FINAL REPORT

GLNG Environmental Impact Statement - Greenhouse Gas

Prepared for

Santos Ltd

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Executive Summary

Climate change is a global issue requiring significant resources to meet complex environmental, energy, economic and political challenges. As a global stakeholder in the energy business, Santos recognises that one of its most important environmental responsibilities is to pursue strategies that address the issue of greenhouse gas emissions. A clean energy strategy is the cornerstone of Santos' new Climate Change Policy, which was published in December 2008. The Policy is based on Santos' vision 'to lower the carbon intensity of its products'.

Santos is proposing to develop coal seam gas (CSG) resources in the area near Roma and Injune in south-west Queensland. The CSG resources will supply gas for a proposed 3 – 4 million tonne per annum (Mtpa) liquefied natural gas (LNG) and export facility (LNG Facility) on Curtis Island, near Gladstone, with planned expansion to 10 Mtpa. A gas transmission pipeline is proposed to be constructed linking the LNG Facility with the CSG fields. The entirety of these activities and facilities is referred to as the Gladstone LNG (GLNG) project (the project).

Scope 1 GHG emissions for the GLNG project were estimated as both an annual average and as a total amount over an assumed 25 year project lifetime for both the 3 Mtpa and 10 Mtpa cases. Scope 2 emissions were calculated for construction activity on the pipeline and assumed to be immaterial for the remainder of the project as it will use CSG to produce any necessary electrical power. Indicative values for Scope 3 emissions were calculated for construction as well as an end use scenario based on transportation of the product LNG to Japan for combustion in a power station.

Total Scope 1 GHG emissions for the 3 Mtpa case average 2,650,699 tonnes CO_2-e a year. For the 10 Mtpa case annual average GHG emissions are 4,960,499 tonnes CO_2-e. The annual figure for the 3 Mtpa case represents 0.46% of annual Australian GHG emissions and 1.55% of annual Queensland emissions. The 10 Mtpa case represents 0.86% of annual Australian and 2.91% of annual Queensland emissions.

While the GLNG project will be a relatively large producer of GHG emissions, Santos has taken steps at every point to reduce emissions to the extent practicable. This is reflected in the benchmarking results which place GLNG in the ranks of the most GHG efficient LNG facilities in the world. Additionally, LNG is in itself a low-emissions fuel, producing roughly half the GHG of coal when used to produce energy. Consequently the GLNG project represents a potential significant reduction in GHG emissions should its product be used in place of other fossil fuels such as coal or oil.

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Introduction Section 1

Santos is proposing to develop coal seam gas (CSG) resources in the area near Roma and Injune in south-west Queensland. The CSG resources will supply gas for a proposed 3 – 4 million tonne per annum (Mtpa) liquefied natural gas (LNG) and export facility (LNG Facility) on Curtis Island, near Gladstone, with planned expansion to 10 Mtpa. A gas transmission pipeline is proposed to be constructed linking the LNG Facility with the CSG fields. The entirety of these activities and facilities is referred to as the Gladstone LNG (GLNG) project (the project).

The components of the project include:

- The CSG field development for the first stage of the LNG Facility will include sufficient exploration and development wells to supply approximately 5,300 petajoules (PJ) (equivalent to 140 billion m^3) of CSG over the project life. The main CSG fields to be developed as part of the Project comprise the regions of Fairview, Roma and Arcadia Valley. Staged development of the CSG fields is likely to consist of 850 development wells being established prior to 2015, with the potential for 1,750 or more additional development wells after 2015. The Project is anticipated to have a 25-year production life. Additional supporting infrastructure including field gathering lines and compressors will also be installed.
- A 435 km long gas transmission pipeline corridor for the delivery of the CSG gas to the Facility.
- An LNG Facility of up to approximately 10 Mtpa capacity on Curtis Island. Currently there are two designs under consideration for construction of the LNG facility, an Optimized Cascade LNG Process (OCP) and a Propane Pre-cooled Mixed Refrigerant (C3MR) process, both with slightly different greenhouse gas emission characteristics. Consequently there are a total of four facility scenarios to consider consisting of two different designs for both the 3 Mtpa and 10 Mtpa developments.

The organisational boundary of the project is defined as the Santos Ltd GLNG project and is delineated by the physical LNG facility study area on Curtis Island, the gas transmission pipeline easement, and the CSG field development activities.

Auxiliary infrastructure such as communications infrastructure, water management systems, and wastewater treatment facilities are not included within the project organisational boundary. Third-party shipping and end use of the LNG product are also outside the project organisational boundary, though included as part of the discussion of Scope 3 emissions.

This report comprises a summary of relevant greenhouse gas (GHG) policies, the methodology used for the inventory, the GHG inventory for the GLNG Project and a comparison of the Project emissions to Queensland, Australian and global emissions.

Section 2 Greenhouse Gas Policy Background

2.1 International Policy

The Kyoto Protocol to the United Nations Framework Convention on Climate Change was signed in 1997 and entered into force in 2005. Australia ratified the Kyoto Protocol in December 2007. Its aim is to limit greenhouse gas emissions of countries that ratified the protocol by setting individual mandatory greenhouse gas emission targets in relation to those countries' 1990 greenhouse gas emissions. Australia has committed to meeting its Kyoto Protocol target of 108% of 1990 emissions by 2008-2012.

The Kyoto Protocol sets out three "flexibility mechanisms" to allow greenhouse gas targets to be met:

- The Clean Development Mechanism;
- Joint Implementation; and
- International Emissions Trading.

The definitions of the three mechanisms above are complex but effectively they allow greenhouse gas reductions to be made at the point where the marginal cost of that reduction is the lowest. Essentially, an industrialised country sponsoring a greenhouse gas reduction project in a developing country can claim that reduction towards its Kyoto Protocol target and those greenhouse gas reductions can be traded.

2.2 Australia's Climate Change Policy

The Australian policy on climate change was released in July 2007[1] and sets out the Commonwealth Government's focus on:

- Reducing Australia's greenhouse gas emissions;
- Adapting to climate change that we cannot avoid; and
- Helping to shape a global solution that both protects the planet and advances Australia's long-term interests.

This Project will operate in accordance with the following climate change policies: CPRS, EEO, and NGER.

Australia's climate change policy is managed by the Department of Climate Change. At the time of writing (January 2009), Australia recently published a baseline report on national GHG emissions but has not yet reported on progress toward Kyoto Protocol or other GHG emissions goals.

2.2.1 Carbon Pollution Reduction Scheme (CPRS)

The Carbon Pollution Reduction Scheme (CPRS) White Paper was released in 2008 and outlines the Government's proposed mechanism to reduce GHG emissions from Australian industries to a target of 5% -15% below 2000 levels. The Government maintains a long-term emissions abatement goal of 60% by 2050 (against 2000 levels) to meet Kyoto Protocol requirements.

A key component of the CPRS is the implementation of a trading scheme which will cap total GHG emissions and allow trading in emissions permits, commencing in 2010. Liable entities will be required to obtain carbon

[1] *Australia's Climate Change Policy*, Department of the Prime Minister and Cabinet, Australian Government, July 2007.

pollution permits to acquit their GHG emission obligations under the scheme. Industry sectors that will be covered by the CPRS are the stationary energy, transport, fugitive emissions, industrial processes, waste and forestry sectors.

The CPRS is supported by the National Greenhouse and Energy Reporting Act 2007 (NGER) which establishes a national framework for Australian corporations to report Scope 1 and Scope 2 greenhouse gas emissions, reductions, removals and offsets, and energy consumption and production, from July 2008. It is designed to provide robust data as a foundation to the CPRS. Facilities that emit 25 kilotonnes (kt) or more of greenhouse gas (CO_2-e), or produce/consume 100 terajoules (TJ) or more of energy annually will be captured by NGER, as well as corporations that emit a total of 125 kt or more greenhouse gas (CO_2-e), or produces/consumes 500 TJ or more of energy annually from facilities that they control. The corporate reporting threshold reduces to 50 kt CO_2-e emissions or 200 TJ of energy production or consumption by the 2010-2011 reporting year.

2.2.2 National Greenhouse and Energy Reporting Act 2007 (NGER)

The NGER Act establishes a national framework for Australian corporations to report Scope 1 and Scope 2 (see Section A.4 for definitions) greenhouse gas emissions, reductions, removals and offsets, and energy consumption and production, from July 2008. It is designed to provide robust data as a foundation to the CPRS.

