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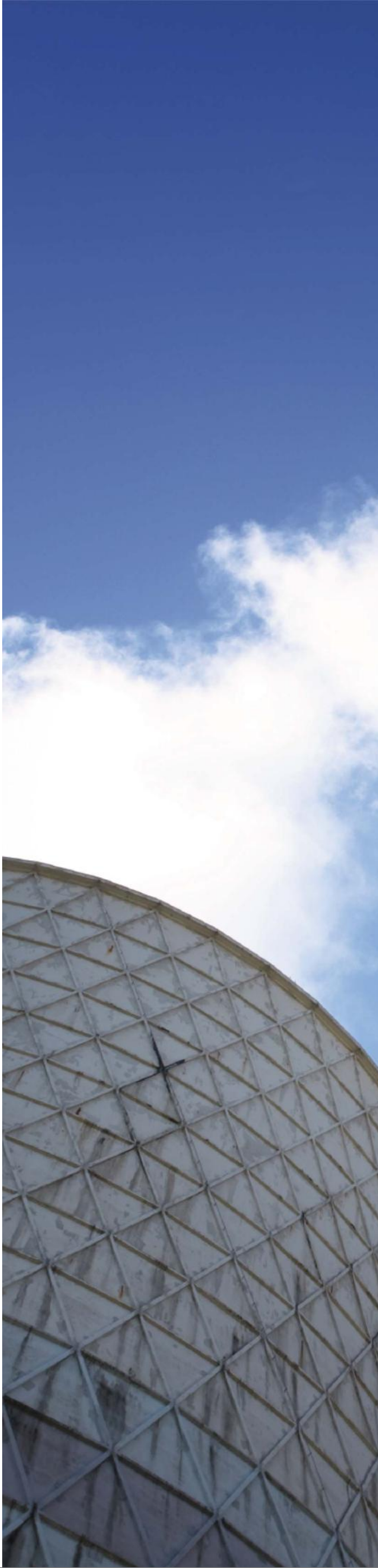

REPORT

SUPPLEMENTARY GREENHOUSE GAS ASSESSMENT REPORT

Coffey Environments

Job No: **3568C**

11 June 2013

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PREPARED FOR:	Coffey Environments
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EXECUTIVE SUMMARY

Arrow Energy Pty Ltd (Arrow) proposes to expand its coal seam gas operations in the Surat Basin through the Surat Gas Project. The Surat Gas Project (the project) is a component of the larger Arrow LNG Project, which incorporates an additional gas field development in the Bowen Basin, transmission gas pipelines and the Arrow LNG Plant.

An environmental impact statement (EIS) was prepared and submitted for the project. Arrow is required to prepare a supplementary report to the EIS (SREIS) to present any refinements to the project description, address issues identified in the EIS that require further consideration and/or information, and to respond to comments raised in the submissions on the EIS. Pacific Environment (formerly PAEHolmes) prepared the greenhouse gas (GHG) assessment for the project's EIS and was requested to assist Coffey Environments Pty Ltd (Coffey Environments) to prepare a supplementary technical study for inclusion in the SREIS.

This supplementary report addresses the changes to the greenhouse gas assessment for the EIS (PAEHolmes, 2011) as a result of refinements to the project description as described in SREIS Chapter 3, Project Description.

The revised total direct (scope 1) and indirect (scope 2) greenhouse emissions for worst-case year 2029 were estimated to be approximately 3.6 Mt CO_2-e/annum. These emissions are approximately 4.5% higher than the estimated emissions for worst-case year 2030 in the EIS for a higher forecast quantity of CSG produced (i.e., approximately 23%). The majority of the emissions generated will now be associated with electricity consumption from the grid as opposed to gas combustion, as a result of Arrow presenting its alternative power supply option (connection to Queensland's electricity grid) as its preferred option in the SREIS.

The scope 1 and scope 2 emissions associated with worst-case year 2029 are expected to contribute approximately 0.012% to Global 2009 emissions. These emissions also represent approximately 0.89% of Australia's 2009 emissions for the energy sector and around 0.69% of the Australian Government's 2020 emissions target.

Combined scope 1 and scope 2 emissions are minor (approximately 13% of the life cycle emissions) in comparison with scope 3 emissions, which will primarily be due to greenhouse emissions associated with the end use of the product fuel.

The refined project design results in estimated cumulative scope 1 and scope 2 emissions for the life of the project of 81 Mt CO_2-e, which is 16% lower than the estimated cumulative emissions of 96 Mt CO_2-e associated with the design at the time of the EIS.

Based on the worst-case year (2029) of this assessment, it was determined that combusting coal seam gas for heating or electricity generation purposes emits overall significantly less greenhouse gas emissions over its life cycle (scope 1 and scope 3) per unit of thermal energy produced in comparison with other fossil fuels, particularly coal. For example, the life cycle emissions associated with the combustion of CSG from this project will be approximately 38% lower than the life cycle emissions associated with the combustion of brown or black coal.

The changes in design for the project, in particular the change in permanent power supply (i.e., self-generation using CSG was assessed in the EIS while electricity from the grid is now assessed in the SREIS), were expected to materially affect the annual and cumulative scope 1 and scope 2 emissions. However, lower refined annual power requirements for the facilities and wells were provided for the SREIS. Consequently, despite the difference in contribution from scope 1 and scope 2 emissions, the revised annual total scope 1 and scope 2 emissions for worst-case year 2029 are comparable to the emissions presented in the EIS for worst-case year 2030. There was however, a substantial reduction in cumulative emissions due to lower annual power requirements, in particular for the ramp-up and ramp-down phases.

Based solely on the emissions for worst-case year 2029, it is predicted that the potential impacts from the project will be slightly higher than those predicted in the EIS, for a higher forecast quantity of CSG produced. The impacts associated with the project, with respect to climate change, will be in proportion with the project's contribution to global greenhouse gas emissions. Therefore, the potential impacts associated with climate change directly attributable to the project on a global scale can be expected to be negligible.

GLOSSARY

Abbreviation	Meaning
a	Annum
AGO	Australian Greenhouse Office
API	American Petroleum Institute
ATO	Australian Taxation Office
BAT	Best Available Technology
C_2H_6	Ethane
CGPF	Central Gas Processing Facility
CH_4	Methane
CO_2	Carbon dioxide
CO_2-e	Carbon dioxide equivalent
CER	Clean Energy Regulator
CSG	Coal Seam Gas
DA	Drainage Area
DCCEE	Department of Climate Change and Energy Efficiency
EEO	Energy Efficiency Opportunities
EIS	Environmental Impact Statement
EITE	Emissions-Intensive Trade-Exposed
FCF	Field Compression Facility
GHG	Greenhouse Gas
GJ	Gigajoule or one billion (10^9) joules
GT	Gas Turbine
GWP	Global Warming Potential
ha	Hectare or ten thousand square metres
HFCs	Hydrofluorocarbons
IPCC	Intergovernmental Panel on Climate Change
km^2	Square kilometre
kmole	Kilomole or one thousand (10^3) moles
kt	Kilotonne or one thousand (10^3) tonnes
kW	kilowatt or one thousand (10^3) watts
LNG	Liquefied Natural Gas
LULUCF	Land Use, Land Use Change and Forestry
m	Metre
Mt	Megatonne or one million (10^6) tonnes
MW	Megawatt or one million (10^6) watts
N_2O	Nitrous oxide
NF_3	Nitrogen trifluoride
NGA	Australia's National Greenhouse Accounts
NGERs	National Greenhouse and Energy Reporting System
OTN	Obligation Transfer Number
PFCs	Perfluorocarbons
PSL	Petroleum Survey Lease
QGS	Queensland Gas Scheme

Abbreviation	Meaning
SESP	Smart Energy Savings Program
Sm^3	Standard cubic metres (under conditions of 15°C and 1 atm pressure)
SREIS	Supplementary Report to the Environmental Impact Statement
SF_6	Sulfur hexafluoride
t	Tonne
TJ	Terajoule or one trillion (10^{12}) joules
USC	Ultra Super Critical

CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

Arrow Energy Pty Ltd (Arrow) proposes to expand its coal seam gas operations in the Surat Basin through the Surat Gas Project. The Surat Gas Project (the project) is a component of the larger Arrow LNG Project, which incorporates an additional gas field development in the Bowen Basin, transmission gas pipelines and the Arrow LNG Plant.

An environmental impact statement (EIS) was prepared and submitted for the project. Arrow is required to prepare a supplementary report to the EIS (SREIS) to present information on refinements to the project description, address issues identified in the EIS as requiring further consideration and/or information, and to respond to comments raised in the submissions on the EIS. Pacific Environment (formerly PAEHolmes) prepared the greenhouse gas (GHG) assessment for the project EIS and was requested to prepare a supplementary technical study for inclusion in the SREIS.

This supplementary report addresses the changes to the greenhouse gas assessment for the EIS (PAEHolmes, 2011) as a result of the identified refinements to the project description (outlined in SREIS Chapter 3, Project Description). This report evaluates whether the emission estimates presented in the EIS were materially affected and whether the mitigation measures applied for the EIS are still relevant and adequate to address the identified potential impacts.

1.1 SREIS Project Description

Since preparation of the Surat Gas Project EIS, further knowledge of the gas reserves has been gained resulting in refinement of the field development plan and basis for design of coal seam gas infrastructure. The refinements which are applicable to the greenhouse gas assessment include:

- A reduction in the size of the project development area including the number of wells and facilities.
- A revised project development schedule for the anticipated construction, operation and decommissioning of facilities and wells.
- An increase in the capacity of production facilities and changes in associated equipment.
- An update of the well type described within the EIS to include the addition of multi-well pads.
- A revised power supply option for facilities and wells, with temporary power generation to be used only in the initial phase of operation until a grid connection is made.
- A revised flaring scenario.

Details of these refinements to the project description are provided below.

Due to the relinquishment of parcels of land within Arrow's exploration tenements, there has been a reduction in the overall size of the project development area from 8,600 km^2 to 6,100 km^2. Advancement in the field development planning since the preparation of the EIS has seen the project development area being separated into eleven drainage areas. It is currently expected that eight of these drainage areas will be initially developed for the Surat Gas Project with each drainage basin incorporating wells with connections to a water gathering network, a gas gathering network and a CGPF. The anticipated commissioning of production wells and facilities has been revised in line with the approach to the initial development of eight drainage areas.

The current project schedule shows construction of wells beginning in 2014. Construction of the eight CGPFs is scheduled to commence in late 2015 and all CGPFs are intended to be operational by 2020. Decommissioning of wells is forecast to begin in 2028. This means the project would have a 35 year lifespan ending in 2048.

Arrow has identified the properties on which four of the eight CGPFs will be located, two of which will have water treatment facilities located adjacent to them (reduced from six water treatment facilities assessed in the EIS). In the EIS this arrangement was referred to as an integrated processing facility. This term will no longer be used and the facilities will be referred to by their function i.e., CGPF and water treatment facility. The exact locations of infrastructure within the properties have not been determined with the final siting of infrastructure to be determined through a constraints analysis.

With the smaller project development area, there has been a reduction in the number of production wells anticipated to be drilled, reducing from 7,500 to approximately 6,500 wells. In addition to single wells, multi-well pads will be drilled, which will comprise an average of 9 wells per pad with the potential for up to 12 wells per pad, spaced approximately 8 m apart.

The EIS assessed the potential impacts associated with power being supplied through self-generation at the site of the facilities and wells, with power supplied by the Queensland electricity grid described as the alternate power supply option that Arrow was considering.

Refinements to Arrow's basis for design include consideration for their power supply, with the alternate option of grid power, now being favoured. Self-generated power may however, still be necessary until connection to a third party's infrastructure can be made. This assessment includes the power requirements for self-generated power at CGPFs (50 MW), at multi-well pads of up to 12 wells (749 kW) and at single wells (60 kW).

The maximum capacity of a CGPF has increased to 225 TJ/day from 150 TJ/day and an additional layout sparing for one extra train (75 TJ/day) may be adopted. The temporary self-generated power supply option for a CGPF allows for up to 50 MW of power to be supplied, which has been assessed through consideration for two typical power generation configurations: 47 reciprocating gas engines each with a capacity of 1.1 MW and 10 gas turbines, each with a capacity of 5.7 MW.

