Appendix R

Greenhouse gas assessment

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Narrabri Gas Project - Environmental Impact Statement - Gasfield

Greenhouse Gas Assessment

August 2016

Executive summary

The Proponent is proposing to develop natural gas in the Gunnedah Basin in New South Wales (NSW), southwest of Narrabri. The primary objective of the Narrabri Gas Project is to commercialise natural gas to be made available to the NSW gas market and to support the energy security needs of NSW.

This report has been prepared to estimate the greenhouse gas emissions associated with the Narrabri Gas Project. Two development options were considered:

- **Option 1**: Project electricity requirements supplied via the construction of an onsite gas-fired electricity plant with an operating capacity of 100 MW.
- **Option 2:** Project electricity requirements sourced from the NSW grid.

Annual direct emissions in a typical operating year will be less than 0.2 per cent of Australia's current annual greenhouse gas emissions, which were approximately 523 million tonnes of carbon dioxide equivalent in 2014.

The assessment results are outlined in the following table.

Emission source	Option 1 (Self-generated electricity) (Mt CO_2-e)	Option 2 (Grid-sourced electricity) (Mt CO_2-e)
Total over project life (25 years)		
Construction, operations and decommissioning	26.30	15.47
Electricity purchases	0	18.33
Third party product use	94.22	94.22
Typical operating year		
Operations	0.96	0.53
Electricity purchases	0	0.73
Third party product use	3.77	3.77

As a global stakeholder in the energy business we recognise that one of our key social and environmental responsibilities is to pursue strategies that address the issue of climate change.

At the highest level, Santos' Climate Change Policy sets out its vision and commitments to achieve this vision. These policy commitments underpin Santos' approach to greenhouse gas emissions management, which is governed through corporate management standards.

Lower-carbon energy sources such as natural gas can help to meet growing global energy demand while reducing relative global greenhouse gas emissions. For example, lifecycle emissions for electricity produced from the natural gas delivered by the project will be nearly 50 per cent less than for the electricity that is currently supplied to the NSW grid (refer Figure 5-1).

Potential management and mitigation measures have been identified and include optimisation of processes during the detailed design phase and strategic energy efficiency reviews.

Greenhouse gas emissions generated by the project are considered to be reasonable given the nature of the project.

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1. Introduction

1.1 Overview

The Proponent is proposing to develop natural gas in the Gunnedah Basin in New South Wales (NSW), southwest of Narrabri (refer to Figure 1-1).

The Narrabri Gas Project (the project) comprises the development and operation of a gas production field, requiring the installation of gas wells, gas and water gathering systems, and supporting infrastructure. The natural gas produced will be treated at a central gas processing facility on a local rural property (Leewood), approximately 25 kilometres south-west of Narrabri. The gas will then be transported via a high-pressure gas transmission pipeline to market. This pipeline will be part of a separate approvals process and is therefore not part of this assessment.

The primary objective of the project is to commercialise natural gas to be made available to the NSW gas market, which will ultimately support the energy security needs of NSW. This project will deliver net economic, environmental and social benefits to the Narrabri region and the broader NSW community.

The key benefits of the project include:

- Increased competition into the gas market through development of a new source of gas supply into NSW.
- Regional economic development through employment, demand for services and supplies.
- Generation of approximately 1,300 jobs during construction and 200 jobs during the operational phase.
- Establishment of a regional community benefit fund, with the contribution from Santos equivalent to five per cent of the royalty payment made to the NSW Government in respect of the production licence area (if matched by the NSW Government, the fund could reach $120 million over the next two decades).
- Lower greenhouse gas emission fuel source (for instance compared to average intensity of NSW electricity grid).

1.2 Description of the project

The project will involve the construction and operation of a range of exploration and production activities and infrastructure including the continued use of some existing infrastructure. The key components of the project are presented in Table 1-1, and are shown on Figure 1-1.

Subject to obtaining the required regulatory approvals, and a financial investment decision, construction of the project is expected to commence in early 2018, with first gas scheduled for 2019/2020.

Progressive construction of the gas processing and water management facilities is expected to take around three years and would be undertaken between approximately early/mid-2018 and early/mid-2021. The gas wells will be progressively drilled during the first 20 or so years of the project. For the purpose of impact assessment, a 25-year construction and operational period has been adopted (assessment period).

Table 1-1 Key project components

Component	Infrastructure / activity
Leewood facility	• a central gas processing facility for the compression, dehydration and treatment of gas • a central water management facility including storage and treatment of produced water and brine • optional power generation for the project • a safety flare • treated water management infrastructure to facilitate the transfer of treated water for irrigation, dust suppression, construction and drilling activities • other supporting infrastructure including storage and utility buildings, staff amenities, equipment shelters, car parking, and diesel and chemical storage • continued use of existing facilities such as the brine and produced water ponds • operation of the facility
Bibblewindi facility	• in-field compression facility • safety flare • supporting infrastructure including storage and utility areas, treated water holding tank, and a communications tower • upgrades and expansion to the staff amenities and car parking • produced water, brine and construction water storage, including recommissioning of two existing ponds • continued use of existing facilities such as the 5ML water balance tank • operation of the expanded facility
Bibblewindi to Leewood infrastructure corridor	• widening of the existing corridor to allow for construction and operation of an additional buried medium pressure gas pipeline, a water pipeline, underground (up to 132 kV) power, and buried communications transmission lines
Leewood to Wilga Park underground power line	• installation and operation of an underground power line (up to 132 kV) within the existing gas pipeline corridor
Gas appraisal and production infrastructure	• seismic geophysical survey • installation of up to 850 new wells on a maximum of 425 well pads – new well types would include exploration, appraisal and production wells – includes well pad surface infrastructure • installation of water and gas gathering lines and supporting infrastructure • construction of new access tracks where required • water balance tanks • communications towers • conversion or upgrade of existing exploration and appraisal wells to production in addition to the 850 new wells

Component	Infrastructure / activity
Ancillary facilities	• upgrades to intersections on the Newell Highway • expansion of workers' accommodation at Westport • a treated water pipeline and diffuser from Leewood to Bohena Creek • treated water irrigation infrastructure including: – pipeline(s) from Leewood to the irrigation area(s) – treated water storage dam(s) off site from Leewood • operation of the irrigation scheme

1.3 Project location

The proposed project area is located in north-western NSW, approximately 20 kilometres south-west of Narrabri, within the Narrabri local government area (LGA) (refer to Figure 1-1).

The project area covers about 950 square kilometres (95,000 hectares), and the project footprint would directly impact about one per cent of that area.

The project area contains a portion of the region known as 'the Pilliga', which is an agglomeration of forested area covering more than 500,000 hectares in north-western NSW around Coonabarabran, Baradine and Narrabri. Nearly half of the Pilliga is allocated to conservation, managed under the NSW National Parks and Wildlife Act 1974. The Pilliga has spiritual meaning and cultural significance for the Aboriginal people of the region.

Other parts of the Pilliga were dedicated as State forest, and set aside for the purpose of 'forestry, recreation and mineral extraction, with a strategic aim to "provide for exploration, mining, petroleum production and extractive industry" under the *Brigalow and Nandewar Community Conservation Area Act 2005*. The parts of the project area on state land are located within this section of the Pilliga.