From 1 July 2008, corporations will be required to register and report if:

- They control facilities that emit 25 kilotonnes or more of greenhouse gas (CO_2-e), or produce/consume 100 terajoules or more of energy annually; or
- Their corporate group emits 125 kilotonnes or more greenhouse gas (CO_2-e), or produces/consumes 500 terajoules or more of energy annually.

Lower thresholds for corporate groups will be phased in by 2010-2011 with the final threshold at 50 kt CO_2-e emissions or 200 terajoules of energy production or consumption for a corporate group. Companies must register by 31st August, and report by 31st October, following the financial year in which they meet a threshold.

2.2.3 Energy Efficiency Opportunities (EEO)

The Energy Efficiency Opportunities legislation[2] came into effect in July 2006, and requires large energy users (over 0.5 PJ of energy consumption per year) to participate in the program. The objective of this program is to drive ongoing improvements in energy consumption amongst large users, and businesses are required to identify, evaluate and report publicly on cost effective energy savings opportunities.

Energy Efficiency Opportunities legislation is designed to lead to:

- Improved identification and uptake of cost-effective energy efficiency opportunities;
- Improved productivity and reduced greenhouse gas emissions; and
- Greater scrutiny of energy use by large energy consumers.

The EEO program will be incorporated into the National Framework for Energy Efficiency. Santos is a registered participant in EEO and the GLNG project will be included in Santos' efforts to meet their obligations under EEO.

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[2] Australian Government. July 2006. Energy Efficiency Opportunities Act 2006.

2.2.4 Greenhouse Challenge Plus

The Greenhouse Challenge Plus program[3] is part of the Australian Government's Climate Change Strategy. It is a voluntary program utilising individual agreements to encourage participants to report their greenhouse gas emissions and make progress towards quantified greenhouse abatement measures. All participants have certain responsibilities under the program, including:

- Measure and monitor greenhouse gas emissions;
- Deliver maximum practical greenhouse gas abatement;
- Continuously improve management of greenhouse gas emissions and sinks;
- Work towards any specific milestones set out under individual agreements;
- Provide timely annual reports with agreed content on greenhouse gas emissions and emission reduction activities;
- Make an accurate annual statement about participation in the program including basic greenhouse gas emissions information;
- Promote industry participants' activities in terms of greenhouse gas management and importantly in terms of their membership in the program; and
- Participate in independent verification of annual progress reports.

Santos is a member of the Greenhouse Challenge Plus program, and the GLNG project will therefore be included in Santos' Greenhouse Challenge inventories and reporting.

2.3 State Policy and Initiatives

The Queensland Government created the Office of Climate Change in October 2007 in order to lead an effective climate change response. As a producer of greenhouse gases in Queensland, the Project will need to adhere to any requirements and guidelines promulgated by the Queensland Government.

2.3.1 ClimateSmart 2050

ClimateSmart 2050 is the Queensland Climate Change Strategy[6]. It aims to reduce greenhouse emissions by 60% from 2000 levels by 2050 in line with the national target by building initiatives into the Queensland Government's 2000 Energy Policy.[4] Its initiatives include:

- The introduction of a Smart Energy Savings Program, which targets large energy users and requires them to undertake energy efficiency audits and implement energy savings measures that have a three year or less payback period;
- The Queensland Future Growth Fund for development of clean coal technologies; and
- Changes to the Queensland Gas Scheme which will oblige major industries to source 18% of all power from Queensland based gas-fired generation.

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[3] Department of the Environment, Water, Heritage and the Arts. Greenhouse Challenge Plus program.

[4] Queensland Government. ClimateSmart 2050. Queensland climate change strategy 2007: a low carbon future. June 2007.

2.4 Santos Policy and Initiatives

Santos has a range of projects based on producing natural gas which play a pivotal role in helping Australia's economy move to a cleaner energy portfolio. Natural gas has approximately half the greenhouse intensity and only uses a minute fraction of the water that coal-fired electricity requires.

Santos has the following research programs and initiatives that are relevant to the greenhouse gas policy mix:

- Santos is a member of the Australian Business and Climate Change Group, which comprises nine major organisations that have come together to identify how Australia can accelerate the development and deployment of low emission technologies. The group is seeking to stimulate debate in Australia between government, industry and the community to determine appropriate policies and measures to trigger a transformation of the energy market towards low emission technologies, while leveraging national comparative advantage;
- Santos is currently developing the Moomba Carbon Storage (MCS) project which has the long-term objective of establishing a large-scale underground carbon storage hub at Moomba, which could eventually store up to 20 million tonnes of carbon dioxide per year and 1 billion tonnes over the life of the project. It would do so by injecting carbon dioxide into the depleted and/or depleting oil and gas reservoirs of the Cooper Basin, thereby providing a secure storage solution for major carbon emitters in Queensland, New South Wales and South Australia;
- Santos has also developed a company Climate Change Policy as follows:

  Our Climate Change Vision: "Santos will lower the carbon intensity of its products"

  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.

  To achieve these commitments we will:

  - *Continue to reduce the carbon intensity of Santos' products by focusing on energy efficiency, technology development and by embedding a carbon price in all activities*
  - *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 aspirational greenhouse gas emission reduction targets*
  - *Pursue no flaring or venting of associated gas, unless there are no feasible alternatives*
  - *Continue to publicly disclose Santos' greenhouse emissions profile and carefully examine forecast emissions*
  - *Understand, manage and monitor climate change risk and develop appropriate adaptation strategies for our business*
  - *Assist governments and engage with other stakeholders on the design of effective and equitable climate change regulations and policy*

  Santos will inform employees about its commitment to climate change and ensure climate change initiatives continue to be implemented. The Santos Board will review progress against this policy quarterly.

Section 2 Greenhouse Gas Policy Background

As reported in its 2007 Sustainability Report, Santos is currently on track to meet its previous GHG emissions intensity reduction target of 20 per cent reduction from 2002 levels by 2008. This has been achieved by continuing participation in a number of projects including the Yellowbank Gas Flare project in partnership with Origin Energy, the Moomba Gas Recovery project, and numerous energy efficiency improvements throughout Santos operations.

3.1 Accounting and Reporting Principles

The greenhouse gas inventory for GLNG is based on the accounting and reporting principles detailed within the Greenhouse Gas Protocol (the Protocol).[5] The Protocol was first established in 1998 to develop internationally accepted accounting and reporting standards for greenhouse gas emissions from companies. The main principles are as follows:

- Relevance: The inventory must contain the information that both internal and external users need for their decision making;
- Completeness: All relevant emissions sources within the inventory boundary need to be accounted for so that a comprehensive and meaningful inventory is compiled;
- Consistency: The consistent application of accounting approaches, inventory boundary and calculation methodologies is essential to producing comparable GHG emissions over time;
- Transparency: Address all relevant issues in a factual and coherent manner, based on a clear audit trail. Disclose any relevant assumptions and make appropriate references to the accounting and calculation methodologies and data sources used; and
- Accuracy: Data should be sufficiently precise to enable intended users to make decisions with reasonable assurance that the reported information is credible.

The greenhouse gas emission inventory for the Project is based on the methodology detailed in the Protocol, and the relevant emission factors in the National Greenhouse Accounts (NGA) Factors, the *Methodology for the Estimation of Greenhouse Gas Emissions and Sinks 2005 – Energy (Fugitive Emissions)* and the relevant Intergovernmental Panel on Climate Change (IPCC) Good Practice Guidance.

A spreadsheet model has been specifically developed for the Project and uses the data sources and emission factors detailed below in order to calculate project emissions for every year of construction and operation according to the Protocol. This model uses the methodology detailed in the NGA Factors.

The main greenhouse gases emitted during the GLNG activities will be carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). To report these emissions, they are converted to carbon dioxide equivalents (CO_2-e) as specified under the Kyoto Protocol. The GWP is a measure of the amount of infrared radiation captured by a gas in comparison to an equivalent mass of CO_2, over a fixed lifetime. GHG inventories in this report are expressed as tonnes of CO_2-e released following this convention. The GWP adopted for each GHG emitted are as follows: carbon dioxide GWP of 1, methane GWP of 21; and nitrous oxide GWP of 210, as detailed in the NGA Factors.