Wells will be either supplied with power from the nearest CGPF or in a few exceptional circumstances may have temporary power generation from a gas engine. A multi-well pad has a power requirement of 720 kW, which for the temporary self-generated power supply option has been assessed through consideration of a 749 kW engine.

Ramp-up flaring is expected to result from commissioning of only eight CGPFs. Planned and unplanned maintenance flaring at CGPFs includes partial (i.e., one train) and full shutdowns which have changed due to the increased capacity of a CGPF and larger train sizes. Pilot flaring of the CGPF will no longer occur as nitrogen will be used for purging. No gas will be flared at a field compression facility (FCF).

1.2 Relevant Updates to the Project Description

Project description updates relevant to the greenhouse gas assessment are described in this section. A summary of the key refinements to the project description is also provided in Table 1.2. The data describing the updates were provided to Pacific Environment by Coffey Environments as advised by Arrow.

1.2.1 Project Schedule and Facilities Development

Since preparation of the project's EIS, a number of parcels of land within Arrow's exploration tenements have been relinquished. This has also led to a revision of the project schedule for the commissioning of the central gas processing facilities (CGPF) and wells.

It is currently expected that there will be eight CGPFs, each fed by an area of wells and associated gathering lines. A further three CGPF locations may be developed, depending on favourable reservoir outcomes and future market conditions. Commissioning of all of the eight CGPFs is expected to occur in the first seven years of the project. To accommodate the construction workforce, six camp sites will also be constructed one year prior to the construction of the CGPFs.

The number of water treatment facilities has reduced from six facilities to two facilities. These water treatment facilities are co-located with two of the CGPFs (i.e., equivalent to an integrated processing facility as defined in the EIS). Therefore, the number of integrated processing facilities has reduced from six to two.

FCFs may be located between the wells and the CGPFs to improve compression at sites where wellhead pressure is not sufficient to transport gas to the larger production facilities. The revised project description retains six FCFs.

1.2.2 CSG Production

The maximum individual CGPF compression capacity has increased to 225 TJ/day (previously 150 TJ/day) with an option of an additional spare train (75 TJ/day). However, the number of CGPFs has decreased to eight (twelve in the EIS). As a result, the maximum cumulative installed compression facility capacity decreased from 1,440 TJ/day to 1,275 TJ/day.

A total sustained gas production of 1,215 TJ/day is forecast across the entire field, which comprises Arrow's domestic gas supply of 80 TJ/day (as described in the EIS) and the revised estimate of 1,135 TJ/day for LNG production (970 TJ/day presented in the EIS).

1.2.3 Flaring

The emissions from ramp-up flaring are expected to reduce as they are now expected to be generated from the commissioning of only eight CGPFs.

Planned and unplanned maintenance flaring at CGPFs included partial and full shutdowns which have changed due to the increased capacity of a CGPF and larger train sizes.

Pilot flaring of the CGPF will no longer occur as nitrogen will be used for purging and was therefore excluded from this assessment.

No gas will be flared at an FCF.

Note that emissions associated with exploration activities do not form part of the Surat Gas Project as they are already approved under a separate environmental authority.

1.2.4 Venting

Water pipelines in the water gathering system will contain high-point vents, allowing for the release of accumulated gas to the atmosphere.

1.2.5 Production Wells

Production wells will be drilled throughout the life of the project (average rate of approximately 400 wells per year), commencing in 2014 and ceasing in 2035.

The EIS estimated that 7,500 wells would be drilled over the life of the project. Due to a refinement of the project description (including the relinquishment of land), only 6,500 wells are anticipated to be commissioned during the life of the project. In the GHG assessment conducted as part of the EIS, the worst-case year considering the expected maximum number of wells that would be operating simultaneously was 5,873 wells in year 2031. For the SREIS assessment, the worst-case year was 2030 with 4,690 wells operating simultaneously.

The SREIS also introduced a method for well pad drilling that further reduces Arrow's footprint, in the form of direction drilling, allowing multiple wells to be drilled from one central surface location. The multi-well pads will be comprised of up to twelve wellheads per pad with an average of nine wellheads, approximately 8 m apart.

The dimensions of the multi-well pads will be approximately up to 200 m by 100 m (approximately 2 ha).

1.2.6 Power Supply

Construction power will be supplied by diesel generators.

Temporary power may be used for commissioning and operation of the CGPFs, water treatment facilities, miscellaneous equipment and wells until connection to the grid is established.

Electricity from the grid will be supplied to the CGPFs and then distributed to water treatment facilities, wells and water transfer stations.

1.2.7 CSG Composition

A revised coal seam gas composition, corresponding to the expected typical CSG composition for Surat Basin gas was provided for the SREIS. The methane content of the CSG is now 96.99% by volume.

Table 1.1: Revised Gas Composition and Properties

Substance	Value	Units
Methane (CH_4)	96.99	mol%
Ethane (C_2H_6)	0.01	mol%
Nitrogen	2.00	mol%
Carbon dioxide (CO_2)	1.00	mol%
Water	0	mol%
Site-specific energy content factor [a]	0.0366	GJ/Sm³
Site-specific density [b]	0.70	kg/Sm³

a As advised by Arrow, this was estimated by Pacific Environment based on the revised gas composition.
b As advised by Arrow, this was estimated by Pacific Environment based on the revised gas composition, the substance molecular weights and the volume of 1 kilomole of gas at STP (23.6444 Sm³/kmole) from (DCCEE, 2012b).

1.2.8 Workforce

The peak construction workforce has more than doubled compared to the workforce estimated at the time of the EIS.

1.2.9 Traffic

The SREIS study for Roads and Transport predicted an increase in the distance travelled by project vehicles calculated for the revised project description. Further information is presented in SREIS Chapter 12, Roads and Transport.

1.2.10 Wastewater Treatment

Arrow will be independent of the public sewage infrastructure for construction purposes. Sewage treatment facilities will be installed at the accommodation sites. Temporary worker accommodation facilities are designed to be self-sufficient for power, water and sewage services.

During operations, Arrow has committed to connect wastewater and sewerage systems to sewers where locally present. Alternatively, Arrow will install wastewater treatment or reuse systems in accordance with relevant legislation and Australian standards. It is anticipated that the wastewater treatment process will be similar to the process currently used at Moranbah Camp (i.e., aerobic process with the sludge being transferred offsite).

1.2.11 Summary of Key Changes in Project Description

A summary of the key refinements to the project description is presented in Table 1.2.

Table 1.2: Summary of Key Refinements to the Project Description

Project Aspect	EIS Case	SREIS Case
Production	80 TJ/day for domestic gas supply 970 TJ/day for sustained production of LNG	80 TJ/day for domestic gas supply 1,135 TJ/day for sustained production of LNG
Project Development Area	8,600 km^2 project development area and five development areas	6,100 km^2 project development area and eleven drainage areas
Wells	Well count: 7,500	Well count: approximately 6,500
	Single wells	Multi-well pads will have a maximum of 12 wellheads. The average multi-well pad will contain nine wells.
Central Gas Processing Facilities	Six integrated processing facilities that will produce 30 to 150 TJ/day Six CGPFs that will produce 30 to 150 TJ/day	Eight CGPFs that will produce between 75 and 225 TJ/day and may have an additional train (75 TJ/day) if required.
Field Compression Facilities	Six FCFs that will produce 30 to 60 TJ/day.	Six FCFs Located within the 12 km radius of potential development identified for the corresponding CGPF
Water Treatment Facilities	Six water treatment facilities (integrated with an integrated processing facility) with 60 ML/d capacity	Two water treatment facilities Approximately 35 ML/d and 90 ML/d capacities co-located at two CGPFs
Power Generation	Primary power from self-generation	Primary power from the grid Option of self-generation may be used until grid connection is established
Flaring	Ramp-up flaring to occur at six CGPFs and six integrated processing facilities Emergency and maintenance flaring to occur at six CGPFs, six integrated processing facilities and six FCFs Pilot flaring to occur at six CGPFs, six integrated processing facilities and six FCFs	Ramp-up flaring to occur at eight CGPFs Emergency and maintenance flaring to occur at eight CGPFs No pilot flaring at CGPFs. No flaring at FCFs.
CSG Composition	Methane content of 98.69% by volume	Methane content of 96.99% by volume
Traffic		The distance travelled by project vehicles has increased from what was presented in the EIS.

2 UPDATES TO LEGISLATIVE AND POLICY CONTEXT OF THE ASSESSMENT

This section describes changes to the relevant aspects of legislation and policy since the submission of the EIS. At the time of the EIS submission, Australia was a participant of the first commitment period of the Kyoto Protocol and the Carbon Pricing Mechanism was still a proposed policy as part of the *Clean Energy Plan* released in July 2011.

Since the submission of the EIS, the Carbon Pricing Mechanism came into effect in July 2012 and therefore, more information about the scheme is now available. Amendments to the Energy Efficiency Opportunities (EEO) Program were also made and Australia has agreed to a second commitment period under the Kyoto Protocol, as the first commitment period ended in December 2012.

2.1 Kyoto Protocol

The Kyoto Protocol first commitment period ended on 31 December 2012. On 9 December 2012, at the United Nations climate change conference in Doha, it was announced that Australia has agreed to a second commitment period under the Kyoto Protocol. The second commitment period of the Kyoto Protocol was scheduled to commence on 1 January 2013 and end in 2020, in line with the start of the new global agreement (Australian Government, 2012).

Australia agreed a Kyoto target to reduce its emissions to five per cent below 2000 levels by 2020; i.e., 530 Mt CO_2-e.[a] However, the option to increase the target to up to 15 or 25 per cent might be considered, depending on the scale of global action (Australian Government, 2012).

An additional greenhouse gas, nitrogen trifluoride (NF_3), was included to the list of the greenhouse gases covered by the Kyoto Protocol for the second commitment period (UNFCCC, 2012). Nitrogen trifluoride is, for instance, predominantly employed in the manufacture of silicon-based thin film solar cells, and therefore, emissions of this substance are not expected from this project.

2.2 EEO Program

According to the amended EEO regulations that came into effect on 1 July 2012, corporations are now allowed to align their assessment liability with their National Greenhouse and Energy Reporting (NGER) liability (DRET, 2012).

The EEO Amendment Regulation 2012 indicates that the EEO program will expand to include new developments and expansion projects from 1 July 2013. Corporations will be required to (DRET, 2012):

- Assess projected energy use after commercial operation has commenced.
- Assess opportunities to improve energy efficiency in the design, commissioning or equivalent process for the project.
- Define participation thresholds.

Corporations not registered for EEO whose projects meet the above thresholds will be required to participate (DRET, 2012).

Further consultation and trials with industry are currently being undertaken to better inform how the program should be implemented (DRET, 2013).

2.3 Smart Energy Savings Program

Under the Queensland government formed in April 2012, the *Smart Energy Savings Program* (SESP) was discontinued to reduce regulatory burden on Queensland businesses (Queensland Government 2013).

[a] Based on 2000 Australian emissions levels for all sectors = 558 Mt CO_2-e (DCCEE, 2010).

This will have no effect on the outcomes of the greenhouse gas assessment for the project as the facility will be required to report under the EEO Program.

2.4 Additional Information on the Carbon Pricing Mechanism

2.4.1 Covered Emissions

Entities are liable as direct emitters under the carbon pricing mechanism if they operate facilities that exceed the threshold for scope 1 emissions covered by the mechanism, or if they supply or use natural gas (CER, 2013a). Scope 1 emissions covered under the carbon pricing mechanism include emissions:

- Released into the atmosphere as a direct result of the operation of the facility.
- Released in Australia.
- For which a method or criterion for measurement has been provided to measure those emissions under the *NGER Act* (DCCEE, 2012c), specified in the *National Greenhouse and Energy Reporting (Measurement) Determination 2008* made under the *NGER Act*.
- That are not part of the excluded types of emissions.

Entities are not directly liable for scope 2 emissions; i.e., emissions released into the atmosphere as a direct result of one or more activities that generate electricity, heating, cooling or steam consumed by the facility, but do not form part of the facility. The electricity generator is liable for the emissions it produces in generating the electricity (CER, 2013a).

