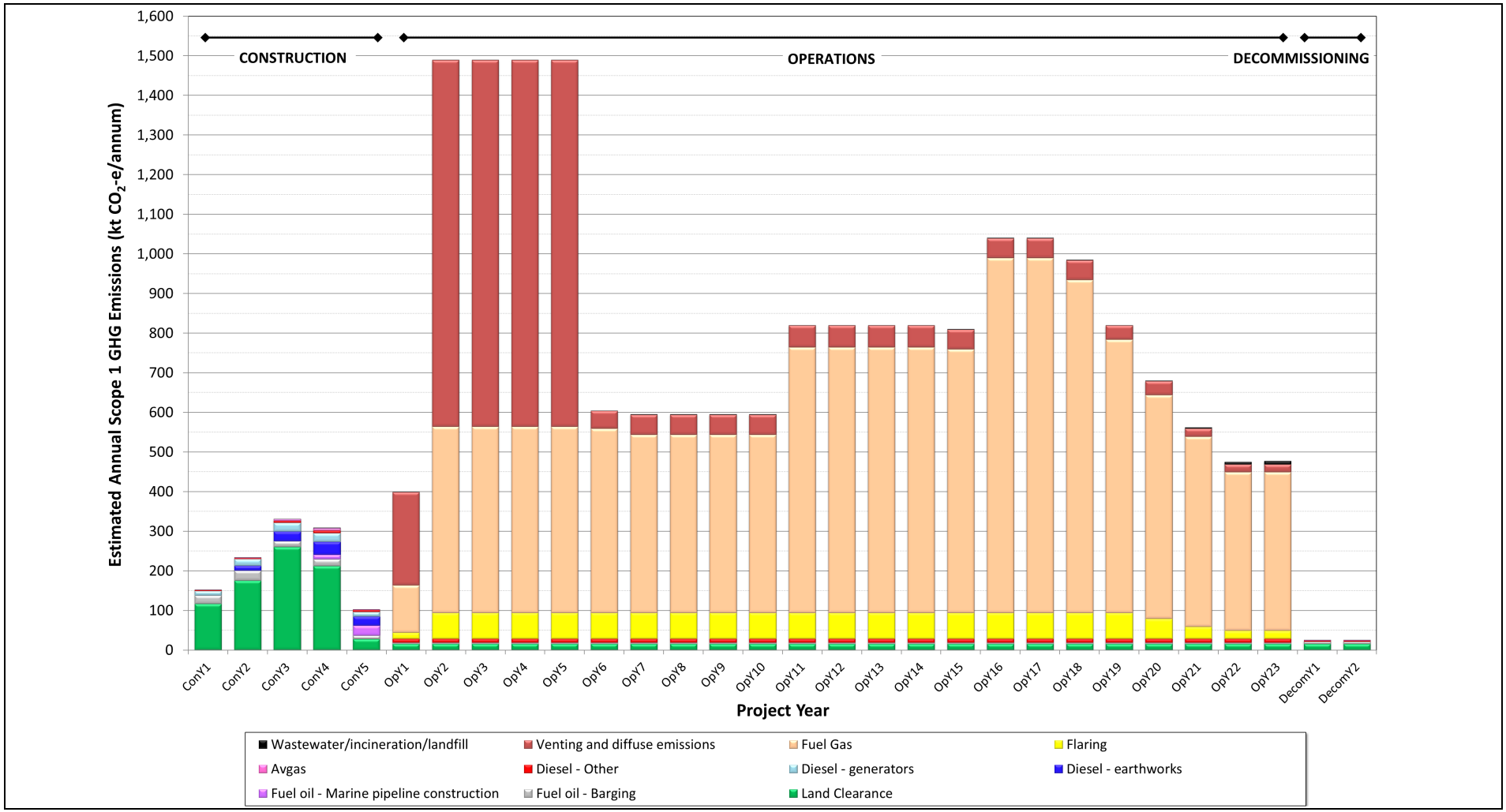
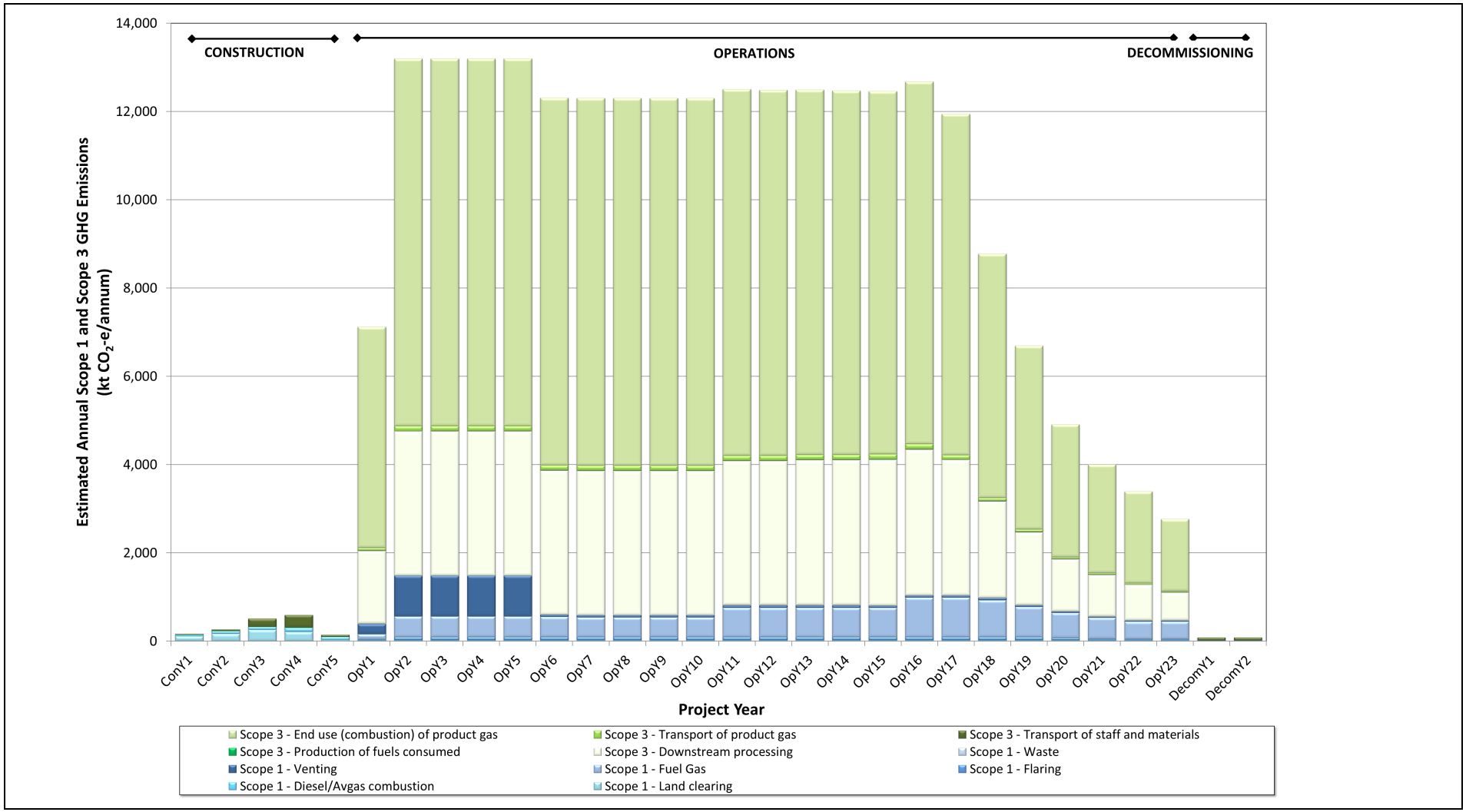


Figure 4 Estimated Annual Scope 1 and Scope 3 GHG Emissions for Each Year of the Project Life



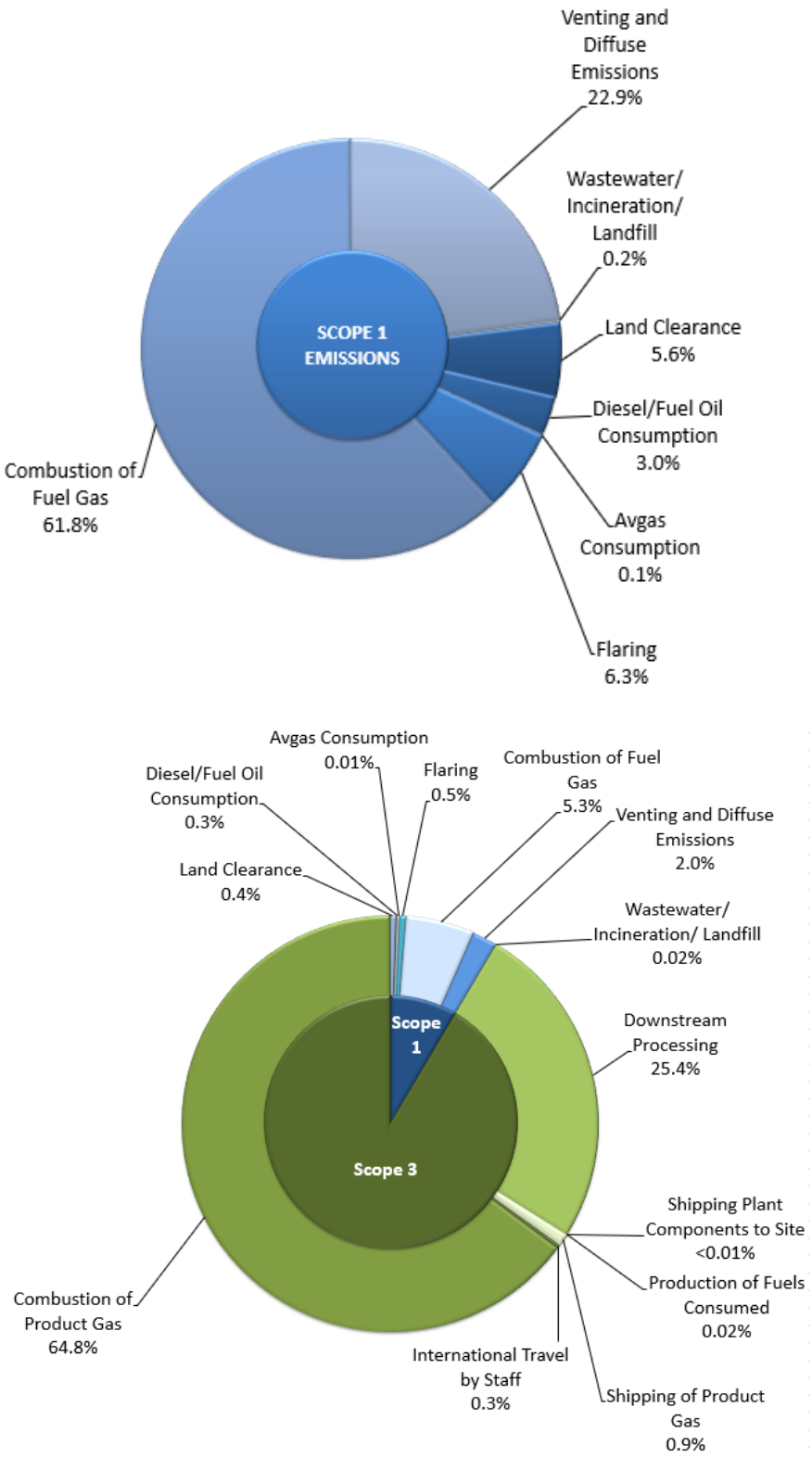
- Over the Project operational lifetime, the major Scope 1 emission source (61.8%) is predicted to be the combustion of fuel gas at the CPF to drive the compressors, run the heating boiler and to generate power (see **Figure 5**).
- The most significant contributors to the estimated Scope 3 emissions over the Project operational lifetime are downstream processing of the gas (25.4%) and combustion of the product gas by the end user (65%).

Table 11 Summary of Estimated Project GHG Emissions

Project Year	Estimated Annual GHG Emissions (kt CO_2-e)		
	Scope 1	Scope 3	Scope 1 + Scope 3
Construction Year 1	152	22	173
Construction Year 2	233	41	274
Construction Year 3	330	184	514
Construction Year 4	309	287	596
Construction Year 5	103	46	149
Operations Year 1 – HP phase, acid gas venting via TO (start-up year)	399	6,726	7,124
Operations Years 2 to 5 – HP phase, acid gas venting via TO (average)	1,489	11,710	13,199
Operations Years 6 to 10 – HP phase, acid gas injection (average)	597	11,710	12,306
Operations Years 11 to 15 – MP phase, acid gas injection (average)	818	11,667	12,485
Operations Years 16 to 23 – LP phase, acid gas injection (average)	760	6,140	6,900
Decommissioning Year 1	25	68	93
Decommissioning Year 2	25	68	93
Total Life of Project GHG Emissions	**20,682**	**220,286**	**240,968**

Note: Columns may not add up exactly due to rounding

Figure 5 Estimated Life of Project GHG Emissions - Source Contribution Analysis



4.6.2 Benchmarking

The international Association of Oil and Gas Producers (IOGP) has collected environmental data from its member companies annually since 1999. The objective of this program is to allow member companies to compare their performance with other companies in the sector, to facilitate improved and more efficient performance. The latest *Environmental Performance Indicators – 2017 Data Report* (IOGP, 2018) has been reviewed to identify current industry GHG emissions intensities against which the emissions presented in **Section 4.6.1** can be compared.

The IOGP 2017 Data Report (IOGP, 2018) summarizes the emissions of GHG (as CO_2-e) per thousand tonnes of hydrocarbon production from 2013 to 2017 as shown in **Figure 6**. The report states that where the source of the emissions is specified, 60% of the reported GHG emissions are from energy use, 23% are from flaring, 13% are from venting or vents and 4% are attributable to fugitive losses. The IOGP report defines fugitive losses as "*unintended emissions released to the air, other than those from stacks or vents from the processing, transmission, and/or transportation of fossil fuels. They are often due to equipment leaks and evaporative processes*".

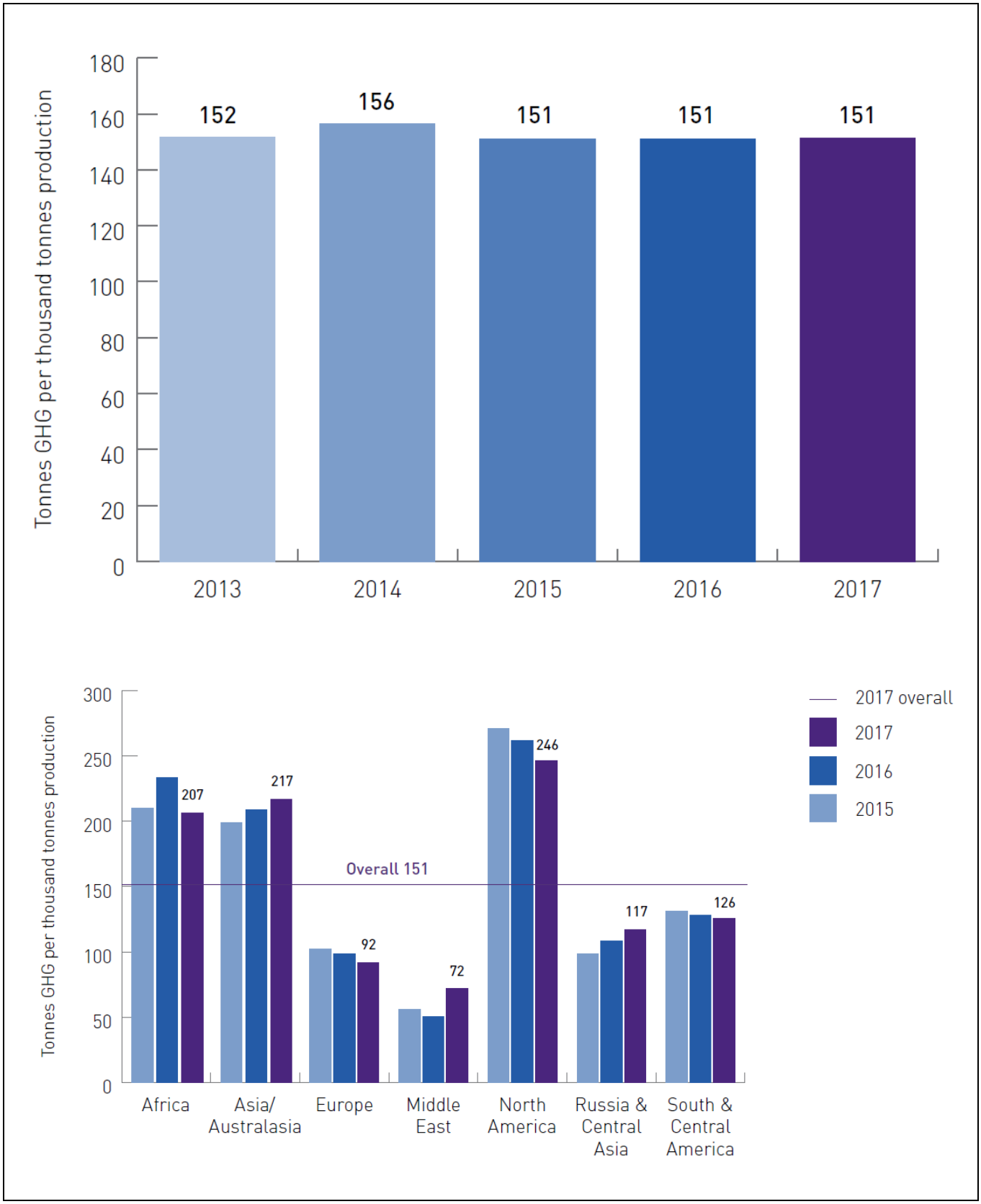
The GHG emissions intensity for the Project (in tonnes GHG per thousand tonnes of hydrocarbon production) has been calculated based on the estimated total life of Project GHG emissions shown in **Table 11** and the following production volumes derived from information on the production profile shown in **Figure A3.2** in **Appendix A**:

- Total production of field condensate (as 1,000 barrels of oil equivalents): 65,426 kboe.
- Total produced (raw) gas: 123,243 kt

The mass of total produced (raw) gas was calculated by multiplying the million standard cubic feet per day (MMSCFD) for each year by 365 and then using a conversion factor of 0.0217 million tonnes per billion cubic feet (QP, 2018). Dividing the number of barrels of condensate by 7.33 boe/tonne of oil equivalent (SPE, 2019) and adding the tonnes of raw gas produced gives a total hydrocarbon production of 132,169 kt over the life of the Project. With an estimated total life of Project Scope 1 GHG emission rate of 20,682 kt CO_2-e (see **Table 11**) the resulting Scope 1 GHG emissions intensity (i.e., excluding downstream processing) is 156.5 tonnes GHG per thousand tonnes of hydrocarbon production.