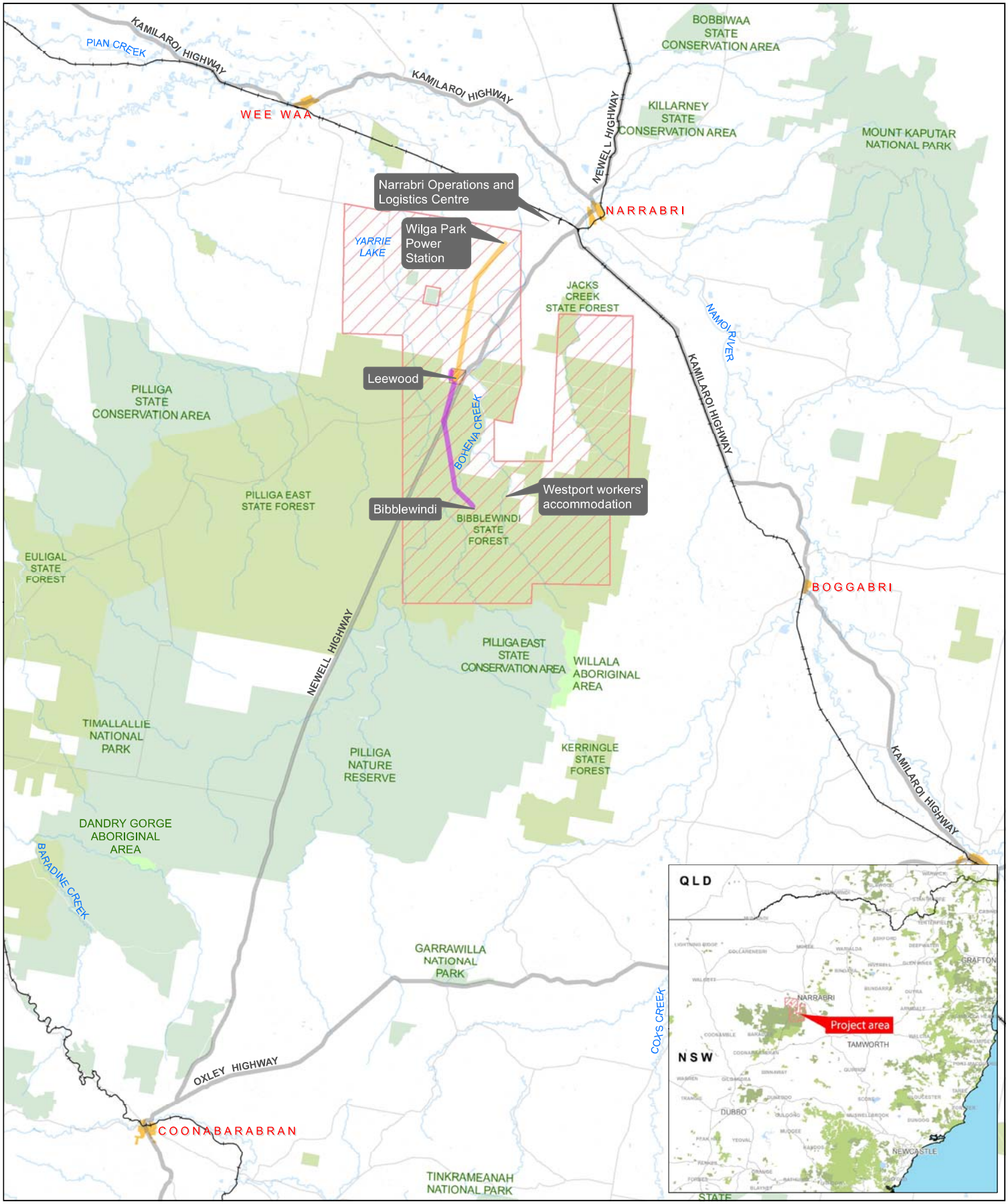
The semi-arid climate of the region and general unsuitability of the soils for agriculture have combined to protect the Pilliga from widespread clearing. Commercial timber harvesting activities in the Pilliga were preceded by unsuccessful attempts in the mid-1800s to establish a wool production industry. Resource exploration has been occurring in the area since the 1960s; initially for oil, but more recently for coal and gas.

The ecology of the Pilliga has been fragmented and otherwise impacted by commercial timber harvesting and related activities over the last century through:

- the establishment of more than 5,000 kilometres of roads, tracks and trails
- the introduction of pest species
- the occurrence of drought and wildfire.

The project area avoids the Pilliga National Park, Pilliga State Conservation Area, Pilliga Nature Reserve and Brigalow Park Nature Reserve. Brigalow State Conservation Area is within the project area but will be protected by a 50 metre surface exclusion zone.

Agriculture is a major land use within the Narrabri LGA; about half of the LGA is used for agriculture, split between cropping and grazing. Although the majority of the project area would be within State forests, much of the remaining area is situated on agricultural land that supports dry-land cropping and livestock. No agricultural land in the project area is mapped by the NSW Government to be biophysical strategic agricultural land (BSAL) and detailed soil analysis has established the absence of BSAL. This has been confirmed by the issuance of a BSAL Certificate for the project area by the NSW Government.



LEGEND

- Project area
- Leewood
- Urban
- State forest
- Parks and reserves
- Aboriginal areas
- Lakes and dams
- Watercourses
- Highways
- Major Roads
- Train line
- Leewood to Wilga Park infrastructure corridor
- Bibblewindi to Leewood infrastructure corridor

0 5 10 20
Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Narrabri Gas Project
EIS Technical Appendix

Regional context and location of key infrastructure

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Figure 1-1

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Data source: NSW Department of Lands: DTDB and DCDB - 2012-13. Santos: Operational and Base Data - 2013. Created by: afoddy

1.4 Planning framework and structure of this report

1.4.1 Planning Framework

The project is permissible with development consent under the *State Environmental Planning Policy (Mining, Petroleum and Extractive Industries) 2007*, and is identified as 'State significant development' under section 89C(2) of the *Environmental Planning and Assessment Act 1979* (EP&A Act) and the *State Environmental Planning Policy (State and Regional Development) 2011*.

The project is subject to the assessment and approval provisions of Division 4.1 of Part 4 of the EP&A Act. The Minister for Planning is the consent authority, who is able to delegate the consent authority function to the Planning Assessment Commission, the Secretary of the Department of Planning and Environment or to any other public authority.

The Secretary's greenhouse gas assessment requirements for the project and section 14 of the *State Environment Planning Policy (Mining, Petroleum Production and Extractive Industries) 2007* require the consent authority to consider:

> '*an assessment of the greenhouse gas emissions (including downstream emissions) of the development, and must do so having regard to any applicable State or national policies, programs or guidelines concerning greenhouse gas emissions*.'