Materiality

Materiality is a concept used in accounting and auditing to minimise the time spent verifying data that does not impact a company's accounts or inventory in a material way. The exact materiality threshold that is used in GHG emissions accounting and auditing is subjective and dependant on the context of the site and the features

[5] World Business Council for Sustainable Development & World Resources Institute (2004), The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard.

of the inventory. Depending on the context, the materiality threshold can be expressed as a percentage of a company's total inventory, a specific amount of GHG emissions, or a combination of both.

Emissions are assumed to be immaterial if they are likely to account for less than 5% of the overall emissions profile. This materiality threshold has been chosen as a standard measure in GHG inventories.

3.2 Inventory Organisational Boundaries

The organisational boundary of the project is defined as the Santos Ltd GLNG project and is delineated by the physical study area on Curtis Island, the gas transmission pipeline easement, and the CSG field activities and includes all the greenhouse gas emissions controlled or produced by the project.

Auxiliary infrastructure located outside the project area, such as water management systems, and wastewater treatment facilities are not included within the project organisational boundary. Third-party shipping and end use of the LNG product are also outside the project organisational boundary, though included as part of the discussion of Scope 3 emissions.

3.3 Inventory Operational Boundaries

The Coordinator-General's Terms of Reference Requirements specify that direct emissions (Scope 1 and Scope 2) from the project should be assessed.

The Protocol further defines direct and indirect emissions through the concept of emission "scopes".

3.3.1 Scope 1: Direct greenhouse gas emissions

Direct greenhouse gas emissions occur from sources that are owned or controlled by a company. For example:

- Emissions from combustion in owned or controlled boilers, furnaces, vehicles, etc.;
- Fugitive emissions of greenhouse gases; and
- Emissions from on-site power generators.

3.3.2 Scope 2: Electricity indirect greenhouse gas emissions

This accounts for greenhouse gas emissions from the generation of purchased electricity consumed by the company. Purchased electricity is defined as electricity that is purchased or otherwise brought into the organisational boundary of the company. Scope 2 emissions physically occur at the facility where electricity is generated but they are allocated to the organisation that owns or controls the facility or equipment where the electricity is consumed. Scope 2 emissions also capture the importing of energy (such as chilled water or steam) into a site.

3.3.3 Scope 3: Other indirect greenhouse gas emissions

This is an optional reporting class that accounts for all other indirect greenhouse gas emissions resulting from a company's activities, but occurring from sources not owned or controlled by the company. Examples include extraction and production of purchased materials; transportation of purchased fuels; and use of sold products and services.

Scope 1 and Scope 2 Emissions

The greenhouse gas Scope 1 emission sources from the project included in this inventory are:

- Fuel consumption in process equipment at the LNG facility and CSG fields;
- On-site power generation via gas turbine power station at the LNG facility;
- Diesel fuel consumption in vehicles for all stages of the project;
- Flaring and venting of gas at the LNG facility and CSG fields;
- Fugitive emissions of gas from process equipment and drilling activities at the CSG fields; and
- Land clearing for all stages of the project.

Scope 2 emissions have only been included for worker accommodations during construction of the pipeline as there will be no other significant purchases of electricity for any portion of the project. Santos will generate electricity at the LNG facility using gas-fired turbines. Field operations will primarily be gas or diesel-powered.

The GHG emissions have been estimated for operation of the LNG facility on an annual basis and for a total lifespan of 25 years. GHG emissions have been estimated for drilling activities on both an average annual basis and a total lifetime basis assuming drilling activities continue for 25 years in Roma, 12 years in Arcadia Valley and 16 years in Fairview over a total project lifespan of 25 years. All CSG field compressor stations have been assumed to operate for the entire 25 year period as a conservative case.

Operation emissions from the pipeline were assumed to be immaterial. The gas transmission pipeline is to be underground and built entirely of welded pipe without any release points, such as pumps or compressor stations, along the gas pipeline corridor. This being the case, GHG releases during routine operations are unlikely.

Carbon sequestration due to rehabilitation of cleared areas has not been included in the inventory.

4.1 Activity Data Sources

Activity data used to assess most Scope 1 emissions for both the 3 – 4 Mtpa and 10 Mtpa facility designs was taken from the pre-FEED studies for the OCP and C3MR designs, Santos document numbers 1603-BTH-2-1.3-0001-PDF and 1603-FWEL-2-3.3-0075-PDF respectively. Data for Scope 1 emissions from drilling and compressor stations was taken from a variety of sources, primarily operations spreadsheets maintained by Santos operations personnel and operational forecasts from Santos engineers.

4.2 Fuel Consumption in Process Equipment

4.2.1 LNG Facility

The primary process equipment at the LNG facility will be the compressors, which are powered by gas-fired turbines. The OCP design lists six GE LM2500+G4 turbines for the 3 Mtpa case and 18 LM2500+G4 turbines for the 10 Mtpa case. The OCP facility design also includes some process equipment such as heaters which consume a small portion of the product stream for process heat.

The C3MR 3 Mtpa design indicates two GE Frame 5 and two Frame 6 compressor turbines; and for the 10 Mtpa design, six Frame 5 and six Frame 6 compressor turbines are proposed. The C3MR design documentation does not describe any other process equipment consuming gas.

GHG emissions estimates were provided by the OCP and C3MR designs on both an hourly basis and an annual basis that included a predicted facility availability rate. This availability rate is the predicted number of hours the facility will be operating in the course of a year, with stoppages assumed to come from scheduled maintenance, inspections, and estimates of downtime due to equipment faults or other unscheduled shutdowns.

All other facility process equipment is powered by electricity produced by the facility's on-site power generation station.

4.2.2 CSG Fields

Field process equipment consists of the compressor stations along the pipelines connecting the wells to the main gas transmission pipeline. These compressors are powered by various engines running on gas taken from the product stream.

Drilling rigs used in well construction were also included in this category for ease of reporting. An average rate of diesel fuel consumption per well during drilling in each field region was provided by Santos based on operating experience.

4.3 Power Generation

4.3.1 LNG Facility

The LNG facility will be powered by turbines fuelled by a portion of the product gas stream. OCP indicates the use of five Solar Taurus turbines for the 3 Mtpa facility and 11 Solar Taurus turbines for the 10 Mtpa facility. The C3MR design plans include three GE Frame 5 turbines for the 3 Mtpa facility and nine GE Frame 5 turbines for the 10 Mtpa facility. As for process equipment, GHG emissions estimates were provided for the OCP and C3MR designs on both an hourly basis and an annual basis that included a predicted facility availability rate.

Worker accommodations on Curtis Island used during construction of Train 1 of the LNG facility will be supplied with electrical power by diesel generators with a total capacity of 2 MW. Power requirements for accommodation during construction of Trains 2 and 3 are assumed to be half of that amount (1 MW) based on workforce numbers.

4.3.2 CSG Fields

Power generation for the compressor stations will be provided by the compressor engines. These emissions have been captured under "Fuel Consumption in Process Equipment". Electrical power needs for the remainder of the field operations are assumed to be immaterial.

4.4 Fuel Consumption in Vehicles

4.4.1 LNG Facility

Diesel consumption by vehicles at the facility was considered immaterial as no large vehicles will be operating on-site on a regular basis and light vehicle traffic will be minimal. However, emissions produced by employee commute traffic and materials and equipment deliveries to the LNG facility have been calculated in order to enable comparison of the two options currently under consideration, specifically access to Curtis Island via a bridge (the base case) or barges and ferries (option). Vehicles included in the “bridge” option are medium and heavy trucks and passenger vehicles. All vehicle trips are assumed to originate in and return to Gladstone. Vehicles included in the “no bridge” option are barges and passenger ferries making return trips to Curtis Island from Auckland Point.

An indicative estimate of emissions from construction equipment has been provided by the LNG Facility design team. In addition, emissions from ferries and barges used to transport workers, materials and equipment to the construction site have been calculated as above for the operational period. As no bridge will be available during construction of Train 1, only marine vessel emissions have been considered. On-site emissions during construction of Trains 2 and 3 are assumed to be 50% of Train 1 each, based on workforce and traffic reports. Emissions from truck, bus and passenger vehicle movements during construction of Trains 2 and 3 have been calculated based on return trips from Gladstone via the bridge.