The following categories of emissions are not part of the covered emissions under the carbon pricing mechanism:

- Emissions from transport fuels. Transport fuels are not covered directly under the carbon pricing mechanism. Where a carbon price applies, it is through fuel tax credits or charges in excise.
- Emissions of synthetic greenhouse gases; i.e., hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6). This does not apply to emissions of PFCs emitted from aluminium production activities. These emissions will be subject to an equivalent carbon price under the *Ozone Protection and Synthetic Greenhouse Gas Management* legislation.
- Emissions from biomass, biofuel and biogas. Carbon dioxide produced from these sources is part of the natural carbon cycle and does not count towards Australia's emissions obligations. Other greenhouse gases from the combustion of these sources are a minor source of emissions and are therefore excluded.

Under the *Clean Energy Act 2011* (CER, 2013b), large users of specified taxable liquid fuels can choose to manage their carbon price liability through the carbon pricing mechanism rather than through the fuel tax or excise systems under the operation of the Australian Taxation Office (ATO) (CER, 2013c).

2.4.2 Obligation Transfer Numbers (OTNs)

An OTN is used to transfer carbon price liability for the potential greenhouse emissions embodied in an amount of natural gas, supplied from a gaseous fuel supplier to the recipient of that gas. It is used to keep track of liability so that liability is not imposed twice on the same quantity of gas (CER, 2013d).

A 'large gas consuming facility' is liable as a direct emitter for the emissions resulting from the combustion of the natural gas supplied to the facility. A facility becomes a 'large gas consuming facility' the second year after it has emissions from natural gas combustion of 25,000 tonnes or more CO_2-e (in any financial year after 1 July 2010). It is mandatory for the recipient of the natural gas supplied for use at a large gas consuming facility to quote an OTN and mandatory for suppliers of natural gas to accept the quotation (CER, 2013d).

2.4.3 Support Measures

Under the carbon pricing mechanism, the *Jobs and Competitiveness Program* provides ongoing assistance to entities that face high carbon costs and are constrained in their capacity to pass through costs in global markets. The program issues free carbon units to eligible applicants.

Through the *Jobs and Competitiveness Program*, highly emissions-intensive trade-exposed (EITE) activities receive assistance to cover 94.5 per cent of industry average carbon costs in the first year of the carbon price. Moderately intensive emissions-intensive trade-exposed activities receive assistance to cover 66 per cent of industry average carbon costs in the first year. Assistance reduces by 1.3 per cent each year to encourage industry to cut pollution (Department of Industry, 2013).

In accordance with the *Clean Energy Regulations 2011*, LNG production activities, which are moderately intensive EITE activities, will receive supplementary allocation of free carbon units under the *Jobs and Competitiveness Program*. The additional number of free carbon units will be estimated based on the final LNG emissions number and the estimated baseline allocation for EITE activities, if assessed as eligible under the *Jobs and Competitiveness Program*.

2.5 Summary of Relevant Policies

A summary of the relevant policies relating to emissions of greenhouse gases and electricity consumption/generation from the Arrow Surat Gas Project is presented in Table 2.1.

Table 2.1: Summary of Greenhouse Gas Emissions Policies Relevant to the Project

Level	Policy	Project Participation	Section in Report	Section in EIS Report
International	Kyoto Protocol Second Commitment Period	INDIRECT As the project is planned to commence in 2014, emissions will count towards Australia's Kyoto target for the 2013 - 2020 period as part of the second commitment period.	Section 2.1	-
Australia	NGER Framework	MANDATORY Arrow already reports under the NGER framework and will have to report greenhouse gas emissions and energy consumption/production associated with the project annually.	-	EIS Appendix D, Section 2.2.3
	EEO Program	MANDATORY Arrow will be required to report the expected energy usage and energy efficiency opportunities associated with the project.	Section 2.2	-
	Carbon Pricing Mechanism	MANDATORY Arrow will participate in the Carbon Pricing Mechanism and will be required to surrender emission permits equivalent to those emitted during each reporting period. Assistance from the government will potentially be given through the *Jobs and Competitiveness Program* if gas production qualifies as an EITE industry.	Section 2.4.3	-
	Direct Action Plan (proposed)	MANDATORY This policy will require businesses to develop and receive approval for an emissions baseline for facilities covered by the policy. Opportunities may exist for the project to receive benefits if emissions intensity is reduced below 'business as usual' levels and businesses that operate with an emissions intensity higher than 'business as usual' will likely incur some form of penalty.	-	EIS Appendix D, Section 2.2.6
Queensland	SESP	NONE The program was discontinued by the Queensland Government. Arrow will only have to report energy efficiency data from the project under the EEO Program.	Section 2.3	EIS Appendix D, Section 2.3.1
	QGS	INDIRECT The project is not a direct participant in trading of gas electricity certificates.	-	EIS Appendix D, Section 2.3.2

Please refer to EIS Appendix D, Section 2 of the EIS for more information on the above policies.

3 GREENHOUSE EMISSIONS ESTIMATION METHODOLOGY

3.1 Summary of Activities

The activities associated with the project during the construction, operation and decommissioning/rehabilitation of Arrow's facilities[b], wells and infrastructure are summarised in Table 3.1. Notably, the changes in design for the project include a change in permanent power supply (i.e., self-generation using CSG was assessed in the EIS while electricity from the grid is now assessed in the SREIS). It is considered a worst-case approach since consuming electricity from the main grid is, overall, more emissions-intensive than combusting CSG to generate power on-site. All other things being equal, any final project design that includes a combination of power supplied from the grid and self-generation will be less emissions-intensive than the scenario modelled for the SREIS.

Table 3.1: Activities Associated with the Project

Category	Activity	Construction	Operation	Decommissioning/ Rehabilitation
Fuel combustion	*Power generation (diesel)*	Construction power	-	Decommissioning/ rehabilitation power
	Power generation (gas)	-	Temporary power supply option for production wells and CGPFs	-
	Light and heavy vehicles (diesel)	Installation of production wells, facilities and gathering infrastructure	Operation and maintenance of production wells, production facilities and gathering infrastructure	Decommissioning and rehabilitation of production wells, facilities and gathering infrastructure
Fugitive emissions	*Venting*	-	Venting from equipment and low pressure vents	-
	Facility-level fugitive emissions	-	Fugitive emissions from gas fields and CGPFs	-
	Flaring	Ramp-up flaring (during commissioning of the CGPFs)	Maintenance flaring	-
Energy consumption	*Electricity consumption*	-	Permanent power supply for production wells and all facilities	-
Land clearing	*Clearing of vegetation*	Site preparation	-	-

[b] For this assessment, 'facilities' includes CGPFs, brine treatment facilities, water treatment facilities and FCFs.

3.2 Methodology Documents Updated Since Submission of EIS

Since the submission of the EIS, the following methodology documents have been updated:

- The *Australian National Greenhouse Accounts - National Greenhouse Accounts (NGA) Factors* (DCCEE, 2012a). [c]
- The *National Greenhouse and Energy Reporting (Measurement) Determination*.
- The *National Greenhouse and Energy Reporting System Measurement Technical Guidelines for the estimation of greenhouse gas emissions by facilities in Australia 2012* (*Technical Guidelines*), (DCCEE, 2012b).

Greenhouse gas emissions presented in this supplementary report are based on the most recent published guidance documents available.

Since the submission of the EIS, the scope 2 and scope 3 emission factors for electricity consumption from the Queensland grid provided in the *NGA Factors* were updated. No other updates relevant to the project were identified.

3.3 Anticipated Changes to the Methodology Documents

This assessment was prepared using a methane global warming potential (GWP) of 21 tonnes CO_2-e/ tonne CH_4, in accordance with the most recent *National Greenhouse and Energy Reporting (Measurement) Determination*.

It should be noted that the Department of Climate Change and Energy Efficiency (DCCEE) has indicated that an updated methane GWP of 25 tonnes CO_2-e/ tonne CH_4 will be adopted by the Australian Government for the purpose of estimating emissions under the carbon pricing mechanism for the 2017/2018 financial year and for determining the equivalent carbon applied to synthetic greenhouse gases from 1 July 2017 (DCCEE, 2013). This revised GWP is sourced from the Intergovernmental Panel on Climate Change (IPCC) 2007 Fourth Assessment Report (AR4) and will replace the value used from the IPCC's Second Assessment Report (AR2). It is possible that this value may be revised in the future by the IPCC.

The IPCC Fourth Assessment Report (IPCC, 2007) also contains an updated GWP value for nitrous oxide of 298 tonnes CO_2-e/ tonne N_2O compared to a current value of 310 tonnes CO_2-e/ tonne N_2O that was used in this assessment.

As a consequence of these potential future changes to the GWP, the cumulative scope 1 and scope 2 emissions estimates prepared for the project would increase by approximately 3%, based on the updated GWPs from IPCC's AR4 assumed to be used from 2017 onwards.

3.4 Project Phases

Emissions from each year of the project were estimated in accordance with the methodologies described above using the emission factors in Appendix A. One worst-case year (i.e., the year predicted to generate the most scope 1 and scope 2 emissions) was selected for each of the three phases of the project's development for presentation in this report, as follows:

- Year 2019 for ramp-up (2014-2019).
- Year 2029 for sustained production (2020-2043).
- Year 2044 for ramp-down (2044-2048).

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[c] The Department of Climate Change and Energy Efficiency (DCCEE) is now known as the Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education (Department of Industry).

The worst-case year (i.e., 2029) was subsequently presented in comparison to Queensland, Australian and global annual emissions to assess the potential impacts of the project.

3.5 Assumptions Associated with this Assessment

The assumptions used for this assessment are presented below. These assumptions were provided by Coffey Environments in consultation with Arrow.

3.5.1 Power Supply

Temporary power may be used for commissioning and operation of the CGPFs, water treatment facilities, miscellaneous equipment and wells until connection to the grid is established.

For assessment purposes, an allowance of two years after commissioning for the CGPFs and six months after commissioning for the wells has been made, after which it is assumed that connection to the Queensland electricity grid can be established. Wells commissioned prior to the construction of a CGPF are assumed to be self-powered for up to two years prior to supply from grid or CGPF. As higher GHG emissions are associated with the use of electricity from the grid, this scenario is considered as the worst-case.

For the purposes of this assessment, the following typical temporary power generation configurations have been adopted:

- 47 of the 1.1 MW engines or 10 of the 5.7 MW gas turbines to deliver 50 MW of power required for each CGPF.
- 60 kW for single wells.
- 749 kW for multi-well pads.

3.5.2 CGPF Construction and Decommissioning

The project development schedule prepared by Coffey Environments in consultation with Arrow was used to characterise construction and decommissioning. Arrow nominated an expected 55 week timeframe for construction of a CGPF and a 60 week timeframe for construction of a CGPF and water treatment facility (CGPF-2 and CGPF-9). For the purposes of estimating annual greenhouse emissions, the emissions generated in any given year were based on the activities that were expected for the majority of the year. Therefore, construction for each CGPF was shown as occurring over 52 weeks. For CGPF-1, CGPF-5 and CGPF-11, construction was assumed to span over two years (with the operations phase commencing mid-way through the second year).

The decommissioning year of each CGPF was estimated based on an approximate 25 year operational life as outlined in SREIS Chapter 3, Project Description. FCFs are expected to have a similar operational life.

3.5.3 Maintenance Flaring

For this assessment, average planned and unplanned maintenance flaring of 662 TJ/year/CGPF during the operational years of a CGPF were used for the eight CGPFs.

3.5.4 Venting

In addition to the emissions sources considered in the EIS, supplementary venting emissions sources (refer to Table 3.2) are included in this assessment based on their historical proportion to Arrow's total gas production, sourced from their 2011/2012 NGER inventory. To estimate venting emissions, the *2012 NGER Technical Guidelines* (DCCEE, 2012b) refers to the methodologies described in specific sections of the *American Petroleum Institute Compendium of Greenhouse Gas Emissions Methodologies for the Oil and Natural Gas Industry* (API Compendium) released in 2009.

