Greenhouse gases 16

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16 Greenhouse gases

16.1 Introduction

This section describes the greenhouse gas (GHG) emissions associated with the GFD Project. The potential impacts arising from the GFD Project activities on GHG emissions are described, and mitigation measures identified. Localised impacts to air quality from the GFD Project are discussed in Section 15: Air quality.

This section has been prepared in accordance with section 4.8 of the *Terms of reference for an environmental impact statement* issued March 2013. The index to locate where each ToR requirement is met within this EIS is included in Appendix B: Terms of reference cross-reference.

The GLNG Project EIS (2009 EIS) and the 2010 supplementary EIS included GHG emissions forecasts for a range of production scenarios from three to ten million tonnes (Mt) of LNG per annum. GHG emissions from the GLNG Project were calculated in the 2009 EIS and 2010 supplementary EIS based on the volume of gas required to supply the LNG facility, rather than the number of wells required (which may vary). Therefore, the GHG emissions associated with the operation of the additional production wells included in the GFD Project were already accounted for in the 2009 EIS and the 2010 supplementary EIS.

To respond to the ToR of the GFD Project EIS, this section presents both the incremental emissions attributable to the GFD Project, as well as the emissions associated with the operation of the GFD wells which were already accounted for in the 2009 EIS and 2010 supplementary EIS. Consequently, there is significant overlap between the emissions presented in this GFD Project EIS and the 2009 EIS and 2010 supplementary EIS and as such the total emissions reported in this GFD Project EIS should not be taken to be wholly additional to those emissions previously reported.

16.2 Regulatory context

This EIS has been prepared in accordance with relevant State and Commonwealth regulatory context described within Appendix C: Regulatory framework. The legislation and guidelines that apply to Australia's GHG emissions and potential impacts of the GFD Project are outlined in Table 16-1.

The introduction of recent legislation and policy means that the requirement in the ToR to have a specific module relating to greenhouse abatement is superseded by requirements to acquit against national obligations.

Table 16-1 Regulatory context of the GFD Project – greenhouse gas emissions

Legislation and guidelines	Relevance to the GFD Project
National Greenhouse and Energy Reporting Act 2007 (Cth) (NGER Act) NGER Act establishes a national framework for Australian corporations to report GHG emissions and energy production, consumption and other data according to prescribed methodologies.	Santos Limited, as the controlling corporation under the NGER Act in respect of the GFD Project, will be required to submit annual GHG emissions and energy production and consumption report under this Act. Santos Limited has submitted independently audited reports for the GLNG Project and other operations under the NGER scheme since the Act came into effect.

Legislation and guidelines	Relevance to the GFD Project
Clean Energy Act 2011 (Cth) The Act placed a price on carbon dioxide emissions with the intent of reducing Australia's greenhouse gas emissions.	Santos Limited, as the entity deemed under the Clean Energy Act to have operational control of the GFD Project, will be required to report its liability and submit one carbon permit for every tonne of carbon dioxide emitted. LNG projects will be eligible for a minimum effective rate of permit assistance of 50%. The GFD Project may also give rise to liability for emissions under the natural gas supplier provisions for any gas sold domestically to small end users.
Energy Efficiency Opportunities Act 2006 (Cth) This legislation requires large energy users to develop five-year energy efficiency assessment plans and report annually against progress.	Santos Limited, as the operator of the GFD Project under this Act, will be required to assess its energy use and report both publicly and to government on the results of the assessment and the business response.
Direct Action Plan (Cth) The Commonwealth Government's policy, the Direct Action Plan is designed to reduce Australia's emissions in 2020 by 5% (on 2000 levels).	The GFD Project will need to comply with the requirements of the Commonwealth Government's proposed Direct Action Plan once it is introduced. This draft policy proposes to establish emissions thresholds and introduce incentives and other mechanisms to encourage improved emissions performance.
The Greenhouse Gas Protocol (World Resources Institute, 2005) The GHG Protocol is the most widely use international accounting tool for quantifying and managing greenhouse gas emissions. The Protocol advocates defining a reporting boundary for an inventory, and then segmenting the greenhouse gas producing sources within that boundary according to their scope.	GHG emissions from the construction, operation, decommissioning and rehabilitation phases of the GFD Project have been provided according to this protocol.
National Greenhouse Accounts (NGA) Factors (Department of Climate Change and Energy Efficiency (DCCEE), 2013) and *the National Greenhouse and Energy Reporting (Measurement) Determination 2008* (DCCEE 2008) (NGER Determination) The NGA Factors is designed for use by companies and individuals to estimate greenhouse gas emissions. While drawing on the *National Greenhouse and Energy Reporting (Measurement) Determination 2008*, the methods used in the NGA Factors have a general application to the estimation of a broader range of greenhouse emissions inventories.	GHG emissions provided in this EIS were estimated in accordance with the GHG emission factors provided in these instruments.
The National Carbon Accounting Toolbox FullCAM (DCCEE, 2005) This accounting system integrates data on land cover change, land use and management, climate, plant productivity, and soil carbon over time to provide a dynamic account of the changing stock of carbon in Australia's land systems since 1970.	The guidance provided in this toolbox was used in estimating GHG emissions associated with land clearing.
Code of Practice for coal seam gas well head emissions, detection and reporting (Department of Employment, Economic Development and Innovation, 2011) The code standardises the detection, remediation and reporting of gas emissions from coal seam gas well facilities, and places particular emphasis on community safety.	This code of practice adopts a standard process for monitoring, identifying and managing gas leaks from gas well facilities in Queensland. Implementation of the code ensures that emissions associated with gas leaks are identified, responded to and classified in a consistent manner, and that wells are monitored effectively by the operators. This code of practice is a mandatory safety requirement that applies to all coal seam gas operators in Queensland.