This emissions intensity value is slightly (4%) above the average value of 151 tonnes GHG per thousand tonnes of hydrocarbon production reported by the IOGP for hydrocarbon production in 2017. However it is less than (72% of) the average intensity value reported for Asia/Australasia of 217 tonnes GHG per thousand tonnes of hydrocarbon production.

Figure 6 Reported GHG Emissions per Unit of Hydrocarbon Production – IOGP Member Companies



Source: (IOGP, 2018)

4.7 Comparison of GHG Emissions with National Totals

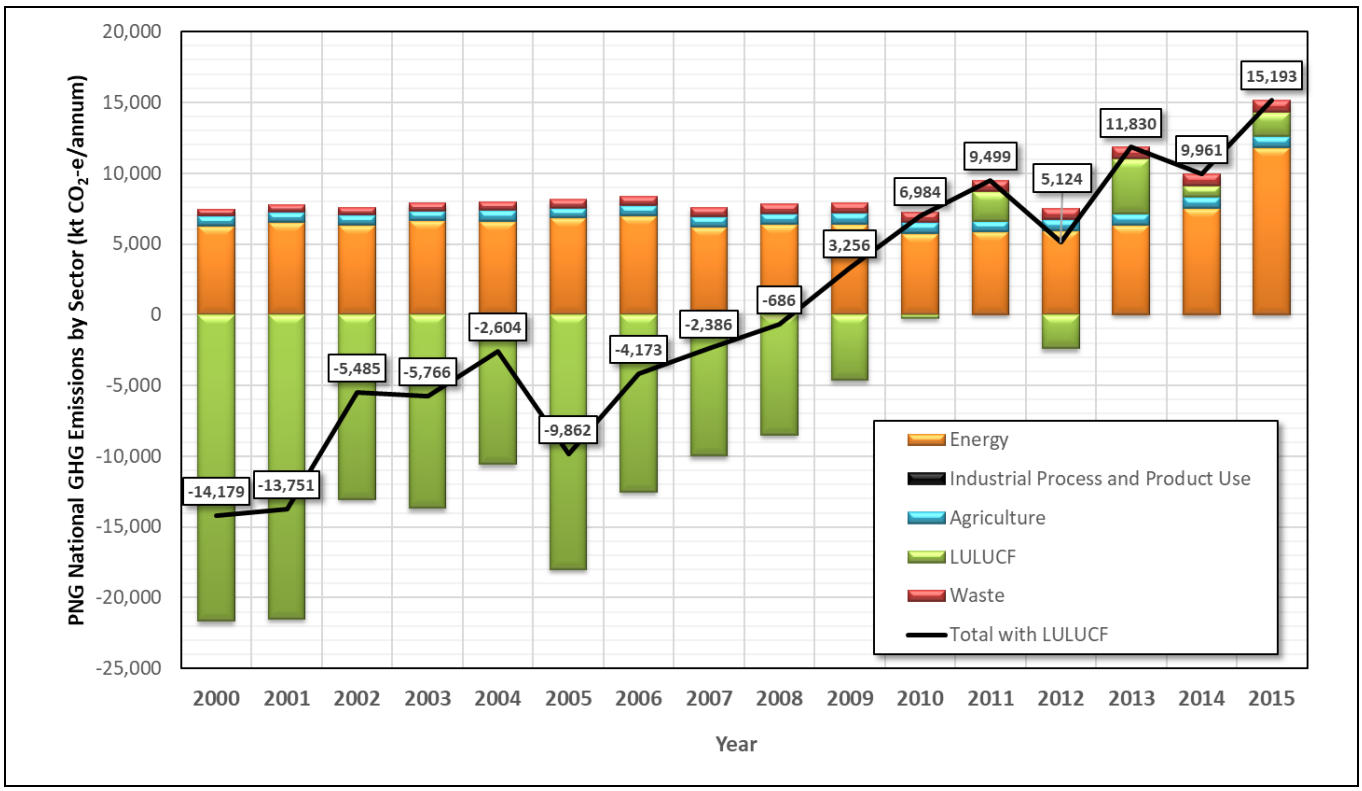
4.7.1 PNG National GHG Emissions Inventory

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) presents an overview of PNG's national circumstances relevant to climate change and presents an inventory of anthropogenic GHG emissions by sources and removals by sinks for years 2000 through to 2015. It also presents 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.

A summary of the PNG GHG emission inventory data presented in the BUR1 report for the period 2000 to 2015 is presented in **Figure 7**. It is stated in the report that the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006) were used to estimate emissions and all sectors of removals for the BUR1 inventory. The emissions and removals 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.

Figure 7 Estimated National GHG Emissions for PNG (2000 to 2015)



Source: (CCDA, 2018)

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

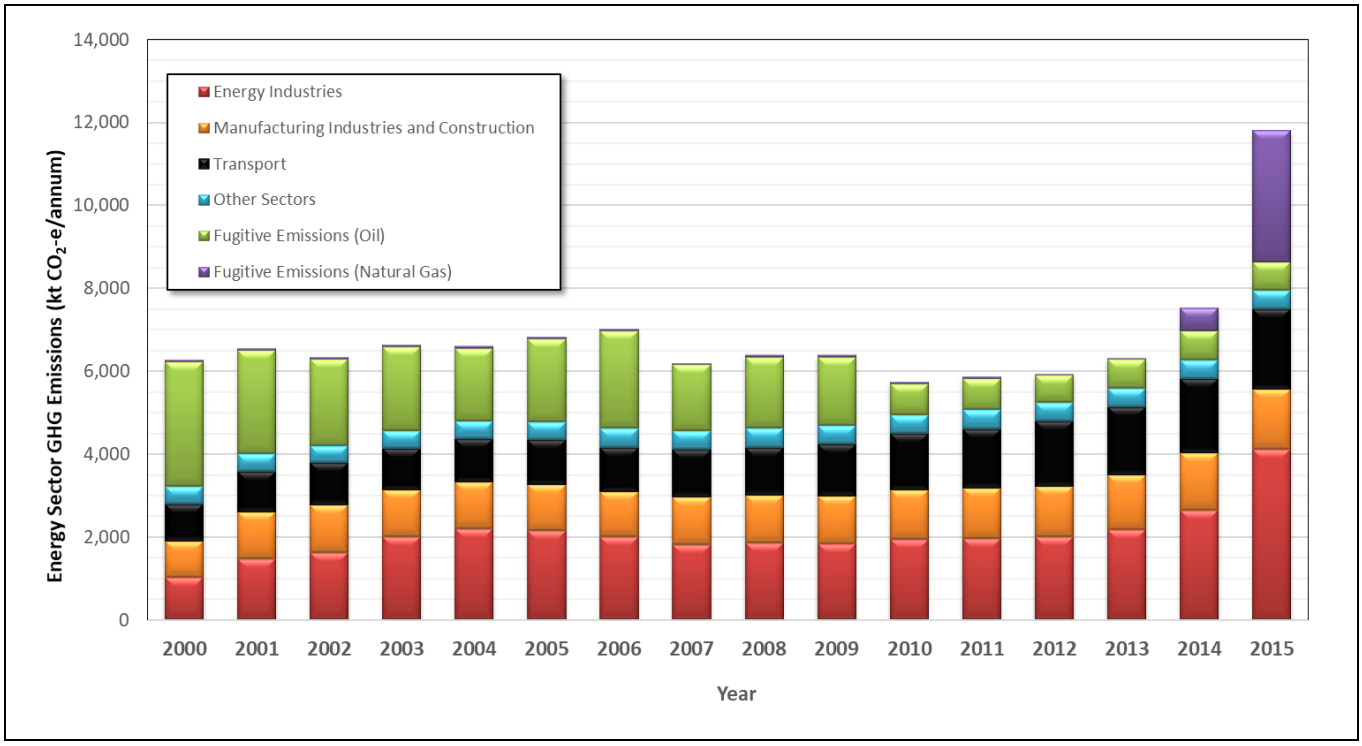
Energy

Emissions from the energy sector amounted to 11,806.28 kt CO_2-e in 2015, an increase of 5,532.37 kt CO_2-e (88.2%) when compared to 2000. The BUR1 report notes that 68% of total sector emissions are CO_2, while CH_4 contributed 31% and N_2O contributed 0.4%.

A breakdown of the estimated emissions for the energy sector is presented in **Figure 8**. Energy Industries was the main emitting subsector from 2000 to 2015, mainly relating to electricity generation. These emissions increased slightly from 2000 to 2004 due to the increase in demand for electricity, remained constant from 2005 to 2013, then increased notably in 2014 and 2015. This is attributed to the PNG LNG Project starting operations.

GHG emissions from the transport subsector increased from 2007 to 2015 as transportation activities increased. Emissions associated with fugitive emissions from the oil sector decreased between 2000 and 2015 as the production of oil decreased, while fugitive emissions from the gas sector increased due to the increase in production of natural gas (i.e., the PNG LNG Project), especially in 2015.

Figure 8 Estimated GHG Emissions from the Energy Sector by Category (2000 to 2015)



Source: (CCDA, 2018)

Industrial Processes and Product Use (IPPU)

PNG has only a few manufacturing companies, which are mostly based in Lae, Morobe Province and Port Moresby. The estimated emissions from this sector cover two categories:

- Non-energy Products from Fuels and Fossil Fuels (Lubricant Use): Accounts for application of lubricants used in transportation and industry in the form of oil types.
- Other Product Manufacture and Use (N_2O for Medical 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.

The total estimated emissions for the IPPU sector was 35.29 kt CO_2-e in 2015, an increase of 1.38 kt CO_2-e (4.1%) when compared to 2000. N_2O from medical use contributed 58%, and lubricant use 42%, to the total sector emissions in 2015. These emissions represent a very minor contribution to the total national emission inventory.

Agriculture, Forestry and Other Land Use

The estimated emissions from the Agriculture, Forestry and Other Land Use Sector cover:

- Direct and indirect emissions from managed soils (N_2O).
- Enteric fermentation (CH_4).
- Direct and indirect manure management (CH_4 and N_2O).
- Burning of crop residues (CH_4 and N_2O).

GHG emitting categories with limited availability of activity data for calculation (such as liming and urea application) were not included in the inventory.

Emissions from this sector amounted to 796 kt CO_2-e in 2015, an increase of 114 kt CO_2-e (16.7%) when compared with the year 2000. Direct and indirect emissions from managed soils contributed 58% of the total sector emissions in 2015, followed by enteric fermentation and manure management that together contributed 41%, while biomass burning of crop residue (specifically, rice, sugarcane and corn) contributed 1% of the total sector emissions.

The BUR1 report states 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.

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

The Land Use Land-Use Change and Forest (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 7**, this sector has become an increasingly smaller sink over time due to a decrease in forest lands, and in 2011, 2013, 2014 and 2015 the LULUCF sector was a net source.

The BUR1 report states that the average annual area of deforestation between 2011 and 2015 (30,667 ha) was more than three times higher than the average between 2001 and 2005. Almost the entire area (99.3%) of deforestation was due to land use conversion from forest land to cropland. Subsistence agriculture is the most significant (69.8%) driver of deforestation, followed by oil palm plantation development (24.4%).

Logging was identified as the major driver of forest degradation, responsible for 90% of the degradation occurring during the reporting period.

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 872.5 kt CO_2-e in 2015, an increase of 354 kt CO_2-e (60.9%) when compared to 2000. Wastewater treatment and discharge contributed 70.6% to total sector emissions in 2015, followed by solid waste disposal (28.7%) and biological treatment of solid waste (0.7%). The report notes that 87.1% of total sector emissions are CH_4 and 15.1% are N_2O.

The BUR1 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 assumptions and expert judgement.

4.7.2 Assessment of Project Contribution to PNG's National GHG Emissions Inventory

Emissions from the Project will be included in PNG's future national GHG emissions inventory as part of the Energy Sector emissions.

The maximum annual Scope 1 GHG emissions estimated for the Project (i.e., during the acid gas venting phase in operations years 2 to 5) are 1,489 kt CO_2-e. This represents an additional 9.8% increase in the total reported national PNG GHG emissions (including LULUCF) for 2015 of 15,193 kt CO_2-e. The contribution during other years of the Project will be less than this (e.g. 3.9% during years 7 to 10).

4.8 GHG Emissions Mitigation and Monitoring

Key design principles that have been adhered to during the pre-project phase to limit the Project's GHG emissions are as follows:

- No flaring during routine operations (flaring of natural gas strictly limited to minimum safety requirements such as start-up, maintenance, emergency situations and flare pilots).
- Injection of native acid gas (H_2S and CO_2) during Project life as soon as technically possible (acid gas venting cannot be avoided during the first four production years until sufficient depletion of the Elk reservoir).
- Waste heat recovery on power turbine exhausts, to reduce the fuel gas requirement for water heating.

The Project will also almost exclusively be generating its own electricity from natural gas, minimizing the use of diesel fuel, which will also result in a lower GHG footprint.

Operational mitigation measures that will be implemented for the Project have been identified as follows:

- Energy efficiency options relating to mobile plant and equipment that contribute to reducing emissions through lowering fuel consumption will be incorporated in maintenance regimes and environmental management plans. For example:
  - Vehicle speed reduction.
  - Reduction in idling times of trucks at construction sites through efficient traffic management.
  - Maintaining roads in good condition to avoid meandering of vehicles on roads.
  - Reducing gradients around site.
  - Optimizing vehicle tire pressures and maintaining vehicles according to the manufacturer's guidance.
- Areas of disturbance will be reduced by:
  - Accurately estimating the land area required for different Project facilities and infrastructure.
  - Siting infrastructure and facilities as close to existing or previously used roads, as practicable.
  - Clearly identifying the boundaries of areas to be disturbed at each Project site prior to works commencing.
- A structured Leak Detection and Repair (LDAR) program will be implemented for all relevant Project infrastructure to identify gas leaks for prompt repair.
- An inventory of GHG emissions from Project activities will be maintained in accordance with relevant standards and guidelines to support annual reporting requirements. GHG reporting will include the development of Project metrics relating to energy efficiency and emissions intensity, and the tracking and reporting of the Project's performance against these metrics.
- TOTAL will monitor emerging issues and technological developments throughout the life of the Project, and will be a fast-follower adopter of feasible technological solutions.

5 Climate Change Study

Climate refers to the average weather conditions prevailing in an area over a long period of time. Climate variability refers to the natural variations in climate that occur from month to month, season to season and year to year. Climate change refers to long-term changes in the average pattern of weather, occurring over decades, centuries or longer, as a result of both natural and man-made processes. It can mean long-term changes in average climate conditions (such as average rainfall and temperature) or in the occurrence of extreme events such as tropical cyclones and droughts.

A climate change study has been performed for the Project to:

- Assess whether the Project is located within a recognized climate-sensitive area, and based on this, assess the Project's vulnerability to the anticipated effects of climate change (e.g., sea-level rise, flooding, extreme weather events). The objectives of the risk identification process are to:
  - Identify potential direct and indirect climate-related adverse effects that may affect the Project during its life-cycle.
  - Identify potential direct and indirect climate-related effects that may be exacerbated by the Project.
- Identify opportunities for how the Project may improve its resilience to the effects of global climate change. This includes the identification of monitoring programs, as appropriate.
- Identify opportunities for how local communities may plan and prepare to reduce their vulnerability to the effects of climate change and to improve their resilience.

5.1 Study Method

This climate change study has been performed with reference to:

- *Climate Change Adaptation and Mitigation (CAM) Methodology Brief* (ICEM, 2011).
- *Assessing Climate Change Risks and Opportunities for Investors - Oil and Gas Processing Sector* (Smith, 2013).

The key steps performed in preparing this climate change study were as follows:

1. A literature review was performed to:
   - Characterize the existing climate of PNG and the Project area, including the current variability in key climatological variables, such as rainfall, flood levels, storm frequency and ambient temperatures.
   - Gain an understanding of the anticipated changes in the climate in the region where the Project is located.
2. Aspects of the Project that are potentially sensitive to the climate changes projected to occur over the Project life cycle were identified. Both direct and indirect climate threats were considered.
3. The level of risk for the Project of each of the identified potential climate threats was then characterized as a function of:
   - The level of exposure to climate change induced threats (based on consideration of factors such as duration, frequency and intensity of the change); and

- The sensitivity of the target assets or system to that exposure (i.e., the degree to which the Project may be affected by the change).

4. The adaptive capacity of the Project to the identified climate threats was then assessed. Adaptive capacity relates to the ability of an asset or system to prepare for a future threat, and in the process, increase resilience and the ability to recover from the impact.
5. Based on the Project's potential exposure and sensitivity to the predicted climate change threats, and the adaptive capacity of the Project in the design, construction and operations phases, its potential vulnerability to climate change was then assessed. A vulnerable system or asset is one that is sensitive to changes and extremes in climate and hydrology, and one for which the ability to adapt is constrained.

The matrix shown in **Table 12** was used to define the level of risk for the Project to the identified potential climate threats, based on considerations of sensitivity and exposure (Step 3 above).