Table 3.2: Venting Emissions Sources Considered in the SREIS

Emission Process [a]	2009 API Compendium Section [a]	Venting Emission Source	Comment
Gas treatment processes	Section 5.1	Glycol dehydrator / glycol pumps	Included. Glycol dehydrators and glycol pumps installed at the CGPFs. Stripping gas will be vented from glycol dehydrator units and the emission factor used is assumed to account for the use of stripping gas.
		Desiccant dehydrators	Not applicable. Not anticipated to be present in the project.
		Other glycol dehydrator alternatives	Not applicable. Not anticipated to be present in the project.
		Acid gas removal/sulfur recovery units	Not applicable. Not anticipated to be present in the project.
Cold process vents	Section 5.3	Cold process vents	Emissions from vents are captured as part of the emergency shutdowns emissions. No additional specific cold process vents were identified as part of this project.
Natural gas blanketed tank emissions	Section 5.4.4	Natural gas blanketed tank emissions	Not applicable. Not anticipated to be present in the project.
Water gathering system	-	High point vents	It was assumed that emissions from high point vents were included in the general leaks emission factor used based on gas throughput.
Other venting sources – gas driven pneumatic devices	Section 5.6.1	Gas-driven pneumatic devices	Included. Gas-driven pneumatic devices installed at the CGPFs and wells.
Other venting sources – gas driven chemical injection pumps	Section 5.6.2	Gas-driven chemical injection pumps	Included. Gas-driven chemical injection pumps installed at the CGPFs and wells.
Other venting sources – coal seam exploratory drilling, well testing and mud degassing	Section 5.6.3	Mud degassing	Applicable to the gas exploration fields. However, no data to characterise mud degassing were available. The exclusion of this source is not expected to significantly influence the annual emissions estimated for the project.
	Section 5.6.6	Coal seam exploratory drilling (methane or natural gas, rather than compressed air, is used as the motive force to drill the wells and is emitted to atmosphere)	Not applicable. This practice is not expected to occur at Arrow's exploratory fields.
		Well testing (using methane to clean coal fines or dust that accumulate in the well)	Not applicable. This practice is not expected to occur at Arrow's exploratory fields.
Non-routine activities – engineering calculation approach	Section 5.7.1	Emergency shutdowns	Included. Low pressure vents installed at the CGPFs.

Emission Process [a]	2009 API Compendium Section [a]	Venting Emission Source	Comment
Non-routine activities – production related non-routine emissions	Section 5.7.2	Pressure vessel blowdowns	Included. Pressure vessels installed at the CGPFs (e.g. Triethylene glycol flash drum) and wells (i.e. separators).
		Compressor starts	Included. Compressors installed at the CGPFs and FCFs.
		Compressor blowdowns	
		Gas well workovers (tubing maintenance)	Included.
		Gathering gas pipeline blowdowns	Included. Gathering gas pipelines connecting the wells to the FCFs/CGPFs and connecting the FCFs to the CGPFs.
		Onshore gas well completion	Not included as venting emissions. Gas is anticipated to be flared during well completions.
		CO_2 well stimulation	Not applicable. This source applies to oil wells.
		Well unloading	Not applicable. This practice is not expected to occur at Arrow's gas fields.
		Well blowouts	Not applicable. Well blowouts are not expected to occur at Arrow's gas fields.
		Pressure relief valves releases	Included. Pressure relief valves installed at the CGPFs, FCFs and wells.
		Gathering gas pipeline mishaps (dig-ins)	Included. Gathering gas pipelines connecting the wells to other infrastructure.
Non-routine activities – gas processing related non-routine emissions	Section 5.7.3	Compressor blowdowns, compressor starts, and other miscellaneous sources (processing plant)	Not applicable. Emissions are estimated for each relevant emission source described above.

a Refer to Section 3.84 of the NGER Technical Guidelines (DCCEE, 2012b).

3.5.5 Wells

A third of the wells commissioned each year were assumed to be single wells. The remaining wells are expected to be part of multi-well pads.

3.5.6 Wastewater Treatment

It is anticipated that the wastewater treatment process will be similar to the process currently used at Arrow's existing Moranbah Camp (i.e., managed aerobic process with sludge transferred offsite). For managed aerobic wastewater treatment processes, the IPCC default methane correction factor is zero (refer to Division 5.4.2 of the *NGER Technical Guidelines*) and as a result, emissions from wastewater handling are expected to be zero. Emissions from wastewater treatment are therefore not included in this assessment.

3.5.7 Transmission Pipeline to Arrow LNG Plant

In accordance with the EIS, the total length of the transmission pipeline was estimated based on the following distances:

- Goodiwindi – Millmeran: 161 km
- Millmeran - Dalby: 99 km
- Dalby – Chinchilla: 82 km

- Chinchilla – Wandoan: 115 km
- Wandoan - Arrow LNG (Gladstone): 303 km.

No emissions associated with transmission of coal seam gas to Arrow LNG Plant are expected to occur for the period 2014 – 2017 as no CGPFs will be operational until 2017.

3.5.8 Camps

As the construction of camp sites will occur a year prior to the construction of the relevant CGPFs, the construction year of the camp sites was estimated based on the locations of the camp sites and of the CGPFs, and the development schedule.

4 REVISED GHG EMISSION ESTIMATES FOR THE SURAT GAS PROJECT

4.1 Project Schedule

The facility construction, operation and decommissioning schedule is presented in Table 4.1.

The project is expected to commence in 2014 with the drilling of production wells, and to cease in 2048. The ramp-up phase and the gas-tail off and decommissioning phase will be approximately five to six years in duration. Decommissioning and rehabilitation activities will commence in 2028 with the decommissioning of some of the production wells after a nominal well life of 15 years. CGPFs will be decommissioned after approximately 25 years of operation. A summary of the project phases considered in this assessment is provided in Table 4.2.

Table 4.1: Facility Construction, Operation and Decommissioning Schedule

Year	Project Year	Facility Construction [a, b]	Facility Operational [b]	Facility Decommissioning [c]
2014	Year 1	-	-	-
2015	Year 2	Camp B, Camp F, Camp A	-	-
2016	Year 3	CGPF-1, CGPF-2, CGPF-8, CGPF-9, Camp E	-	-
2017	Year 4	CGPF-1, CGPF-7, Camp D	CGPF-1, CGPF-2, CGPF-8, CGPF-9	-
2018	Year 5	CGPF-5, CGPF-11, Camp G	CGPF-7	-
2019	Year 6	CGPF-5, CGPF-10, CGPF-11	CGPF-5, CGPF-11	-
2020	Year 7	-	CGPF-10	-
2021	Year 8	-	-	-
2022	Year 9			
2023	Year 10	FCF-2, FCF-1	-	-
2024	Year 11	FCF-7	FCF-2, FCF-1	-
2025	Year 12	FCF-5, FCF-11	FCF-7	-
2026	Year 13	FCF-10	FCF-5, FCF-11	-
2027	Year 14	-	FCF-10	-
2028 - 2040	Year 15 to Year 27	-	-	-
2041	Year 28	-	-	CGPF-9,CGPF-2,CGPF-8
2042	Year 29	-	-	CGPF-1, CGPF-7
2043	Year 30	-	-	-
2044	Year 31	-	-	CGPF-5,CGPF-10,CGPF-11
2045	Year 32	-	-	-
2046	Year 33	-	-	-
2047	Year 34	-	-	FCF-2,FCF-1
2048	Year 35	-	-	FCF-7

a The construction of camp sites will occur a year prior to the construction of the CGPFs in the vicinity. The construction years of the camp sites were determined based on:
- the location of the CGPFs as advised by Arrow
- the development schedule of the CGPFs as advised by Arrow.

b CGPFs and FCFs construction periods and first operational year based on the project schedule. Arrow nominated an expected 55 week timeframe for the construction of a CGPF.

c The decommissioning year of the CGPFs was estimated based on a 25 year operational life as outlined in SREIS Chapter 3, Project Description. FCFs are expected to have a similar operational life.

Table 4.2: Summary of Project Phases

Project Phase	Description	Project Years	Estimated Years
Ramp-up	Ramp-up is expected to be approximately six years. Production potential must be built up by drilling and completing wells and commissioning upstream facilities until sufficient capacity is available to commission LNG trains at the Arrow LNG plant. All camp sites and seven CGPFs will be constructed during this period.	Year 1 to Year 6	2014 to 2019
Sustained Production	Sustained gas production is expected for approximately 24 years. Production wells will be drilled until 2035 while some wells will start being decommissioned in 2028 after an estimated production life of between 15 to 20 years. CGPFs will start being decommissioned in 2041 after approximately 25 years of operation.	Year 7to Year 27	2020 to 2043
Ramp-down	An approximate five-year gas tail-off and decommissioning phase is anticipated. FCFs will start being decommissioned in 2047.	Year 31 to Year 35	2044 to 2048

4.2 Summary of GHG Emissions Sources

A summary of all greenhouse gas emission sources considered in this supplementary report is provided in Table 4.3.

Table 4.3: Emission Sources Considered in the SREIS

Scope 1 Emissions	Scope 2 Emissions	Scope 3 Emissions
CONSTRUCTION		
Diesel combustion in: ➢ construction vehicles/equipment ➢ heavy duty vehicles transporting construction materials and waste materials ➢ passenger vehicles ➢ drills ➢ generators for construction power supply. Ramp-up flaring which includes: ➢ well completions ➢ dewatering. Land clearing.	N/A	Full fuel cycle of diesel
OPERATION		
CSG combustion in gas-driven generators (temporary power supply until a grid connection is made): ➢ two years for CGPFs ➢ six months for wells. Diesel combustion in: ➢ heavy duty vehicles transporting waste materials ➢ passenger vehicles. Flaring during maintenance activities. Venting from routine and non-routine activities from equipment and low pressure vents: ➢ Venting from the glycol dehydrator installed at the CGPFs. ➢ Venting from gas-driven pneumatic devices installed at the CGPFs and wells. ➢ Venting from gas-driven chemical injection pumps installed at the CGPFs and wells. ➢ Venting from low pressure vents at the CGPFs during emergency shutdowns. ➢ Pressure vessel blowdowns at the CGPFs and wells. ➢ Compressor starts and blowdowns from CGPFs and FCFs. ➢ Well workovers. ➢ Gathering gas pipeline blowdowns and mishaps (dig-ins) - from well heads to FCFs/CGPFs and from FCFs to CGPFs. ➢ Pressure relief valves releases installed at the CGPFs, FCFs and wells. Facility-level fugitive emissions (i.e., general leaks) from the gas fields and CGPFs.	Consumption of electricity from the grid (permanent power supply) at: ➢ CGPFs ➢ brine treatment facilities ➢ water treatment facilities ➢ FCFs ➢ wells ➢ water transfer facilities ➢ water injection pumps.	Full fuel cycle of: ➢ diesel ➢ electricity. End-use of CSG. Third party infrastructure for gas export: ➢ transmission to Arrow LNG Plant ➢ downstream processing at Arrow LNG Plant.
DECOMISSIONING		
Diesel combustion in: ➢ machinery/plant for decommissioning/ rehabilitation activities ➢ heavy duty vehicles transporting waste materials ➢ passenger vehicles.	N/A	Full fuel cycle of diesel.

4.3 Revised Estimated Emissions

Figure 1 shows the annual scope 1 and scope 2 greenhouse gas emissions associated with the construction, operation and decommissioning/rehabilitation activities for the life of the project. Based on Figure 1, the year that generates the highest scope 1 and scope 2 greenhouse emission estimates was selected for each project phase (i.e., ramp-up, sustained production and ramp-down) in order to present the most conservative estimates (i.e., a worst-case year). Year 2019, Year 2029 and Year 2044 were selected as the worst-case years for the three selected phases. The greenhouse emission estimates for each worst-case year are presented in sections 4.3.1 to 4.3.3.

Note that only scope 1 and scope 2 emissions were presented in Figure 1 as these emissions provide the most robust basis for comparing performance with other projects. Scope 3 emissions do not provide useful comparisons with other projects due to differing project boundaries in many cases.

CGPFs will start being decommissioned in 2041 after approximately 25 years of operation, which explains the significant drop in emissions for that year.