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This EIS seeks to obtain primary approvals for the project including the Queensland Government Coordinator-Generals Report and Commonwealth Government *Environment Protection and Biodiversity Conservation Act 1999* (Cth) approval.

Application for or amendments to existing environmental authorities will occur subsequent to this EIS process. Other subsequent approvals required after the EIS process has been completed, corresponding triggers and legislative frameworks applicable to the GFD Project are identified in Section 2: Project approvals.

Approval of this EIS will trigger a number of subsequent approvals required for the GFD Project to proceed. Approvals will be required on tenure and off-tenure. Section 2: Project approvals summarises the key approvals necessary for the planning, construction, operations and decommissioning of the GFD Project. The triggers for each approval, the relevant administering authority and application details are provided. Consultation on the subsequent approvals will be ongoing with the administering authorities.

16.3 Assessment methodology

This assessment describes the GHG values and assesses the GFD Project's potential impacts on these values. Impacts were assessed using the compliance assessment methodology, in accordance with the principles outlined in the Greenhouse Gas Protocol (World Business Council for Sustainable Development and the World Resource Institute 2004) and the methodologies described under the NGER Act and NGER Determination.

16.3.1 Greenhouse gas emissions estimation methodology

16.3.1.1 Scope of greenhouse gas assessment

GHG emission management was addressed in the 2009 EIS and 2010 supplementary EIS. This assessment gave consideration to GHG emissions from the gas fields, pipelines, liquefaction processes on Curtis Island, shipping and product end-use associated with the GLNG Project. The 2009 EIS and 2010 supplementary EIS projected total annual GHG emissions of up to 7.2 million tonnes of carbon dioxide equivalent ($MtCO_2e$). This total was calculated based on the throughput of gas required to supply three trains capable of delivering up to 10 Mt per annum of LNG.

The construction and decommissioning of the additional production wells associated with the GFD Project will generate GHG emissions as a result of land clearing, fuel use for drilling and vehicles associated with construction, flaring from well completion and connection activities, and fuel use for decommissioning. Emissions from these sources are dependent on the number of wells constructed. Other emissions (i.e. emissions from operation of those wells) are driven by the total volume of gas being produced, and were assessed within the 2009 EIS and 2010 supplementary EIS.

The GHG assessment in this GFD Project EIS includes both the incremental emissions associated with the construction and decommissioning of the additional wells as well as the operations emissions that were already accounted for in the 2009 EIS and the 2010 supplementary EIS.

16.3.1.2 Sources of greenhouse gas emissions

Emissions from each activity assessed in the GFD Project EIS are categorised as either scope 1 or 2, as per NGER principles, as follows:

- Scope 1 GHG emissions are defined as emissions that occur directly from GFD Project infrastructure
- Scope 2 GHG emissions are from the external generation of purchased electricity.

The emissions sources are listed in Table 16-2 according to their scope and project phase.

Table 16-2 Emission sources

Project phase	Scope	Emission source
Construction	Scope 1	• Diesel fuel used in drilling rigs • Diesel fuel used in construction equipment • Diesel fuel for transportation of equipment, materials and personnel • Diesel fuel for generators in camps • Land clearing for well lease, water management and gas processing facilities, camps, access roads, gas and water gathering lines • Flaring during well completion activities.
Operations*	Scope 1	• Gas fuel used for self-generated electricity production to power gas compression, water management and camps • Gas fuel used for compression • Flaring during abnormal conditions at facilities • Fugitive emissions (other than flaring and venting).
	Scope 2	• Electricity purchased from grid for pumps, gas compression, water management and camps.
Decommissioning and rehabilitation	Scope 1	• Diesel fuel used for transporting personnel and equipment • Diesel fuel used for rehabilitating land.

* Note that operations emissions from the GFD Project gas field were included in the assessment in the 2009 EIS and 2010 supplementary EIS.

The GFD Project will self-generate electricity and source electricity from external grid connections. Energy sources, including gas-fired power options, will be investigated during the GFD Project's gas field development phase.