Exposure is the degree of climate stress on a particular asset or Project. It is influenced by long-term changes in climate conditions, and by changes in climate variability, including the magnitude and frequency of extreme events. The following criteria are identified by the CAM Methodology Brief as influencing exposure:

- Duration (e.g. hours or days of flooding).
- Location (e.g. distance from flood).
- Intensity (e.g. strength of rainfall, speed of flood).
- Magnitude (e.g. volume, flow or size of event).
- Aspect (orientation to the threat, e.g., wind and waves).

Sensitivity is the degree to which a system will be affected by, or responsive to, climate change exposure. For infrastructure, like the CPF and other Project assets, sensitivity is the degree to which the exposure to a threat will negatively affect the integrity or operation of that asset. The following variables are identified by the CAM Methodology Brief as affecting infrastructure sensitivity:

- Materials.
- Construction quality.
- Levels of maintenance.
- Protective system(s).
- Design (including safety margins).

Table 12 Climate Change Risk Matrix for Climate Change Threats to a System

Sensitivity of System to Climate Threat	Exposure of System to Climate Threat				
	Very Low	Low	Medium	High	Very High
Very High	Medium	Medium	High	Very High	Very High
High	Low	Medium	Medium	High	Very High
Medium	Low	Medium	Medium	High	Very High
Low	Low	Low	Medium	Medium	High
Very Low	Very Low	Low	Low	Medium	High

Source: (ICEM, 2011).

The matrix shown in **Table 13** was used to define the vulnerability of the Project to the identified potential impacts, based on considerations of sensitivity and adaptive capacity (Step 5 above). Adaptive capacity relates to the ability of the Project to prepare for, and recover from, the impact of each identified future climate-related threat. This can relate to factors such as:

- The ability of the Project to enable projected climate impacts to be factored into the design phase of the Project (e.g., selection of access road routes and construction methods to reduce the risk of road closures due to landslides and flooding, siting and designing coastal and riverside infrastructure based on projected sea level rises and flood levels).
- The availability of back up systems (e.g., alternative site access options in the event of road closures, such as by air).
- Potential management, maintenance and response systems that can be implemented as part of the Project, including policies, structures, technical staff and budgets.
- Availability of physical resources (e.g., materials and equipment to rebuild roads damaged by more frequent or intense storm events).

Table 13 Vulnerability Assessment Matrix for Climate Change Threats to a System

Adaptive Capacity	Impact				
	Very Low Inconvenience (days)	**Low** Short disruption to system function (weeks)	**Medium** Medium term disruption to system function (months)	**High** Long term damage to system property or function (years)	**Very High** Loss of life, livelihood or system integrity
Very Low	Medium	Medium	High	Very High	Very High
Low	Low	Medium	Medium	High	Very High
Medium	Low	Medium	Medium	High	Very High
High	Low	Low	Medium	Medium	High
Very High	Very Low	Low	Low	Medium	High

Source: (ICEM, 2011).

5.2 Existing Climate Features of the Study Area and Past Trends

The following summary of the historical and existing climate features of Papua New Guinea has been compiled based on information contained within reports published by the Australian Bureau of Meteorology (BoM) and the Commonwealth Scientific and Industrial Research Organisation (CSIRO), as part of the Pacific Climate Change Science Program (PCCSP). The PCCSP is a collaborative research partnership between Australian Government agencies, East Timor and 14 Pacific Island countries including Papua New Guinea. The reports reviewed included:

- *Climate Variability, Extremes and Change in the Western Tropical Pacific: New Science and Updated Country Reports* (BoM, CSIRO, 2014).
- *Climate Change in the Pacific: Scientific Assessment and New Research, Volume 1: Regional Overview* (BoM, CSIRO, 2011a).

- *Climate Change in the Pacific: Scientific Assessment and New Research, Volume 2: Country Reports* (BoM, CSIRO, 2011b).

Climate variability in the western tropical Pacific region occurs on a wide range of time scales. Natural cycles cause variations in the climate on time scales of months, seasons and years. The annual cycle of wet and dry seasons is one example of natural climate variability experienced by every island in this region. This cycle varies in timing and intensity between years. Much of year-to-year climate variability is caused by natural variations in the conditions of the atmosphere and ocean, such as the El Niño-Southern Oscillation (ENSO). ENSO is a coupled atmosphere-ocean phenomenon, with time scales of about two to seven years. Throughout the region, ENSO affects the year-to-year risk of droughts, floods, tropical cyclones, extreme sea levels and coral bleaching and is the major cause of year-to-year climate variability in the Pacific. It is a natural cycle of the climate system, with two extreme phases: El Niño and La Niña. If neither phase is apparent, conditions are termed ENSO neutral. The extent and timing of the influence of the El Niño-Southern Oscillation varies between countries. As well as ENSO there are other natural patterns of climate variability that influence the region, including the Interdecadal Pacific Oscillation and the closely related Pacific Decadal Oscillation.

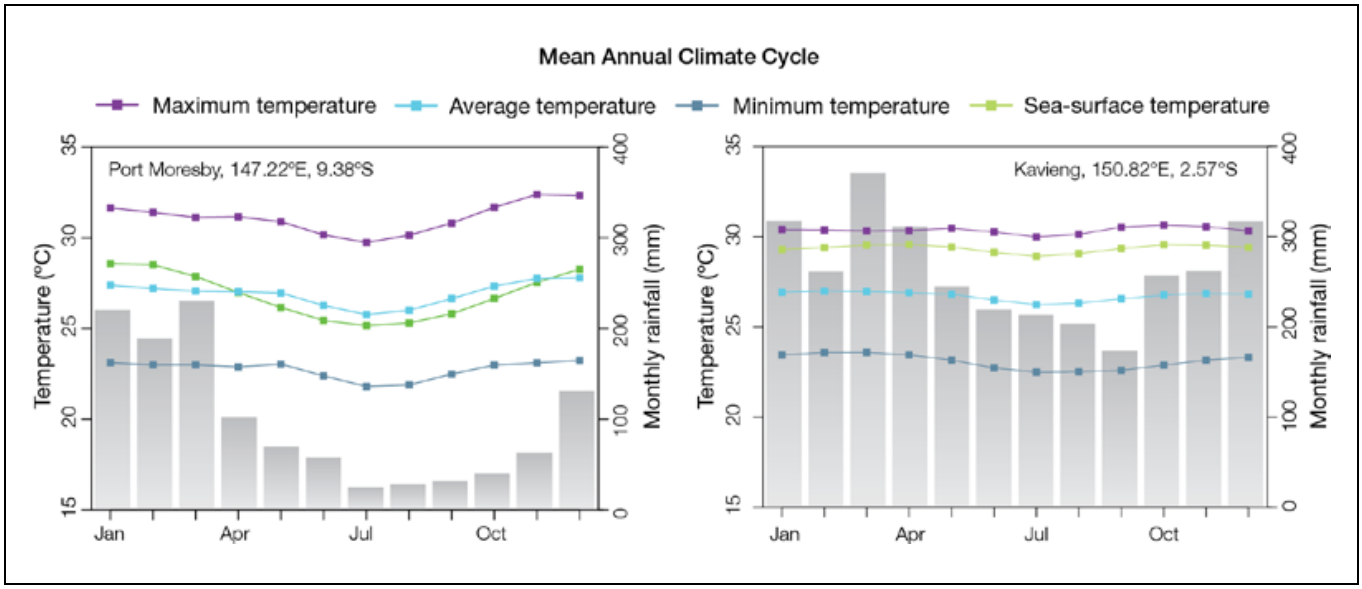
The 2014 climate report prepared by PCCSP (BoM, CSIRO, 2014) states that there are currently 39 operational meteorological stations in Papua New Guinea. Multiple observations within a 24-hour period are taken at 18 stations: four synoptic stations in Momase, two in the Highlands, six in the Southern region and six in the New Guinea Islands. In addition, there are three single observation climate stations and 18 single observation rainfall stations. The primary climate station, Port Moresby Weather Office, is located at Jacksons Airport near Port Moresby.

Historical rainfall and air temperature data from Port Moresby and Kavieng have been analyzed by PCCSP to characterize the current climate in Papua New Guinea and to identify trends in the data over the last 70 years (BoM, CSIRO, 2011b) (BoM, CSIRO, 2014). A summary of the findings follows, focusing on the information available for Port Moresby, as the closest location to the Project area.

Temperature

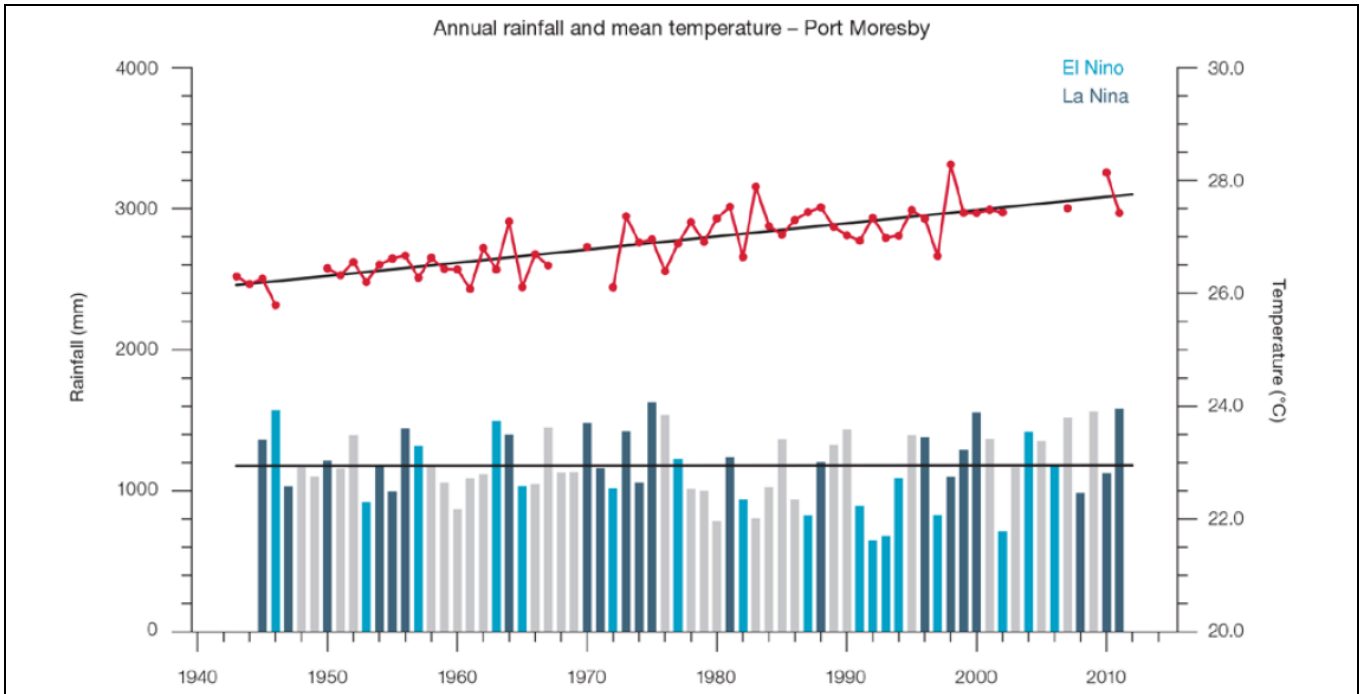
- Sites in Papua New Guinea have very weak seasonal variations in temperature (see **Figure 9**). Sea-surface temperatures have a strong influence on average monthly air temperatures.
- Warming trends are evident in both annual and seasonal mean air temperatures at Port Moresby since 1943 (see **Figure 10**). Annual and half-year air temperatures at Kavieng have also been warming since 1962. These trends are considerably stronger in minimum air temperatures when compared to maximum air temperatures.
- Warm temperature extremes have increased and cool temperature extremes have decreased at both sites (see **Figure 11** for Port Moresby data summary). All temperature trends are consistent with global warming.

Figure 9 Mean Annual Cycle of Daily Maximum, Minimum and Mean Air Temperatures and Rainfall at Port Moresby



Source: (BoM, CSIRO, 2011b).

Figure 10 Annual Mean Temperatures and Rainfall at Port Moresby (1945 – 2011)

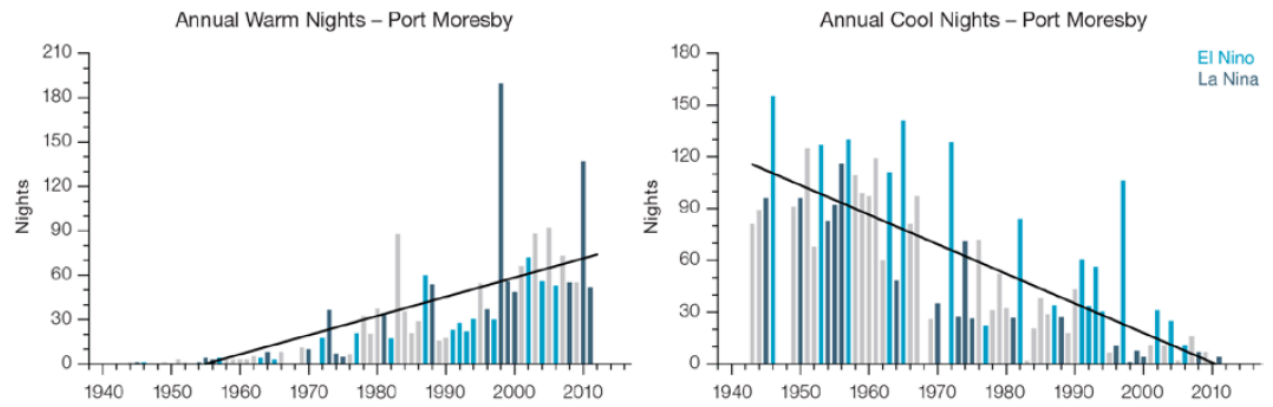


Note: Observed time series of annual average values of mean air temperature (red dots and line) and total rainfall (bars) at Port Moresby. Light blue, dark blue and grey bars denote El Niño, La Niña and neutral years respectively. Solid black trend lines indicate a least squares fit.

Source: (BoM, CSIRO, 2014).

Note: 'Least squares fit' is a method of determining the curve that best describes the relationship between expected and observed sets of data by minimizing the sums of the squares of deviation between observed and expected values.

Figure 11 Time Series of Annual Number of Warm Nights and Cool Nights at Port Moresby (1945 – 2011)



Note: Light blue, dark blue and grey bars denote El Niño, La Niña and neutral years respectively. Solid black trend lines indicate a least squares fit.

Source: (BoM, CSIRO, 2014).

Notes: 'Warm Nights' defined as the number of days with minimum temperature greater than the 90th percentile for the base period 1971 to 2000.

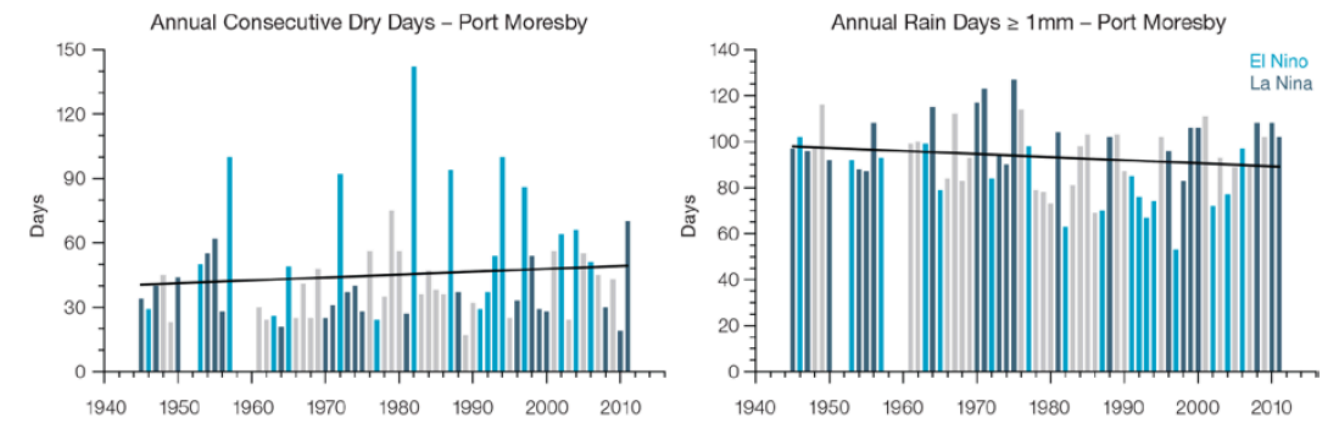
'Cool Nights' defined as the number of days with minimum temperature less than the 10th percentile for the base period 1971 to 2000.

'Least squares fit' is a method of determining the curve that best describes the relationship between expected and observed sets of data by minimizing the sums of the squares of deviation between observed and expected values.

Rainfall

- PCCSP (BoM, CSIRO, 2011b) states that the south of Papua New Guinea has a wet season from November to April and a dry season from May to October, while further north rainfall is more consistent throughout the year (as per **Figure 9**). The upper Purari catchment is similar to this, but lower in the Purari catchment in PRL-15, significantly higher rainfall occurs during the southeast trade wind season (May to October) than during the northwest monsoon (December to March), representing a reverse of the rainfall patterns experienced in upper parts of the catchment. Toward the coast, rainfall is lower and more evenly spread throughout the year.
- Year-to-year variability in rainfall is high in Papua New Guinea. At both Port Moresby and Kavieng, the wettest years receive up to three times the rainfall of the driest years (as shown in **Figure 10** for Port Moresby). The ENSO drives much of this variability. Generally, El Niño years are drier than average while La Niña years are wetter than average.
- Trends in annual and seasonal rainfall are not statistically significant and these parameters show little change at Port Moresby and Kavieng. There are also no statistically significant trends in the annual Consecutive Dry Days and Rain Days ≥1 mm (days with rainfall) recorded at Port Moresby (see **Figure 12**).

Figure 12 Time Series of Annual Consecutive Dry Days and Rain Days ≥ 1 mm at Port Moresby (1945 – 2011)



Note: Light blue, dark blue and grey bars denote El Niño, La Niña and neutral years respectively. Solid black trend lines indicate a least squares fit.

Source: (BoM, CSIRO, 2014).