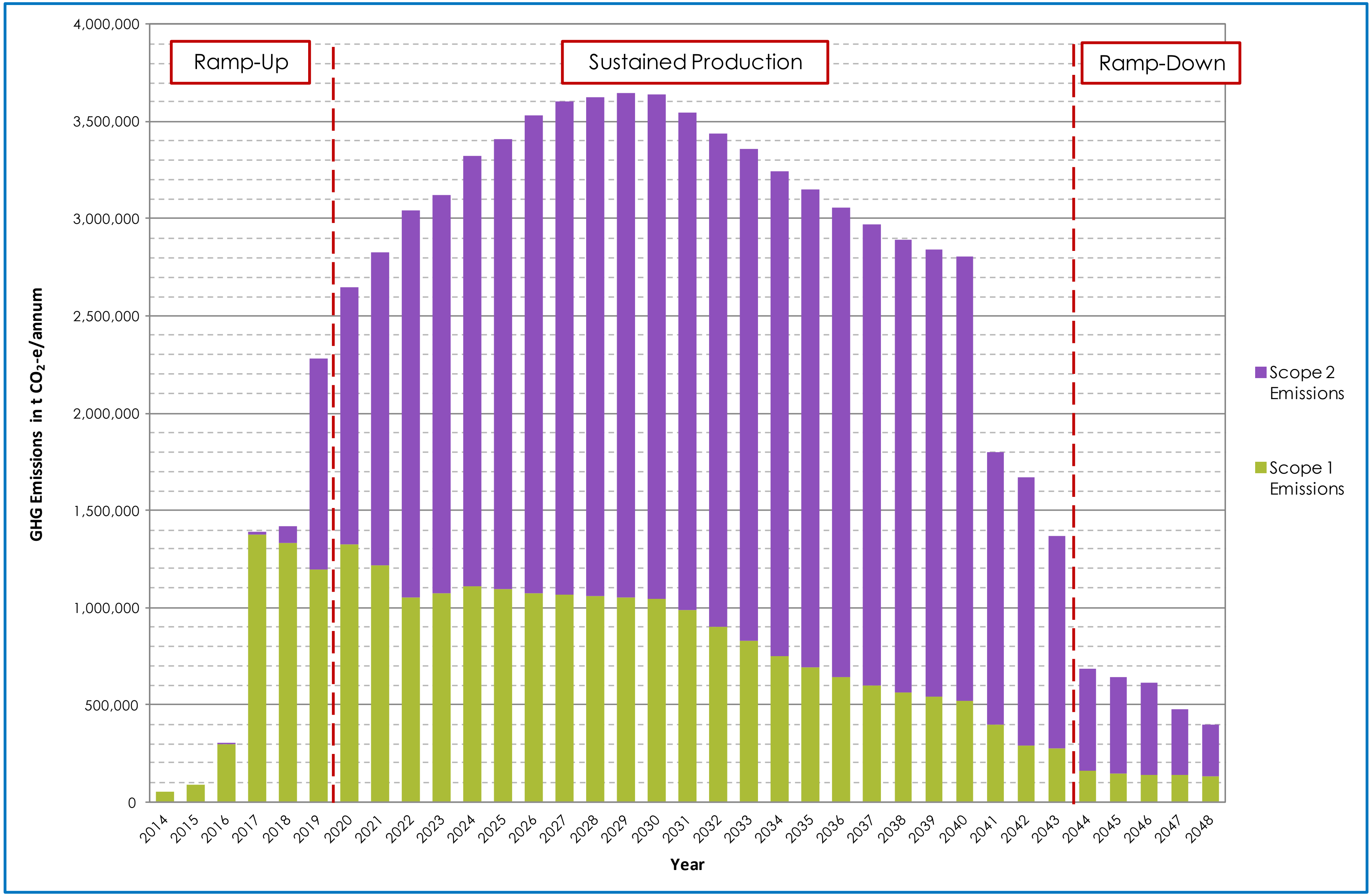

Figure 1: Total Scope 1 and Scope 2 Emissions in tonnes CO_2-e for the 35-year project life

4.3.1 Ramp-up Emissions

The combined scope 1 and scope 2 emissions generated during worst-case year 2019 during the ramp-up phase (i.e., 2014 to 2019) were estimated to be approximately 2,281 kt CO_2-e. The breakdown of scope 1, scope 2 and scope 3 emission estimates, categorised by source, for year 2019 is presented in Table 4.4.

In 2019, an equivalent [d] number of 371 wells are expected to be self-powered whereas an equivalent number of 990 wells will be connected to the grid for the entire year. Three of the commissioned CGPFs are anticipated to be self- powered for six months and connected to the main grid for the remaining six months, while the fourth CGPF will be self-powered for the entire year.

Scope 1 ramp-up emissions will be mainly associated with gas combustion in gas-driven generators (to provide temporary power to wells and CGPFs until a grid connection is made), and fugitive emissions. The total annual scope 1 emissions were estimated to be approximately 1,199 kt CO_2-e/annum (i.e., 52.6% of the total scope 1 and scope 2 emissions), as shown in Table 4.4.

Scope 2 ramp-up emissions will be mainly associated with the consumption of electricity at all facilities and wells (once connection to the grid is made, negating the need for gas-driven generators to supply power to the wells and CGPFs). The total annual scope 2 emissions were estimated to be approximately 1,082 kt CO_2-e/annum, as shown in Table 4.4, which will represent 47.4% of the scope 1 and scope 2 emissions that will be generated during Year 2019.

Scope 3 emissions will primarily be associated with the combustion of CSG by end-users. The total annual scope 3 emissions were estimated to be approximately 15,840 kt CO_2-e/annum (see Table 4.4), which will correspond to around seven times the quantity of scope 1 and scope 2 emissions generated during Year 2019.

[d] As some wells will be self-powered for a duration of two years and other wells will be self-powered for a duration of six months, an equivalent number of self-powered wells for the full year is presented.

Table 4.4: Forecast Greenhouse Gas Emissions during the Ramp-Up Phase (Worst-Case Year 2019)

Category	Activity	Emissions [tonnes CO_2-e/annum] [a]			
		CO_2	CH_4	N_2O	Total
RAMP-UP - SCOPE 1 EMISSIONS					
Fuel Combustion	CSG combusted in gas-driven generators to provide temporary power to wells and CGPFs	298,211	1,167	175	**299,554**
	Diesel combustion in generators to provide construction power (includes drills)	33,985	75	177	**34,237**
	Diesel combustion in light and heavy vehicles for construction, operations and decommissioning activities	31,516	91	228	**31,835**
Land Clearing	Land clearing	31,416	-	-	**31,416**
Fugitive Emissions	Ramp-up flaring	65,708	16,427	704	**82,839**
	Maintenance flaring	239,660	8,876	2,663	**251,199**
	Facility-level fugitive emissions (assumed to include high point vents)	-	200,310	-	**200,310**
	Venting from routine and non-routine activities from equipment and low pressure vents	-	267,448	-	**267,448**
RAMP-UP - SCOPE 2 EMISSIONS					
Energy Consumption	Electricity supplied to facilities and wells (permanent power supply option)	1,082,089	-	-	**1,082,089**
RAMP-UP - SCOPE 3 EMISSIONS					
Energy Consumption/ Production	End-use (combustion of CSG produced)	14,874,546	58,217	8,733	**14,941,496**
	Full fuel cycle (diesel) [b]	5,017	-	-	**5,017**
	Full fuel cycle (electricity) [b]	150,989	-	-	**150,989**
	Third party infrastructure - CSG transmission to Arrow LNG Plant	15	6,609	-	**6,624**
	Third party infrastructure - CSG downstream processing at Arrow LNG Plant	631,085	104,468	581	**736,135**
TOTAL SCOPE 1 EMISSIONS		**700,496**	**494,395**	**3,947**	**1,198,838**
TOTAL SCOPE 2 EMISSIONS [b]		**1,082,089**	**-**	**-**	**1,082,089**
TOTAL SCOPE 3 EMISSIONS		**15,661,652**	**169,294**	**9,314**	**15,840,260**
OVERALL		**17,444,238**	**663,689**	**13,260**	**18,121,188**

a Calculated based on activity data and emission estimation techniques described in Appendix A. The emissions presented in this table were rounded to the nearest tonne of CO_2-e. As a result, the combined emissions for all individual emissions sources in the table might not correspond to the total scope 1, scope 2 and scope 3 emissions presented.

b Scope 2 and scope 3 emissions are presented as CO_2 emissions while they are in fact a combination of CO_2, CH_4 and N_2O emissions (i.e. the emission factors were expressed as CO_2-e only).

4.3.2 Sustained Production Emissions

Worst-case year 2029 is anticipated to generate the highest emissions for the entire life of the project. As a result, the emissions generated for this year were compared to Queensland, Australian and Global annual emissions to assess the potential impacts of the project.

The combined scope 1 and scope 2 emissions generated during year 2029 during the sustained production phase (i.e., 2020 to 2043) was estimated to be approximately 3,644 kt CO_2-e. The breakdown of scope 1, scope 2 and scope 3 emission estimates, categorised by source, for year 2029 are presented in Table 4.5.

Scope 1 emissions will be mainly associated with fugitive emissions, which include maintenance flaring, facility-level fugitive emissions and venting. Commissioning of all facilities (including the FCFs) will be completed by 2027. At this time, it is planned all CGPFs and FCFs will be powered from the Queensland electricity grid and temporary gas-driven generators will only be in operation at some wells. Ramp-up flaring (occurring during the commissioning of the CGPFs) will have also ceased at this time. The total annual scope 1 emissions were estimated to be approximately 1,053 kt CO_2-e/annum (i.e., 28.9% of the total scope 1 and scope 2 emissions), as shown in Table 4.5.

Scope 2 emissions will be mainly associated with the consumption of electricity from the grid at the facilities and wells. The total annual scope 2 emissions were estimated to be approximately 2,590 kt CO_2-e/annum, as shown in Table 4.5, which will represent approximately 71.1% of the scope 1 and scope 2 emissions that will be generated during Year 2029.

Scope 3 emissions will primarily be associated with the combustion of CSG by end-users. The total annual scope 3 emissions were estimated to be approximately 24,880 kt CO_2-e/annum, as shown in Table 4.5. This corresponds to around seven times the quantity of scope 1 and scope 2 emissions generated during Year 2029.

Table 4.5: Forecast Greenhouse Gas Emissions during the Sustained Production Phase (Worst-Case Year 2029)

Category	Activity	Emissions [tonnes CO_2-e/annum] [a]			
		CO_2	CH_4	N_2O	Total
SUSTAINED PRODUCTION - SCOPE 1 EMISSIONS					
Fuel Combustion	CSG combusted in gas-driven generators to provide temporary power to wells and CGPFs	8,797	34	5	**8,837**
	Diesel combustion in generators to provide construction power (includes drills)	18,647	40	95	**18,782**
	Diesel combustion in light and heavy vehicles for construction, operations and decommissioning activities	31,742	92	229	**32,063**
Land Clearing	Land clearing	14,733	-	-	**14,733**
Fugitive Emissions	Ramp-up flaring	N/A	N/A	N/A	**N/A**
	Maintenance flaring	273,897	10,144	3,043	**287,085**
	Facility-level fugitive emissions (assumed to include high point vents)	-	292,345	-	**292,345**
	Venting from routine and non-routine activities from equipment and low pressure vents	-	399,326	-	**399,326**
SUSTAINED PRODUCTION - SCOPE 2 EMISSIONS					
Energy Consumption	Electricity supplied to facilities and wells (permanent power supply option)	2,590,340	-	-	**2,590,340**
SUSTAINED PRODUCTION - SCOPE 3 EMISSIONS					
Energy Consumption/ Production	End-use (combustion of CSG produced)	22,209,606	86,926	13,039	**22,309,571**
	Full fuel cycle (diesel) [b]	3,859	-	-	**3,859**
	Full fuel cycle (electricity) [b]	361,443	-	-	**361,443**
	Third party infrastructure - CSG transmission to Arrow LNG Plant	15	6,609	-	**6,624**
	Third party infrastructure - CSG downstream processing at Arrow LNG Plant	1,884,583	311,969	1,735	**2,198,287**
TOTAL SCOPE 1 EMISSIONS		**347,816**	**701,982**	**3,373**	**1,053,171**
TOTAL SCOPE 2 EMISSIONS [b]		**2,590,340**	**-**	**-**	**2,590,340**
TOTAL SCOPE 3 EMISSIONS		**24,459,506**	**405,504**	**14,774**	**24,879,784**
OVERALL		**27,397,663**	**1,107,486**	**18,147**	**28,523,295**

a Calculated based on activity data and emission estimation techniques described in Appendix A. The emissions presented in this table were rounded to the nearest tonne of CO_2-e. As a result, the combined emissions for all individual emissions sources in the table might not correspond to the total scope 1, scope 2 and scope 3 emissions presented.

b Scope 2 and scope 3 emissions are presented as CO_2 emissions while they are in fact a combination of CO_2, CH_4 and N_2O emissions (i.e. the emission factors were expressed as CO_2-e only).

4.3.3 Ramp-down Emissions

Worst-case year 2044 for the ramp-down phase (i.e., 2044 – 2048) is anticipated to generate significantly less emissions than the worst-case years associated with the ramp-up and sustained production phases.