16.3.1.3 Greenhouse emissions estimation methodology

The GHG emission calculation methodology is consistent with the 2009 EIS and 2010 supplementary EIS and the principles and guidelines discussed in Table 16-1, including the principles of the NGER Act.

GHG emission factors are generally expressed in terms of the quantity of related activity data, either GHG per unit of energy consumed (kilogram of carbon dioxide equivalent per gigajoule) or per unit of mass (tonne of carbon dioxide equivalent per tonne for flaring and fugitive emissions). GHG emissions can be estimated by multiplying activity data of an emission source by the GHG emission factor.

16.3.1.4 Global warming potential

In accordance with the *Greenhouse Gas Protocol*, emissions are estimated and expressed in values of carbon dioxide equivalent (CO_2e). To be able to compare the warming effects of different greenhouse gases, scientists have calculated the global warming potential (GWP) of each gas. GWP measures how much a particular GHG contributes to global warming. The GWP compares the radiative forcing, or warming ability, of a particular gas to that of carbon dioxide, which is used as a reference.

At the United Nations Framework Convention on Climate Change meeting in 2011, it was agreed to adopt updated GWPs published in the Intergovernmental Panel on Climate Change's (IPCC)'s 2007 *Fourth Assessment Report* (AR4) from 2015 onwards. The Australian Government has announced it will delay the application of the updated GWPs in domestic legislation until the 2017/18 financial year.

The updated GWPs are:

- Carbon dioxide (CO_2) GWP of 1
- Methane (CH_4) GWP of 25
- Nitrous oxide (N_2O) GWP of 298.

For example, to express emissions of methane in terms of its carbon dioxide equivalent, the mass of methane emitted is multiplied by a GWP factor of 25.

For the purposes of this EIS, the updated GWPs have been used in assessing projected GHG emissions.

16.3.2 Greenhouse gas emission factors

Emission factors were sourced from the NGA (DCCEE 2013) and the NGER Determination (DCCEE 2008), and amended to reflect the AR4 GWPs, as shown in Table 16-3.

Table 16-3 Default greenhouse gas emission factors

Emissions factor	Source	CO_2	CH_4	N_2O	CO_2e	Energy content
Coal seam methane that is captured for combustion kg CO_2e/GJ	NGER Determination	51.1	0.2	0.03	-	37.7 x 10^{-3} GJ/m^3
	GWP amendment	51.1	0.238	0.0288	-	37.7 x 10-3 GJ/m^3
Gas flared from natural gas production and processing tCO_2e/t	NGER Determination	2.7	0.1	0.03	-	37.7 x 10^{-3} GJ/m^3
	GWP amendment	2.7	0.119	0.0288	-	37.7 x 10^{-3} GJ/m^3
Fugitive emissions (other than vented or flared) tCO_2e/t	NGER Determination	-	0.0012	-	-	37.7 x 10^{-3} GJ/m^3
	GWP amendment	-	0.0014	-	-	37.7 x 10^{-3} GJ/m^3
Diesel oil – stationary purposes kg CO_2e/GJ	NGER Determination	69.2	0.1	0.2	-	38.6 GJ/kL
	GWP amendment	69.2	0.119	0.192	-	38.6 GJ/kL
Diesel oil – transport purposes kg CO_2e/GJ	NGER Determination	69.2	0.2	0.5	-	38.6 GJ/kL
	GWP amendment	69.2	0.238	0.481	-	38.6 GJ/kL
Electricity – scope 2 emission factor, Queensland kg CO_2e/kWh	NGA 2013	-	-	-	0.84	-

CO_2: carbon dioxide. CH4: methane. N_2O: nitrous oxide. CO_2e: carbon dioxide equivalent.

16.3.3 Key greenhouse gas emission estimation assumptions

16.3.3.1 Energy use assumptions

For the purposes of this EIS, energy requirements for construction, decommissioning and operations phases of the GFD Project have been determined under a maximum development scenario, providing a conservative or high estimate of emissions. To facilitate gas compression and provide power for water management and gas production activities under this scenario, the following assumptions have been used as a basis for the maximum annual energy requirements:

- 150 megawatts (MW) to power co-located nodal and hub gas compression facilities, including control systems, water management and reticulated power to well leases for water pumps
- 150 MW to power turbine compressor engines, either gas-driven or electric motors with electricity from the grid
- 20 MW to power nodal gas compression facilities.

Fuel requirements for generation and compression were calculated based on Siemens Gas Turbine SGT-400 used for power generation or mechanical drive. Electrical efficiency for the SGT-400 is 34.8% for power generation and 36.2% for mechanical drive applications (Siemens, 2009).

Scope 2 emissions associated with purchased power from the grid were calculated using the latest NGA scope 2 electricity emissions factor for Queensland.

As the ratio between electricity purchased from the grid and own-use gas is uncertain, three scenarios have been presented: 0% electrification (100% own-use gas), 50% electrification (50% own-use gas) and 100% electrification.