1.4.2 Structure of report

Chapter 1	Introduction	Overview of the project and project area
Chapter 2	Methodology	Scope, emissions sources and calculation methodology
Chapter 3	Legislative context	Legislation, policies, programs and guidelines relating to greenhouse gas emissions
Chapter 4	Existing environment	Overview of current greenhouse gas emissions
Chapter 5	Impact assessment	Potential greenhouse gas impacts of the project
Chapter 6	Mitigation measures	Santos approach to manage and where practicable mitigate greenhouse gas emissions
Chapter 7	Conclusion	Overview of the assessment outcomes

1.5 Definitions

Greenhouse gas terms used in this assessment have the following meanings:

Carbon dioxide equivalent (CO_2-e)	Quantities of greenhouse gases are reported in units known as carbon dioxide equivalents. This is a measure based on the global warming potential of each greenhouse gas in comparison to carbon dioxide. Volumes of greenhouse gas emissions can therefore be reported using a common unit while still reflecting their relative impacts – usually reported as tonnes (t) or million tonnes (Mt).
De minimis	Exclusion of greenhouse gas emission sources that are less than 1% of the total greenhouse gas emissions from the project where the sum of all exclusions is less than 5% of the total emissions from the project.
Flaring and venting	Vents and flares are important safety devices that release excess hydrocarbon gases which cannot reasonably be recovered or recycled. When the hydrocarbon is combusted it is a flare, venting is the release of gas without flaring.
Fugitives	Fugitive emissions (excluding venting and flaring) are minor losses of gas that are assumed to occur from equipment and infrastructure. They are measured by applying legislative emission factors.

Greenhouse gas	A gas that contributes to the greenhouse effect by absorbing infrared radiation.
Joules	Unit of measurement of energy (Petajoule (PJ) = 10^{15} joules, Terajoule (TJ) =10^{12} joules, Gigajoule (GJ) =10^{9} joules).
ktC	Kilo tonnes carbon, measurement used for reporting vegetation sequestration.
MMSCF	Million standard cubic feet of gas.
Scope 1 emissions	Greenhouse gas emissions created directly by a person or business from sources that are owned or controlled by that person or business.
Scope 2 emissions	Greenhouse gases created as a result of the generation of electricity, heating, cooling or steam that is purchased and consumed by a person or business. These are indirect emissions as they arise from sources that are not controlled by the business who consumes the electricity.
Scope 3 emissions	Greenhouse gas emissions that are generated in the wider economy as a consequence of a person's or business's activities. These are indirect emissions as they arise from sources that are not owned or controlled by that person or business but they exclude Scope 2.
TWh	Terawatt hours = 10^{12} watt hours: unit of measurement of electricity.

2. Methodology

2.1 Overview

The greenhouse gas assessment was prepared in accordance with the following standards, guidelines and legislation:

- *The Greenhouse Gas Protocol, A Corporate Accounting and Reporting Standard, Revised Edition,* developed by the World Resource Institute and the World Business Council for Sustainable Development (GHG Protocol);
- The Commonwealth *National Greenhouse and Energy Reporting Act 2007* and associated legislative instruments;
- American Petroleum Institute, *Compendium of greenhouse gas emissions methodologies for the oil and gas industry*, August 2009 (API Compendium); and
- The Commonwealth Department of the Environment *National Greenhouse Accounts (NGA) Factors*, August 2016 (DoE 2016).
- The Commonwealth Department of the Environment and Energy National Inventory Report 2014 (Revised), August 2016 (DoEE 2016).

These are considered to represent current best practice in Australian greenhouse gas accounting.

Conservative estimates were used so that emissions are overestimated rather than underestimated. For example:

- It was assumed that the project would produce 200 TJ per day (TJ/day) of sales gas for the full 25-year assessment period. This volume is the maximum quantity of gas that would be produced for availability to the market at any time during the assessment period. In reality, at commencement of the project, the quantity of gas will be significantly less than 200 TJ/day given that the project will still be under construction. Using 200 TJ/day for the life of the project is therefore a conservative estimate of the amount of methane and carbon dioxide emitted during gas processing.
- Similarly, power and heat requirements for the project were assumed to be those that would be required to produce 200 TJ/day of sales gas. Basing the power and heat requirements on the maximum daily production will also result in a conservative estimate of the quantity of methane combusted and/or the quantity of electricity sourced from the grid in order to power project operations.

2.2 Greenhouse gases and global warming potentials

The Intergovernmental Panel on Climate Change (IPCC) states that warming of the climate system is unequivocal, and is in large part due to an increase in greenhouse gas emissions from human activities.

The United Nations Framework Convention on Climate Change (UNFCCC) identifies carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride as greenhouse gases.

The three greenhouse gases relevant to this assessment and their associated global warming potential (GWP) are listed in Table 2-1.

At the UNFCCC meeting in 2011, it was agreed to adopt updated GWPs as published in the IPCC's 2007 *Fourth Assessment Report* (AR4) from 2015 onwards.

Table 2-1 Greenhouse gas' global warming potentials

Greenhouse gas	Global warming potential (as per AR4 / NGER 2015+)
Carbon dioxide (CO_2)	1
Methane (CH_4)	25
Nitrous oxide (N_2O)	298

2.3 Emission scope classification

In order to avoid double-counting, emissions associated with an activity undertaken by a person or business are categorised into Scopes 1, 2 and 3 under the GHG Protocol. These scopes are defined as follows:

1. Scope 1 emissions are greenhouse gas emissions created directly by the person or business from sources that are owned or controlled by that person or business.
2. Scope 2 emissions are greenhouse gas emissions created as a result of the generation of electricity, heating, cooling or steam that is purchased and consumed by the person or business. These are indirect emissions as they arise from sources that are not owned or controlled by the person or business who consumes the electricity.
3. Scope 3 emissions are greenhouse gas emissions that are generated in the wider economy as a consequence of the person's or business's activities. These are indirect emissions as they arise from sources that are not owned or controlled by that person or business but they exclude Scope 2.

In the context of the project, Scope 1 emissions are produced by the combustion of fuels such as diesel in vehicles and in on-site electricity generation. Scope 1 emissions are also produced by processing operations, flares and vents. Emissions that arise from lost sequestration as a result of vegetation removal are also treated as Scope 1 emissions. In this assessment, Scope 1 emissions are described as 'direct' emissions of the project.

Scope 2 emissions for the project are third party emissions resulting from electricity purchases (i.e. combustion of fuel for electricity by the power stations).

Downstream product use emissions, and emissions arising from third party extraction, processing, transportation and distribution of fuels and electricity, are classified as Scope 3 emissions.