The combined scope 1 and scope 2 emissions generated during Year 2044 for the ramp-down phase were estimated to be approximately 688 kt CO_2-e. The breakdown of scope 1, scope 2 and scope 3 emission estimates, categorised by source, for year 2044 are presented in Table 4.6.

Scope 1 ramp-down emissions will be mainly associated with fugitive emissions, which include facility-level fugitive emissions and venting. However, these emissions will be less significant than for Year 2029, as most of the CGPFs will be decommissioned by that time. The total annual scope 1 emissions were estimated to be approximately 158 kt CO_2-e (i.e., 23.1% of the total scope 1 and scope 2 emissions), as shown in Table 4.6.

Scope 2 ramp-down emissions will be mainly associated with the consumption of electricity from the grid at the remaining facilities and wells. However, these emissions will be less significant than for Year 2029 as 75% of the wells and the majority of the CGPFs are anticipated to be decommissioned by that stage. The total annual scope 2 emissions were estimated to be approximately 529 kt CO_2-e, as shown in Table 4.6, which represent approximately 76.9% of the scope 1 and scope 2 emissions that will be generated during Year 2044.

Scope 3 emissions will primarily be associated with the combustion of CSG by end-users. The total annual scope 3 emissions were estimated to be approximately 4,818 kt CO_2-e/annum, as shown in Table 4.6, which corresponds to around seven times the quantity of scope 1 and scope 2 emissions generated during Year 2044.

Table 4.6: Forecast Greenhouse Gas Emissions during the Ramp-Down Phase (Worst-Case Year 2044)

Category	Activity	Emissions [tonnes CO_2-e/annum] [a]			
		CO_2	CH_4	N_2O	Total
RAMP-DOWN - SCOPE 1 EMISSIONS					
Fuel Combustion	CSG combusted in gas-driven generators to provide temporary power to wells and CGPFs	0	0	0	**0**
	Diesel combustion in generators to provide decommissioning/rehabilitation power	3,953	6	11	**3,970**
	Diesel combustion in light and heavy vehicles for construction, operations and decommissioning activities	21,325	62	154	**21,541**
Land Clearing	Land clearing	N/A	N/A	N/A	**N/A**
Fugitive Emissions	Ramp-up flaring	N/A	N/A	N/A	**N/A**
	Maintenance flaring	0	0	0	**0**
	Facility-level fugitive emissions (assumed to include high point vents)	-	55,802	-	**55,802**
	Venting from routine and non-routine activities from equipment and low pressure vents	-	77,181	-	**77,181**
RAMP-DOWN - SCOPE 2 EMISSIONS					
Energy Consumption	Electricity supplied to facilities and wells (permanent power supply option)	529,081	-	-	**529,081**
RAMP-DOWN - SCOPE 3 EMISSIONS					
Energy Consumption/ Production	End-use (combustion of CSG produced)	4,291,902	16,798	2,520	**4,311,220**
	Full fuel cycle (diesel) [b]	1,936	-	-	**1,936**
	Full fuel cycle (electricity) [b]	73,825	-	-	**73,825**
	Third party infrastructure - CSG transmission to Arrow LNG Plant	15	6,609	-	**6,624**
	Third party infrastructure - CSG downstream processing at Arrow LNG Plant	364,187	60,287	335	**424,809**
TOTAL SCOPE 1 EMISSIONS		**25,278**	**133,050**	**166**	**158,493**
TOTAL SCOPE 2 EMISSIONS [b]		**529,081**	**-**	**-**	**529,081**
TOTAL SCOPE 3 EMISSIONS		**4,731,865**	**83,693**	**2,855**	**4,818,413**
OVERALL		**5,286,224**	**216,743**	**3,021**	**5,505,988**

a Calculated based on activity data and emission estimation techniques described in Appendix A. The emissions presented in this table were rounded to the nearest tonne of CO_2-e. As a result, the combined emissions for all individual emissions sources in the table might not correspond to the total scope 1, scope 2 and scope 3 emissions presented.

b Scope 2 and scope 3 emissions are presented as CO_2 emissions while they are in fact a combination of CO_2, CH_4 and N_2O emissions (i.e. the emission factors were expressed as CO_2-e only).

4.3.4 Annual and Cumulative Emissions

Annual emissions for the entire life of the project are presented in Table 4.7. The cumulative scope 1 and scope 2 emissions associated with the project were estimated to be 80.9 Mt CO_2-e. The total cumulative emissions for the project (scope 1, scope 2 and scope 3 emissions) were estimated to be 533.8 Mt CO_2-e. The methodology and data used to generate these annual emission estimates are provided in Appendix A.

Table 4.7: Forecast Annual Greenhouse Gas Emissions for the Life of the Project (2014-2048)

Phase	Year	Project Year	Scope 1 Emissions [a]	Scope 2 Emissions [a]	Scope 3 Emissions [a]	Total Emissions [a]
			[t CO_2-e/year]			
Ramp-up	2014	Year 1	55,529	0	1,504,148	**1,559,677**
	2015	Year 2	88,880	0	1,877,769	**1,966,649**
	2016	Year 3	296,059	2,927	2,257,696	**2,556,681**
	2017	Year 4	1,371,513	20,627	2,455,783	**3,847,924**
	2018	Year 5	1,334,906	80,836	7,715,180	**9,130,922**
	2019	Year 6	1,198,838	1,082,089	15,840,260	**18,121,188**
Sustained Production	2020	Year 7	1,327,089	1,320,236	17,506,176	**20,153,501**
	2021	Year 8	1,218,731	1,605,404	20,103,122	**22,927,257**
	2022	Year 9	1,049,701	1,994,152	22,124,876	**25,168,729**
	2023	Year 10	1,071,106	2,052,757	22,957,043	**26,080,906**
	2024	Year 11	1,108,143	2,212,858	24,260,149	**27,581,150**
	2025	Year 12	1,092,134	2,316,253	24,274,107	**27,682,494**
	2026	Year 13	1,075,713	2,459,001	25,436,357	**28,971,071**
	2027	Year 14	1,064,562	2,540,306	25,387,572	**28,992,439**
	2028	Year 15	1,060,783	2,565,044	25,082,193	**28,708,020**
	2029	Year 16	1,053,171	2,590,340	24,879,784	**28,523,295**
	2030	Year 17	1,046,919	2,591,664	24,056,409	**27,694,992**
	2031	Year 18	990,052	2,557,936	21,786,080	**25,334,068**
	2032	Year 19	900,851	2,539,469	19,105,813	**22,546,133**
	2033	Year 20	826,547	2,528,738	17,044,569	**20,399,854**
	2034	Year 21	750,436	2,494,522	14,362,334	**17,607,291**
	2035	Year 22	695,421	2,455,707	12,708,995	**15,860,123**
	2036	Year 23	643,356	2,413,756	10,849,530	**13,906,643**
	2037	Year 24	597,474	2,371,945	9,196,072	**12,165,490**
	2038	Year 25	561,292	2,330,412	7,954,424	**10,846,127**
	2039	Year 26	537,940	2,300,308	7,126,380	**9,964,627**
	2040	Year 27	520,416	2,281,771	6,505,910	**9,308,098**
	2041	Year 28	395,941	1,400,661	5,970,936	**7,767,538**
	2042	Year 29	290,733	1,379,685	5,518,587	**7,189,005**
	2043	Year 30	273,115	1,091,778	5,102,875	**6,467,769**
Ramp-down	2044	Year 31	158,493	529,081	4,818,413	**5,505,988**
	2045	Year 32	148,973	496,050	4,607,564	**5,252,587**
	2046	Year 33	142,202	469,012	4,397,760	**5,008,974**
	2047	Year 34	136,062	343,894	4,174,318	**4,654,273**
	2048	Year 35	129,398	270,324	3,958,029	**4,357,751**
Cumulative emissions for time period 2014 - 2048			**25,212,478**	**55,689,544**	**452,907,213**	**533,809,235**

a The emissions presented in this table were rounded to the nearest tonne of CO_2-e and as a result, the combined scope 1, scope 2 and scope 3 emissions might not correspond to the cumulative scope 1, scope 2 and scope 3 emissions presented.

4.4 Comparison with the Previous Assessment

A comparison between the emissions estimates presented in the EIS and presented in the SREIS is provided in this section. This comparison will assist in assessing the impacts of the revisions made to the project description on the projected greenhouse emission estimates.

Comparative emission estimates for each determined worst-case year and explanations for the encountered variations are presented in:

- Table 4.8 for Year 2019 of the ramp-up phase. Year 2019 was also calculated as the worst-case year for the ramp-up phase in the EIS.
- Table 4.9 for Year 2029 of the sustained production phase. Year 2030 was calculated as the worst-case year for the sustained production phase in the EIS.
- Table 4.10 for Year 2044 of the ramp-down phase. Year 2040 was calculated as the worst-case year for the ramp-down phase in the EIS.

Table 4.8: Comparison of Forecast GHG Emissions for the Ramp-Up Phase (Worst-Case Year 2019)

Category	Activity	Emissions [tonnes CO_2-e /annum] [a]		Variation	Explanations for Variation in Estimated Emissions
		Original EIS	SREIS		
RAMP-UP - SCOPE 1 EMISSIONS					
Fuel Combustion	Coal seam gas combusted in gas-driven generators to provide temporary power to wells and CGPFs	1,826,858	299,554	-82%	On-site power generation from CSG was selected as the primary permanent source of power for the EIS. For the SREIS, this option is retained as a temporary power supply option for the CGPFs and wells until a connection to the grid is made. Based on the refined project description, electricity from the main grid will be used to meet all permanent power requirements of the facilities and wells. The significant reduction in combustion emissions is due to refined annual power requirements for all facilities and wells (as a result of advances in field development planning). For the EIS, all power requirements were conservatively assumed to be met using 10% of the gas production plateau (i.e. 97 TJ/day).
	Diesel combustion in generators to provide power for construction activities		34,237		
	Diesel combustion in light vehicles and heavy vehicles	4,820	31,835	+560%	The peak construction workforce is anticipated to be more than doubled compared to the workforce estimated at the time of the EIS. In addition, twice as many wells are expected to be commissioned in 2019 for the SREIS. As a result, emissions from vehicles increased significantly.
Land Clearing	Land clearing	26,418	31,416	+19%	For the SREIS, twice as many wells are expected to be commissioned in 2019. This is offset somewhat by a reduction in the land clearing footprint due to the reduction in the overall number of wells and the introduction of multi-well pads which include an average of nine wells (single well option only was assessed for the EIS).
Fugitive Emissions	Ramp-up flaring	0	82,839		No ramp-up flaring was expected in 2019 for the EIS.
	Maintenance flaring	260,836	251,199	-4%	For the SREIS, there is an anticipated increase of 20% in the average quantity of maintenance losses from the CGPFs. However, eight facilities (CGPFs or integrated processing facilities) were to be commissioned in 2019 in the EIS whereas seven CGPFs are to be commissioned in the SREIS. Note that pilot flaring was included in the EIS emission estimates and is now excluded from the SREIS emission estimates.

Category	Activity	Emissions [tonnes CO_2-e /annum] [a]		Variation	Explanations for Variation in Estimated Emissions
		Original EIS	SREIS		
	Facility-level fugitive emissions (assumed to include high point vents)	223,931	200,310	-11%	The revised quantity of CSG throughput is 6% lower than the quantity predicted for the EIS. An additional 0.01% gas losses (based on gas throughput) from the water gathering system (high point vents) was also included in the EIS. However, for the SREIS, it is assumed that these emissions are accounted for in the facility-average fugitive emission factor, in accordance with current reporting convention.
	Venting from routine and non-routine activities from equipment and low pressure vents	18,801	267,448	+1323%	Additional venting emissions sources were included in the SREIS based on their historical proportion to Arrow's total gas production, sourced from the 2011/2012 NGER inventory. This approach should provide a comprehensive and representative inventory of venting emissions as it is based on data collected from Arrow's current operating gas field and gas processing facilities.
RAMP-UP - SCOPE 2 EMISSIONS					
Energy Consumption	Electricity supplied to facilities and wells (permanent power supply option)	216,467	1,082,089	+400%	The increase in scope 2 emissions is approximately proportional to the increased consumption of electricity from the grid. Note that the default scope 2 emission factor for Queensland decreased by 3% since the submission of the EIS.
RAMP-UP - SCOPE 3 EMISSIONS					
Energy Consumption/ Production	End-use (combustion of CSG produced)	16,223,842	14,941,496	-8%	The reduction in scope 3 emissions for the combustion of CSG produced is directly proportional to the reduction in the revised quantity of CSG that will be produced during Year 2019.
	Full fuel cycle (diesel)	365	5,017	+1273%	Available data now allow for diesel combustion in generators for construction power to be included in the inventory. For the EIS, it was conservatively assumed that the construction power requirements would be met through on-site gas-driven generators. This increase in emissions is also due to an increase in diesel consumption by vehicles.