4.4.2 CSG Fields

Diesel fuel is consumed by vehicles during well drilling, exploration and operations. Estimates of diesel fuel consumption per well drilled were provided by Santos field personnel. These estimates were combined with the schedule of drilling provided to calculate both annual and total GHG emissions from drilling equipment. No information was available on fuel consumption during exploration or operation of the CSG fields.

4.4.3 Gas Transmission Pipeline

Two options are currently under consideration for construction of the pipeline as well, the base case being delivery of pipe joints by truck with an option of delivering pipe joins to central laydown points by rail with final delivery by truck. Construction in both cases is assumed to continue for 21 months, of which 6 months will be ramp-up and ramp-down periods with activity rates 50% of that occurring during the main construction period (15 months). Accommodation and bus emissions are included for 1000 workers for 15 months and 500 workers for 6 months. Construction equipment is also included assuming 100 heavy vehicles operating 10 hours a day for 15 months and 50 heavy vehicles 10 hours a day for 6 months. Heavy trucks delivering pipe joints are assumed to travel on average half the length of the pipeline in the base case. For the rail option, laydown points would be provided at the halfway mark of the pipeline and at two other locations equally spaced between the pipeline terminus at Gladstone and the halfway mark. Pipe joints would be unloaded from the trains at these points and delivered to the construction location by truck.

4.5 Flaring and Venting

4.5.1 LNG Facility

Flaring rates have been provided for all facility designs based on flaring required for scheduled shutdowns for maintenance and inspection. Flaring for emergency situations has not been included as this is assumed to be a rare or non-occurring situation and unlikely to represent a significant contributor to total greenhouse emissions.

CO_2 will also be present in the gas stream in small quantities, approximately 0.3% of the incoming gas stream. This CO_2 is considered a contaminant in the product LNG stream and will be removed at the facility and vented directly to the atmosphere.

4.5.2 CSG Fields

Gas will be regularly flared during drilling activities and well development, before the well is connected to the in-field gathering pipeline, to reduce the GHG impacts from fugitive gas releases. Flaring and venting will be minimised to the extent practical. Flaring will convert the greenhouse gas content of the released gas from methane (CH_4) to carbon dioxide (CO_2), thus reducing its greenhouse impact by changing its GWP. Santos has provided an average flaring rate for well development activities based on its experience.

Of the 12 compressor stations 10 include flares which are utilised in the case of emergency shutdown or maintenance. The remaining two use cold vents, which vent the gas stream directly to the atmosphere without flaring. The cold vents are also only used in case of emergency shutdown or maintenance.

4.6 Fugitive Emissions

4.6.1 LNG Facility

Fugitive emissions include all those quantities of gas that are lost directly to the atmosphere through uncontrolled sources such as leaks or during well drilling. Leaks typically occur at pipe joints such as flanges, caps, plugs, valves, pump seals, and connection points. Estimates of fugitive emission rates from the facility designs have been provided for the OCP and are assumed to be the same for the C3MR design.

4.6.2 CSG Fields

Some gas will be lost to the atmosphere during well development and operation, as well as from the in-field gathering pipeline and associated equipment. Venting of gas may take place during well drilling, though flaring will be preferred if at all possible due to its reduced GHG impact. A conservative estimate of 0.1% gas lost has been assumed, based on industry accepted practices. Field totals are calculated using the average number of wells constructed per year in each region, which is estimated to be 53 in Fairview, 56 in Roma and 33 in Arcadia Valley.

4.7 Land Clearing

Trees and other vegetation metabolise carbon and store a portion of it as biomass as they grow. When this vegetation is cleared the stored carbon is typically lost to the atmosphere as CO_2 along with small amounts of CO and CH_4. Estimates of the area of cleared land resulting from the Project have been provided by the C3MR design team and Santos. This information has been combined with vegetation studies of the Project site performed by URS and used as input for a carbon loss model. The model used was FullCAM, from the Department of Climate Change's National Carbon Accounting Toolbox[6].

Land clearing emissions from the LNG facility site and pipeline ROW are short-term, occurring only as land is cleared during construction

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[6] Australian Department of Climate Change. National Carbon Accounting Toolbox. http://www.climatechange.gov.au/ncas/ncat/index.html accessed 17 Nov 2008.

4.8 Emission Factors

Direct measurement of greenhouse gases (GHG) at the emission source can give the most accurate and precise assessment of GHG emissions but this is not feasible for this project as it is still in the design phase. However, detailed engineering calculations of emission rates have been provided for most of the major sources in the facility and CSG field operations as some portions of the CSG field are already in operation and emissions can be measured. For the remaining sources, emission factors have been used in accordance with the GHG Protocol methodology. Emission factors are a factor expressed as the amount of GHG emissions per unit of activity, which can be used to determine inventories for a site and remove the need for site specific testing of emissions.

Emission factors can be obtained from various sources, for example, the Department of Climate Change, from site-specific information or from operational details obtained from similar emission sources. Emission factors used to calculate GHG emissions (as CO_2-e) from the combustion of diesel and natural gas and electricity consumption have been sourced from the Department of Climate Change NGA Factors Workbook, 2008 as indicated in Table 4-1 below.

Table 4-1 Emission factors used in the Formation of the Project GHG Inventory

Emission Source	Emission Factor	Units	Source
Scope 1 Emissions			
Combustion emission factor diesel	2.7	t CO_2-e/kL	NGA Factors. Table 3, (fuel combustion for transport) Column C
Consumption of Natural Gas (or CSG) - Queensland	51.3	t CO_2-e/GJ	NGA Factors. Table 2 (consumption of natural gas)
Scope 2 Emissions			
Electricity Consumption - Queensland	0.91	kg CO_2-e/kWh	NGA Factors. Table 5 (consumption of purchased electricity) Column A

Emission factors for the carbon loss associated with land clearing activities specific to locations in the Project site were obtained using the FullCAM model in combination with data on vegetation types and amounts in those locations provided by URS biologists. Emissions factors for each area differ due to the amount of previously cleared land and the specific types of vegetation present in that area. Specific emission factors are as follows:

- For the LNG facility a factor of 54.88 tonnes carbon per hectare (t C/ha) (201 tonnes CO_2-e/ha) was used;
- 42.25 t C/ha (155 t CO_2-e/ha) for the Roma area;
- 43.41 t C/ha (159 t CO_2-e/ha) for Fairview;
- 26.09 t C/ha (96 t CO_2-e/ha) for Arcadia Valley; and
- A value of 36.7 t C/ha (135 t CO_2-e/ha) was calculated for the gas transmission pipeline by modelling several points along the pipeline with representative types and amounts of vegetation and averaging the results.

Estimates of release rates for elemental carbon (C) were converted to CO_2-e by using the molecular weights of CO_2 and C (44 and 12, respectively).

Emissions from land clearing have been calculated assuming an extreme worst case highly unlikely to occur during actual construction and operation. For the CSG fields, it was assumed that Santos will clear all vegetation (assumed to be mature Eucalypt woodland) in a 4 ha area at all drilling locations with no regard to the type or amount of vegetation present. In practice, Santos will avoid land clearing to the greatest extent possible both as a matter of economics and of explicit policy. Santos will actively seek drilling locations that have already been cleared and has procedures in place to minimize land clearing to the greatest extent possible at those locations that do have some existing vegetation. Cleared areas will generally be much smaller than 4 ha, which is an absolute maximum including construction laydown areas, access road construction and several other factors that will not be required at all locations. Additionally, once a well is operational a significant amount of revegetation will occur which has not been taken into account. Similar factors apply to the pipeline and facility land clearing calculations.

4.9 Summary of Scope 1 and Scope 2 Emissions

4.9.1 LNG Facility

Scope 1 emissions are provided for the 3 – 4 Mtpa and 10 Mtpa scenarios for both OCP and C3MR facility designs in Table 4-3. Emission rates for facility operations are taken from data supplied for the OCP and C3MR designs. For the purpose of converting hourly emission rates to annual emissions, all facility configurations are assumed to be operational 8,313 hours per year, or approximately 95% availability, per advice from Santos. As flaring and venting data for C3MR facility designs are incomplete, emissions for these activities have been assumed to be the same as for the respective OCP designs. Emissions for the C3MR 10 Mtpa facility were assumed to be three times the emissions from the C3MR 3 Mtpa facility as rates specific to the 10 Mtpa configuration were not available. 150 ha of land was assumed to be cleared during LNG facility construction, as stated in the C3MR design documentation.