16.3.3.2 Flaring assumptions

Flaring rates were estimated based on existing NGER facilities operated by Santos Limited. A conservative rate of two percent of total gas throughput has been used; however, improvements in efficiency and operations procedures are likely to result in lower rates in the future.

16.3.3.3 Well completions assumptions

Seven days of continuous flaring at the maximum rate of production for a typical well has been allowed for well completions activities. While the completions process may take longer for some wells, the rate of production is likely to be significantly less than assumed, as peak gas production is not reached until enough water has been removed to reduce the confining hydrostatic pressure.

16.3.3.4 Land clearing assumptions

An estimate of GHG emissions from land clearing has been based on a very conservative (i.e. high emission) scenario; however it does not take into consideration the preferential location of infrastructure on land that has already been cleared. The GFD Project will avoid land clearing to the extent practicable by preferentially selecting drilling locations that have already been cleared and minimising disturbance where clearing is required.

The estimate of emissions from land clearing is also based on a cleared area of four hectares per production well. This footprint includes the well lease (including laydown areas), access road, power infrastructure and gathering lines. In practice, cleared areas may on average be smaller than four hectares per well, especially in instances where multi-well leases are appropriate and feasible. This will result in a larger well lease area, but will considerably reduce the number of leases required and consequently reduce the overall area of disturbance. The footprint of nodal and hub gas compression facilities, camps and water management facilities are estimated using construction footprints described in Table 4–4 of Section 4: Project description.

16.3.3.5 Rehabilitation assumptions

Projected emissions do not take into account emissions abatement from rehabilitation programs, which will largely negate the impact of land clearing.

16.3.3.6 Decommissioning assumptions

Emissions from decommissioning activities include fuel consumption in vehicles and heavy earthmoving or mechanical equipment. As a conservative estimate, fuel requirements for decommissioning were assumed to be half of the requirements for construction, given that no use of vehicles is required for land clearing during decommissioning.

16.3.4 Projected greenhouse gas emissions

An emission profile has been calculated for the GFD Project's 6,100 production wells:

- Within scope of profile: emissions from the construction and decommissioning of the production wells associated with land clearing, drilling and well completions, and transport (see Table 16-4)
- Outside scope of profile: emissions (scope 1 and 2) associated with operation of these wells, for example from gas compression, as these emissions have already been covered within the 2009 EIS (see Table 16-5).

As reported in the 2009 EIS, projected GHG emissions for the entire GLNG Project (i.e. field production, pipeline, LNG plant) were up to approximately 7.2 $MtCO_2e$. Emissions from the operation of natural gas wells (field production) were calculated based on the total volume of gas required to be produced (not the total number of wells), as fuel requirements are based on volume of product required to be transported. Therefore, even though an additional 6,100 wells may be drilled as part of the GFD Project, operations emissions for field production will be largely unchanged.

Typical annual GHG emissions for construction of the GFD Project wells are projected to be in the order of 160,000 tCO_2e (see Table 16-4, which shows sources of emissions during 2029 when the GFD Project will be in full production).

Table 16-4 GFD Project annual greenhouse gas emissions for construction (2029)

Activity	CO_2 (tCO_2e)	CH_4 (tCO_2e)	N_2O (tCO_2e)	Total (tCO_2e)
Land clearing*	132,942	-	-	132,942
Fuel consumption in drilling	11,346	16	33	11,396
Fuel consumption in vehicles	6,132	18	44	6,194
Well completions and connections	12,882	568	138	13587
Total emissions	**163,302**	**602**	**215**	**164,119**

*Rehabilitation programs will largely negate emissions from land clearing.

GLNG Project emissions were reported in detail in the 2009 EIS and 2010 supplementary EIS. Operations GHG emissions provided in Table 16-5 are a subset of the GLNG Project emissions and relate to operations in the GFD Project area only.

A range of energy source options are being considered for the GFD Project. Annual operations GHG emissions projections have been provided in Table 16-5 for three scenarios:

- Electrification (0%): Annual scope 1 emissions are 1.8 $MtCO_2e$ per year and there are no scope 2 emissions
- Electrification (50%): Annual scope 1 emissions are 1.1 $MtCO_2e$ per year and total annual emissions (i.e. scope 1 and 2) are 2.2 MtCO2e per year
- Electrification (100%): annual scope 1 emissions are 0.3 $MtCO_2e$ per year and total annual emissions (i.e. scope 1 and 2) are 2.6 MtCO2e per year.