2.4 Boundary of assessment

The assessment boundary is depicted in Figure 2-1 and categorises the emissions included in this assessment. The assessment included emissions from the following project activities:

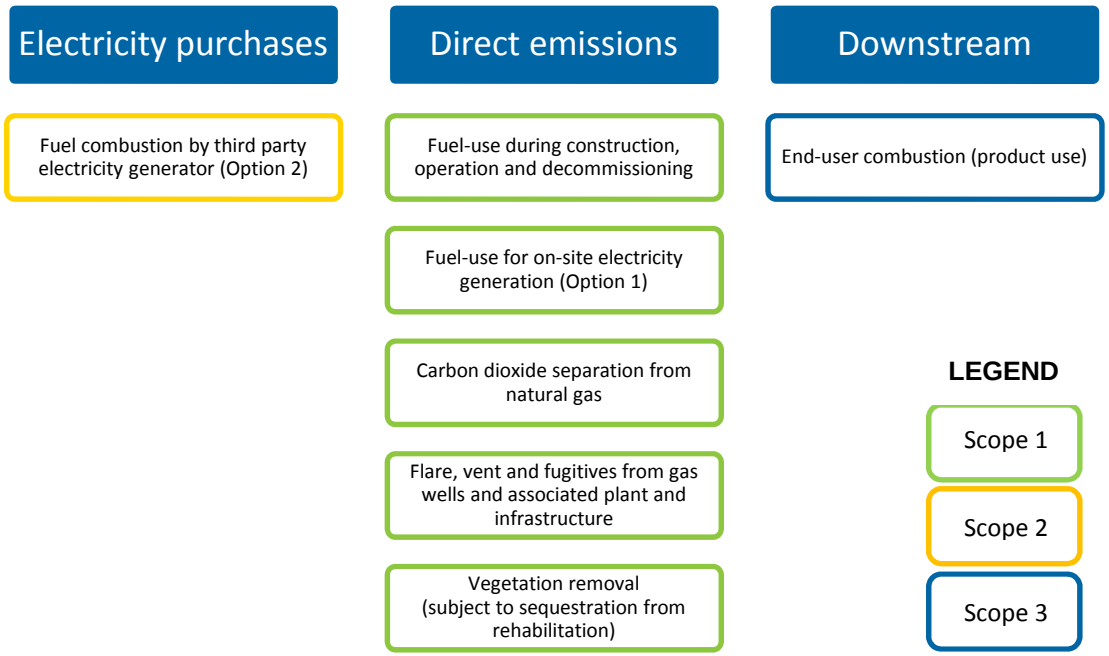
- Fuel-use (combustion in engines) during the construction, operation and decommissioning of the project.
- Flaring, venting and fugitive emissions from gas wells and associated plant and infrastructure.
- Vegetation removal (subject to any sequestration through vegetation rehabilitation).
- Fuel-use for gas-fired onsite electricity generation (*if required*).
- Scope 2 emissions from the purchase of electricity (*if required*).
- Scope 3 emissions resulting from the end-use of our product (natural gas), which typically is combusted for energy generation.

Two electricity options for the project were considered in the greenhouse gas assessment:

- Option 1: an on-site gas-fired electricity plant consisting of gas turbine engines with an operating capacity of 100 MW.
- Option 2: electricity sourced from the NSW grid.

The greenhouse gas emissions for both options are quantified in this assessment.

Figure 2-1 Assessment boundary



2.5 Calculation methodology and assumptions

The calculation methodology and emission factors applied in estimating the greenhouse gas emissions for the project are listed in Table 2-2 for major emissions sources (notionally greater than 0.05 Mt CO_2-e / year) and Table 2-3 for minor emissions sources.

Classification of major and minor emissions sources were based on the relative contribution to the total greenhouse gas emissions over the life of the project.

Table 2-2 Assumptions for major emission sources

Parameter measured	Assumptions
Construction	
Methane combustion – flaring	Quantity of methane combusted in pilot flares was estimated as 525 kt assuming a maximum of 25 pilot well pads with a maximum flowrate of 1 MMSCF per day each, operating for a duration of three years. Emissions were calculated in accordance with the *National Greenhouse and Energy Reporting (Measurement) Determination 2008* Section 3.44. Emission factor was sourced from *National Greenhouse and Energy Reporting (Measurement) Determination 2008* Section 3.44.
Operations	
Methane combustion – electricity generation (Option 1)	Quantity of methane consumed for electricity generation was estimated as 188 PJ based on 20.6 TJ per day. Emissions were calculated in accordance with the *National Greenhouse and Energy Reporting (Measurement) Determination 2008* Section 2.20. Emission factor was sourced from *National Greenhouse and Energy Reporting (Measurement) Determination 2008* Schedule 1 Part 2 Item 18.
Methane combustion – operations	The total quantity of methane combusted as a consequence of gas processing was estimated as 40 PJ based on a use of 4.4 TJ per day. Emissions were calculated in accordance with the *National Greenhouse and Energy Reporting (Measurement) Determination 2008* Section 2.20. Emission factors were sourced from *National Greenhouse and Energy Reporting (Measurement) Determination 2008* Schedule 1 Part 2 Item 18.
Emissions during gas processing – CO_2	Quantity of carbon dioxide released was estimated as: • 12.0 Mt for Option 1 • 10.9 Mt for Option 2. The estimates were based on extracted gas containing 10 mol% carbon dioxide, a production target of 200 TJ/day sales gas and a project life of 25 years. Note that the quantity of gas extracted was estimated at approximately 225 TJ/day for Option 1 and 204 TJ/day for Option 2. The difference is the additional gas required for the electricity plant for Option 1. It was assumed that all carbon dioxide extracted from gas being processed is emitted. The assumed carbon dioxide content of gas was based on industry experience.
Grid electricity (Option 2)	Quantity of electricity imported from the grid was estimated as 21.3 TWh and reflects the electricity requirements to support operations across the project life. The emission factor for grid electricity was sourced from *National Greenhouse Accounts Factors August 2016*, Table 41.
Downstream	
End-user consumption of gas	Total gas combusted by end-users was estimated as 1,825 PJ based on 200 TJ/day and an assessment period of 25 years. To forecast a reasonable estimate of downstream emissions from product use, it was assumed that 100% of the gas delivered to end-users from the project would be combusted for energy generation (e.g. electricity generation, large end-user energy requirements, heating and cooking. This provides a conservative basis for calculation of these emissions, as if gas is used for industrial processing (e.g. conversion into plastics) rather than combustion, the associated downstream emissions will be less. Emission factor was sourced from *National Greenhouse and Energy Reporting (Measurement) Determination 2008* Schedule 1 Part 2 Item 18.

Table 2-3 Assumptions for minor emission sources

Parameter measured	Assumptions
Construction	
Diesel fuel use	Volume of diesel to be used during construction activities was quantified (50 ML) based on proposed activities (well construction, trenching, land clearing), duration of activities, and fuel consumption for vehicles and equipment used by those activities (generators and light vehicles). Emissions were calculated in accordance with the *National Greenhouse and Energy Reporting (Measurement) Determination 2008* Section 2.41. Emission factor was sourced from *National Greenhouse and Energy Reporting (Measurement) Determination 2008* Schedule 1 Part 3 Item 40 and Schedule 1 Part 4 Item 65.
Vegetation removal – gas field	Total carbon in vegetation removed was estimated as 55 kilo tonnes carbon (ktC). It was assumed that all carbon was emitted as carbon dioxide. Vegetation types and areas of clearance were determined based on results of the ecological studies that form part of this EIS. Greenhouse gas emissions due to vegetation clearing were quantified using the Department of Environment's Full Carbon Accounting Model (FullCAM).
Well completions	The number of well completions was estimated at 850 on the basis of that the project will involve construction of 850 wells. No material methane venting is expected to occur during the completion phase. To release the natural gas from within the coal seam, the well must first be dewatered, this process releases the pressure within the coal seam and enables the natural gas to flow to the surface via the well. At which time the well is completed and tied into the gathering system.
Operations	
Facility safety flaring	It was assumed that safety flares at both Leewood and Bibblewindi will flare gas at a rate of 0.02 TJ/day (see project description). Emissions were calculated in accordance with the *National Greenhouse and Energy Reporting (Measurement) Determination 2008* Section 3.85. Emission factor was sourced from *National Greenhouse and Energy Reporting (Measurement) Determination 2008* Section 3.85.
Gas processing flaring non-routine emissions	Flared emissions was based on the total methane processed (54,500 Mm^3 CH_4 for Option 1 and 49,500 Mm^3 CH_4 for Option 2). Emission factor was sourced from API Compendium 2009 Table 4-11.
Gathering gas pipeline maintenance (e.g. blowdowns)	Fugitive emissions from gathering pipe maintenance were based on a gathering pipeline length of 600 km and an assessment period of 25 years. Emissions were calculated in accordance with the *National Greenhouse and Energy Reporting (Measurement) Determination 2008* Section 3.84. Emission factor was sourced from API Compendium 2009 Table 5-23 and Table 5-24.