Extreme Events

- Tropical cyclones affect the Southern Hemisphere portion of Papua New Guinea, mainly between November and April. An average of 15 cyclones per decade developed within or crossed the Papua New Guinea Exclusive Economic Zone (EEZ) between the 1969/70 and 2010/11 seasons.
- On average, Port Moresby experiences six tropical cyclones per decade, with most occurring between November and April.
- The differences between tropical cyclone average occurrence in El Niño, La Niña and neutral years are not statistically significant.
- Eleven of the 43 tropical cyclones (26%) between the 1981/82 and 2010/11 seasons were severe events (Category 3 or stronger) in the Papua New Guinea EEZ. Available data are not suitable for assessing long-term trends.
- In the southern Papua New Guinea region, prolonged rainfall during La Niña events leads to serious floods and landslides. El Niño events are associated with droughts.

Sea Level

- Monthly averages of the historical tide gauge, satellite (since 1993) and gridded sea-level (since 1950) data agree well after 1993 and indicate inter-annual variability in sea levels of about 23 cm (estimated 5-95% range) after removal of the seasonal cycle.
- The sea-level rise near Papua New Guinea measured by satellite altimeters since 1993 is about 7 mm per year, larger than the global average of 3.2 ± 0.4 mm per year. This rise is partly linked to a pattern related to climate variability from year to year and decade to decade.

Sea-Surface Temperature and Ocean Acidification

- Water temperatures in the Papua New Guinea region have risen gradually since the 1950s. Since the 1970s, the rate of warming has been approximately 0.11°C per decade.

- Seawater aragonite saturation states above 4 have been identified as optimal for coral growth and for the development of healthy reef ecosystems, with values from 3.5 to 4 adequate for coral growth, and values between 3 and 3.5, marginal. Seawater aragonite saturation states below 3 are classified as extremely marginal for supporting coral growth. In the Papua New Guinea region, the aragonite saturation state has declined from about 4.5 in the late 18th century to an observed value of about 3.9 ± 0.1 by 2000.

Wind Waves

Surface wind-wave driven processes can impact on many aspects of Pacific Island coastal environments, including coastal flooding during storm wave events, coastal erosion (both during episodic storm events and due to long-term changes in the wave climate), characterization of reef morphology and marine habitat/ species distribution, flushing and circulation of lagoons, and potential shipping and renewable wave energy solutions. The surface offshore wind-wave climate can be described by characteristic wave heights, lengths or periods, and directions.

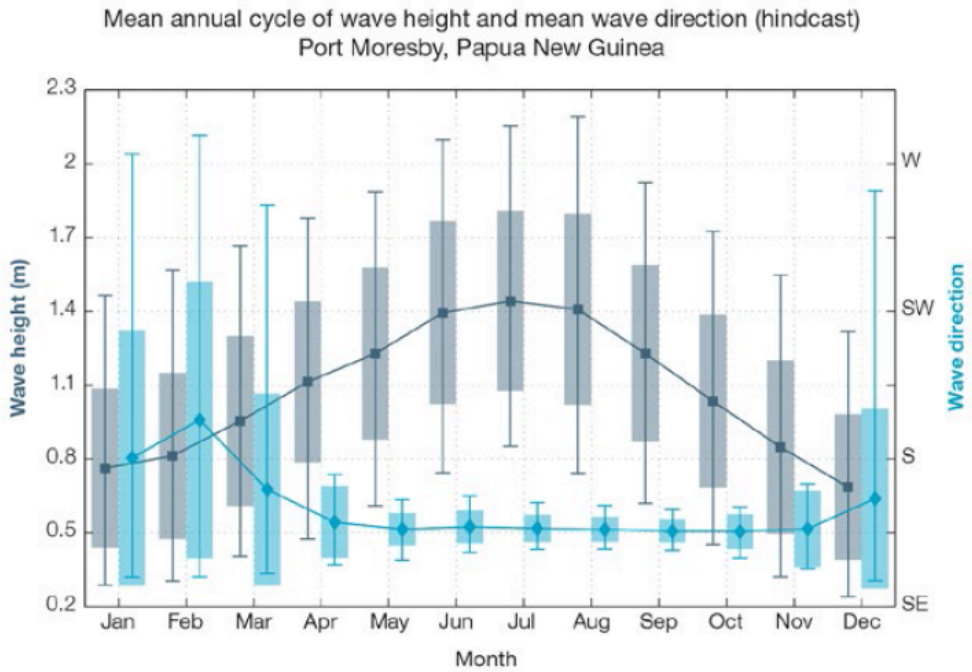
The analysis of the wind-wave climate of Papua New Guinea showed:

- Wind-waves around Papua New Guinea are typically not large, with markedly different behavior on the north and south coasts.
- On the south coast (e.g., south of Port Moresby):
  - Waves are predominantly directed from the southeast throughout the year, but display a strong seasonal variability in their magnitude with the Southern Hemisphere trade winds and monsoon winds.
  - From June to September, mean waves are largest (seasonal mean height around 1.4 m) (see **Figure 13**), consisting of trade wind generated waves from the southeast, and a small component of swell propagated from storm events in the Tasman Sea and in the south.
  - During the wetter months of December to March, mean waves reach a minimum (seasonal mean height around 0.8 m) (see **Figure 13**) and are directed from the south with some locally generated monsoonal westerly waves.
  - Waves larger than 2.3 m (99th percentile) at Port Moresby occur predominantly during the dry months, usually directed from the south, with some large westerly and southwesterly waves observed during the monsoon season.
  - The height of a 1-in-50 year wave event near Port Moresby was calculated to be 4.1 m.
- On the northern coast (e.g., Kavieng):
  - Waves are characterized by variability of trade winds and monsoon systems.
  - From December to March, waves near Kavieng have slightly higher magnitude (mean height around 1.4 m) and a longer period (around 9.3 s) than the annual mean. These waves consist of local monsoon-generated westerly waves, and northeasterly swell generated by trade winds and northern Pacific extra-tropical storms.
  - From June to September, the observed easterly waves are typically generated locally by trade winds with north-easterly swell, and are smaller (mean height around 0.9 m) and of shorter period (about 7.3 s) than the annual mean.

- Waves larger than 2.0 m (99th percentile) occur in December to March from the northwest to northeast due to tropical storms. Some large easterly and north-easterly waves are seen in the dry months.
- The height of a 1-in-50 year wave event at Kavieng was calculated to be 3.0 m.

- The wind-wave climate displays strong inter-annual variability on the north coast of Papua New Guinea (near Kavieng), varying strongly with the El Niño–Southern Oscillation (ENSO). Wave power is much greater during La Niña years than El Niño years in June to September, with waves more strongly directed from the east in both December to March and June to September, associated with increased trade wind strength and changed monsoonal influence in the wet season. The ENSO variability of wave climate on the south coast (e.g., near Port Moresby) is less prominent.
- No suitable dataset is available to assess long-term historical trends in the Papua New Guinea wave climate.

Figure 13 Mean Annual Cycle of Wave Height and Mean Wave Direction at Port Moresby (1979–2009)



Note: To give an indication of inter-annual variability of the monthly means of the hindcast data, shaded boxes show 1 standard deviation around the monthly means, and error bars show the 5–95% range. The direction from which the waves are travelling is shown.

Source: (BoM, CSIRO, 2014).

5.3 Climate Change Projections for the Study Area

The complexity of the climate system means that past trends cannot be simply extrapolated to forecast future conditions. Instead, mathematical representations of the Earth's climate system are used to simulate the fundamental processes affecting weather and climate. Global climate models calculate variables such as temperature and rainfall at points over the globe spaced 100 to 400 km apart, with about 30 layers in the ocean and 30 layers in the atmosphere (BoM, CSIRO, 2014). They have been used extensively over recent decades to not only estimate future climate change, but also to help better understand the present and past climate. How well the models agree with the observed present climate is used to assess model reliability, with the underlying assumption that a model which adequately simulates the present climate will provide more reliable projections of the future.

No single climate model is the 'best' in representing all aspects of climate, so a range of models need to be considered when making projections of future climate. After analyzing data from 27 global climate models from around the world, the PCCSP identified a set of 24 models which provide a reasonable representation of observed climate for Papua New Guinea. These 24 models have been used by the PCCSP to construct projections of future climate for Papua New Guinea (BoM, CSIRO, 2014).

The projections use four different GHG and aerosol concentration emission scenarios, called Representative Concentration Pathways (RCPs):

- **RCP8.5** (very high emissions) – Represents a future with little curbing of emissions, with atmospheric CO_2 concentrations continuing to rapidly rise, reaching 940 ppm by 2100.
- **RCP6** (medium emissions) – Represents lower emissions, achieved by application of some mitigation strategies and technologies. CO_2 concentrations rising less rapidly (than RCP8.5), but still reaching 660 ppm by 2100 and total radiative forcing stabilizing shortly after 2100.
- **RCP4.5** (low emissions) – CO_2 concentrations are slightly above those of RCP6.0 until after mid-century, but emissions peak earlier (around 2040), and the CO_2 concentration reaches 540 ppm by 2100.
- **RCP2.6** (very low emissions) – Represents the most ambitious mitigation scenario, with emissions peaking early in the century (around 2020), then rapidly declining. Such a pathway would require early participation from all emitters, including developing countries, as well as the application of technologies for actively removing CO_2 from the atmosphere. The CO_2 concentration reaches 440 ppm by 2040 then slowly declines to 420 ppm by 2100.

The lowest scenario shows the likely outcome of reducing emissions (mitigation), and the highest scenario shows the impact of a pathway with no climate policy and high emissions.

PCCSP's climate projections for Papua New Guinea are outlined below (BoM, CSIRO, 2014). A confidence rating (very high, high, medium, and low) is given by PCCSP for the direction and magnitude of change of each projection, consistent with the IPCC guidance on confidence assessment. Confidence in the magnitude of change indicates how well the model represents the expected change for a particular scenario. The confidence in the magnitude of change is often lower than the confidence in the direction of change. Confidence is reduced when there are model biases in relevant climate features and where there is a wide range of projections from the models (BoM, CSIRO, 2014).

ENSO

- El Niño and La Niña events will continue to occur in the future (*very high confidence*), but there is little consensus on whether these events will change in intensity or frequency.

Temperature

- Further warming is expected over Papua New Guinea. Annual mean temperatures and extremely high daily temperatures will continue to rise (*very high confidence*), however there is *medium confidence* in the magnitude of the model average temperature change.
- Under all RCPs, the warming is up to 1.1°C by 2030, relative to 1995, but after 2030 there is a growing difference in warming between each RCP. For example, in Papua New Guinea by 2090, a warming of 2.1 to 4.2°C is projected for RCP8.5 while a warming of 0.4 to 1.3°C is projected for RCP2.6.
- While relatively warm and cool years and decades will still occur due to natural variability, there is projected to be more warm years and decades on average in a warmer climate.

Rainfall

- Average rainfall is projected to increase in most areas (*medium confidence*), along with more extreme rain events (*high confidence*). The projected increase in long-term average rainfall is greater for the higher emissions scenarios, especially towards the end of the century. Almost all models project an increase in rainfall in both the May to October and November to April seasons.
- The year-to-year rainfall variability over Papua New Guinea is much larger than the projected change, except in the upper range of models in the highest emissions scenario by 2090. There will still be wet and dry years and decades due to natural variability, but most models show that the long-term average is expected to be wetter. The effect of climate change on average rainfall, however, may not be obvious in the short or medium term due to natural variability.
- Downscaling of the climate model simulations suggests that there may be a large spatial variation in rainfall changes across Papua New Guinea. Specifically, this work indicates that increases greater than the regional average are possible on northern-facing slopes in both May to October and November to April seasons. Conversely, increases less than the regional average, or even decreases, are possible in some highlands and southern-facing slope regions. These spatial patterns relate to the effects of mountains and the position within the monsoon flow.

Extreme Events

- The temperature on extremely hot days is projected to increase by about the same amount as average temperature. The frequency of extremely hot days is also expected to increase. The temperature of the 1-in-20-year hot day is projected to increase by approximately 0.6°C by 2030 under RCP2.6 and by 0.8°C under RCP8.5. By 2090, the projected temperature of the 1-in-20-year hot day is expected to decrease by 0.8°C for RCP2.6 and increase by 3°C for RCP8.5.
- The frequency and intensity of extreme rainfall events are projected to increase, however there is *low confidence* in the magnitude of the projected change in extreme rainfall. By 2030, the current 1-in-20-year daily rainfall amount is projected to increase by approximately 14 mm under RCP2.6 and 12 mm under RCP8.5. By 2090, it is projected to increase by approximately 21 mm for RCP2.6 and by 55 mm for RCP8.5. By 2090, the majority of models project the current 1-in-20-year daily rainfall event will become, on average, a 1-in-7 year event for RCP2.6 and a 1-in-4 year event for RCP8.5.

- The overall proportion of time spent in drought is expected to decrease in most locations under all scenarios. Under RCP8.5, the frequency and duration of drought in all categories is projected to decrease. Under RCP2.6 the frequency of mild drought is projected to increase slightly, while the frequency of severe and extreme drought is projected to decrease slightly. The duration of mild drought events is projected to remain stable, while the duration of events in all categories is projected to decrease slightly under RCP2.6. There is *medium confidence* in this direction of change.
- The modeling projects a decrease in the frequency of cyclone formation for the southwest basin with a *medium confidence* level. This is consistent with a projected decrease in the frequency of cyclones globally, where the magnitude of the decrease varies from 6% to 35% depending on the modeling study. There is also a general agreement between models that there will be an increase in the mean maximum wind speed of cyclones by between 2% and 11% globally, and an increase in rainfall rates of the order of 20% within 100 km of the cyclone center. Hence cyclones are projected to become less frequent, but more intense.

Sea Level

- Mean sea level is projected to continue to rise over the course of the 21st century under all RCP emissions scenarios. There is very *high confidence* in the direction of change.
- The models project a mean sea level rise of between approximately 7 to 17 cm by 2030 (very similar values for different RCPs), with increases of 41 to 87 cm by 2090 under RCP8.5. There is *medium confidence* in the range mainly because there is still uncertainty associated with projections of the Antarctic ice sheet contribution.
- Inter-annual variability of sea level will lead to periods of lower and higher regional sea levels. In the past, this inter-annual variability has been about 23 cm and it is likely that a similar range will continue through the 21st century.

Sea-Surface Temperature and Ocean Acidification

- As atmospheric CO_2 concentrations continue to rise, oceans will warm and continue to acidify (*high confidence*). These changes will impact the health and viability of marine ecosystems, including coral reefs that provide many key ecosystem services.
- Ocean acidification is expected to continue (*very high confidence*) and the risk of coral bleaching will increase in the future (*very high confidence*).
- All models show that the aragonite saturation state, a proxy for coral reef growth rate, will continue to decrease. Under RCPs 8.5 and 4.5, the median aragonite saturation state will transition to marginal conditions (3.5) around 2030. In RCP8.5 the aragonite saturation state continues to strongly decline thereafter to values where coral reefs have not historically been found (<3.0). Under RCP4.5 the aragonite saturation plateaus around 3.2 (i.e., marginal conditions for healthy coral reefs). Under RCP2.6, the median aragonite saturation state never falls below 3.5, and increases slightly toward the end of the century, suggesting that conditions remain adequate for healthy coral reefs. There is *medium confidence* in this range and distribution of possible futures.

Wind Waves

- No changes in waves along the Coral Sea coast of Papua New Guinea are projected (*low confidence*).

- On the northern coasts, December-March wave heights are projected to decrease, accompanied by a slight decrease in wave period and possible anticlockwise rotation (more northerly waves) during December to March consistent with a weakening trade wind contribution (*low confidence*). During June to September, projected changes in wave climate are small and not significant (*low confidence*). These features are characteristic of a decrease in strength of the northeasterly trade winds. A decrease in larger waves is suggested (*low confidence*).

5.4 Identification of Climate-Related Risks for the Project

The climate-related risks identified for the Project are summarized in **Table 14** for the key climate variables that have future projections available for Papua New Guinea. This table includes a summary of the scale of the potential climate change impacts projected by the PCCSP (BoM, CSIRO, 2014) for the two extreme GHG and aerosol concentration emission scenarios used in the Global Climate Models; RCP2.6 (very low emissions) and RCP8.5 (very high emissions). These projected magnitudes of change have been considered when identifying potential risks for the Project. For example, as the frequencies of cyclones and droughts are not projected to increase, no significant impacts related to increased risks of storm damage or decreased water availability have been identified for the Project.

Existing wave conditions in the nearshore zone and at the river mouths have been identified as potentially being a restriction on vessel operations for the Project. While the PCCSP concludes that the climate models currently do not identify any significant changes in waves along the Coral Sea coast of Papua New Guinea in the future, this projection has a *low confidence* (BoM, CSIRO, 2014). Given that wave conditions already pose a potential risk for the Project, and there is a *low confidence* in whether they are likely to change in the future due to climate change, they have been included in **Table 14** so that adaptation measures can be identified for implementation as required.

The climate-related Project risks identified in **Table 14** take into consideration the proposed Project design life of 25 years, by focusing (subject to data availability) on the projected climate change impacts up to approximately the year 2050. The risks identified also focus on the operations phase of the Project, as the majority of the construction works would be completed prior to the projected climate change predictions being realized. This includes construction of the pipeline, CPF and Logistics Base, which would all be complete within five years after the Final Investment Decision. However additional, less intensive, construction activities would be required at the CPF at later stages of the Project life to install additional compressors as the Project moves into the medium pressure (MP) and low pressure (LP) phases, which have been considered.