Table 16-5 GFD Project annual greenhouse gas emissions for operations (2029)

Activity	Electrification scenario (%)	CO_2 (tCO_2e)	CH_4 (tCO_2e)	N_2O (tCO_2e)	Total (tCO_2e)
Flaring	-	234,727	10,350	2,507	247,584
Fugitives	-	0	6,210	0	6,210
Fuel combustion for power generation	0	752,876	3,508	425	756,809
	50	376,438	1,754	212	378,404
	100	0	0	0	0
Fuel consumption for stationary equipment (including compression)	0	824,036	3,840	465	828,341
	50	447,598	441	253	448,292
	100	71,160	332	40	71,532
Electricity purchased (scope 2)	0	-	-	-	-
	50	-	-	-	1,151,093
	100	-	-	-	2,302,186
Total operations scope 1 emissions	0	1,811,639	23,908	3,397	1,838,944
	50	1,058,763	18,755	2,972	1,080,490
	100	305,887	16,892	2,547	325,326
Total operations scope 1 and 2 emissions	0	1,811,639	23,908	3,397	1,838,944
	50	2,209,856	18,755	2,972	2,231,583
	100	2,608,073	16,892	2,547	2,627,512

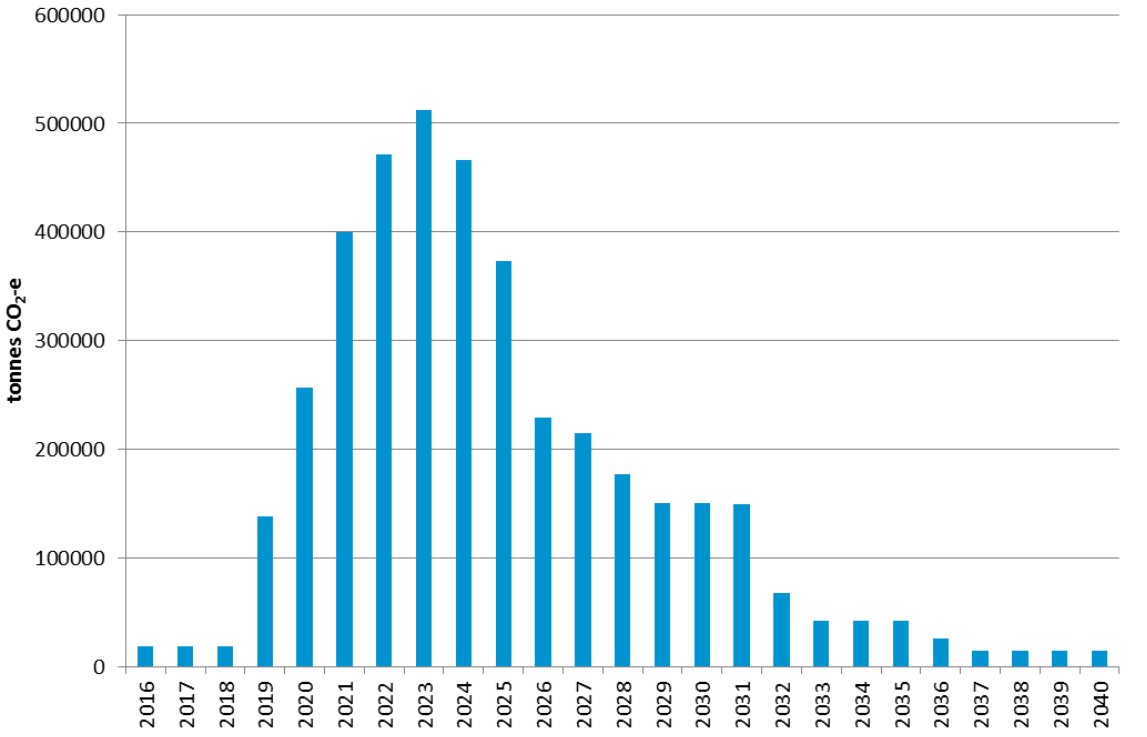
Table 16-6 shows the GHG emissions from construction and decommissioning of the GFD Project's production wells over the lifetime of the project. These emissions are incremental to the emissions for the GLNG Project reported in the 2009 EIS and 2010 supplementary EIS. The total incremental emissions for the lifetime of the GFD Project are estimated to be 4.5 MtCO2e.

Table 16-6 GFD Project lifetime incremental greenhouse gas emissions

Activity	CO_2 (t CO_2e)	CH_4 (t CO_2e)	N_2O (t CO_2e)	Total (t CO_2e)
Construction				
Land clearing	3,632,900	-	-	3,632,900
Fuel consumption in drilling	288,100	400	800	289,300
Fuel consumption in vehicles	150,800	400	1,100	152,300
Well completions and connections	316,800	14,000	3,400	334,200
Decommissioning				
Fuel consumption in vehicles and heavy machinery	75,400	200	550	76,150
Total incremental emissions	**4,464,000**	**15,000**	**5,850**	**4,484,850**

Figure 16-1 shows the lifetime incremental (construction) annual GHG emissions for the GFD Project over and above those already reported in the 2009 EIS and 2010 supplementary EIS.

Figure 16-1 GFD Project incremental annual greenhouse gas emissions (construction)



Total GHG emissions for operations of the GFD Project wells over the lifetime of the GFD Project are summarised in Table 16-7 for the 50% electrification scenario. These operations emissions are a subset of the total GLNG Project emissions and were previously included in the assessment in the 2009 EIS and 2010 supplementary EIS.