Scope 2 emissions from the facility were assumed to be zero as no connection with the electrical power grid is planned for the facility.

4.9.2 CSG Fields

Santos, as a member of the Greenhouse Challenge Plus program reports its greenhouse gas emissions. These are calculated using estimates including values for diesel fuel consumption per well drilled, amount of gas flared, amount of land cleared per well during well construction, and the types and number of engines in field compressor stations. Field GHG emission rates are average values as field operations will vary from year to year, with drilling starting at different times in Roma, Fairview and Arcadia Valley as well as continuing for different lengths of time in each region. Emission rates were therefore calculated on a per well basis then multiplied by the average number of wells drilled per year in each region to provide an overall average.

CSG field emissions have been assumed to be the same for all facility designs, with no information currently available regarding fugitive emissions in the field. Calculations of GHG emission rates per well during drilling from diesel fuel consumption are shown in Table 4-2 below.

Table 4-2 Average GHG Emissions per Well from Fuel Consumption during Construction

Location	Activity	Diesel Consumed (L)	Emission Factor (t CO_2-e/kL)	Emissions (t CO_2-e per well)
Fairview	Vehicles	9,250	2.7	25
	Process Equipment	22,000	2.7	59
Roma	Vehicles	9,250	2.7	25
	Process Equipment	16,200	2.7	44
Arcadia Valley	Vehicles	9,250	2.7	25
	Process Equipment	16,200	2.7	44

Emissions from flaring were calculated using a base assumption provided by Santos of 1 MMscf of gas flared per well during construction. This figure was converted to GJ of gas flared and multiplied by the emission factor for gas consumption in Table 4-1 to give an emission rate per well.

Santos estimates an average of 4 ha of land is cleared per well, including access roads and pipeline easements. This clearing activity would take place as the wells are progressively developed over the early years of the Project, but in order to provide a comparable annual figure the total carbon loss has been spread over the entire Project lifetime to give an annual rate.

Scope 1 emissions from compressor stations were calculated in a separate study provided by Santos and are based on the total amount of gas compressed, the fuel gas usage per unit of gas compressed and the precise composition of the fuel gas.

Electrical power consumption in the CSG fields will be minimal and primarily occurring at the compressor stations, where it would be generated by the compressor station engines rather than taken from the grid. Emissions from the compressor engines have been captured as Scope 1 as described above. Consequently Scope 2 emissions in the field have been assumed to be immaterial.

4.9.3 Pipeline

Operation emissions from the pipeline were assumed to be immaterial as discussed in Section A.4. Carbon loss due to land clearing was calculated assuming a 435 km pipeline with a 30 m wide cleared easement and included in the construction emissions estimates.

4.9.4 Annual Operational Greenhouse Gas Emissions

A summary of greenhouse gas emissions from the LNG facility and field, calculated on an annual basis, are presented in Table 4-3. Drilling and other construction activity for the wells is also included as it is continuous over the majority of the life of the project.

Each train in the LNG facility will require 5,300 PJ of gas delivered from the gas fields. For the 3 Mtpa case this has been assumed to require 2,650 wells (see Section 3.6 for further details) in the RFD area. This assumption is highly conservative and intended to encompass the significant uncertainties regarding actual gas production rates present in the field development program. While it is likely that far less than 2,650 wells will ultimately be required for the 3 Mtpa case, the actual number required cannot be known until the field development program is substantially progressed. Should development in the RFD area provide more than 5,300 PJ, the excess could be used for supply to trains 2 and 3.

Well development figures for the 10 Mtpa case are highly uncertain as they depend not only on production in the RFD area but also on future CSG field development areas about which little is known. Consequently, GHG emissions from the field for the 10 Mtpa case will be reported as a range of values. This range is based on an assumption of between 2,650 and 6,625 total wells being required to supply all three trains, with 6,625 wells being used as an extremely conservative figure intended to represent the worst case development that is highly unlikely to occur. The figure of 6,625 wells has been assumed only for the purposes of making an assessment of GHG emissions from the 10 Mtpa case and does not represent an estimate of the actual number of wells planned for the GLNG Project. As for the 3 Mtpa case, the final number of wells required for the 10 Mtpa case cannot be known until the field development program is complete.

The GHG inventory presented below assumes that the gas required for the 10 Mtpa case will be supplied from Santos-operated gas wells, hence GHG emissions are reported as Scope 1. Future gas needs may also be met through purchase of gas from other suppliers, which will result in a decrease in Scope 1 emissions but an increase in Scope 3 GHG emissions from the purchased gas. Since the extent of any gas purchase is currently unknown, all gas well development has been assessed as Scope 1 emissions.

Table 4-3 Summary of Average Annual Greenhouse Gas Emissions for Operation (tonnes CO_2-e per year)

Project Section	Activity Type	OCP Scope 1		C3MR Scope 1	
		3 Mtpa	10 Mtpa	3 Mtpa	10 Mtpa
Facility	Fuel Consumption in Process Equipment.	825,764	2,471,724	690,830	2,072,491
	Power Generation.	102,735	319,196	325,005	975,015
	Fugitive Emissions.	653	1,959	653	1,959
	Flaring and Venting.	233,570	679,642	233,570	679,642
CSG fields	Fuel Consumption in Process Equipment.	1,401,047	1,401,047 – 3,502,618	1,401,047	1,401,047 – 3,502,618
	Fuel Consumption in Vehicles.	3,549	3,549 – 8,873	3,549	3,549 – 8,873
	Fugitive Emissions.	1,486	1,486 – 3,715	1,486	1,486 – 3,715
	Flaring and Venting.	23,994	23,994 – 59,985	23,994	23,994 – 59,985
	Land Clearing.	57,902	57,902-144,755	57,902	57,902-144,755
Total		**2,650,699**	**4,960,500 – 7,192,467**	**2,738,037**	**5,217,085 – 7,449,052**

Emissions were also calculated on the basis of individual totals for CO_2, CH_4 and N_2O where possible. However, for most sources, emission factors are only available in terms of carbon dioxide equivalents and thus emissions of individual gases can not be provided. Only emissions from the OCP facility design were provided as specific values for CO_2, CH_4 and N_2O, as presented in Table 4-4 below.

Table 4-4 Average Annual Emission Rates for Individual Greenhouse Gases from the LNG Facility (tonnes CO_2-e /year)

Activity Type	OCP Facility, Scope 1					
	3 Mtpa			10 Mtpa		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
Fuel Consumption in Process Equipment.	821,835	165	1.50	2,465,500	230	4.49
Power Generation.	102,065	29	0.19	317,599	68	0.58
Fugitive Emissions.		31			1,959	
Flaring and Venting.	51,045	60	0.10	139,459	164	0.26

4.9.5 Construction Greenhouse Gas Emissions

A summary of the total greenhouse gas emissions resulting from construction activities for the LNG facility and pipeline are presented in Table 4-5 and Table 4-6, respectively, below. Field construction activities are not included as they will continue over most of the life of the project and are thus better presented as annual emissions in Table 4-3. LNG facility construction emissions are reported for both the base case, which includes construction of a bridge to Curtis Island, and the option of continuing operation and potentially constructing Trains 2 and 3 without such a bridge. Construction of the pipeline also involves two options, with an option of replacing some truck movements for delivery of construction materials with rail movements. These options have not been reported here as emissions for both the delivery trucks and the rail are considered Scope 3 and therefore have no impact on Scope 1 or Scope 2 emissions.

Table 4-5 Total Scope 1 Greenhouse Gas Emissions from Construction of the LNG Facility (tonnes CO_2-e)

	Emissions Source	3 Mtpa Scope 1	10 Mtpa Scope 1
Bridge (Base Case)	Facility Construction Equipment	38,000	76,000
	Accommodation	13,738	27,476
	Land Clearing	30,184	30,184
	Passenger Ferry	11,621	23,242
	Barge Transport, Facility Materials	16,140	32,280
	Bridge Construction Equipment	8,133	8,133
	Transport, Bridge Material	8,076	8,076
	Subtotal	125,892	205,391
Barge Option	Facility Construction Equipment	38,000	76,000
	Accommodation	13,738	27,476
	Land Clearing	30,184	30,184
	Passenger Ferry	11,621	11,621
	Barge Transport, Facility Materials	16,140	16,140
	Subtotal	**109,683**	**161,421**

Table 4-6 Total Scope 1 and Scope 2 Greenhouse Gas Emissions from Construction of the Pipeline (tonnes CO_2-e)

	Scope 1 Emissions	Scope 2 Emissions
Construction Equipment	2,962	0
Land Clearing	171,588	0
Accommodation	0	4,095
Total	**174,550**	**4,095**

4.9.6 Life of Project Greenhouse Gas Emissions

Greenhouse emissions were also calculated as a total over a 25 year period in order to capture the project's full impact and eliminate the averaging used to produce the annual emission rates. Values for two possible development scenarios are presented in Table 4-7, including the base case of building an access bridge to Curtis Island and the option of not building the bridge. Development of the facility will be staged, with the initial 3 – 4 Mtpa configuration operational by 2014 and the final 10 Mtpa configuration operational as early as 2022. The figures given here are assuming the final facility capacity of either 3 - 4 Mtpa or 10 Mtpa.