Category	Activity	Emissions [tonnes CO_2-e /annum] [a]		Variation	Explanations for Variation in Estimated Emissions
		Original EIS	SREIS		
	Full fuel cycle (electricity)	31,619	150,989	+378%	The increase in scope 3 emissions for full fuel cycle of electricity is approximately proportional to the increased consumption of electricity from the grid. Note that the default scope 3 emission factor for Queensland decreased by 8% since the submission of the EIS.
	Third party infrastructure - CSG transmission to Arrow LNG Plant	8,054	6,624	-18%	The length of the transmission pipeline between the Surat Gas project and the Arrow LNG plant was revised. It was originally assumed that the transmission pipeline would originate from Dalby but it is now known to originate from Wandoan.
	Third party infrastructure - CSG downstream processing at Arrow LNG Plant	2,149,526	736,135	-66%	The revised quantity of CSG that will be exported to the Arrow LNG plant is 8% lower than the quantity predicted for the EIS. The scope 1 and scope 2 emissions generated by the Arrow LNG Project correspond to the scope 3 emissions associated with downstream processing of the gas produced by the Surat Gas Project. For the EIS, downstream emissions associated with the worst-case scenario (i.e., "all electrical" scenario) considered for the Arrow LNG Project EIS were used. For the SREIS, downstream emissions associated with the revised worst-case scenario (i.e., "partial auxiliary power import case") considered for the Arrow LNG Project SREIS were used, which were 67% lower than the Arrow LNG Project EIS emissions.
TOTAL SCOPE 1 EMISSIONS		**2,361,663**	**1,198,838**	-49%	The overall decrease in scope 1 emissions is mainly due to the usage of electricity from the grid as a permanent power supply option and the decrease in total power requirement for all facilities and wells.
TOTAL SCOPE 2 EMISSIONS		**216,467**	**1,082,089**	+400%	The increase in scope 2 emissions is proportional to the increased consumption of electricity from the grid.
TOTAL SCOPE 1 AND SCOPE 2 EMISSIONS		**2,578,130**	**2,280,927**	-12%	Despite using a conservative approach in selecting electricity from the grid as a permanent power supply for all facilities and wells, there is an overall decrease in total scope 1 and scope 2 emissions in comparison to the EIS. This is because significantly lower refined annual power requirements for all facilities and wells were supplied for the SREIS as a result of advances in field development planning.

Category	Activity	Emissions [tonnes CO_2-e /annum] [a]		Variation	Explanations for Variation in Estimated Emissions
		Original EIS	SREIS		
TOTAL SCOPE 3 EMISSIONS		**18,413,406**	**15,840,260**	-14%	The overall decrease in scope 3 emissions is mainly due to the reduction in the revised quantity of CSG that will be produced in 2019 and the decrease in downstream emissions generated at the Arrow LNG plant for the processing of the gas.
LIFE CYCLE EMISSIONS		**20,991,537**	**18,121,188**	-14%	The overall decrease in life cycle emissions is proportional to the overall decrease in scope 3 emissions, which are the most significant emissions included in the inventory.

a The emissions presented in this table were rounded to the nearest tonne CO_2-e and as a result, the combined emissions for all individual emissions sources might not correspond to the total scope 1, scope 2 and scope 3 emissions presented.

Table 4.9: Comparison of Forecast GHG Emissions for the Sustained Production Phase (Worst-Case Year 2029)

Category	Activity	Emissions [tonnes CO_2-e /annum] [a]		Variation	Explanations for Variation in Estimated Emissions
		Original EIS	SREIS		
SUSTAINED PRODUCTION - SCOPE 1 EMISSIONS					
Fuel Combustion	Coal seam gas combusted in gas-driven generators to provide temporary power to wells and CGPFs	1,852,938	8,837	-99%	On-site power generation from CSG was selected as the primary permanent source of power for the EIS. For the SREIS, this option is now only retained as a temporary power supply option for the CGPFs and wells until a connection to the grid is made. Based on the refined project description, electricity from the main grid will now be used to meet all permanent power requirements of the facilities and wells. For the SREIS, all CGPFs are anticipated to be commissioned by Year 2029 and therefore, temporary power will only be required to be supplied to the new wells. The significant reduction in combustion emissions is due to revised annual power requirements for all facilities and wells (as a result of advances in field development planning). Previously, all power requirements were conservatively assumed to be met using 10% of the gas production plateau (i.e. 97 TJ/day).
	Diesel combustion in generators to provide construction power and in drills		18,782		
	Diesel combustion in light vehicles, heavy vehicles for construction activities	14,549	32,063	+120%	The increase in emissions is due to the use of refined traffic data.
Land Clearing	Land clearing	87,465	14,733	-83%	For the SREIS, there will be a decrease of 73% in the number of wells anticipated to be commissioned between the EIS worst-case year and the SREIS worst-case year. There will also be a reduction in the land clearing footprint due to the reduction in the total number of wells and the introduction of multi-well pads which include an average of nine wells (single wells option only for the EIS).
Fugitive Emissions	Ramp-up flaring	41,235	N/A	N/A	For the SREIS, no ramp-up flaring is anticipated for Year 2029 as all CGPFs will be commissioned by this stage of the project.

Category	Activity	Emissions [tonnes CO_2-e /annum] [a]		Variation	Explanations for Variation in Estimated Emissions
		Original EIS	SREIS		
	Maintenance flaring	498,562	287,085	-42%	There is an anticipated increase of 20% in the average quantity of maintenance losses from the CGPFs. However, in 2029, eight CGPFs are predicted to be commissioned (in comparison with ten in the EIS). In addition, emissions from maintenance flaring were included for all FCFs in the EIS while maintenance flaring is only considered for the CGPFs in the SREIS. Note that pilot flaring was included in the EIS emission estimates and is now excluded from the SREIS emission estimates.
	Facility-level fugitive emissions (assumed to include high point vents)	253,680	292,345	+15%	The revised quantity of CSG throughput is 21% higher than the quantity predicted for the EIS. However, an additional 0.01% gas losses (based on gas throughput) from the water gathering system (high point vents) was also included in the EIS. However, for the SREIS, it is assumed that these emissions are accounted for in the facility-average fugitive emission factor, in accordance with current reporting convention.
	Venting from routine and non-routine activities from equipment and low pressure vents	58,615	399,326	+581%	Additional venting emissions sources were included for the SREIS based on their historical proportion to Arrow's total gas production, sourced from the 2011/2012 NGER inventory. This approach should provide a comprehensive and representative inventory of venting emissions as it is based on data collected from Arrow's current operating gas field and gas processing facilities.
SUSTAINED PRODUCTION - SCOPE 2 EMISSIONS					
Energy Consumption	Electricity supplied to facilities and wells (permanent power supply option)	678,053	2,590,340	+282%	The increase in scope 2 emissions is approximately proportional to the increased consumption of electricity from the grid. Note that the default scope 2 emission factor for Queensland slightly decreased by 3% since the submission of the EIS.
SUSTAINED PRODUCTION - SCOPE 3 EMISSIONS					

Category	Activity	Emissions [tonnes CO_2-e /annum] [a]		Variation	Explanations for Variation in Estimated Emissions
		Original EIS	SREIS		
Energy Consumption/ Production	End-use (combustion of CSG produced)	18,172,329	22,309,571	+23%	The increase in scope 3 emissions for combustion of CSG produced is directly proportional to the increase in the quantity of CSG produced between the EIS worst-case year and the SREIS worst-case year.
	Full fuel cycle (diesel)	1,103	3,859	+250%	Available data now allows for diesel combustion in generators for construction power to be included in the inventory. It was previously assumed that the construction power requirements would be met through on-site gas-driven generators. This increase in emissions is also due to an increase in diesel consumption by vehicles.
	Full fuel cycle (electricity)	99,041	361,443	+265%	The increase in scope 3 emissions for full fuel cycle of electricity is approximately proportional to the increased consumption of electricity from the grid. Note that the default scope 3 emission factor for Queensland decreased by 8% since the submission of the EIS.
	Third party infrastructure - CSG transmission to Arrow LNG Plant	8,054	6,624	-18%	The length of the transmission pipeline between the Surat Gas project and the Arrow LNG plant was revised. It was originally assumed that the transmission pipeline would originate from Dalby but it is now known to originate from Wandoan.
	Third party infrastructure - CSG downstream processing at Arrow LNG Plant	4,815,369	2,198,287	-54%	The revised quantity of CSG that will be exported to the Arrow LNG plant is 23% higher than the quantity predicted for the EIS. The scope 1 and scope 2 emissions generated by the Arrow LNG Project correspond to the scope 3 emissions associated with downstream processing of the gas produced by the Surat Gas Project. For the EIS, downstream emissions associated with the worst-case scenario (i.e., "all electrical" scenario) considered for the Arrow LNG Project EIS were used. For the SREIS, downstream emissions associated with the revised worst-case scenario (i.e., "partial auxiliary power import case") considered for the Arrow LNG Project SREIS were used, which were 67% lower than the Arrow LNG Project EIS emissions.

Category	Activity	Emissions [tonnes CO_2-e /annum] [a]		Variation	Explanations for Variation in Estimated Emissions
		Original EIS	SREIS		
TOTAL SCOPE 1 EMISSIONS		**2,807,044**	**1,053,171**	-62%	The overall decrease in scope 1 emissions is mainly due to the usage of electricity from the grid as a permanent power supply option and the decrease in total power requirement for all facilities and wells.
TOTAL SCOPE 2 EMISSIONS		**678,053**	**2,590,340**	+282%	The increase in scope 2 emissions is proportional to the increased consumption of electricity from the grid.
TOTAL SCOPE 1 AND SCOPE 2 EMISSIONS		**3,485,097**	**3,643,511**	+5%	Despite using a conservative approach in selecting electricity from the grid as a permanent power supply for all facilities and wells, only a slight overall increase in total scope 1 and scope 2 emissions is anticipated in comparison to the EIS. This is because lower refined annual power requirements for all facilities and wells were supplied for the SREIS as a result of advances in field development planning.
TOTAL SCOPE 3 EMISSIONS		**23,095,897**	**24,879,784**	+8%	The overall increase in scope 3 emissions is mainly due to the increase in the revised quantity of CSG that will be produced in 2029 which is offset by the decrease in downstream emissions generated at the Arrow LNG plant for the processing of the gas.
LIFE CYCLE EMISSIONS		**26,580,994**	**28,523,295**	+7%	The overall increase in life cycle emissions is mainly due to the overall increase in scope 3 emissions, which are the most significant emissions included in the inventory.

a The emissions presented in this table were rounded to the nearest tonne CO_2-e and as a result, the combined emissions for all individual emissions sources might not correspond to the total scope 1, scope 2 and scope 3 emissions presented.

Table 4.10: Comparison of Forecast GHG Emissions for the Ramp-Down Phase (Worst-Case Year 2044)

Category	Activity	Emissions [tonnes CO_2-e /annum] [a]		Variation	Explanations for Variation in Estimated Emissions
		Original EIS	SREIS		
RAMP-DOWN - SCOPE 1 EMISSIONS					
Fuel Combustion	Coal seam gas combusted in gas-driven generators to provide temporary power to wells and CGPFs	1,817,339	0	-100%	On-site power generation from CSG was selected as the primary permanent source of power for the EIS. For the SREIS, this option is now only retained as a temporary power supply option for the CGPFs and wells until a connection to the grid is made. Based on the refined project description, electricity from the main grid will now be used to meet all permanent power requirements of the facilities and wells. No on-site generation from CSG will occur in 2044 as well commissioning will end in 2042.
	Diesel combustion in generators to provide construction power and in drills		3,970		
	Diesel combustion in light vehicles, heavy vehicles for construction activities	13,283	21,541	+62%	The increase in emissions is due to the use of refined traffic data.
Land Clearing	Land clearing	N/A	N/A	N/A	No land clearing will occur during the decommissioning phase.
Fugitive Emissions	Ramp-up flaring	N/A	N/A	N/A	No ramp-up flaring will occur during the decommissioning phase.
	Maintenance flaring	536,862	0	-100%	In 2044, all the CGPFs are anticipated to be decommissioned. The decrease in emissions is due to the fact that the worst-case year for the ramp-down phase was Year 2040 for the EIS while it is Year 2044 for the SREIS. Note that pilot flaring was included in the original emission estimates while this emission source is now excluded from the revised emission estimates.