Table 16-7 GFD Project (50% electrification) lifetime greenhouse gas emissions (operations, scope 1 and 2)

Activity	CO_2 (t CO_2e)	CH_4 (t CO_2e)	N_2O (t CO_2e)	Total (t CO_2e)
Flaring	5,600,800	247,000	59,800	5,907,600
Fugitives	-	148,200	-	148,200
Fuel combustion for power generation	9,686,600	45,100	5,500	9,737,200
Fuel consumption for stationary equipment	11,436,900	53,300	6,500	11,496,700
Electricity purchased (scope 2)	-	-	-	29,620,000
Total operation scope 1 emissions	**26,724,300**	**493,600**	**71,800**	**27,289,700**
Total operation scope 1 and 2 emissions	**56,344,300**	**493,600**	**71,800**	**56,909,700**

16.4 Environmental values

There is considerable scientific concern that the level of GHG emissions in the atmosphere has dramatically increased due to anthropogenic activities and it is very likely (90% to 99% probability) to be responsible for most of the observed increases in temperature (IPCC, 2007; CSIRO and BoM, 2012).

The potential impacts of climatic events on the GFD Project are discussed in Section 7: Climate and climate change.

16.5 Potential impacts

The challenge for the international community is to reduce anthropogenic GHG emissions while continuing to provide reliable and affordable energy.

Global energy demand is expected to increase by 33% from 2010 to 2035 (International Energy Agency, 2011). Lower carbon energy sources such as natural gas and renewables can fuel this growth and reduce relative global GHG emissions.

The incremental impact of the GHG emissions from the GFD Project should be assessed in terms of national and global emissions and its relative contribution to energy markets.

16.5.1 Impact on national and State emissions

Annual emissions from the GFD Project are shown as a percentage of Australia's and Queensland's GHG emissions in Table 16-8. The emissions presented in this analysis are based on the year of maximum emissions (2029) whereas the emissions for Australia and Queensland represent those from 2010/11. Therefore, emissions will be considerably lower than those shown in Table 16-8 over most of the GFD Project life.

Table 16-8 GFD Project (50% electrification) emissions comparison to 2010/11 emissions

Sector	2010/11 emissions (Mt CO_2e)	Total GFD Project emissions as a percentage of the sector* (%)	GFD Project incremental emissions as a percentage of the sector ** (%)
Queensland energy sector	99.5	2.4	0.16
Total Queensland	**155.5**	**1.5**	**0.10**
Australian energy sector	422.0	0.6	0.04
Total Australia	**563.1**	**0.4**	**0.03**

Source: Adapted from DCCEE, 2013.
* Construction and operations emissions for the 50% electrification scenario in the worst case year (2029), i.e. 2.40 Mt CO_2e. ** Construction emissions in 2029, i.e. 0.16 Mt CO_2e.

16.5.2 Lifecycle emissions

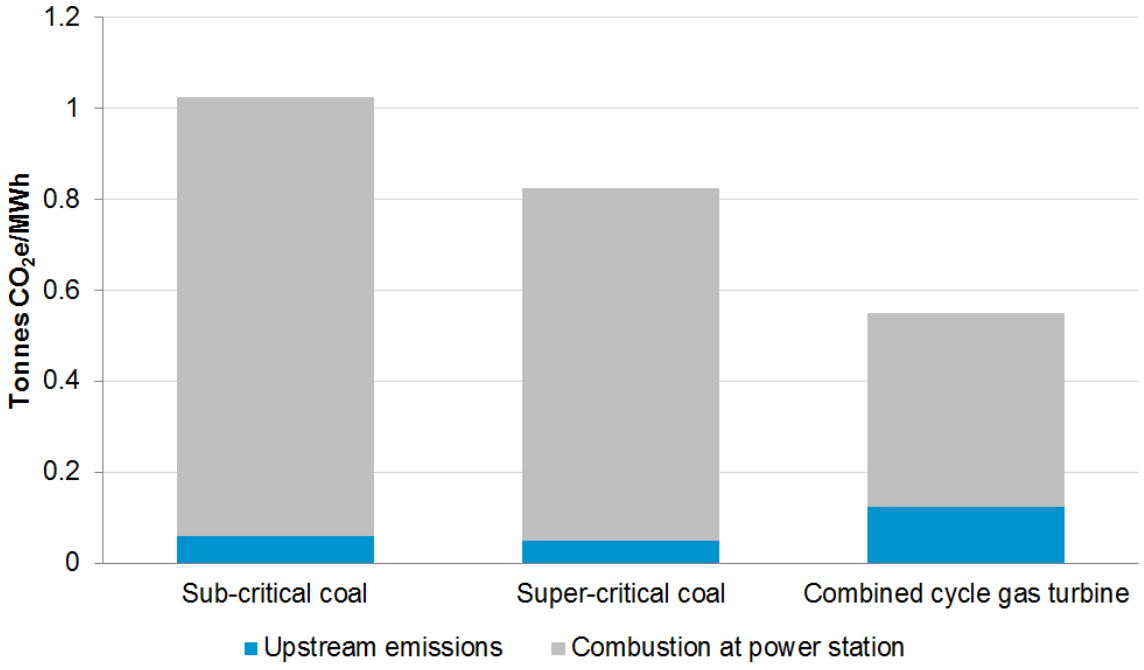
Full lifecycle emissions include emissions associated with combustion of gas produced. Gas provides an opportunity for a net reduction in global GHG emissions having a positive impact on societies worldwide.