Parameter measured	Assumptions
Glycol dehydrator units - processing	Fugitive emissions were based on the total methane processed (54,500 Mm^3 CH_4 for Option 1 and 49,500 Mm^3 CH_4 for Option 2). Emissions were calculated in accordance with the *National Greenhouse and Energy Reporting (Measurement) Determination 2008* Section 3.84. Emission factor was sourced from API Compendium 2009 Table 5-2.
Well maintenance (e.g. work-overs)	Quantity of well work-overs was estimated as 1,700 based on two work-overs per well. Emissions were calculated in accordance with the *National Greenhouse and Energy Reporting (Measurement) Determination 2008* Section 3.84. Emission factor was sourced from API Compendium 2009 Table 5-23.
General fugitive emissions	Fugitive emissions were based on the total methane processed (36.9 Mt CH_4 for Option 1 and 33.5 Mt CH_4 for Option 2). General fugitive emissions relate to fugitive emissions from production and processing, that is from wellheads, gathering infrastructure and gas processing. This excludes any fugitive emissions that must be separately calculated under the *National Greenhouse and Energy Reporting (Measurement) Determination 2008,* as outlined above. Emissions were calculated in accordance with the *National Greenhouse and Energy Reporting (Measurement) Determination 2008* Section 3.72. Emission factor was sourced from *National Greenhouse and Energy Reporting (Measurement) Determination 2008* section 3.72.
Decommissioning & rehabilitation	
Diesel fuel use	Quantity of diesel used during decommissioning and rehabilitation was estimated as 14.2 ML based on expected fuel consumption from well and gathering system rehabilitation activities and light vehicles. Emissions were calculated in accordance with the *National Greenhouse and Energy Reporting (Measurement) Determination 2008* Section 2.41. Emission factor was sourced from *National Greenhouse and Energy Reporting (Measurement) Determination 2008* Schedule 1 Part 3 Item 40 and Schedule 1 Part 4 Item 65.
Carbon sequestration from vegetation rehabilitation	Carbon sequestration from vegetation rehabilitation was estimated as 9.5 ktC based on the footprint of the well pads reducing from the cleared area of approximately 1 hectare, to approximately 0.25 hectares during operations. The rehabilitated area was assumed to be maintained as grassland. It was assumed that grasslands contain 30 tC / hectare.

The minor emission sources included in this assessment are those sources directly applicable to natural gas production activities. The *de minimis* principle has been applied to other minor emission sources where applicable to ensure that this assessment focuses on the material sources.

This is consistent with the principles of ISO 14064-1 *Greenhouse gases -- Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals* and international greenhouse accounting programs such as the Certified Emissions Measurement and Reduction Scheme (CEMARS).

Emissions that are considered to be negligible or otherwise have been confirmed as satisfying the *de minimis* principle include the following:

- Emissions associated with hydrofluorocarbons in air conditioning and refrigeration units, and sulphur hexafluoride in electrical equipment.
- Emissions associated with combustion of oils and greases in construction and operational vehicles and equipment.
- Emissions associated with sewage and disposal of waste in landfill.
- Emissions associated with third party extraction, production or manufacture of construction materials, consumables and fuel.
- Emissions associated with the transportation of fuel, construction materials, consumables and electricity to the project site and transportation of waste from the site.

All greenhouse gas emissions excluded from this assessment satisfy the *de minimis* principle, that is, any exclusion would be less than 1% of the total greenhouse gas emissions from the project and the sum of all exclusions would be less than 5% of the total greenhouse gas emissions from the project.

3. Legislative context

Clause 14 of the *State Environment Planning Policy (Mining, Petroleum Production and Extractive Industries) 2007* requires the consent authority to consider "*an assessment of the greenhouse gas emissions (including downstream emissions) of the development, and must do so having regard to any applicable State or national policies, programs or guidelines concerning greenhouse gas emissions*."

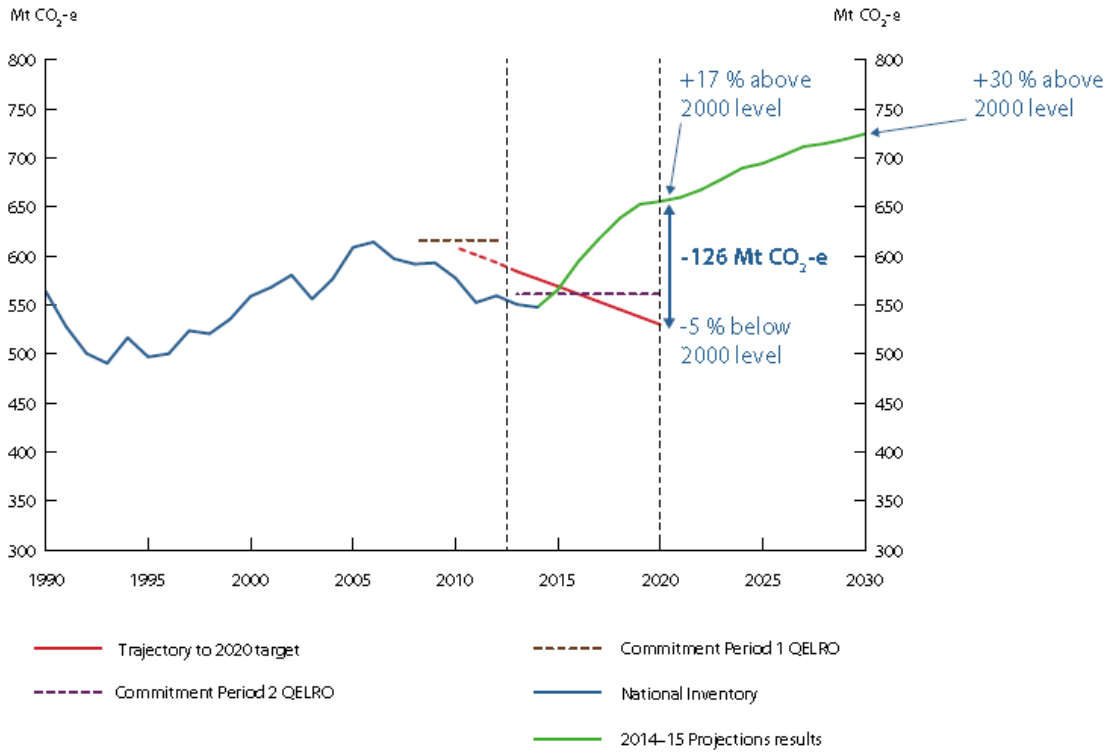
3.1 Current policies, programs and guidelines

Australia's 2020 target for greenhouse gas emission reductions

The Australian Government has committed to a target of reducing Australia's annual greenhouse gas emissions to five per cent below 2000 levels by 2020.