Table 14 Summary of Projected Climate Changes for PNG and Associated Potential Project Impacts

Variable	Projected Magnitude of Change for PNG *				Potential Impacts on the Project
	Emission Scenario	2030	2050	2070	
Surface air temperature (°C)	RCP2.6	+0.6 (0.5 - 0.9)	+0.8 (0.6-1.2)	+0.8 (0.5-1.3)	- Higher power demand and fuel gas consumption (e.g., increased air conditioning demand, compressors operating less efficiently, increased inlet air chilling) - Increased risk of worker illness from mosquito-borne diseases (e.g., malaria, chikungunya and dengue fever) - Increased risk of worker illness from heat stress
	RCP8.5	+0.8 (0.5 - 1.1)	+1.4 (1.0-2.0)	+2.2 (1.6-3.2)	
Maximum temperature (°C) [1 in 20 year event]	RCP2.6	+0.6 (0.3 - 0.8)	+0.7 (0.4-1.1)	+0.7 (0.4-1.1)	
	RCP8.5	+0.8 (0.5 - 1.1)	+1.5 (0.9-2.0)	+2.3 (1.5-3.3)	
Minimum temperature (°C) [1 in 20 year event]	RCP2.6	+0.6 (0.3 - 0.9)	+0.7 (0.2-1.1)	+0.8 (0.4-1.1)	
	RCP8.5	+0.8 (0.4 - 1.3)	+1.5 (1.0-2.1)	+2.3 (1.6-3.4)	
Annual Rainfall (%)	RCP2.6	+4 (-5 - +13)	+6 (-1 - +15)	+7 (0 - +18)	- Increased risk of flooding at logistics facilities (Herd Base, Logistics Base and Purari Airstrip) resulting in supply chain disruptions and temporary loss of access - Increased risk of barges and other water craft colliding with uprooted trees and other debris during or after flooding events - Increased risk of erosion and landslides damaging CPF, pipelines, wellpads - Increased risk of temporary loss of access to Project infrastructure and supply chain disruption caused by damage to access roads due to landslides/flooding - Increased risks from airlifting supplies and workers during extreme events - Increased leachate management requirements for landfills - Delays to construction and decommissioning activities - Increased risk of accidents (e.g., driving hazards) during wet weather
	RCP8.5	+4 (-2 - +12)	+8 (2 - +18)	+12 (2 - +28)	
Nov – April Rainfall (%)	RCP2.6	+4 (-5 - +13)	+6 (-1 - +15)	+7 (0 - +18)	
	RCP8.5	+4 (-2 - +12)	+8 (2 - +18)	+12 (2 - +28)	
May – Oct Rainfall (%)	RCP2.6	+4 (-5 - +13)	+6 (-1 - +15)	+7 (0 - +18)	
	RCP8.5	+4 (-2 - +12)	+8 (2 - +18)	+12 (2 - +28)	
Extreme rainfall events	RCP2.6	2030: 1-in-20-year daily rainfall increase of 14 mm 2090: 1-in-20-year daily rainfall increase of 21 mm 2090: current 1-in-20-year daily rainfall event will become, on average, a 1-in-7 year event			
	RCP8.5	2030: 1-in-20-year daily rainfall increase of 12 mm 2090: 1-in-20-year daily rainfall increase of 55 mm 2090: current 1-in-20-year daily rainfall event will become, on average, a 1-in-4 year event			

Variable	Projected Magnitude of Change for PNG *				Potential Impacts on the Project
Annual Mean Sea Level (cm)	RCP2.6	+4 (-5 - +13)	+6 (-1 - +15)	+7 (0 - +18)	- Inundation of pipeline structures at Orokolo Bay and Caution Bay - Restricted barge access at the coast due to changes in the sea bed
	RCP8.5	+4 (-2 - +12)	+8 (2 - +18)	+12 (2 - +28)	
Cyclones	A decrease in the frequency of cyclone formation is projected for the southwest basin (*medium confidence*), however the intensity of cyclones is projected to increase globally				- Increased risk of damage to Project infrastructure due to more intense cyclones (higher winds and higher rainfall)
Droughts	The proportion of time spent in drought is expected to remain stable or to decrease (*medium confidence*)				- No associated risks identified
Wind waves	No changes in waves along the Coral Sea coast of Papua New Guinea are projected (*low confidence*)				- Wave conditions already pose a restriction on Project vessel operations and any unforeseen increases in wave heights etc. due to climate change could exacerbate this

* Projected changes are shown for three 20-year periods centred on 2030, 2050 and 2070, relative to a 20-year period centred on 1995. Values represent the multi-model mean change, with the 5–95% range of uncertainty in brackets.

In addition to the direct impacts listed in **Table 14**, there is potential for climate change to result in indirect impacts on the Project. These include:

- Climate change impacts such as sea level rise and more intense cyclones damaging infrastructure owned or operated by suppliers to the Project, or having other significant adverse financial or physical impacts on these organizations. This includes the international airport and port facilities in Port Moresby, which will be critical logistics hubs for the Project.
- Changes in the regulatory landscape to implement climate change policies resulting in more intense regulation of oil and gas activities. For example, refineries are amongst the industry groups already included in the EU and (now repealed) Australian carbon price/emissions trading schemes, while an increasing number of governments globally are moving to eliminate gas flaring (noting that the Project will not flare gas except during start-up and emergency operations).
- Climate change policies driving down demand for natural gas. Barring the development of commercially viable technology able to significantly reduce the emissions released in the burning of fossil fuels, a transition to a low carbon global economy will require a significant reduction in the use of fossil fuels.

5.5 Climate Change Adaptation Measures

Table 15 lists adaptation strategies that will be used to mitigate each of the climate-related risks identified for the Project in **Table 14**. Based on anticipated effectiveness of the identified adaptation strategies the adaptive capacity of the Project in relation to each risk has been categorized as Very High, High, Medium, Low or Very Low. The basis for the category assigned is noted in the table.

In addition to the Project-specific adaptation strategies listed in in **Table 15**, TOTAL is committed to supporting government efforts to establish and implement a clear, stable policy framework towards a global warming trajectory of 2°C in line with the Paris Agreement. To do this, TOTAL will maintain engagement with PNG government climate authorities, e.g. the CCDA, and policy-makers.

Table 15 Climate Change Adaptation Strategies and Adaptive Capacity of the Project

Identified Climate Threat	Identified Adaptation Strategies	Adaptive Capacity of the Project
Higher power demand and fuel gas consumption due to increased ambient temperatures	- Use of more energy efficient chillers and air-conditioning systems. - Training of staff in efficient use of chillers and air-conditioning systems. - Ensuring the Project design includes appropriate assumptions regarding energy demand over the life of the Project to enable it to accommodate any reduction in fuel efficiency in the compressor engines associated with the projected ambient temperature increases.	**Very High** *Project will have full control over factors influencing energy demand such as equipment selection and training* *Electricity demand will be met internally and does not rely on a 3rd party power supply*
Increased risk of worker illness from diseases (e.g., malaria) due to increased ambient temperatures and rainfall	- Implementation of mosquito control measures at work sites and camps (minimization of areas of standing water, provision of mosquito nets and repellants). - Worker training in preventative health measures. - Provision of on-site medical facilities and health monitoring systems for workers.	**High** *Mitigation measures to minimize disease transmission in the region are well understood and are already in place for the current workforce*
Increased risk of worker illness from heat stress due to increased ambient temperatures	- Inclusion of heat stress mitigation and management measures in the Project occupational health and safety (OHS) systems. - Worker training in heat stress risks and controls. - Provision of on-site medical facilities.	**High** *Project will have a high level of control over procedures to be followed during extreme heat events*
Increased risk of flooding at logistics facilities resulting in supply chain disruptions and temporary loss of access for workforce due to increased rainfall and more intense rainfall events	- Consideration of future flood projection levels in the design and construction of Project infrastructure. - Construction and maintenance of helicopter landing areas to provide an alternative transport option in the event of flooding.	**Very High** *Project has full control over the design and construction of the logistics facilities to ensure the required mitigation measures are implemented*
Increased risk of barges and other water craft colliding with uprooted trees and other debris during or after flooding events	- Implementation of Project OHS systems, training, emergency response procedures, first aid, emergency communication systems, etc. - Appropriate specification and maintenance of water craft. - Delay barge movements during and immediately after flooding events, until risk of water hazards has reduced.	**High** *Project will have a high level of control over procedures to be followed to minimize the risk of collisions*

Identified Climate Threat	Identified Adaptation Strategies	Adaptive Capacity of the Project
Increased risk of erosion and landslides damaging CPF, pipelines, wellpads, etc., due to increased rainfall and more intense rainfall events	- Inclusion of best practice soil erosion management strategies and drainage systems in the design and construction of pipelines, wellpads and other infrastructure. - Regular inspection and maintenance of retaining walls, benching, etc. - Revegetation after construction to re-establish root systems to support slopes and to maximize the water-holding capacity of the land.	**Medium** *The large footprint of the Project infrastructure, remoteness of the area and complex topography means that some risk of landslides and slips will remain even after controls are implemented*
Increased risk of temporary loss of access to Project infrastructure and supply chain disruption caused by damage of access roads due to landslides/flooding associated with increased rainfall and more intense rainfall events	- Minimization of risks associated with landslides/flooding during the design and construction of access roads, such as route planning and construction method. - Regular inspections and maintenance of roads to identify and mitigate landslides and other risks (e.g., re-grading of road surface, maintenance of road batters and retaining structures, etc.). - Revegetation after construction to re-establish root systems to support slopes and to maximize the water-holding capacity of the land. - Construction and maintenance of helicopter landing areas to provide an alternative transport option in the event of flooding.	**Medium** *The remoteness of the area and complex topography means that some risk of damage to roads due to landslides and flooding will remain even after controls are implemented*
Increased leachate management requirements for landfills due to increased rainfall and more intense rainfall events	- Consideration of rainfall projection levels in the design and construction of landfills and associated surface water controls and leachate management systems. - Monitoring of leachate water quality and appropriate treatment prior to release to the environment.	**Very High** *Project has full control over the design and construction of the landfills to ensure the required mitigation measures are implemented*
Delays to construction and decommissioning activities due to increased rainfall and more intense rainfall events	- Appropriate planning and scheduling taking into account the most recent climate data available at the time of future construction activities (e.g., installation of additional compressors as the Project moves into the medium pressure (MP) and low pressure (LP) phases).	**High** *Project has control over the construction schedules and will have up to date knowledge of current climate risks at the time of any future construction activities.* *However, extreme weather events can occur with little warning and disrupt site works.*

Identified Climate Threat	Identified Adaptation Strategies	Adaptive Capacity of the Project
Increased risk of accidents (e.g., flight/driving hazards) during wet weather due to increased rainfall and more intense rainfall events	- Implementation of Project OHS systems, job safety assessments (JSAs), journey management plans, driver training, emergency response procedures, first aid, emergency communication systems. - Appropriate specification and maintenance of equipment and vehicles (including aircraft). - Minimization of wet weather driving hazards through the appropriate design, construction and maintenance of access roads. - Regular inspections and maintenance of roads, Purari Airstrip, helicopter pads and other Project infrastructure to identify and mitigate any hazards arising from, or potentially exacerbated by, intense rainfall events.	**Medium** *The large footprint of the Project infrastructure, remoteness of the area and nature of the works being undertaken means that some risk of accidents will remain even after controls are implemented*
Inundation of pipeline structures at Orokolo Bay and Caution Bay due to rising sea levels	- Consideration of future sea levels and predicted storm surge in the location, design and construction of Project infrastructure. - Elevation of equipment above ground level as required to maximum protection against sea level rise and storm surges.	**Very High** *Project has full control over the location, design and construction of the pipeline landfall infrastructure to ensure the required mitigation measures are implemented*
Increased risk of damage to Project infrastructure due to more intense cyclones (higher winds and higher rainfall)	- Consideration of projected increases in cyclone intensity in the location, design and construction of Project infrastructure. - Development of emergency procedures to prepare for a cyclone event in the event a cyclone warning is issued for the Project area.	**Very High** *Project has full control over the design and construction of infrastructure to ensure the required mitigation measures are implemented. The main Project infrastructure is also located inland.*
Restricted barge access at the coast due to changes in sea bed associated with rising sea levels, wave conditions, storm surges, etc.	- Regular inspection and maintenance of barging routes, including dredging if required, to maintain access. - Appropriate specification and maintenance of watercraft, and use of experienced and trained navigators. - Ongoing assessment of the optimal barging route considering the three marine accesses from the sea to the CPF (Urika-Ivo, Purari and Wame-Varoi branches). - Planning of delivery of large high value equipment and/or bulk aggregate during the wet season (identified as the optimal 'navigation season').	**High** *Project has the capacity to dredge to facilitate barge access, if required.*

5.6 Climate Change Vulnerability Assessment

Using the matrices presented in **Table 12** and **Table 13**, the vulnerability of the Project to each of the climate-related risks identified in **Table 14** has been assessed. The results of this vulnerability assessment are presented in **Table 16**.

As shown in **Table 16** the main vulnerabilities for the Project relate to:

- The increased risk of flooding and landslides and the potential for these events to result in damage to infrastructure and/or disruptions to logistics activities (barging, roads).
- Restricted barge access at the coast due to changes in the seabed associated with sea level rise and (possibly) increased wave action.

Table 16 Climate Change Vulnerability Assessment

Climate Threat	Sensitivity of Project to Climate Threat	Exposure of Project to Climate Threat	Impact [a]	Adaptive Capacity of Project [b]	Vulnerability of Project [c]
Higher power demand and fuel gas consumption (e.g., increased air conditioning demand, compressors operating less efficiently)	Low	Low	Low	Very High	Low
Increased risk of worker illness from diseases	Very Low	Low	Low	High	Low
Increased risk of worker illness from heat stress	Very Low	Low	Low	High	Low
Increased risk of flooding at logistics facilities (Herd Base, Logistics Base and Purari Airstrip) resulting in supply chain disruptions and temporary loss of access for workforce	Low	Medium	Medium	Very High	Low
Increased risk of barges and other water craft colliding with uprooted trees and other debris during or after flooding events	Low	Medium	Medium	High	Medium
Increased risk of erosion and landslides damaging CPF, pipelines, wellpads, etc.	Low	Medium	Medium	Medium	Medium
Increased risk of temporary loss of access to Project infrastructure and supply chain disruption caused by damage of access roads due to landslides/flooding	Low	Medium	Medium	Medium	Medium
Increased leachate management requirements for landfills	Very Low	Low	Low	Very High	Low
Delays to construction and decommissioning activities	Very Low	Medium	Low	High	Low
Increased risk of accidents (e.g., driving hazards) during wet weather	Very Low	Medium	Low	Medium	Medium
Inundation of pipeline structures at Orokolo Bay and Caution Bay	Very Low	Low	Low	Very High	Low
Increased risk of damage to Project infrastructure due to more intense cyclones	Medium	Low	Medium	Very High	Low

Climate Threat	Sensitivity of Project to Climate Threat	Exposure of Project to Climate Threat	Impact [a]	Adaptive Capacity of Project [b]	Vulnerability of Project [c]
Restricted barge access at the coast due to changes in sea bed associated with seal level rise	High	Low	Medium	High	Medium

a From **Table 12**

b From **Table 15**

c From **Table 13**

5.7 Potential Climate Change Impacts on the Local Community

Extreme weather events and landslides have potential to result in damage to community and non-Project infrastructure, which in turn would have potential to impact on production. Improving community resilience to climate change impacts could therefore result in improved productivity for the Project.

The effects of climate change on communities in Papua New Guinea will be addressed through the PNG Government's climate and GHG initiatives and strategies, including those relating to deforestation and climate change adaption. Economic development, including through the expansion of the oil and gas sector, will assist in providing PNG with resources to develop and implement climate resilience projects, as well as improve infrastructure for the local PNG communities in general.

6 Conclusions

This report presents the method, inputs, assumptions, findings and conclusions of a GHG assessment and climate change study performed by SLR for the Papua LNG Project.

GHG emission sources associated with the construction, operations and decommissioning phases of the Project were identified by a review of the Project description. Scope 1, 2 and 3 emissions were considered in compiling the inventory as follows:

- The geographical boundary set for Scope 1 emissions covers the footprint of the wellpads, CPF, Logistics Base, the existing Herd Base, Purari Airstrip, onshore and offshore pipelines, and the Caution Bay landfall approach. GHG emissions associated with the transportation of materials and workforce from Port Moresby to the Project area have also been considered as Scope 1 emissions, as well as emissions associated with their movement within the Project area.
- Scope 2 emissions have not been included as the Project will not be externally sourcing any appreciable quantities of electricity hence any associated GHG emissions will be minimal.
- GHG emissions associated with the international transport of materials and workers to/from Port Moresby, transport of product gas to end users and consumption of the gas by end users have been included in the assessment as Scope 3 emissions.
- It is understood that TEP PNG will be responsible for processing of the gas produced by the Project at the PNG LNG Facility as part of a multi-operator site arrangement. However, for the purposes of this assessment, GHG emissions associated with the downstream processing of the gas have been included as a Scope 3 emission source and not as a Scope 1 emission source as the downstream processing is beyond the scope of this EIS.

Relevant GHG emission factors were sourced from international guidelines and industry publications. In addition, annual GHG emission estimates calculated by the Project design team for fuel gas combustion, flaring venting/diffuse emissions at the CPF were adopted as part of this GHG assessment. The relevant activity data required for the calculations (land clearance areas, fuel consumption rates, barging activity data) were compiled based on the Project description and in consultation with TOTAL.

The annual and Life of Project emissions calculated for the Project indicate the following:

- The main contributor to the estimated Scope 1 emissions for the construction phase is the loss of carbon stocks due to land clearing, while the major Scope 1 emission source over the Project operational lifetime (61.8%) is the combustion of fuel gas.
- The Scope 1 emissions are shown to be highest during Years 2 to 5 of operation, which is due to the venting of acid gas (containing CO_2) via the thermal oxidizer. This reduces significantly after Year 5, when acid gas injection begins.
- Maximum calculated annual emissions of GHG (Scope 1 and 3) associated with Project operations are predicted to occur during Years 2 to 5 of operation, due to the Scope 1 emissions associated with the venting of acid gas via the thermal oxidizer. Over the Project life however, the most significant contributors to the estimated Scope 1 and 3 emissions are downstream processing of the gas (25.4%) and combustion of the product gas by the end user (64.8%).