In the transition to a lower-carbon world, LNG offers a unique opportunity for Australia – both for growing the domestic economy and providing a lower carbon fossil fuel alternative. Emissions from the combustion of LNG are approximately 40% less than those from the combustion of black coal of equivalent energy content.[1]

Considering the full lifecycle GHG emissions of both black coal and gas from coal seams, the cleaner burning properties of natural gas more than compensate for the upstream emissions resulting from its extraction and processing (Figure 16-2). Each unit of electricity produced by natural gas produces lower lifecycle GHG emissions than electricity produced in coal-fired power stations.

Figure 16-2 below shows the comparison between full lifecycle GHG emissions for gas from coal seams (combusted in a combined cycle gas turbine power station) and the full lifecycle emissions from black coal combusted in a sub-critical coal-fired power station and a super-critical coal-fired power station.

Figure 16-2 Comparative lifecycle greenhouse gas emissions



Source: Adapted from Worley Parsons, 2011

[1] These calculations were estimated by applying the emission factors in the Schedule 1 of the Measurement Determination, the comparisons do not take into consideration the varying efficiencies of power generators.

16.5.3 Fugitive emissions

Fugitive emissions are minor intentional or unintentional GHG releases that occur during natural gas exploration, production and processing. In the NGER Determination, minor unintentional releases are defined as “those emissions other than emissions that are vented or flared” (2008). These emissions include minor losses from valves, flanges and other equipment and are quantified using legislated emissions factors rather than direct measurements. Essentially, they are small leaks that may be barely detectable and may or may not occur, but are reported regardless as an assumed percentage of throughput.

Based on Santos Limited's reported 2011/12 NGER emissions, minor unintentional releases are approximately 0.3% of total upstream emissions or 0.04% of total lifecycle emissions.

These are calculated by applying a factor to the throughput of gas through the system in its entirety — inclusive of the well lease, transmission pipelines and gas compression facilities. This factor is applied to these systems, regardless of whether leaks actually occur. It is likely that, in many cases, fugitive emissions may be over-estimated.

Given the increasing importance of unconventional gas resources globally in the transition to a low carbon economy, the fugitive emission profile of coal seam gas wells has been reviewed in detail. Howarth *et al* (2011) published a widely criticised paper that purported to show fugitive methane emissions from shale gas production to be higher than Santos Limited’s estimates and 30% higher than conventional gas.

More recently, Allen *et al* (2013) have completed a robust, peer reviewed measurement study at production sites in the United States delivering results an order of magnitude lower than Howarth *et al*, at 0.42% of production. This appears higher than the figure Santos Limited uses to estimate minor unintentional releases (0.0014 tCO_2e per tonne of throughput or 0.0056%) for two main reasons:

- Allen *et al*’s study measures emissions from shale gas wells and includes sources of emissions not necessarily found in coal seam gas wells
- Allen *et al*’s figures include emissions from venting, whereas in accordance with the NGER Determination, Santos Limited measures vented emissions separately and they are not included in the fugitive emission factor for minor unintentional releases, but reported separately as flaring and venting emissions.

When fugitive and vented emissions from Santos Limited’s gas fields are calculated as a percentage of throughput, the results are in line with Allen *et al’s* study.

The Australian oil and gas sector has recognised the value of independent studies to clarify the emissions from the coal seam gas industry. Santos Limited is taking a lead role in Australia to ensure research-based science continues to form the basis of discussions concerning its GHG emissions such as:

- In conjunction with other coal seam gas operators in eastern Australia, Santos Limited is collaborating with the Commonwealth Scientific and Industrial Research Organisation (CSIRO) in a study to measure fugitive emissions from a sample of operations well leases throughout Queensland
- In a separate study, CSIRO is measuring seepage and migration of natural gas from disbanded exploration wells and seeps that may occur naturally
- Santos Limited is working with the University of Adelaide to establish the methodology and standard operating procedure to assess baseline emissions.

Through the studies listed above, Santos Limited is demonstrating its commitment to transparency by engaging with government and other independent research groups to participate in data gathering exercises. By having access to peer-reviewed facts, this knowledge should enhance stakeholders' confidence in the GHG emissions reported by the industry, the methods used to calculate them and in the global benefits of natural gas.