This target has been reported as a commitment under the UNFCCC. On the basis of projections from the Department of Environment released in March 2015, and as shown in Figure 3.1, Australia's annual greenhouse gas emissions in 2020 will need to be 126 Mt CO_2-e lower than currently projected (or no more than 530 Mt CO_2-e) in order for Australia to achieve the five per cent emissions reduction target.

Figure 3-1 Australia's annual emissions trends, 1990 to 2030



Source: Commonwealth of Australia, Department of the Environment, *Australia's emissions projections 2014–15,* March 2015, based on data reported in Commonwealth of Australia, *Australian National Greenhouse Accounts: Quarterly Update of Australia's National Greenhouse Gas Inventory September Quarter 2014.* Note: Years refer to the financial year ending in the year shown.

The Australian Government has also made a commitment under the Kyoto Protocol to reduce Australia's annual greenhouse gas emissions to 99.5 per cent of 1990 emission levels for the duration of the Protocol's second commitment period, which extends from 2013 to 2020.

Australia's 2030 target for greenhouse gas emission reductions

As part of the UNFCCC process to develop a post-2020 international climate change agreement, the Australian Government has announced a greenhouse gas emission reduction target of 26-28% below 2005 levels.

Internationally agreed reduction targets will ultimately drive Australian greenhouse gas emissions policy.

National Greenhouse and Energy Reporting Scheme

The National Greenhouse and Energy Reporting Scheme (NGERS) is a national framework established under the *National Greenhouse and Energy Reporting Act 1997* (Cth) for corporations to report on Scope 1 and Scope 2 greenhouse gas emissions, energy consumption and energy production above certain thresholds. The scheme is administered by the Clean Energy Regulator.

The *National Greenhouse and Energy Reporting (Measurement) Determination 2008* established to support NGERS sets out methodologies for quantifying emissions, and provides emission factors for use in those calculations. Santos reports its Scope 1 and Scope 2 greenhouse gas emissions, energy consumption and energy production from its existing facilities in accordance with NGERS. The emissions and energy data associated with construction and operation of the project will also be included in Santos' annual reports to the Clean Energy Regulator.

Emissions Reduction Fund

The Emissions Reduction Fund (ERF) expands the Carbon Farming Initiative (CFI) to enable operators in a broad range of industry sectors the ability to generate carbon units by undertaking projects to reduce greenhouse gas emissions. It is anticipated at the time of this assessment that these projects will include industrial energy efficiency and fuel efficiency projects. The ERF is administered under the *Carbon Credits (Carbon Farming Initiative) Act 2011* by the Clean Energy Regulator.

Once the Narrabri Gas Project has commenced operation, there may be opportunities for Santos to participate in the ERF where potential energy efficiency or fuel efficiency improvement projects are identified.

3.2 Proposed policies, programs and guidelines

National Greenhouse and Energy Reporting Scheme – Safeguarding Mechanism

Amendments to the National Greenhouse and Energy Reporting Act in late 2014 introduced a framework for a greenhouse gas safeguarding mechanism which came into effect on 1 July 2016. The associated rules were tabled in Parliament in October 2015.

Compliance with the mechanism will be the obligation of the person with operational control of a "designated large facility" that emits more than a threshold of 100,000 tonnes of CO_2-e per year. The mechanism provides for the person to pay a penalty if an "excess emissions situation" exists in relation to the facility. An excess emissions situation exists if the net emissions number for the facility is greater than its baseline emissions number.

It is likely that in a typical operating year, the Narrabri Gas Project will trigger the 100,000 tonnes threshold.

Santos will comply with any statutory obligations under the safeguarding mechanism that apply in respect of the greenhouse gas emissions from the project.

Review of emissions reduction policies

The Australian Government has stated that it will in 2017-18 undertake a review to determine further post-2020 domestic emissions reduction policies. As part of this process, the Government will consider a potential long term emissions reduction goal for Australia, beyond 2030, taking into account international trends and technology developments.

4. Existing environment

The Commonwealth Department of the Environment and Energy reports national annual greenhouse gas emissions in accordance with the requirements of the UNFCCC and the Kyoto Protocol.

Baseline fugitive methane emissions are reasonably expected to be comparable with the existing activities in the area, including agriculture, waste management, and naturally occurring anaerobic processes and seeps.

Table 4-1 shows that Australia's annual emissions totalled 523.3 Mt CO_2-e in 2014.

Table 4-1 Australia's greenhouse gas emissions in 2014

Sector	Australia emissions (Mt CO_2-e)	Percentage of Australia emissions
Electricity	180.8	34.5 %
Agriculture and land	73.3	14.0%
Stationary energy other than electricity	93.8	17.9%
Transport	92.9	17.8%
Industrial processes	32.4	6.2%
Coal mining	25.15	4.8%
Oil and gas	12.94	2.5 %
Waste	12.0	2.3 %
Total	**523.3**	**100%**

In Table 4-1, "*Stationary energy*" includes emissions from fuel use for manufacturing, mining and households. "*Industrial processes*" includes emissions from the production of chemical, metal and minerals products. "*Coal mining*" includes flaring and venting but excludes electricity and fuel use. "*Oil and gas*" includes flaring, venting and fugitive emissions from production, processing and distribution activities.

Global emissions are currently estimated to be approximately 49 billion tonnes CO_2-e per year (49,000 Mt CO_2-e).[1]

[1] Intergovernmental Panel on Climate Change Fifth Assessment: Synthesis Report (2014)

5. Impact assessment

The greenhouse gas emissions for the project were calculated based on estimated energy usage, vegetation removal, fuel combustion and processing emissions including emissions from vents and flares.

5.1 Direct greenhouse gas emissions

As shown in the following tables, total direct greenhouse gas emissions associated with the project would equal about 26.3 Mt CO_2-e for Option 1 (self-generated electricity), or 15.5 Mt CO_2-e for Option 2 (electricity sourced from the national grid).

Table 5-1: Total direct greenhouse gas emissions over 25 year period – Option 1 (Mt CO_2-e)

Phase	Fuel	Flare	Vent	CO_2 Vent	Fugitive	Vegetation clearance	Total
Construction	0.1	1.9	0	0	0	0.2	**2.2**
Operation	11.8	0.1	0.1	12.0	0.05	0	**24.1**
Decommissioning	0.04	0	0	0	0	(0.04)	**0.0**
Total	12.0	2.0	0.1	12.00	0.1	0.2	**26.3**

Table 5-2 Total direct greenhouse gas emissions over 25 year period – Option 2 (Mt CO_2-e)

Phase	Fuel	Flare	Vent	CO_2 Vent	Fugitive	Vegetation clearance	Total
Construction	0.1	1.9	0	0	0	0.2	**2.2**
Operation	2.1	0.1	0.1	10.9	0.05	0	**13.3**
Decommissioning	0.04	0	0	0	0	(0.04)	**0.0**
Total	2.2	2.0	0.1	10.9	0.0	0.2	**15.5**

Table 5-3 shows the direct greenhouse gas emissions that would be emitted in a typical operating year (i.e. peak operations, post principal construction and prior to decommissioning). Direct greenhouse gas emissions in a typical operating year would be about 0.96 Mt CO_2-e with Option 1 (self-generation), or 0.53 Mt CO_2-e with Option 2 (grid sourced electricity). This is less than 0.2 per cent of Australia's current annual emissions of 523.3 Mt CO_2-e.