Scope 2 emissions are not included as they are immaterial in the context of total emissions. Field emissions are assumed to be identical for all cases, and flaring and venting in the facilities is based on rates provided for the OCP design.

Table 4-7 Total Greenhouse Gas Emissions over Project Lifetime (tonnes CO_2-e)

	OCP Scope 1		C3MR Scope 1	
	3 Mtpa	10 Mtpa	3 Mtpa	10 Mtpa
Base Case – Bridge	66,449,911	110,367,394 - 165,989,546	68,633,340	115,777,395 – 211,399,547
No Bridge Option	66,433,702	110,351,185 - 165,973,337	68,617,131	115,761,186 – 211,383,338

4.9.7 Performance Measures

The GHG performance of the Project is measured as emissions intensity, as defined by the Greenhouse Gas Protocol[7]. Emissions intensity for the GLNG Project is defined as tonnes CO_2-e/ tonnes product LNG.

Table 4-8 shows the emissions intensity by production options on the basis of operational Scope 1 emissions from the Project. The average annual value refers to greenhouse emission rates in Table 4-3 and does not include construction emissions. Actual product LNG quantities are assumed to be the nominal values of 3 Mtpa and 10 Mtpa.

Table 4-8 Emissions Intensity (tonnes CO_2-e per tonne product LNG)

	OCP		C3MR	
	3 Mtpa	10 Mtpa	3 Mtpa	10 Mtpa
Average Annual Emissions Intensity	0.89	0.50 – 0.72	0.91	0.52 – 0.75

[7] World Business Council for Sustainable Development & World Resources Institute (2004), The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard

Section 5 Scope 3 Emissions

Scope 3 emissions are defined in the Greenhouse Gas Protocol as an optional reporting class that accounts for GHG emissions resulting from a company's activities, but occurring from sources not owned or controlled by the company. Examples include extraction and production of purchased materials, transportation of purchased fuels, and employee business travel and commuting.

Scope 3 emissions are not routinely reported by companies because:

- Emissions are difficult to estimate accurately;
- The company does not have effective control of the emissions sources; and
- A company's Scope 3 emissions will be reported elsewhere by a second company as their Scope 1 emissions. As an example, emissions from gas combustion in a power station for electricity generation will be reported by the power station as one of its Scope 1 emissions.

For this project, Scope 3 emissions from construction, transport to and operation of the LNG facility and end use have been investigated and indicative estimates arrived at using numerous assumptions. Scope 3 construction and operation emissions have been estimated for four scenarios, encompassing options for not constructing a bridge to Curtis Island and using rail to deliver materials to laydown points along the pipeline ROW. These emissions have been calculated as total emissions based on a 25 year project lifespan and are shown below in Table 5-1.

Table 5-1 Total Scope 3 Emissions from Construction and Transport (tonnes CO_2-e)

Scenario	3 Mtpa	10 Mtpa
Bridge, no rail	24,612	37,390
Bridge, rail	23,047	35,825
No bridge, no rail	19,415	19,415
No bridge, rail	17,850	17,850

The overwhelming majority of Scope 3 emissions from the project are due to the end use of the gas, most likely by retail consumers or for electricity generation. The most likely destinations for export of the LNG are in Asia, specifically Japan, China and Korea. No end-use agreements or contracts have been made, but an indicative estimate of Scope 3 emissions resulting from transport[8] of the GLNG product to Japan for use in a power plant has been made. The estimates provided in Table 5-2 assume a one-way distance of roughly 5,950 km from Gladstone to Japan and make use of emission factors published in the National Greenhouse Gas Inventory from Japan[9].

[8] Heede, Richard. *LNG Supply Chain Greenhouse Gas Emissions for the Cabrillo Deepwater Port: Natural Gas from Australia to California.* 17 May 2006, Colorado, USA

[9] Greenhouse Gas Inventory Office of Japan. *National Greenhouse Gas Inventory Report of Japan (2008).* Onogawa, Japan

Table 5-2 Scope 3 Emissions due to Transport and Combustion of GLNG Product (tonnes CO_2-e/year)

	3 Mtpa Case	10 Mtpa Case
Transport	312,182	936,545
Combustion for Power Generation	20,205,000	67,350,000

For the purpose of comparison, emissions from the combustion of coal and oil in Japan to produce the equivalent amount of power generated by the 3 Mtpa and 10 Mtpa cases for LNG were estimated, also using emission factors from the Japanese National Greenhouse Gas Inventory and power plant thermal efficiencies found in a life cycle analysis of power generation in Japan[10]. The results are shown in Table 5-3.

Table 5-3 Comparative Scope 3 Combustion Emissions

	3 Mtpa Case (tonnes CO_2-e/year)	10 Mtpa Case (tonnes CO_2-e/year)
LNG	20,205,000	67,350,000
Oil	34,130,000	113,800,000
Coal	43,920,000	146,400,000

5.1.1 Relative Greenhouse Impact of LNG

Even though specific end use contracts do not yet exist for the GLNG product (LNG), it is expected to be shipped to Asia where it will most likely provide power either in a generator station or industrial setting. As a primary energy source, LNG has numerous benefits over competing fuels such as coal and oil. These benefits include lower emissions of nitrogen oxides, sulphur dioxide, particulate matter and greenhouse gas emissions. A recent life cycle analysis of power generation systems based on conditions in Japan[11] calculated the emission factors in Table 5-4.

Table 5-4 Life Cycle CO_2 Emission Factors

Source Type	Direct Emission Factor (g CO_2/kWh)	Indirect Emission Factor (g CO_2/kWh)	Total Emission Factor (g CO_2/kWh)
Coal-fired	887	88	975
Oil-fired	704	38	742
LNG-fired	478	130	608
LNG-Closed Cycle	407	111	518

[10] Hondo, Hiroki. *Life cycle GHG emission analysis of power generation systems: Japanese case*. 2005. Yokohama, Japan.

[11] Hondo, Hiroki. *Life cycle GHG emission analysis of power generation systems: Japanese case*. 2005. Yokohama, Japan.

Section 5 Scope 3 Emissions

Based on the total emission factors above, a closed-cycle power plant using LNG fuel produces 53% of the GHG emissions of an equivalent coal-fired plant and 70% of an oil-fired one in Japan, a likely destination for LNG from the GLNG project.

Similarly, it is possible to compare the Australian Department of Climate Change's (DCC) emission factor for coal combustion for electricity with natural gas combustion. The DCC provides emission factors for burning black coal for electricity which average 95.85 kg CO_2-e/GJ for the full fuel cycle. The average full fuel cycle emission factor for natural gas is 60.24 kg CO_2-e/GJ, or 63% of the coal emission factor[12].

It should be noted that the Japanese life cycle analysis incorporates power plant efficiencies in order to produce an emission factor based on electrical energy production (kWh) whereas the DCC factors are based on fuel energy content (GJ) and do not address any specific end use. Consequently the figures are not directly comparable, but both show the GHG emission characteristics of LNG relative to other fuels.

The general result is that while GLNG greenhouse emissions may represent a small gain in Australian emissions, the net effect of the project is likely to provide a net global savings in greenhouse emissions assuming the LNG displaces another more emissions-intensive fuel such as coal.

[12] Department of Climate Change (2008) National Greenhouse Accounts (NGA) Factors

6.1 Australian Emissions

The National Greenhouse Gas Inventory (Department of Climate Change, 2008) is the latest available national account of Australia's GHG emissions. The National Greenhouse Gas Inventory has been prepared in accordance with the Revised 1996 and 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The IPCC guidance defines six sectors for reporting greenhouse gas emissions:

1) Energy;
2) Industrial Processes;
3) Solvent and Other Product Use;
4) Agriculture;
5) Land Use, Land Use Change and Forestry (LULUCF); and
6) Waste.