- The indicative Scope 1 emission estimates compiled for the decommissioning phase are 25 kt CO_2-e per annum emitted for the assumed two year decommissioning period. These emissions represent a minor component of the Project in its entirety and are indicative only. 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 Project.
- The Scope 1 GHG emissions intensity (i.e. excluding downstream processing) is estimated to be 156.5 t GHG per thousand tonnes of hydrocarbon production. This emissions intensity value is slightly (4%) above the average value of 151 tonnes GHG per thousand tonnes of hydrocarbon production reported by the IOGP for Asia/Australia in 2017.
- Emissions from the Project would be included in PNG's national GHG emissions inventory as part of the Energy Sector emissions. The maximum annual Scope 1 GHG emissions estimated for the Project (i.e., during the acid gas venting phase in operations years 2 to 5) are 1,489 kt CO_2-e. This represents an additional 9.8% increase in the total reported national PNG GHG emissions (including LULUCF) for 2015 of 15,193 kt CO_2-e. The contribution during other years of the Project will be less than this (e.g. 3.9% during years 7 to 10).

Key design principles that have been adhered to during the pre-project phase to limit the Project's GHG emissions are as follows:

- No flaring during routine operations (flaring of natural gas strictly limited to minimum safety requirements such as start-up, maintenance, emergency situations and flare pilots).
- Injection of native acid gas (H_2S and CO_2) during Project life as soon as technically possible (acid gas venting (after removal of sulfur by the SRU) cannot be avoided during the first production years until sufficient depletion of the Elk reservoir)
- Waste Heat Recovery on power turbines

The Project will almost exclusively generate its own electricity from natural gas, minimizing the use of diesel fuel, which will also result in a lower GHG footprint.

A climate change study has also been performed to assess the Project's vulnerability to the effects of climate change projected to occur within the region. The objectives of this study were to identify potential direct and indirect climate-related adverse effects that may affect the Project during its life-cycle and to identify opportunities for how the Project may improve its resilience to the effects of global climate change.

As part of this study, the existing climate features of Papua New Guinea and projections of the future climate were reviewed based on information contained within reports published by the Pacific Climate Change Science Program (PCCSP). Aspects of the Project that are potentially sensitive to climate changes projected to occur over the Project life cycle were then identified. These potential impacts were characterized as a function of the level of exposure to climate change (with consideration of factors such as duration, frequency and intensity of the change) and Project sensitivity (i.e., the degree to which the Project may be affected by the change). The adaptive capacity of the Project to the identified impacts was also assessed.

Based on the Project's potential exposure and sensitivity to the predicted climate change impacts, and the adaptive capacity of the Project in the design, construction and operations phases, its potential vulnerability to climate change was assessed. The main findings of this vulnerability assessment were as follows:

- There is an increased risk of flooding and landslides over the life of the Project associated with higher rainfalls and higher frequency of extreme rainfall events, and the potential for these events to result in damage to infrastructure and/or disruptions to logistics activities (barging, roads).
- The Project is concluded to have a low vulnerability to projected increased ambient temperatures due to its high adaptive capacity to the associated risks.
- Existing wave conditions in the nearshore zone and at river mouths have been identified as potentially being a restriction on vessel operations for the Project. While the PCCSP concludes that the climate models currently do not identify any significant changes in waves along the Coral Sea coast of Papua New Guinea in the future, this projection has a *low confidence*. Given that wave conditions already pose a risk for the Project, any unforeseen increases in wave heights, etc., due to climate change could exacerbate this. Relevant adaptation measures have therefore been included for implementation as required.

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APPENDIX A

GHG Emission Estimation Method

The derivation and source of emission factors are presented below for those emission sources for which emissions have been calculated as part of the preparation of this report. Minor emissions associated with waste management have also been calculated using a scaling factor based on findings from the P'nyang Project GHG Assessment (CNS, 2015).

A1 Land Disturbance

Although biomass is carbon neutral (e.g., no net release of CO_2 if the growth/reduction cycle is sustained), an area of biomass can act as a carbon sink, as atmospheric CO_2 is used in photosynthesis to form organic compounds. As biomass increases, so does the quantity of carbon stored in the area. Clearing of an area of biomass removes both the carbon stored in that biomass and removes (at least temporarily) the ability for the area to assimilate any further CO_2.

A1.1 Initial Loss During Clearing

Burning of the cleared biomass would result in a 'pulse' of CO_2 being released to the atmosphere as opposed to the gradual release when exposed to decay over decadal timeframes. In either case, the same quantity of carbon is released back into the atmosphere. Estimation of the total carbon stock lost, and the incremental loss in carbon sink due to clearance have been performed using emission factors within '*Estimation of GHG emissions due to clearing, burning and decay of existing vegetation attributable to a CDM A/R project activity*' (UNFCCC, 2009) which is based on the method outlined in Chapter 2 and Chapter 4 of IPCC (2006).

$$EF_{BLc} = (A \times B_{AB}(1 + R) \times CF)\frac{44}{12}$$

where:

EF_{BLc}	= CO_2 emissions from loss of biomass as a result of site clearing (t CO_2-e)
A	= area of land cleared (ha)
B_{AB}	= average above ground biomass stock of vegetation (t d.m. / ha) (*where t d.m. = tonne dry mass*)
R	= ratio of below ground biomass to above ground biomass (t root d.m. / t shoot d.m.)
CF	= carbon fraction of above ground biomass (t C / t d.m.)
$\frac{44}{12}$	= conversion factor: ratio of molecular weights of CO_2 and C; mol mol^{-1}

A1.2 Ongoing Annual Losses

The ongoing annual losses of carbon due to cleared vegetation not being available to assimilate any further have been calculated using Equations 1, 2 and 3 of UNFCCC (2009):

$$E_{BLo} = (A \times BG_{AG}(1 + R) \times CF)\frac{44}{12}$$

where:

EF_{BLo}	= ongoing annual loss due to cleared vegetation (t CO_2-e)
A	= area of land cleared (ha)
B_{AG}	= average above ground biomass stock of vegetation (t d.m. / ha)
R	= ratio of below ground biomass to above ground biomass (t root d.m. / t shoot d.m.)

CF = carbon fraction of above ground biomass (t C / t d.m.)

$\frac{44}{12}$ = conversion factor: ratio of molecular weights of CO_2 and C; mol mol^{-1}

Key variables have been selected for the calculation of biomass losses as presented in **Table A1.1**.

The area cleared for pipeline construction will be allowed to revegetate, although only to a limited extent as vegetation will be cut to low levels and trees with extensive root systems will not be allowed to grow. To account for this, the land clearance area associated with pipeline construction activities was not included in the calculation of ongoing annual losses. This was done as a simplified, conservative approach to account for the proposed revegetation, as detailed calculations to estimate the change in annual carbon fixation rates due to the change in land use are not considered to be warranted given the small contribution of this source (i.e. the ongoing annual losses) to total Project emissions (less than 2% of Scope 1 emissions).

Table A1.1 Key Variables in Calculation of Biomass Losses and Resulting Emission Factors

Variable		Value	Source
Climate region		TAr (Tropical Rain Forest)	Vol. 4 Chapter 4, IPCC (2006)
Carbon fraction of above ground biomass	(CF)	0.47 t C / t d.m.	Table 4.3 Vol. 4 Chapter 4, IPCC (2006) (default)
Ratio of below ground biomass to above ground biomass	(R)	0.37 t root d.m. / t shoot d m	Table 4.4 Vol. 4 Chapter 4, IPCC (2006) (Tropical Rain Forest)
Above ground biomass in forests	B_{AG}	350 (280 – 520) t d.m. / ha	Table 4.7 Vol. 4 Chapter 4, IPCC (2006) (Tropical Rain Forest (Asia [insular])
Above ground net biomass growth in natural in forests (≤20 yr)	BG_{AG}	13 t d.m. / ha / yr	Table 4.9 Vol. 4 Chapter 4, IPCC (2006) (Tropical Rain Forest (Asia [insular])
Emission Factor	E_{BLc}	**826**	**Biomass loss from clearing**
Emission Factor	E_{BLo}	**31**	**Ongoing annual losses due to clearing**

A2 Consumption of Fuel

A2.1 Combustion of Fuels

Emission factors for the combustion of diesel and aviation gasoline (Avgas) have been sourced from IPCC (2006) and are reproduced in **Table A2.1**. Use of these emission factors require an estimate of the kL/annum of fuel to be consumed over the life of the Project.

Scope 1 emissions associated with fuel combustion in mobile plant and equipment (including vehicle movements) reference the emission factor for diesel oil consumption in off-road vehicles, emissions associated with fuel combustion in portable generators reference the emission factor for diesel oil consumption in stationary plant, and emissions associated with in-country air travel (fixed wing aircraft and helicopters) reference the emission factor for Avgas.

Table A2.1 GHG Emission Factors Used for Fuel Combustion

Fuel	Energy Content (GJ/kL) *	Emission Factor (kg CO_2-e/GJ)	Source
Diesel – Stationary plant	43.0	74.35	Table 2.2, IPCC (2006)
Diesel – Off-Road		82.73	Table 3.3.1, IPCC (2006)
Aviation Gasoline	44.3	70.61	Table 3.6.4 and 3.6.5, IPCC (2006)
Residual fuel oil - Waterborne navigation	40.4	78.17	Table 3.5.2 and 3.5.3, IPCC (2006)

* From IPCC (2006), Table 1.2, using AR4 GWPs from **Section 2.3**

Because fuel consumption estimates are unavailable for the Project for the barging activities, emissions associated with this source (as well as for Scope 3 emissions from the international transport of plant modules and product gas) were estimated using emission factors published by the European Chemical Industry Council in *Guidelines for Measuring and Managing CO_2 Emission from Freight Transport Operations* (Cefic, 2011). The factors used are reproduced in **Table A2.2**. Use of these emission factors requires an estimate of the annual tonnes-km for each vessel type over the life of the Project.

Emissions from the use of vessels during the offshore pipeline construction works were calculated using the IPCC emission factor for the consumption of residual fuel oil in waterborne navigation in kg CO_2-e/GJ (see **Table A2.1**) and an estimate of the potential fuel use for this activity based on the number of vessels required, an assumed fuel consumption rate in liters/hour, and the duration of the works. This source will be a minor contributor to the total Project emissions due to the short timeframe of the activities (nine months), hence an approximate estimate of the likely fuel use is considered to be acceptable.

Table A2.2 GHG Emissions Factors Used for Marine Transport

Activity	Emission Factor ($gC0_2$/t-km)		
	Upstream	Downstream	Average
Tank/Solid Bulk Barges (50% Load Factor)[1]			
800 t	70.8	27.3	49.1
1,250 t	62.6	24.1	43.4
1,750 t	57.7	22.3	40.0
2,500 t	46.0	18.1	32.1
Bulk Ships[2]			
Large tanker/Deep sea tanker	5.0		
Container Vessels[3]			
Average deep sea container vessel	8.4		

[1] Source: (Cefic, 2011), Table 5 – The average emission factors were used to calculate Scope 1 emissions associated with return travel along the river. To be conservative, the upstream factors were used for return travel between Port Moresby and the Lower Purari River mouth. The factors for 800 t barges were used for the 700 t barges proposed to be used in the Project, the 1,750 t barge factors were used for the 1,600 t barges, and the 2,500 t barge factor was used for the 2,300 t barges.

[2] Source: (Cefic, 2011), Table 6 – Used to calculate Scope 3 emissions associated with international transport of product gas to customers.

[3] Source: (Cefic, 2011), Table 6 – Used to calculate Scope 3 emissions associated with international transport of plant modules to PNG.

A2.2 Production and Supply of Fuels Consumed

Scope 3 GHG emissions resulting from the production and supply of fuels consumed have been accounted for using emission factors from Table 40 in the NGA Factors Workbook (DEE, 2018), which is 3.6 kg CO_2-e/GJ for all fuels referenced. The energy content of each fuel is as noted in **Table A2.1**.

A3 CPF Fuel Gas Combustion, Venting and Flaring

Annual GHG emission estimates have been calculated by the pre-FEED design team for the following operations phase sources:

- Combustion of fuel gas.
- Flaring.
- Venting/diffuse emissions.

These estimates were performed for selected modeling cases to compare emissions for several production schemes, differing mostly in the handling of acid gas. The results presented below are for the base (Partial Injection) case which is based on the following:

- For approximately four years from startup, acid gas (CO_2 and H_2S) from the acid gas removal unit is combusted in a thermal oxidizer (TO) and then treated in a sulfur recovery unit (SRU). CO_2 within the acid gas will pass through the TO and be vented to the atmosphere via the TO stack.
- After approximately four years, acid gas is injected and the SRU is stopped.

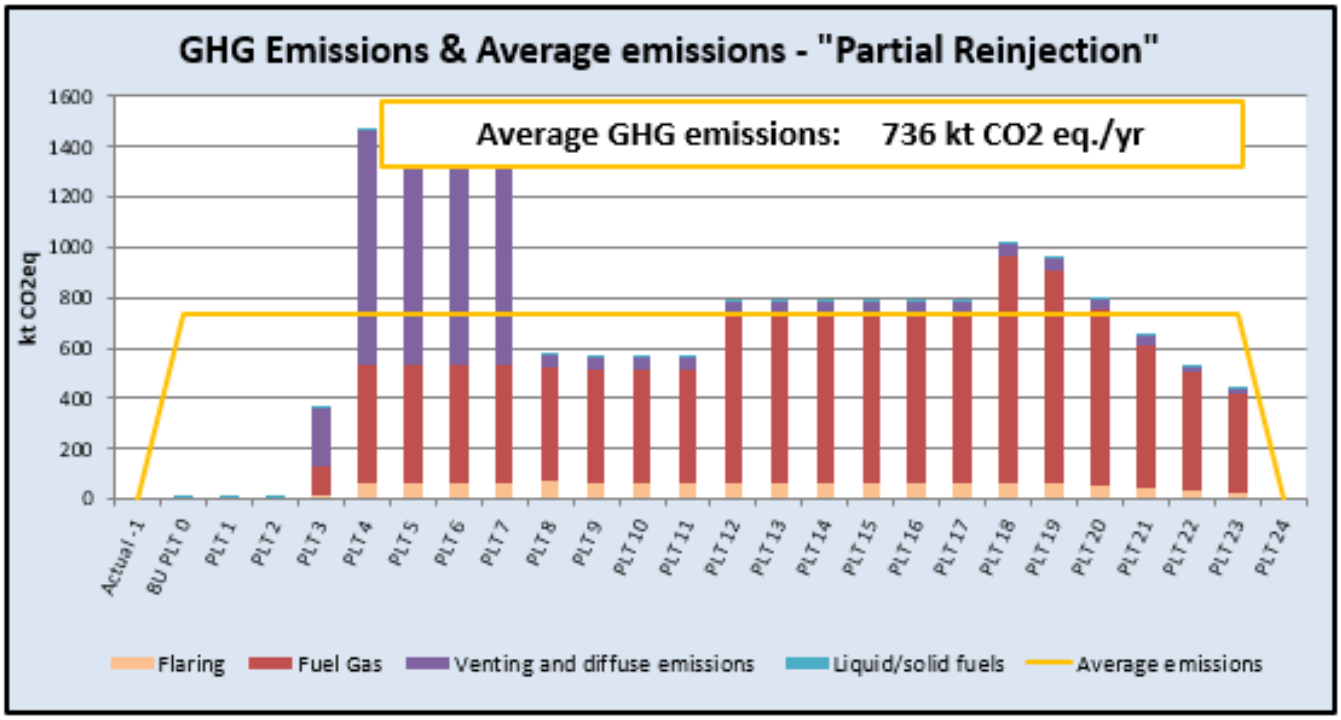
Because the CPF will produce (and consume) two fuel gases with different properties, 'hybrid' fuel gas was used. The hybrid fuel gas composition was changed through the production life to account for fuel gas changes associated with the high pressure (HP), medium pressure (MP), and low pressure (LP) phases. Acid gas passing through the TO before discharge to the atmosphere was counted as vented CO_2 and its sulfur content was accounted for with changes to the sulfur content (only) of flared gas. This allowed the flared gas quantity to not be skewed by the inclusion of the acid gas volume, but to still capture the SO_2 emissions contribution of this gas.

The preliminary results of the modeling are presented in **Table A3.1** and **Figure A3.1**.

Table A3.1 Pre-FEED Preliminary GHG Calculation Results – Partial Injection

PNG Pre-Project – 24 Years Project Life	Units	Partial Injection
Production	Mboe	1,058
Flared Gas	$MMSm^3$	468
Energy Used	Mboe	35.1
Autoconsumption	%	3.3
Total GHG Emissions	kt CO_2-e	17,655
Emissions Intensity	kt CO_2-e/Mboe	16.69

Figure A3.1 Pre-FEED Preliminary GHG Calculation Results



In the absence of annual activity data (i.e., annual projected flaring and venting volumes, annual fuel gas combustion rates) being provided for use in this GHG assessment, the annual GHG emission estimates presented in **Figure A3.1** for fuel gas combustion, venting and flaring have been adopted for use in this study. Emissions associated with the combustion of liquid fuels are addressed in **Section A.2** and the values shown in **Figure A3.1** were not used.

Figure A3.1 shows there is an increase in the fuel gas combustion rates in year 'PLT12' and 'PLT18'. The latest production profile included in the Project description (see **Figure A3.2**) shows that MP compression and LP compression are projected to begin in 2011 and 2016 respectively. The annual GHG emissions shown in **Figure A3.1** (which were still being finalized at the time of preparing this report) for fuel gas combustion were therefore redistributed slightly to better match the production profile. This will not have a material impact on the conclusions, but is more consistent with the latest available project information. A plot of the emission loads used in this assessment is included as **Figure A3.3** for comparison against **Figure A3.1**.