Table 5-3 Direct greenhouse gas emissions in a typical operating year (Mt CO_2-e)

	Fuel	Flare	Vent	CO_2 Vent	Fugitive	Vegetation clearance	Total
Option 1	0.47	0.005	0.005	0.48	0.002	0	0.96
Option 2	0.08	0.004	0.004	0.44	0.002	0	0.53

5.2 Purchased electricity

If Option 2 is the preferred development scenario, electricity will be purchased from the national grid. Although the emissions associated with the electricity generation will be the direct emissions of the third party electricity generator, for completeness Santos reports these emissions as Scope 2 emissions for the project.

For Option 2, the Scope 2 emissions for the project will be approximately 18 Mt CO_2-e over the 25-year assessment period and will be 0.72 Mt CO_2-e in a typical operating year.

There will be no Scope 2 emissions if the project incorporates an on-site electricity plant (Option 1). The emissions generated by the on-site electricity plant will be incorporated into the direct emissions of the project.

5.3 Downstream emissions

Product use emissions due to downstream combustion of gas by consumers although beyond the operational control of Santos, have been estimated. Based on an assumption that the project will deliver 200 TJ of gas per day for the 25-year assessment period, annual product use emissions from combustion of the gas by end-users would be in the order of 3.77 Mt CO_2-e.

Downstream emissions are a result of consumer demand for energy.

5.4 Impact assessment

The challenge for the international community is to reduce anthropogenic greenhouse gas emissions while continuing to provide reliable and affordable energy and meet rapidly growing energy demands. By 2040, global energy demand is expected to have increased by 37% from the present.[2]

Current global greenhouse gas emissions are estimated to be approximately 49 billion tonnes CO_2-e per year (49,000 Mt CO_2-e).[3] Australia's emissions (523.3 Mt CO_2-e) equate to approximately 1% of global emissions.

As shown in Table 5-4, the annual direct emissions from the project are equivalent to less than 0.2% of Australia's current annual emissions. This contribution is less than 0.002% of global greenhouse gas emissions.

Table 5-4 Comparison of project greenhouse gas emissions to Australia's 2014 emissions

Sector	2014 emissions (Mt CO_2-e)	Option 1 (Self-generated electricity)	Option 2 (Grid-sourced electricity)
Australian energy sector	405.6	0.24%	0.13%
Total Australia	**523.3**	**0.18%**	**0.1%**

Notes:

- Percentages based on average annual direct greenhouse gas emissions for a typical operating year i.e. Option 1: 0.96 Mt CO_2-e and 0.53 Mt CO_2-e for Option 2 (Table 5.3).
- Australia's emissions as reported in the most recently published National Inventory Report, dated August 2016.

[2] IEA, 2014, *World Energy Outlook*, *2014*. Accessed 26 February 2015 at http://www.iea.org/publications/freepublications/publication/WEO_2014_ES_English_WEB.pdf
[3] Intergovernmental Panel on Climate Change Fifth Assessment: Synthesis Report (2014)

The relatively small incremental increase (less than 0.2%) in Australia's annual greenhouse gas emissions associated with the project, and its contribution to global emissions, should be considered in terms of the net environmental benefit of the natural gas generated by the project.

In the transition to a lower-carbon economy, natural gas offers a unique opportunity for Australia by providing a lower-carbon alternative to existing fossil fuel energy sources.

Fuel switching to natural gas for electricity generation can deliver an improvement in emissions intensity of the electricity grid. This has occurred in the United States of America, where it is reported that fuel switching to natural gas from the shale gas boom has resulted in an emissions reduction of 200 Mt CO_2-e per year[4].

In comparison on a lifecycle basis, where both upstream and downstream emissions are taken into account, energy (such as heat or electricity) produced by the combustion of natural gas has significantly lower greenhouse gas emissions than the electricity that is currently supplied to the NSW grid (see Figure 5-1).

- Upstream emissions for fossil fuel supplies are those emitted in the extraction, processing and transportation of the fuel product (i.e. coal or gas).
- Downstream emissions are those emitted from the combustion of the fuel by the end user.

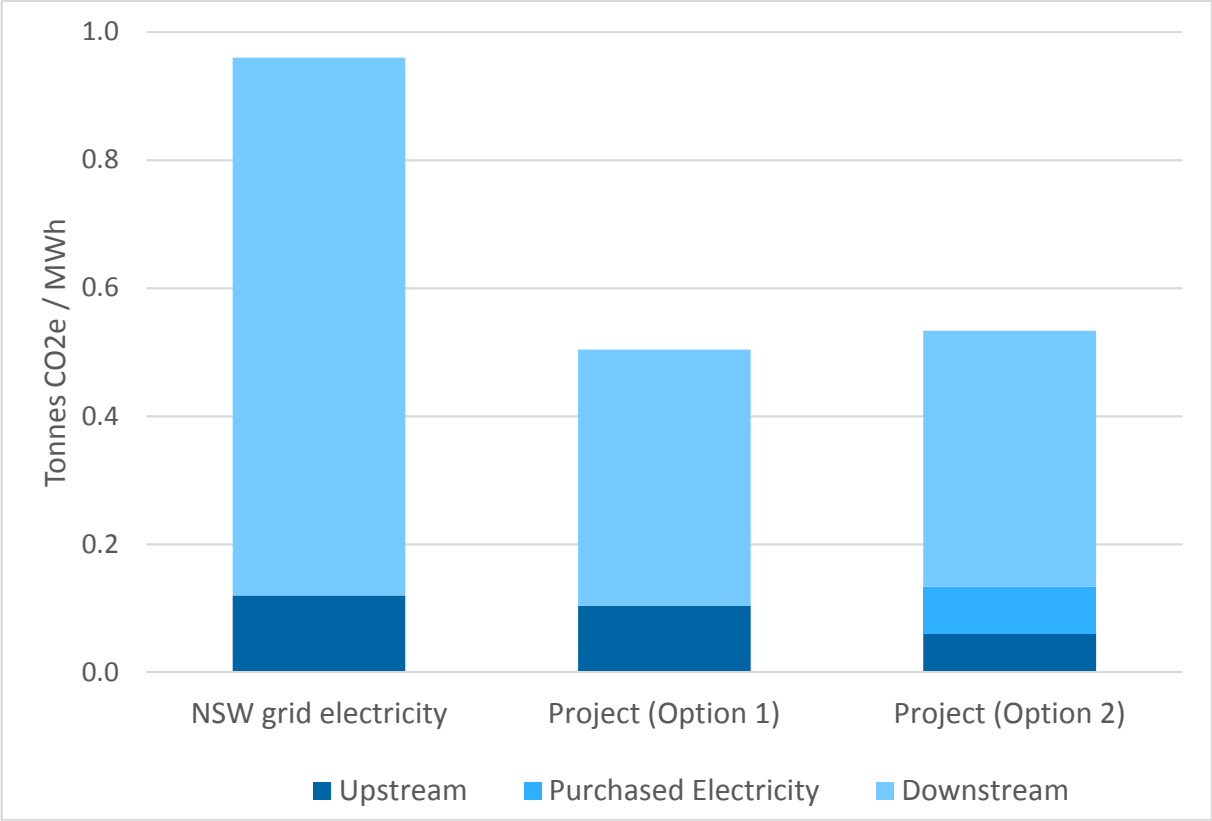
Upstream emissions form only a small proportion of the total lifecycle emissions for energy generation. Consequently, it is the downstream emissions that have by far the greatest bearing on the emissions intensity of the energy.