Australia's net greenhouse gas emissions across all sectors totalled 576 Mt CO_2-e in 2006, with the energy sector being the largest emitter at 400.9 Mt CO_2-e. Emissions from LNG facilities are captured under the energy category of the IPCC methodology. Approximately 34.5 Mt of energy sector emissions were attributable to fugitive emissions, representing 6.0% of national emissions.

Table 6-1 shows average annual Scope 1 emissions from the Project as a percentage of Australian energy sector emissions and total Australian emissions taken from the National Greenhouse Gas Inventory 2006, the most recent published inventory at the time of writing (January 2009).

Table 6-1 Project GHG Emissions as a Percentage of Australian Emissions

	OCP		C3MR	
	3 Mtpa	10 Mtpa	3 Mtpa	10 Mtpa
Australian Energy Sector Emissions	0.66%	1.24 - 1.79%	0.68%	1.30% - 1.85%
Total Australian Emissions	0.46%	0.86 - 1.25%	0.48%	0.91 – 1.30%

6.2 Queensland Emissions

Table 6-2 shows average annual Scope 1 emissions as a percentage of Queensland energy sector emissions taken from the National Greenhouse Gas Inventory 2006.

Queensland total emissions were 170.9 Mt CO_2-e and energy sector emissions were 94.9 Mt CO_2-e according to the National Greenhouse Inventory 2006.

Table 6-2 Project GHG Emissions as a Percentage of Queensland Emissions

	OCP		C3MR	
	3 Mtpa	10 Mtpa	3 Mtpa	10 Mtpa
Queensland Energy Sector Emissions	2.80%	5.23 – 7.58%	2.89%	5.50 – 7.85%
Total Queensland Emissions	1.55%	2.91 – 4.21%	1.61%	3.06 – 4.36%

6.2.1 Impact of the Project on Queensland Emissions Targets

The Queensland government has proposed to reduce greenhouse gas emissions by 60% by 2050 based on 2000 levels in line with the national target.[13] This equates to a reduction of approximately 98 Mt CO_2-e.

At peak average annual greenhouse gas emissions, Scope 1 emissions from the Project will be 5.0 – 7.2 Mt CO_2-e. These Scope 1 emissions will be equal to 2.9% - 4.2% of the state inventory. Project emissions are likely to have a small impact on Queensland government emissions targets.

6.3 Comparison with World Emissions

According to the United Nations Framework Convention on Climate Change (UNFCCC), aggregate emissions from Annex I countries in 2005, including the contribution from land use, land use change and forestry (LULUCF) was 16,700 Mt CO_2-e.[14] Emissions from non-Annex I countries including LULUCF was 11,900 Mt CO_2-e in 1994[15], the most recent year for which data from non-Annex I countries is available.

Using these two figures, annual global GHG emissions can be estimated as 28,600 Mt CO_2-e. The project's maximum GHG emissions are 5.0 Mt to 7.2 Mt CO_2-e for the OCP design for a 10 Mtpa facility. This represents 0.017% to 0.025% of annual global GHG emissions.

6.4 Benchmarking Greenhouse Gas Emission Performance

Benchmarking facilitates the comparison of the GLNG greenhouse emissions intensity to other LNG developments around the world. Greenhouse emission intensity is a ratio of the volume of greenhouse gas emissions emitted to the atmosphere for each tonne of LNG produced from the facility.

Benchmark data is not widely published and where available, it is restricted to the emissions intensity of the LNG manufacturing alone. The data often does not represent the full suite of greenhouse gas emissions for a particular development as it does not include emissions from exploration or construction.

Greenhouse emissions data from LNG facilities is variable for a number of reasons, some of which include:

- The complexity of the facility (e.g. number of equipment, power generation requirements);

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[13] Queensland Government. ClimateSmart 2050. Queensland climate change strategy 2007: a low carbon future. June 2007

[14] UNFCCC, National Inventory Greenhouse Data for the period 2000-2005, United Nations, 2007

[15] UNFCC, Sixth compilation and synthesis of initial national communications from Parties not included in Annex I to the Convention, United Nations, 2005

- The degree to which greenhouse gas emissions from supporting infrastructure such as offshore facilities, pipelines, and transport of gas or LNG have been included in the estimates; and
- The CO_2 concentration of the incoming facility gas stream.

Greenhouse gas emission intensity is an industry recognized benchmark by which comparisons can be made between LNG facilities. For the purpose of this report, the greenhouse emissions intensity has been compared with published data from the following developments:

- Northwest Shelf Train 4 Project – Australia;
- Darwin LNG Project – Australia;
- Gorgon Development – Australia;
- Snohvit – Norway;
- Oman LNG – Oman;
- Nigeria LNG – Nigeria;
- RasGas – Qatar;
- Qatargas – Qatar; and
- Atlantic LNG – Trinidad.

Figure 6-1 shows the LNG greenhouse gas emissions intensity of the GLNG facility benchmarked against these other LNG facilities[16]. The LNG efficiency includes CO_2 removed from the feed gas and vented to atmosphere.

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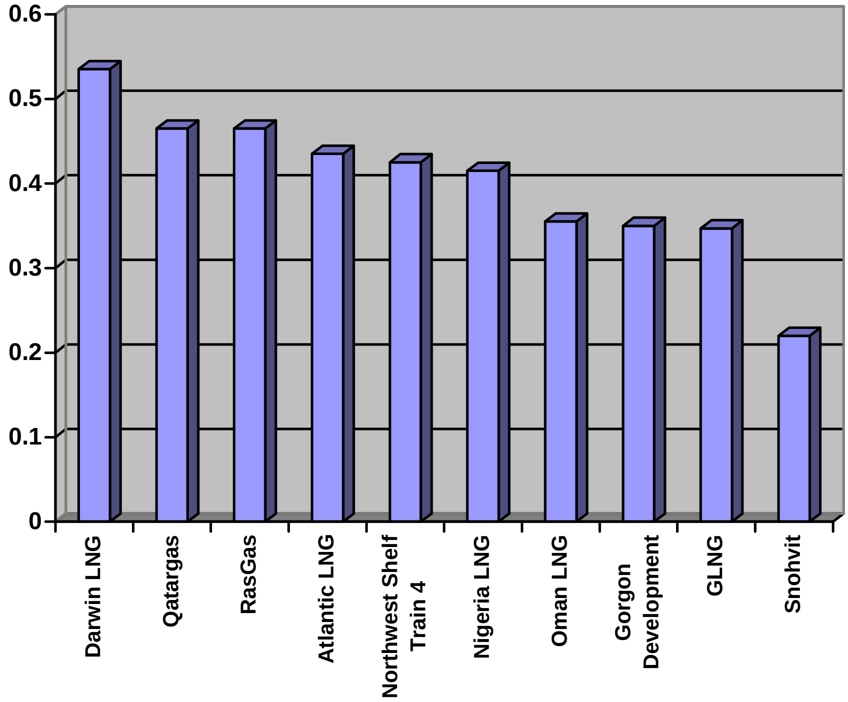
[16] All values except GLNG from the Draft Environmental Impact Statement/Environmental Review and Management Programme for the Gorgon Development, Chevron Australia Pty Ltd, September 2005

Figure 6-1 Benchmarked Greenhouse Gas Efficiency (tonnes CO_2-e / tonnes LNG)



The greenhouse gas emission intensity is estimated at 0.347 tonnes of CO_2-e per tonne of LNG produced. This efficiency is based on 10 Mtpa LNG production and includes only the emissions related to the production of LNG at the facility. As depicted in Figure 6-1, the GLNG emission intensity compares favourably against other worldwide LNG facilities.

7.1 Abatement Objectives, Measures and Performance Standards

The GLNG project is subject to international, national, state and corporate greenhouse gas policies with abatement objectives and performance standards as discussed in Section 2. Some of these policies are mandatory, such as the NGER and EEO, and others are voluntary, such as the Greenhouse Challenge Plus program and Santos' internal climate change policy. Santos will comply with all mandatory requirements as well as those voluntary commitments they have made, as detailed below.