Figure A3.2 Production Profile

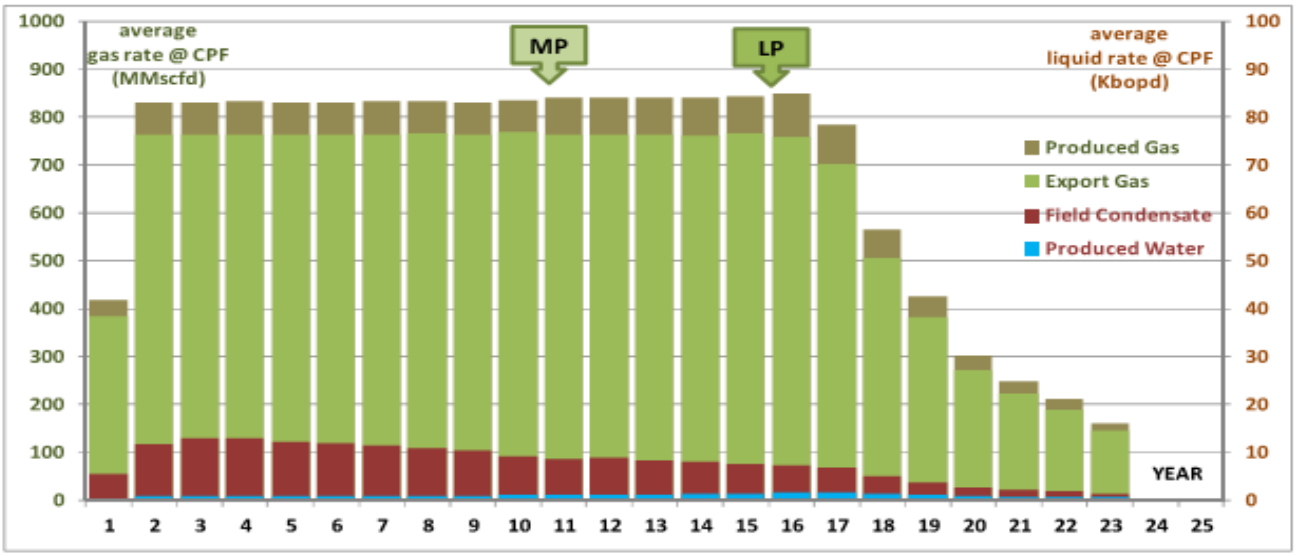
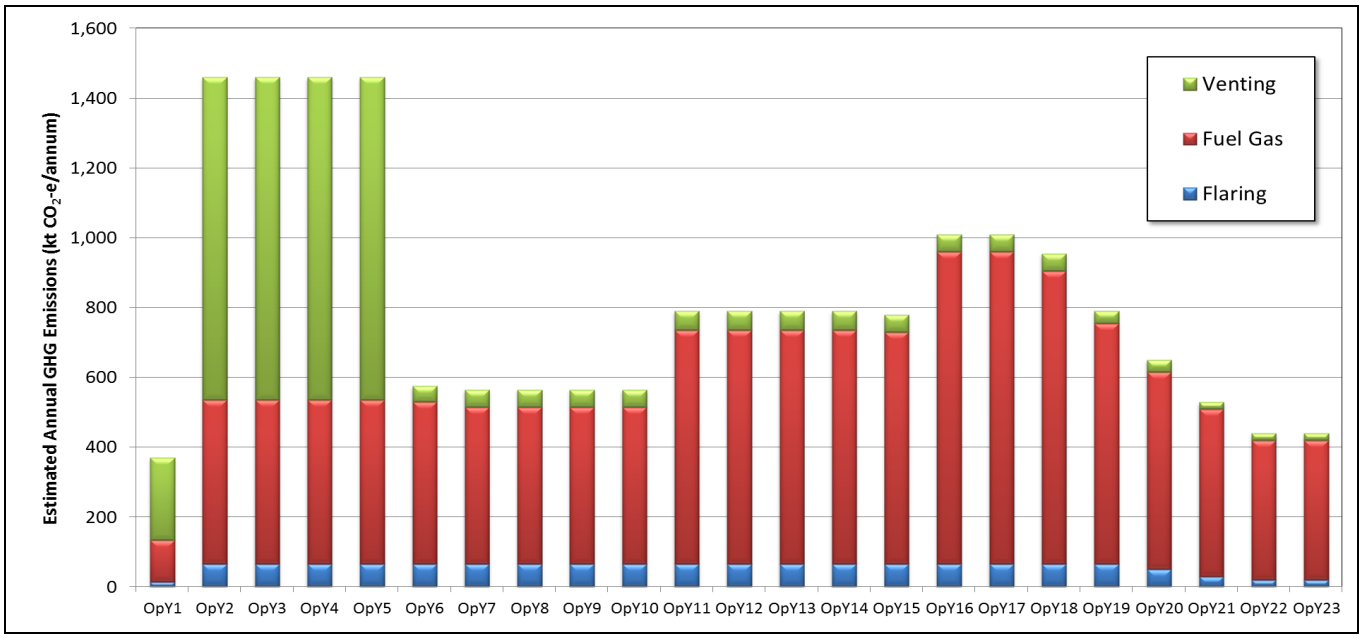


Figure A3.3 Annual GHG Emissions Profile for Fuel Gas Combustion, Venting and Flaring



A4 Waste Management

Detailed information on anticipated waste volumes and quantities to be disposed of via incineration, landfill and sewage treatment are not available at the time of preparing this report. However, SLR's experience in preparing GHG assessments for similar projects in PNG and Australia has shown that GHG emissions from waste management activities will be a minor contributor to the total Project emissions.

Given the above, indicative estimates of the GHG emissions from waste incineration, landfilling and sewage treatment have therefore been calculated by scaling the emission estimates for the P'nyang Project (CNS, 2015) as follows:

- Emissions from waste incineration, landfilling and sewage treatment associated with construction of the pipeline were scaled based on the length of the pipeline.
- Emissions from waste incineration, landfilling and sewage treatment associated with construction and operation of the CPF and other non-pipeline infrastructure were scaled from the P'nyang Project estimates based on the estimated number of workers for each year of the Project.

A brief overview of the methods and key assumptions used to estimate GHG emissions from waste management activities for the P'nyang Project is provided below:

- It was assumed that 5% of the organic waste produced by the Project will be sent to landfill.
- The Australian Government Clean Energy Regulator National Greenhouse and Energy Reporting (NGER) Solid Waste Calculator tool (Clean Energy Regulator, 2014) was used to calculate GHG emissions associated with landfilling and incineration of solid waste.
- GHG emissions resulting from wastewater treatment of domestic and commercial wastewater were calculated using the Australian Government Clean Energy Regulator NGER (Domestic and Commercial) Wastewater Calculator tool (Clean Energy Regulator, 2014). No capture of methane was assumed to occur.

A5 Downstream Processing of Gas

Emissions associated with the processing of the gas delivered by the Project to the Caution Bay facility have been included as Scope 3 emissions for the purposes of this assessment, as downstream processing is outside the scope of the EIS and as detailed information on projected GHG emissions from downstream processing are not available for use in this assessment. For this assessment, emissions from downstream processing have been estimated based on a review of publicly available information contained within Oil Search's Carbon Disclosure Project (CDP) Carbon Submission for the 2016 calendar year (Oil Search, 2017) and their 2016 Annual Report (Oil Search).

Oil Search's 2017 Carbon submission reported Scope 3 GHG emissions of 542.595 kt CO2-e from gas processing at the PNG LNG plant for 2016.

The 2016 Annual Report states that '*The Oil Search-operated AG and SE Gobe fields delivered gas to the Project at an average rate of 138 million standard cubic feet per day (mmscf/day) during 2016, representing approximately 13% of the total gas delivered to the LNG plant*'.

Using a gas density of 0.021 million tonnes (MT) per billion standard cubic feet,[2] this gives an emission factor of 512.961 kt CO_2-e/MTPA gas delivered to the PNG LNG facility. This factor has been used to estimate Scope 3 emissions associated with gas processing at the PNG LNG Facility for the Project.

[2] https://qp.com.qa/en/Pages/ConversionFactor.aspx

A6 Combustion by End User

As noted under Table A2.2, Scope 3 GHG emissions associated with the international transport of product gas to customers were estimated using the emission factor for large tankers published by the European Chemical Industry Council in *Guidelines for Measuring and Managing CO_2 Emission from Freight Transport Operations* (Cefic, 2011).

Scope 3 emissions associated with combustion of the product gas by the end user have been estimated using an emission factor for LNG combustion from IPCC (2006), as reproduced in **Table A6.1**.

Table A6.1 GHG Emission Factor Used for Combustion of Product Gas by End Users

Fuel	Energy Content (GJ/kL) *	Emission Factor (kg CO_2-e/GJ)	Source
Liquefied petroleum gases (power/manufacturing)	48.0	63.15	Table 2.2, IPCC (2006)

* From IPCC (2006), Table 1.2, using AR4 GWPs from **Section 2.3.**

APPENDIX B

Activity Data and Estimated Emissions

Activity Data - Scope 1	Units	ConY1	ConY2	ConY3	ConY4	ConY5
Land clearance						
Land Clearance	ha	140	206	300	232	-
Fuel Combustion						
Diesel consumption - earthworks	kL	-	3,464	6,830	9,093	6,561
Diesel consumption - barging:	kL					
- POM <---> HB/NLB - return - 700t (river)	t-km	58,257,606	36,444,343	13,869,044	13,869,044	13,869,044
- POM <---> HB/NLB - return - 1600t (river)	t-km	35,319,736	79,469,406	52,979,604	52,979,604	26,489,802
- POM <---> HB/NLB - return - 2300t (river)	t-km	-	-	-	10,849,933	-
- POM <---> HB/NLB - return - 700t (sea)	t-km	158,884,381	99,255,111	39,625,841	39,625,841	39,625,841
- POM <---> HB/NLB - return - 1600t (sea)	t-km	105,959,208	238,408,218	158,938,812	158,938,812	79,469,406
- POM <---> HB/NLB - return - 2300t (sea)	t-km	-	-	-	32,549,798	-
Diesel consumption - generators	kL	3,504	5,256	7,008	7,008	3,504
Diesel consumption - OTHER (ie vehicles, drill-rigs etc)	kL	693	693	1,366	1,819	1,312
Fuel oil consumption - marine pipeline construction	kL	-	-	-	3,527	7,055
Fuel oil consumption - barging	kL	15,827	17,742	9,973	11,174	6,359
AVGAS consumption	kL	206	411	1,404	2,086	428
HP Fuel gas combusted		-	-	-	-	-
LP Fuel gas combusted		-	-	-	-	-
Gas venting						
Venting and diffuse emissions	m3		-	-	-	-
Waste						

Activity Data - Scope 3		ConY1	ConY2	ConY3	ConY4	ConY5
Gas Processing						
Gas sent to LNG Plant	MTPA	0	0	0	0	0
Production of Fuels Consumed						
Production of diesel consumed	kL	4,197	9,413	15,204	17,920	11,377
Production of fuel oil consumed	kL	15,827	17,742	9,973	14,701	13,414
Production of AVGAS consumed	kL	206	411	1,404	2,086	428
Third Party Transport						
Shipping plant components (Shanghai - POM)	t-km					103,544,000
Transport of product to end user	million t-km	-	-	-	-	-
International flights	hours	74,175	148,349	718,323	1,126,934	166,568
End Use of Gas Produced						
Gas to end user	kL	0	0	0	0	0

Estimated Emissions - Scope 1	Units	ConY1	ConY2	ConY3	ConY4	ConY5
Land clearance						
Land Clearance	t CO2-e	115,770	169,936	248,116	191,380	-
Ongoing loss	t CO2-e	-	4,300	10,612	19,828	26,936
Fuel Consumption						
Diesel - earthworks	t CO2-e	-	12,323	24,295	32,347	23,340
Fuel oil - Barging	t CO2-e	21,633	25,750	14,776	16,621	9,131
Diesel - generators	t CO2-e	11,203	16,805	22,406	22,406	11,203
Diesel - Other	t CO2-e	2,465	2,465	4,859	6,469	4,668
Fuel oil - Marine pipeline construction	t CO2-e	-	-	-	11,857	25,096
AVGAS	t CO2-e	643	1,287	4,391	6,524	1,340
CPF Operations						
Flaring	t CO2-e	-	-	-	-	-
Fuel Gas	t CO2-e	-	-	-	-	-
Gas venting						
Venting and diffuse emissions	t CO2-e	-	-	-	-	-
Waste						
Waste incineration	t CO2-e	62	136	680	889	889
Landfilling	t CO2-e	-	7	24	38	26
Wastewater	t CO2-e	15	34	168	220	220

Estimated Emissions - Scope 3		ConY1	ConY2	ConY3	ConY4	ConY5
Gas Processing						
PNG LNG Processing Emissions	t CO2-e	-	-	-	-	-
Production of Fuels Consumed						
Production of diesel consumed	t CO2-e	650	1,457	2,354	2,774	1,761
Production of fuel oil consumed	t CO2-e	2,302	2,580	1,450	2,138	1,951
Production of AVGAS consumed	t CO2-e	33	66	224	333	68
Third Party Transport						
Shipping plant components	t CO2-e	-	-	-	-	870
Transport of product to end user	t CO2-e	-	-	-	-	-
International flights	t CO2-e	18,544	37,087	179,581	281,734	41,642
End Use of Gas Produced						
Gas combustion	t CO2-e	-	-	-	-	-

Activity Data - Scope 1	Units	OpY1	OpY2	OpY3	OpY4	OpY5
Land clearance						
Land Clearance	ha					
Fuel Combustion						
Diesel consumption - earthworks	kL					
Diesel consumption - barging:	kL					
- POM <---> HB/NLB - return - 700t (river)	t-km	3,632,369	3,632,369	3,632,369	3,632,369	3,632,369
- POM <---> HB/NLB - return - 1600t (river)	t-km	7,547,779	7,547,779	7,547,779	7,547,779	7,547,779
- POM <---> HB/NLB - return - 2300t (river)	t-km	-	-	-	-	-
- POM <---> HB/NLB - return - 700t (sea)	t-km	9,906,460	9,906,460	9,906,460	9,906,460	9,906,460
- POM <---> HB/NLB - return - 1600t (sea)	t-km	22,643,338	22,643,338	22,643,338	22,643,338	22,643,338
- POM <---> HB/NLB - return - 2300t (sea)	t-km	-	-	-	-	-
Diesel consumption - generators	kL	110	110	110	110	110
Diesel consumption - OTHER (ie vehicles, drill-rigs etc)	kL	2,752	2,752	2,752	2,752	2,752
Fuel oil consumption - marine pipeline construction	kL					
Fuel oil consumption - barging	kL	1,716	1,716	1,716	1,716	1,716
AVGAS consumption	kL	173	173	173	173	173
HP Fuel gas combusted		Utilise TOTAL Pre-FEED GHG Modelling Calculation Results				
LP Fuel gas combusted		Utilise TOTAL Pre-FEED GHG Modelling Calculation Results				
Gas venting						
Venting and diffuse emissions	m3	Utilise TOTAL Pre-FEED GHG Modelling Calculation Results				
Waste						

Activity Data - Scope 3		OpY1	OpY2	OpY3	OpY4	OpY5
Gas Processing						
Gas sent to LNG Plant	MTPA	3.33	6.57	6.57	6.57	6.57
Production of Fuels Consumed						
Production of diesel consumed	kL	2,862	2,862	2,862	2,862	2,862
Production of fuel oil consumed	kL	1,716	1,716	1,716	1,716	1,716
Production of AVGAS consumed	kL	173	173	173	173	173
Third Party Transport						
Shipping plant components (Shanghai - POM)	t-km					
Transport of product to end user	million t-km	11,859	23,436	23,436	23,436	23,436
International flights	hours	15,604	15,604	15,604	15,604	15,604
End Use of Gas Produced						
Gas to end user	kL	1,652,771	3,262,612	3,262,612	3,262,612	3,262,612

Estimated Emissions - Scope 1	Units	OpY1	OpY2	OpY3	OpY4	OpY5
Land clearance						
Land Clearance	t CO2-e					
Ongoing loss	t CO2-e	15,169	15,169	15,169	15,169	15,169
Fuel Consumption						
Diesel - earthworks	t CO2-e	-	-	-	-	-
Fuel oil - Barging	t CO2-e	2,488	2,488	2,488	2,488	2,488
Diesel - generators	t CO2-e	352	352	352	352	352
Diesel - Other	t CO2-e	9,791	9,791	9,791	9,791	9,791
Fuel oil - Marine pipeline construction	t CO2-e	-	-	-	-	-
AVGAS	t CO2-e	541	541	541	541	541
CPF Operations						
Flaring	t CO2-e	15,000	65,000	65,000	65,000	65,000
Fuel Gas	t CO2-e	120,000	470,000	470,000	470,000	470,000
Gas venting						
Venting and diffuse emissions	t CO2-e	235,000	925,000	925,000	925,000	925,000
Waste						
Waste incineration	t CO2-e	401	658	988	1,028	1,028
Landfilling	t CO2-e	31	24	19	16	14
Wastewater	t CO2-e	25	25	25	25	25

Estimated Emissions - Scope 3		OpY1	OpY2	OpY3	OpY4	OpY5
Gas Processing						
PNG LNG Processing Emissions	t CO2-e	1,651,376	3,263,434	3,263,434	3,263,434	3,263,434
Production of Fuels Consumed						
Production of diesel consumed	t CO2-e	443	443	443	443	443
Production of fuel oil consumed	t CO2-e	250	250	250	250	250
Production of AVGAS consumed	t CO2-e	28	28	28	28	28
Third Party Transport						
Shipping plant components	t CO2-e	-	-	-	-	-
Transport of product to end user	t CO2-e	59,297	117,182	117,182	117,182	117,182
International flights	t CO2-e	3,901	3,901	3,901	3,901	3,901
End Use of Gas Produced						
Gas combustion	t CO2-e	5,010,259	8,324,405	8,324,405	8,324,405	8,324,405