Santos GLNG has integrated a number of activities into its operations to monitor, and where possible reduce, emissions including:

- As part of its well integrity programme, an infra-red camera is used to detect leaks of methane at flanges, gauges and couplings. If required, corrective action is undertaken
- During the process of well completions, there is the potential for methane emissions to occur if procedures are not in place to tie-in the well immediately. To minimise these emissions, Santos GLNG has developed the rapid deployment appraisal separator package, which was designed to address the challenge of separating methane from coal seam water. This has been successfully implemented at four locations in Santos GLNG's gas fields. Gases are flared rather than vented, significantly reducing GHG emissions while minimising land disturbance, as no excavation is required
- The Queensland Government has also developed a Code of Practice for coal seam gas well head emissions, detection and reporting, which is a preferred standard under the *Petroleum and Gas (Production and Safety) Regulation 2004* (Qld).

16.6 Mitigation measures

Climate change is a global issue requiring significant resources to meet complex environmental, economic and political challenges. Santos GLNG has a strong record of working with government, industry and the community to address GHG emissions with specific focus on addressing energy efficiency, the transition to lower emission technologies and reporting transparency.

Santos GLNG has its own corporate Climate change policy which reflects a commitment to energy efficiency and reducing emissions across its operations, including the GFD Project (refer to Section 6: Management framework). This policy includes commitments to:

- Continue to reduce the carbon intensity of its 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 emission reduction targets
- Pursue no flaring or venting of associated gas, unless there are no feasible alternatives
- Continue to publicly disclose GHG emissions profile and carefully examine forecast emissions.
- Understand, manage and monitor climate change risk and develop appropriate adaptation strategies for Santos GLNG activities
- Assist governments and engage with other stakeholders on the design of effective and equitable climate change regulations and policy
- 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.

In reference to the GFD Project, Santos GLNG is committed to implementing the measures detailed in Table 16-9 in order to reduce, monitor and disclose its GHG emissions.

Table 16-9 Management framework and mitigation measures for greenhouse gases

Management plan	Mitigation measures
Draft Environmental management plan (Draft EM plan)	The Draft EM plan identifies the environmental values potentially affected by the GFD Project and proposes measures to manage the risk of potential adverse impact to these environmental values. The Draft EM Plan comprises: • Environmental values potentially affected by the GFD Project • Environmental management objectives and associated management measures • Environmental monitoring and reporting • Coal seam water management • Proposed conditions. In accordance with the NGER Act, annual reporting of GHG emissions, energy production and energy consumption will be completed. Key activities that will be implemented to reduce GHG emissions include measure such as: • Efficient design principles Project engineers will review the plant design and equipment options to efficiently and safely: — Minimise energy usage — Optimise heat balancing — Review options for fuel type and volumes — Develop more accurate emissions measure to ensure control systems are efficient — Design metering and measurement systems (in compliance with reporting requirements such as NGER Act). Measurement and disclosure — Annual independent assurance of GHG emissions — Regular audits in relation to implementation of, conformance with and effectiveness of, the Santos GLNG environmental, health and safety management system — Monitoring and review of energy efficiency opportunities — Other audits of compliance with internal policies and procedures related to GHG reduction through the internal audit program. — Santos GLNG will review emission measurements to identify areas for improvement, followed by implementation of projects for metering upgrades. • Energy efficiency — An annually reviewed energy/loss reduction record — Energy efficiency plans with site-specific targets — Site utility management programs aimed at reducing fuel use for utilities and minimising wastage — Transport reduction plans — Preparation and implementation of standard operating procedures for reducing energy use and loss — Energy awareness in competency training modules — Equipment maintenance service program to ensure that equipment uses fuel efficiently — An incentive program for the reduction of fuel utilisation and loss — Consideration of energy use in purchasing procedures for new plant and equipment and for new acquisitions. • Where possible, Santos GLNG will plan transport logistics for the GFD Project to minimise energy consumption and use the most fuel efficient vehicles and equipment. • Santos GLNG will minimise vegetation clearing for construction to minimise carbon loss associated with land clearing and implement rehabilitation practices to encourage vegetation re-growth on cleared areas that are not required to be kept free for asset protection and maintenance.

An assessment of the opportunity for carbon dioxide capture and storage found that, due to low reservoir concentrations of carbon dioxide, the GHG emissions emitted through fuel use for capture and reinjection would exceed the volume of carbon dioxide being recovered from the reservoir stream for reinjection. Based on this assessment, it is not environmentally effective to pursue capture and sequestration of reservoir carbon dioxide for the GFD Project.

16.7 Conclusions

Total incremental emissions (from construction and decommissioning of the additional wells associated with the GFD Project) for the lifetime of the GFD Project are estimated to be 4.5 Mt carbon dioxide equivalent.

These incremental emissions include emissions from land clearing, drilling and well completions and transport during construction and decommissioning. Emissions associated with the operation of the GFD wells (including gas compression) are a function of the total volume of gas production, and were already included in the assessment in the 2009 EIS and 2010 SEIS.