7.1.1 International and National Objectives

By ratifying the Kyoto Protocol, Australia has pledged to reduce national greenhouse gas emissions to a level equivalent to 108% of national emissions in 1990 by 2008-2012. Australia is currently on track to meet its Kyoto commitments. However, the Australian government has also set its own goals to reduce emissions including a target of a 60% reduction of emission rates from the levels in 2000, to be met by 2050. In order to meet this target the government has passed the National Greenhouse and Energy Reporting Act (NGER) and the Energy Efficiency Opportunities (EEO) legislation, published a green paper proposing an emissions cap and trade system known as the Carbon Pollution Reduction Scheme (CPRS), and established the Greenhouse Challenge Plus program. The requirements of each of these have been presented in Section 2.

Santos will report Scope 1 and Scope 2 emissions and emission reduction measures, as well as energy consumption and production from GLNG, as part of the requirements of the NGER. Santos will report any abatement or mitigation of GHG as part of this report. As a reporting protocol, NGER does not require any abatement or mitigation itself; however the data reported under NGER will be used to provide input to the CPRS, which is described in Section 2.2.1. Santos expects that its operations, including the GLNG project, will be required to participate in the CPRS, though official regulations and guidelines have not been published at the time of writing in January 2009.

Santos is also registered with the EEO program, which requires thorough assessments of energy use patterns and opportunities for reduced energy consumption every 5 years. Santos registered in March 2007 and has submitted their EEO assessment and reporting schedule for this cycle. The GLNG project will be included in EEO assessments, and will therefore be carefully examined for opportunities to reduce energy consumption in accordance with EEO guidelines and requirements. The EEO provides an Assessment Framework that is based on the Australian/New Zealand Energy Audit Standard (3598:2000) and includes six key elements that all assessments must address, including:

- Leadership support for the assessment and the improvement of energy use;
- The involvement of a range of skilled and experienced people, and people with a direct and indirect influence on energy use during the assessment process;
- Information and data that is appropriately, comprehensively and accurately measured and analysed;
- A process to identify, investigate and evaluate energy efficiency opportunities with paybacks of four years or less;
- Business decision making and planning for opportunities that are to be implemented or investigated further; and

Section 7 Greenhouse Gas Abatement

- Communicating the outcomes of the assessment and the investment decisions made regarding the opportunities identified and proposed business response, to senior management, the board and personnel involved.

The results of EEO assessments are reported publicly and independently verified in conjunction with the Greenhouse Challenge Plus program.

Santos has been a participant in the voluntary Greenhouse Challenge program via the Australian Petroleum Production and Exploration Association (APPEA) since 1998, in the Greenhouse Challenge Plus program via APPEA since 2005 and as an individual member since 2007. As part of their Greenhouse Challenge Plus Cooperative Agreement, Santos has pledged to pursue a target of 20% reduction from 2002 levels in greenhouse emissions intensity (tonnes of greenhouse emissions per tonnes of product) by 2008. Santos has steadily reduced its greenhouse gas intensity and as of the latest available report is forecast to meet its target. As part of their Cooperative Agreement, Santos is also committed to achieving effective emission reduction targets, to the pursuit of energy efficiency strategies and to the identification and implementation of opportunities to use either less greenhouse emitting or renewable sources of energy. This will be achieved through identifying and promoting opportunities for natural gas to replace higher greenhouse gas emitting fuels, investing in energy and process research and development and examining forecast greenhouse gas emissions for new projects and acquisitions.

7.1.2 Queensland Objectives

Queensland state climate change policies are briefly described in Section 2.3. Many of these programs are similar to national programs and Santos will be in compliance through participation in the EEO and Greenhouse Challenge Plus programs and reporting energy use and greenhouse emissions in accordance with NGER requirements. Additionally, state objectives include increasing the share of Queensland electricity produced in gas-fired generation to 18% by 2020. As a major energy consumer that will generate nearly all of its own electricity from gas, GLNG will be assisting in reaching this goal.

7.1.3 Santos Objectives

Santos has produced a comprehensive company policy on greenhouse gas emissions as detailed in Section 2.4. This policy consolidates the actions and values needed for Santos to meet its climate change obligations, both required and voluntary. The results of Santos' actions as well as ongoing and future efforts are reported in Santos' annual Sustainability Report, which is publicly available. This policy includes requirements for new projects, which are being followed during design and planning of GLNG; specifically:

- Require all operations to develop energy efficiency and greenhouse management plans with site-specific targets;
- Identify and promote opportunities for natural gas to replace higher greenhouse gas emitting fuels; and
- Carefully examine the forecast greenhouse gas emissions and energy use in planned new projects and acquisitions, to ensure emission intensity and energy efficiency levels are consistent with the Company's goals.

Greenhouse Gas Abatement — Section 7

Careful analysis and planning of the GLNG equipment and processes made it possible to identify opportunities to reduce greenhouse emissions and improve energy efficiency. Some of the opportunities identified are as follows:

- Gas liquefaction processes that are highly efficient and minimise flaring of gas;
- High-efficiency compressor and power generation turbines at the LNG facility running on CSG, reducing energy consumption and reliance on coal-based electricity from the grid;
- Use of boil-off gas in the LNG facility as fuel rather than venting or flaring to improve overall plant energy efficiency;
- As part of the carbon dioxide removal process, careful selection of solvent to minimise the co-release of methane;
- Gas-fired in-field pipeline compressor station engines to replace the less efficient diesel fuel or electricity powered compressor engines; and
- Field operation protocols designed to minimise flaring, venting and other emissions sources.

Equipment to be installed at the LNG facility will be compared against best practice environmental performance as each stage undergoes the detailed FEED stage, to ensure that the most up-to-date technologies are used. In particular, this will focus on maximising the energy efficiency of operations and minimising the overall GHG emissions from the plant.

It is difficult to provide a quantitative assessment of the effectiveness of the measures mentioned above on the operation of the Project as a whole. However, some portions of the Project can be discussed in specific terms. One significant item is the choice of aeroderivative turbines for compression and power generation in the LNG facility. Traditionally, LNG plants use heavy duty “frame” type turbines for compression. However, recent experience with aeroderivative turbines has shown that they can be reliably used for LNG production. Aeroderivative turbines have much higher thermal efficiencies than frame turbines and consequently use less fuel to produce an equivalent amount of power. The GHG emissions from the aeroderivative turbines chosen by Santos are lower than those of a frame turbine. The aeroderivative turbines are also more flexible from an operational and maintenance viewpoint, providing greater facility availability due to shorter maintenance periods and better performance during startup. Increased facility availability leads to greater energy efficiency as shutdown and startup cycles are less efficient than steady-state operation.

Santos has also made improvements to its field compressor stations to reduce greenhouse emissions. Initial compressor station designs used cold vents, which vent CSG directly to the atmosphere, as an emergency relief system. Subsequent compressor stations use flares in place of the cold vents, which convert the CSG to CO_2 and thereby reduces the net emissions in terms of CO_2 equivalent emissions.

Additionally, as mentioned above, land clearing emissions as calculated represent a worst-case scenario and will be considerably less, given Santos’ commitment to minimizing actual land clearing to the greatest extent possible. Rough estimates indicate that actual land clearing could be less than 50% of the figure used in calculation of greenhouse emissions. Net emissions would also be reduced by revegetation in many areas that will be cleared only for temporary activities such as construction. This would be especially relevant to the field areas, where the majority of any land clearing would be for the initial well construction. Well areas would then be revegetated with the exception of access roads and a small area immediately surrounding the actual well, likely resulting in a restoration of over 50% of the cleared area.

Section 7 Greenhouse Gas Abatement

As discussed previously, Santos is also developing the Moomba Carbon Storage project. The Moomba project could store up to 20,000,000 tonnes of carbon dioxide a year and up to a total of 1 billion tonnes over its lifetime. This is would be sufficient to offset the entire CO_2 output of the GLNG project as well as several others, making the net greenhouse impact of GLNG effectively zero.

All actions undertaken and goals set to reduce greenhouse emissions at GLNG facilities will be assessed, reported and verified as required under the various agreements and programs of which Santos is a member as well as the company's Climate Change Policy. Emissions from GLNG operations will be reported and verified as well under NGER and Greenhouse Challenge Plus requirements and it is expected that these emissions will be fully offset under the proposed CPRS, though requirements of the CPRS or other offset programs have not yet been finalised.