Activity Data - Scope 1	Units	OpY6	OpY7	OpY8	OpY9	OpY10
Land clearance						
Land Clearance	ha					
Fuel Combustion						
Diesel consumption - earthworks	kL					
Diesel consumption - barging:	kL					
- POM <---> HB/NLB - return - 700t (river)	t-km	3,632,369	3,632,369	3,632,369	3,632,369	3,632,369
- POM <---> HB/NLB - return - 1600t (river)	t-km	7,547,779	7,547,779	7,547,779	7,547,779	7,547,779
- POM <---> HB/NLB - return - 2300t (river)	t-km	-	-	-	-	-
- POM <---> HB/NLB - return - 700t (sea)	t-km	9,906,460	9,906,460	9,906,460	9,906,460	9,906,460
- POM <---> HB/NLB - return - 1600t (sea)	t-km	22,643,338	22,643,338	22,643,338	22,643,338	22,643,338
- POM <---> HB/NLB - return - 2300t (sea)	t-km	-	-	-	-	-
Diesel consumption - generators	kL	110	110	110	110	110
Diesel consumption - OTHER (ie vehicles, drill-rigs etc)	kL	2,752	2,752	2,752	2,752	2,752
Fuel oil consumption - marine pipeline construction	kL					
Fuel oil consumption - barging	kL	1,716	1,716	1,716	1,716	1,716
AVGAS consumption	kL	173	173	173	173	173
HP Fuel gas combusted		Utilise TOTAL Pre-FEED GHG Modelling Calculation Results				
LP Fuel gas combusted		Utilise TOTAL Pre-FEED GHG Modelling Calculation Results				
Gas venting						
Venting and diffuse emissions	m3	Utilise TOTAL Pre-FEED GHG Modelling Calculation Results				
Waste						
Activity Data - Scope 3		**OpY6**	**OpY7**	**OpY8**	**OpY9**	**OpY10**
Gas Processing						
Gas sent to LNG Plant	MTPA	6.57	6.57	6.57	6.57	6.57
Production of Fuels Consumed						
Production of diesel consumed	kL	2,862	2,862	2,862	2,862	2,862
Production of fuel oil consumed	kL	1,716	1,716	1,716	1,716	1,716
Production of AVGAS consumed	kL	173	173	173	173	173
Third Party Transport						
Shipping plant components (Shanghai - POM)	t-km					
Transport of product to end user	million t-km	23,436	23,436	23,436	23,436	23,436
International flights	hours	15,604	15,604	15,604	15,604	15,604
End Use of Gas Produced						
Gas to end user	kL	3,262,612	3,262,612	3,262,612	3,262,612	3,262,612

Estimated Emissions - Scope 1	Units	OpY6	OpY7	OpY8	OpY9	OpY10
Land clearance						
Land Clearance	t CO2-e					
Ongoing loss	t CO2-e	15,169	15,169	15,169	15,169	15,169
Fuel Consumption						
Diesel - earthworks	t CO2-e	-	-	-	-	-
Fuel oil - Barging	t CO2-e	2,488	2,488	2,488	2,488	2,488
Diesel - generators	t CO2-e	352	352	352	352	352
Diesel - Other	t CO2-e	9,791	9,791	9,791	9,791	9,791
Fuel oil - Marine pipeline construction	t CO2-e	-	-	-	-	-
AVGAS	t CO2-e	541	541	541	541	541
CPF Operations						
Flaring	t CO2-e	65,000	65,000	65,000	65,000	65,000
Fuel Gas	t CO2-e	465,000	450,000	450,000	450,000	450,000
Gas venting						
Venting and diffuse emissions	t CO2-e	45,000	50,000	50,000	50,000	50,000
Waste						
Waste incineration	t CO2-e	988	1,432	1,372	1,291	1,291
Landfilling	t CO2-e	12	11	10	10	9
Wastewater	t CO2-e	25	25	25	25	25
Estimated Emissions - Scope 3		**OpY6**	**OpY7**	**OpY8**	**OpY9**	**OpY10**
Gas Processing						
PNG LNG Processing Emissions	t CO2-e	3,263,434	3,263,434	3,263,434	3,263,434	3,263,434
Production of Fuels Consumed						
Production of diesel consumed	t CO2-e	443	443	443	443	443
Production of fuel oil consumed	t CO2-e	250	250	250	250	250
Production of AVGAS consumed	t CO2-e	28	28	28	28	28
Third Party Transport						
Shipping plant components	t CO2-e	-	-	-	-	-
Transport of product to end user	t CO2-e	117,182	117,182	117,182	117,182	117,182
International flights	t CO2-e	3,901	3,901	3,901	3,901	3,901
End Use of Gas Produced						
Gas combustion	t CO2-e	8,324,405	8,324,405	8,324,405	8,324,405	8,324,405

Activity Data - Scope 1	Units	OpY11	OpY12	OpY13	OpY14	OpY15
Land clearance						
Land Clearance	ha					
Fuel Combustion						
Diesel consumption - earthworks	kL					
Diesel consumption - barging:	kL					
- POM <---> HB/NLB - return - 700t (river)	t-km	3,632,369	3,632,369	3,632,369	3,632,369	3,632,369
- POM <---> HB/NLB - return - 1600t (river)	t-km	7,547,779	7,547,779	7,547,779	7,547,779	7,547,779
- POM <---> HB/NLB - return - 2300t (river)	t-km	-	-	-	-	-
- POM <---> HB/NLB - return - 700t (sea)	t-km	9,906,460	9,906,460	9,906,460	9,906,460	9,906,460
- POM <---> HB/NLB - return - 1600t (sea)	t-km	22,643,338	22,643,338	22,643,338	22,643,338	22,643,338
- POM <---> HB/NLB - return - 2300t (sea)	t-km	-	-	-	-	-
Diesel consumption - generators	kL	110	110	110	110	110
Diesel consumption - OTHER (ie vehicles, drill-rigs etc)	kL	2,752	2,752	2,752	2,752	2,752
Fuel oil consumption - marine pipeline construction	kL					
Fuel oil consumption - barging	kL	1,716	1,716	1,716	1,716	1,716
AVGAS consumption	kL	173	173	173	173	173
HP Fuel gas combusted		Utilise TOTAL Pre-FEED GHG Modelling Calculation Results				
LP Fuel gas combusted		Utilise TOTAL Pre-FEED GHG Modelling Calculation Results				
Gas venting						
Venting and diffuse emissions	m3	Utilise TOTAL Pre-FEED GHG Modelling Calculation Results				
Waste						

Activity Data - Scope 3		OpY11	OpY12	OpY13	OpY14	OpY15
Gas Processing						
Gas sent to LNG Plant	MTPA	6.57	6.57	6.61	6.61	6.65
Production of Fuels Consumed						
Production of diesel consumed	kL	2,862	2,862	2,862	2,862	2,862
Production of fuel oil consumed	kL	1,716	1,716	1,716	1,716	1,716
Production of AVGAS consumed	kL	173	173	173	173	173
Third Party Transport						
Shipping plant components (Shanghai - POM)	t-km					
Transport of product to end user	million t-km	23,436	23,436	23,578	23,578	23,719
International flights	hours	15,604	15,604	15,604	15,604	15,604
End Use of Gas Produced						
Gas to end user	kL	3,254,027	3,245,441	3,241,148	3,232,562	3,223,976

Estimated Emissions - Scope 1	Units	OpY11	OpY12	OpY13	OpY14	OpY15
Land clearance						
Land Clearance	t CO2-e					
Ongoing loss	t CO2-e	15,169	15,169	15,169	15,169	15,169
Fuel Consumption						
Diesel - earthworks	t CO2-e	-	-	-	-	-
Fuel oil - Barging	t CO2-e	2,488	2,488	2,488	2,488	2,488
Diesel - generators	t CO2-e	352	352	352	352	352
Diesel - Other	t CO2-e	9,791	9,791	9,791	9,791	9,791
Fuel oil - Marine pipeline construction	t CO2-e	-	-	-	-	-
AVGAS	t CO2-e	541	541	541	541	541
CPF Operations						
Flaring	t CO2-e	65,000	65,000	65,000	65,000	65,000
Fuel Gas	t CO2-e	670,000	670,000	670,000	670,000	665,000
Gas venting						
Venting and diffuse emissions	t CO2-e	55,000	55,000	55,000	55,000	50,000
Waste						
Waste incineration	t CO2-e	1,311	1,331	1,372	1,432	1,432
Landfilling	t CO2-e	9	9	8	8	8
Wastewater	t CO2-e	25	25	25	25	25

Estimated Emissions - Scope 3		OpY11	OpY12	OpY13	OpY14	OpY15
Gas Processing						
PNG LNG Processing Emissions	t CO2-e	3,263,434	3,263,434	3,283,093	3,283,093	3,302,752
Production of Fuels Consumed						
Production of diesel consumed	t CO2-e	443	443	443	443	443
Production of fuel oil consumed	t CO2-e	250	250	250	250	250
Production of AVGAS consumed	t CO2-e	28	28	28	28	28
Third Party Transport						
Shipping plant components	t CO2-e	-	-	-	-	-
Transport of product to end user	t CO2-e	117,182	117,182	117,888	117,888	118,594
International flights	t CO2-e	3,901	3,901	3,901	3,901	3,901
End Use of Gas Produced						
Gas combustion	t CO2-e	8,302,499	8,280,592	8,269,639	8,247,733	8,225,827

Activity Data - Scope 1	Units	OpY16	OpY17	OpY18	OpY19	OpY20
Land clearance						
Land Clearance	ha					
Fuel Combustion						
Diesel consumption - earthworks	kL					
Diesel consumption - barging:	kL					
- POM <---> HB/NLB - return - 700t (river)	t-km	3,632,369	3,632,369	3,632,369	3,632,369	3,632,369
- POM <---> HB/NLB - return - 1600t (river)	t-km	7,547,779	7,547,779	7,547,779	7,547,779	7,547,779
- POM <---> HB/NLB - return - 2300t (river)	t-km	-	-	-	-	-
- POM <---> HB/NLB - return - 700t (sea)	t-km	9,906,460	9,906,460	9,906,460	9,906,460	9,906,460
- POM <---> HB/NLB - return - 1600t (sea)	t-km	22,643,338	22,643,338	22,643,338	22,643,338	22,643,338
- POM <---> HB/NLB - return - 2300t (sea)	t-km	-	-	-	-	-
Diesel consumption - generators	kL	110	110	110	110	110
Diesel consumption - OTHER (ie vehicles, drill-rigs etc)	kL	2,752	2,752	2,752	2,752	2,752
Fuel oil consumption - marine pipeline construction	kL					
Fuel oil consumption - barging	kL	1,716	1,716	1,716	1,716	1,716
AVGAS consumption	kL	173	173	173	173	173
HP Fuel gas combusted		Utilise TOTAL Pre-FEED GHG Modelling Calculation Results				
LP Fuel gas combusted		Utilise TOTAL Pre-FEED GHG Modelling Calculation Results				
Gas venting						
Venting and diffuse emissions	m3	Utilise TOTAL Pre-FEED GHG Modelling Calculation Results				
Waste						

Activity Data - Scope 3		OpY16	OpY17	OpY18	OpY19	OpY20
Gas Processing						
Gas sent to LNG Plant	MTPA	6.65	6.18	4.40	3.33	2.38
Production of Fuels Consumed						
Production of diesel consumed	kL	2,862	2,862	2,862	2,862	2,862
Production of fuel oil consumed	kL	1,716	1,716	1,716	1,716	1,716
Production of AVGAS consumed	kL	173	173	173	173	173
Third Party Transport						
Shipping plant components (Shanghai - POM)	t-km					
Transport of product to end user	million t-km	23,719	22,025	15,671	11,859	8,471
International flights	hours	15,604	15,604	15,604	15,604	15,604
End Use of Gas Produced						
Gas to end user	kL	3,219,683	3,026,502	2,167,920	1,631,306	1,180,551

Estimated Emissions - Scope 1	Units	OpY16	OpY17	OpY18	OpY19	OpY20
Land clearance						
Land Clearance	t CO2-e					
Ongoing loss	t CO2-e	15,169	15,169	15,169	15,169	15,169
Fuel Consumption						
Diesel - earthworks	t CO2-e	-	-	-	-	-
Fuel oil - Barging	t CO2-e	2,488	2,488	2,488	2,488	2,488
Diesel - generators	t CO2-e	352	352	352	352	352
Diesel - Other	t CO2-e	9,791	9,791	9,791	9,791	9,791
Fuel oil - Marine pipeline construction	t CO2-e	-	-	-	-	-
AVGAS	t CO2-e	541	541	541	541	541
CPF Operations						
Flaring	t CO2-e	65,000	65,000	65,000	65,000	50,000
Fuel Gas	t CO2-e	895,000	895,000	840,000	690,000	565,000
Gas venting						
Venting and diffuse emissions	t CO2-e	50,000	50,000	50,000	35,000	35,000
Waste						
Waste incineration	t CO2-e	1,453	1,453	1,473	1,143	1,648
Landfilling	t CO2-e	8	8	8	8	8
Wastewater	t CO2-e	25	25	25	25	25

Estimated Emissions - Scope 3		OpY16	OpY17	OpY18	OpY19	OpY20
Gas Processing						
PNG LNG Processing Emissions	t CO2-e	3,302,752	3,066,841	2,182,176	1,651,376	1,179,554
Production of Fuels Consumed						
Production of diesel consumed	t CO2-e	443	443	443	443	443
Production of fuel oil consumed	t CO2-e	250	250	250	250	250
Production of AVGAS consumed	t CO2-e	28	28	28	28	28
Third Party Transport						
Shipping plant components	t CO2-e	-	-	-	-	-
Transport of product to end user	t CO2-e	118,594	110,123	78,357	59,297	42,355
International flights	t CO2-e	3,901	3,901	3,901	3,901	3,901
End Use of Gas Produced						
Gas combustion	t CO2-e	8,214,873	7,721,981	5,531,348	4,162,203	3,012,120

Activity Data - Scope 1	Units	OpY21	OpY22	OpY23	DecomY1	DecomY2
Land clearance						
Land Clearance	ha					
Fuel Combustion						
Diesel consumption - earthworks	kL					
Diesel consumption - barging:	kL					
- POM <---> HB/NLB - return - 700t (river)	t-km	3,632,369	3,632,369	3,632,369	7,264,737	7,264,737
- POM <---> HB/NLB - return - 1600t (river)	t-km	7,547,779	7,547,779	7,547,779	15,095,558	15,095,558
- POM <---> HB/NLB - return - 2300t (river)	t-km	-	-	-	-	-
- POM <---> HB/NLB - return - 700t (sea)	t-km	9,906,460	9,906,460	9,906,460	19,812,920	19,812,920
- POM <---> HB/NLB - return - 1600t (sea)	t-km	22,643,338	22,643,338	22,643,338	45,286,675	45,286,675
- POM <---> HB/NLB - return - 2300t (sea)	t-km	-	-	-	-	-
Diesel consumption - generators	kL	110	110	110	110	110
Diesel consumption - OTHER (ie vehicles, drill-rigs etc)	kL	2,752	2,752	2,752	649	649
Fuel oil consumption - marine pipeline construction	kL					
Fuel oil consumption - barging	kL	1,716	1,716	1,716	3,432	3,432
AVGAS consumption	kL	173	173	173	541	541
HP Fuel gas combusted		Utilise TOTAL Pre-FEED GHG Modelling Calc			-	-
LP Fuel gas combusted		Utilise TOTAL Pre-FEED GHG Modelling Calc			-	-
Gas venting						
Venting and diffuse emissions	m3	Utilise TOTAL Pre-FEED GHG Modelling Calc			-	-
Waste						

Activity Data - Scope 3		OpY21	OpY22	OpY23	DecomY1	DecomY2
Gas Processing						
Gas sent to LNG Plant	MTPA	1.90	1.62	1.27	0	0
Production of Fuels Consumed						
Production of diesel consumed	kL	2,862	2,862	2,862	759	759
Production of fuel oil consumed	kL	1,716	1,716	1,716	3,432	3,432
Production of AVGAS consumed	kL	173	173	173	541	541
Third Party Transport						
Shipping plant components (Shanghai - POM)	t-km					
Transport of product to end user	million t-km	6,777	5,788	4,518	-	-
International flights	hours	15,604	15,604	15,604	270,022	270,022
End Use of Gas Produced						
Gas to end user	kL	965,905	815,653	643,937	0	0

Estimated Emissions - Scope 1	Units	OpY21	OpY22	OpY23	DecomY1	DecomY2
Land clearance						
Land Clearance	t CO2-e					
Ongoing loss	t CO2-e	15,169	15,169	15,169	15,169	15,169
Fuel Consumption						
Diesel - earthworks	t CO2-e	-	-	-	-	-
Fuel oil - Barging	t CO2-e	2,488	2,488	2,488	4,976	4,976
Diesel - generators	t CO2-e	352	352	352	352	352
Diesel - Other	t CO2-e	9,791	9,791	9,791	2,308	2,308
Fuel oil - Marine pipeline construction	t CO2-e	-	-	-	-	-
AVGAS	t CO2-e	541	541	541	1,693	1,693
CPF Operations						
Flaring	t CO2-e	30,000	20,000	20,000	-	-
Fuel Gas	t CO2-e	480,000	400,000	400,000	-	-
Gas venting						
Venting and diffuse emissions	t CO2-e	20,000	20,000	20,000	-	-
Waste						
Waste incineration	t CO2-e	3,681	6,401	8,858	169	169
Landfilling	t CO2-e	8	8	8	8	17
Wastewater	t CO2-e	25	25	25	4	4

Estimated Emissions - Scope 3		OpY21	OpY22	OpY23	DecomY1	DecomY2
Gas Processing						
PNG LNG Processing Emissions	t CO2-e	943,643	806,029	629,096	-	-
Production of Fuels Consumed						
Production of diesel consumed	t CO2-e	443	443	443	117	117
Production of fuel oil consumed	t CO2-e	250	250	250	499	499
Production of AVGAS consumed	t CO2-e	28	28	28	86	86
Third Party Transport						
Shipping plant components	t CO2-e	-	-	-	-	-
Transport of product to end user	t CO2-e	33,884	28,942	22,589	-	-
International flights	t CO2-e	3,901	3,901	3,901	67,505	67,505
End Use of Gas Produced						
Gas combustion	t CO2-e	2,464,462	2,081,101	1,642,975	-	-

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