To illustrate this comparison, Figure 5-1 shows that the lifecycle emissions for electricity produced by combustion of the gas delivered by the project would be approximately 50% less than for the production of the electricity that is currently supplied to the NSW grid.

In the context of these net environmental benefits, the project is consistent with the principles of ecologically sustainable development.

[4] EIA, 2014, *U.S. Energy-Related Carbon Dioxide Emissions, 2013*.

Figure 5-1 Comparative lifecycle greenhouse gas emissions intensity of electricity[5]



[5] NSW grid electricity emissions: National Greenhouse Accounts Factors, Department of Environment (August 2015 Update); Project emissions: Project analysis reported in Table 5-3, section 5.3 and section 5.4; and Option 1 and Option 2 downstream emissions intensity: Based on new combined cycle gas turbine (CCGT) manufacturer specifications.

6. Mitigation measures

As a general principle, the proponent will consider all reasonable and practicable measures to minimise greenhouse gas emissions from project emission sources within its control.

6.1 Governance approach

Climate change is a long-term issue, requiring urgent but informed action to stabilise atmospheric greenhouse gas concentrations. As a global stakeholder in the energy business we recognise that one of our key social and environmental responsibilities is to pursue strategies that address the issue of climate change.

In accordance with its Climate Change Policy, Santos will:

- Continue to reduce the carbon intensity of its products by focusing on energy efficiency and technology development.
- Use energy more efficiently by identifying opportunities to implement energy efficiency projects and report their progress.
- Examine the commercial development of low emission technologies, including storage solutions, which will contribute towards long-term emission reduction targets.
- Pursue no flaring or venting of associated gas, unless there are no feasible alternatives.
- Continue to publicly disclose its greenhouse gas emissions profile and carefully examine forecast emissions.
- Understand, manage and monitor climate change risk and develop appropriate adaptation strategies for its business.
- Inform employees about its commitment to climate change and ensure climate change initiatives continue to be implemented.
- Report progress against these commitments to the Board of Santos.

These policy commitments underpin Santos' approach to greenhouse gas emissions management, which is governed through a suite of corporate standards, guidelines and manuals.

Santos' Environment, Health and Safety Management System (EHSMS) outlines the structured approach necessary for our operations to manage risks and drive improvement in a consistent and systematic manner. Each standard within the EHSMS defines the requirements for all employees and contractors to achieve this outcome in a clear and comprehensive manner. Features of these standards include:

- Details of Santos' approach to climate change and greenhouse gas emissions, building on Santos' Climate Change Policy commitments and setting out requirements for identifying, measuring and reporting greenhouse gas emissions, and systematically assessing energy efficiency opportunities;
- Details of Santos' approach to driving energy efficiency improvements, covering both energy use (fuel and electricity) and energy loss (flare, vent and fugitives);
- Details of how energy efficiency assessments are conducted and requirements for energy efficiency opportunities to be assessed during the design process for new projects;

- Details of how greenhouse gas emissions management should be applied to each stage of development, including in respect of the measurement and reporting of emissions and energy consumption, energy efficiency and greenhouse gas abatement.

Santos has a dedicated Carbon and Sustainability team with oversight of Santos' greenhouse gas emissions management approach. The team maintains a set of detailed compliance manuals that describe the processes and methodologies that are required to be used for data collection, emissions calculation and reporting.

Each year, Santos' greenhouse gas emission reports are assured by an independent third party auditor and reported publicly via Santos' sustainability reports and to the National Greenhouse and Energy Reporting authority.

Progress against Santos' Climate Change Policy is reported quarterly to the Santos Environment, Health, Safety and Sustainability Committee of the Board.

6.2 Measures

Santos' standard practice is to consider, and where practicable implement, a range of energy efficiency and greenhouse gas management measures in relation to its activities. These measures are described in the table below.

Table 6-1 Mitigation and management measures for the project

Mitigation/management measure	Timing
The design of infrastructure and selection of plant, vehicles, equipment and fuels will be reviewed for energy efficiency.	Pre-construction
Measurement systems will be incorporated into the design to comply with *National Greenhouse and Energy Reporting Act 2007* requirements.	Pre-construction
Transport logistics will be planned to minimise energy use, and the most fuel-efficient vehicles and equipment will be used where economically viable.	Construction Operation
Energy use will be considered when procuring plant, vehicles and equipment.	Construction Operation
Plant, vehicles and equipment will be maintained in good operating condition to maintain fuel use efficiency.	Construction Operation
Energy efficiency opportunities will be monitored and periodically reviewed.	Construction Operation
Greenhouse gas emissions will be reported and independently assured on an annual basis in accordance with the *National Greenhouse and Energy Reporting Act 2007*.	Construction Operation
A leak detection and repair program approved by the NSW Environment Protection Authority will be implemented to identify and minimise fugitive emissions.	Operation

7. Conclusion

Natural gas can underpin the transition to a low carbon economy.

Lower-carbon energy sources such as natural gas can help to meet growing global energy demand while reducing relative global greenhouse gas emissions. For example, lifecycle emissions for energy produced from the combustion of the natural gas delivered by the project will be nearly 50% less than for electricity that is currently supplied to the NSW grid (See Figure 5-1).

Annual direct greenhouse gas emissions for the project in a typical operating year would be about 0.96 Mt CO_2-e with the on-site power generation facility, or 0.53 Mt CO_2-e with electricity sourced from the national grid. This is the equivalent of less than 0.2 per cent of current annual emissions in Australia and less than 0.002 per cent of current global emissions.

Given the environmental benefits of lower-carbon energy sources, the project is consistent with the principles of ecologically sustainable development.

Santos has a strong track record of working cooperatively with government, industry and the community to address greenhouse gas emissions with specific focus on addressing energy efficiency, the transition to lower emission technologies and reporting transparency. Santos is committed to implementing reasonable and practicable measures to reduce, monitor and disclose its greenhouse gas emissions throughout the life of the project.

Santos will report project greenhouse gas emissions, energy consumption and energy production in accordance with the *National Greenhouse and Energy Reporting Act 2007* and manage any compliance obligations under the Safeguarding Mechanism or any future carbon policy

As such, the residual environmental risk presented by the project is low with regard to greenhouse gas emissions.

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