Category	Activity	Emissions [tonnes CO_2-e /annum] [a]		Variation	Explanations for Variation in Estimated Emissions
		Original EIS	SREIS		
	Facility-level fugitive emissions (assumed to include high point vents)	224,649	55,802	-75%	The revised quantity of CSG throughput is 73% lower than the quantity predicted for the EIS. An additional 0.01% gas losses (based on gas throughput) from the water gathering system (high point vents) was also included in the EIS. However, for the SREIS, it is assumed that these emissions are accounted for in the facility-average fugitive emission factor, in accordance with current reporting convention.
	Venting from routine and non-routine activities from equipment and low pressure vents	26,985	77,181	+186%	Additional venting emissions sources were included for the SREIS based on their historical proportion to Arrow's total gas production, sourced from the 2011/2012 NGER inventory. This approach should provide a comprehensive and representative inventory of venting emissions as it is based on data collected from Arrow's current operating gas field and gas processing facilities.
RAMP-DOWN - SCOPE 2 EMISSIONS					
Energy Consumption	Electricity supplied to facilities and wells (permanent power supply option)	305,229	529,081	+73%	Despite a reduction of 38% in the number of wells between the EIS worst-case year and the SREIS worst-case year, scope 2 emissions are now higher due to an increased consumption of electricity from the Queensland's grid. Note that the default scope 2 emission factor for Queensland decreased by 3% since the submission of the EIS.
RAMP-DOWN - SCOPE 3 EMISSIONS					
Energy Consumption/ Production	End-use (combustion of CSG produced)	16,018,037	4,311,220	-73%	The decrease in scope 3 emissions for the combustion of CSG produced is directly proportional to the decrease in the quantity of CSG produced between the previously selected worst-case year and the revised worst-case year.

Category	Activity	Emissions [tonnes CO_2-e /annum] [a]		Variation	Explanations for Variation in Estimated Emissions
		Original EIS	SREIS		
	Full fuel cycle (diesel)	1,007	1,936	+92%	Available data now allows for diesel combustion in generators for decommissioning/ rehabilitation power to be included in the inventory. It was previously conservatively assumed that the construction power requirements would be met through on-site gas-driven generators. This increase in emissions is also due to an increase in diesel consumption by vehicles.
	Full fuel cycle (electricity)	44,584	73,825	+66%	The increase in scope 3 emissions is associated with the increased consumption of electricity from the grid between the EIS worst-case year and the SREIS worst-case year. Note that the default scope 3 emission factor for Queensland decreased by 8% since the submission of the EIS.
	Third party infrastructure - CSG transmission to Arrow LNG Plant	8,054	6,624	-18%	The length of the transmission pipeline between the Surat Gas project and the Arrow LNG plant was revised. It was originally assumed that the transmission pipeline would originate from Dalby but it is now known to originate from Wandoan.
	Third party infrastructure - CSG downstream processing at Arrow LNG Plant	4,244,517	424,809	-90%	The revised quantity of CSG that will be exported to the Arrow LNG plant is 73% lower than the quantity predicted for the EIS selected worst-case year. The scope 1 and scope 2 emissions generated by the Arrow LNG Project correspond to the scope 3 emissions associated with downstream processing of the gas produced by the Surat Gas Project. For the EIS, downstream emissions associated with the worst-case scenario (i.e., "all electrical" scenario) considered for the Arrow LNG Project EIS were used. For the SREIS, downstream emissions associated with the revised worst-case scenario (i.e., "partial auxiliary power import case") considered for the Arrow LNG Project SREIS were used, which were 67% lower than the Arrow LNG Project EIS emissions.
TOTAL SCOPE 1 EMISSIONS		**2,619,118**	**158,493**	-94%	The overall decrease in scope 1 emissions is mainly due to the usage of electricity from the grid as a permanent power supply option and the decrease in total power requirement for all facilities and wells.

Category	Activity	Emissions [tonnes CO_2-e /annum] [a]		Variation	Explanations for Variation in Estimated Emissions
		Original EIS	SREIS		
TOTAL SCOPE 2 EMISSIONS		**305,229**	**529,081**	+73%	The increase in scope 2 emissions is proportional to the increased consumption of electricity from the grid.
TOTAL SCOPE 1 AND SCOPE 2 EMISSIONS		**2,924,347**	**687,574**	-76%	Despite using a conservative approach in selecting electricity from the grid as a permanent power supply for all facilities and wells, there is an overall decrease in total scope 1 and scope 2 emissions in comparison to the EIS. This is because lower refined annual power requirements for all facilities and wells were supplied for the SREIS as a result of advances in field development planning.
TOTAL SCOPE 3 EMISSIONS		**20,316,199**	**4,818,413**	-76%	The overall decrease in scope 3 emissions is mainly due to the reduction in the revised quantity of CSG that will be produced between the SREIS worst-case year and the EIS worst-case year, and the decrease in indirect emissions generated at the Arrow LNG plant for the downstream processing of the gas.
OVERALL EMISSIONS		**23,240,547**	**5,505,988**	-76%	The overall decrease in life cycle emissions is proportional to the overall decrease in scope 3 emissions, which are the most significant emissions included in the inventory.

a The emissions presented in this table were rounded to the nearest tonne CO_2-e and as a result, the combined emissions for all individual emissions sources might not correspond to the total scope 1, scope 2 and scope 3 emissions presented.

5 ASSESSMENT OF IMPACT OF GHG EMISSIONS FROM THE SURAT GAS PROJECT

Table 5.1 and Table 5.2 present the emission estimates for the EIS and the SREIS associated with the worst-case years and the cumulative emissions for the life of the project. As shown in Table 5.2, the revised life cycle emissions (i.e. scope 1, scope 2 and scope 3) are anticipated to be approximately 14% lower for the ramp-up worst-case year and approximately 76% lower for the ramp-down worst-case year than the estimated emissions for the EIS. However, for the sustained production worst-case year, the revised emissions are predicted to be approximately 7% higher than the emissions estimated for the EIS.

The revised total cumulative emissions were estimated to be approximately 533.8 Mt CO_2-e in comparison to an estimate of 675.6 Mt CO_2-e associated with the EIS (which was not presented in the EIS). This corresponds to a 21% decrease in total cumulative emissions. Figure 2 presents the cumulative scope 1, scope 2 and scope 3 emissions estimated for the EIS and for the SREIS.

Table 5.1: Summary of Estimated Emissions for the EIS

Phase	EIS Worst-Case Year	EIS Emissions Estimates [a] [Mt CO_2-e/year]			
		Scope 1	Scope 2	Scope 3	TOTAL
Ramp-up	**2019**	2.4	0.2	18.4	**21.0**
Sustained Production	**2030**	2.8	0.7	23.1	**26.6**
Ramp-down	**2040**	2.6	0.3	20.3	**23.2**
Cumulative total (2013 - 2047)		**84.5**	**11.8**	**579.3**	**675.6**

a The emissions are presented using one decimal place and as a result, the combined scope 1, scope 2 and scope 3 emissions might not correspond to the total emissions presented for each phase.

Table 5.2: Summary of Estimated Emissions for the SREIS

Scenario	SREIS Worst-Case Year	SREIS Emissions Estimates [a] [Mt CO_2-e/year]				Variation between EIS and SREIS Emissions
		Scope 1	Scope 2	Scope 3	TOTAL	
Ramp-up	**2019**	1.2	1.1	15.8	**18.1**	-14%
Sustained Production	**2029**	1.1	2.6	24.9	**28.5**	+7%
Ramp-down	**2044**	0.2	0.5	4.8	**5.5**	-76%
Cumulative total (2014 - 2048)		**25.2**	**55.7**	**452.9**	**533.8**	-21%

a The emissions are presented using one decimal place and as a result, the combined scope 1, scope 2 and scope 3 emissions might not correspond to the total emissions presented for each phase.

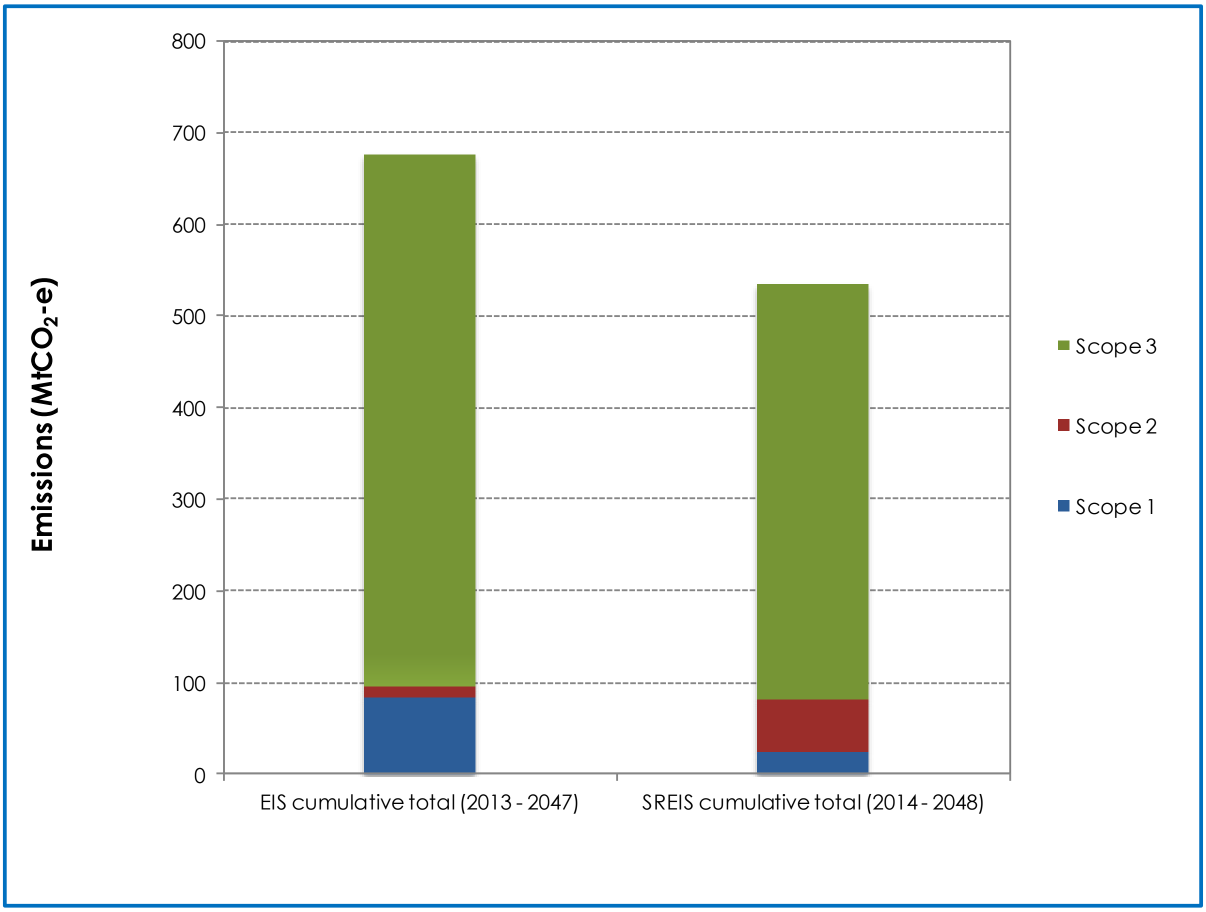

Figure 2: Comparison of Cumulative Emissions between the EIS and the SREIS

The revised direct (scope 1) and indirect (scope 2) greenhouse emissions for worst-case year 2029 were estimated to be approximately 3.6 Mt CO_2-e/annum (refer to Table 5.3). These emissions are approximately 4.5% higher than the estimated emissions for worst-case year 2030 in the EIS (approximately 3.5 Mt CO_2-e/annum) for a higher forecast quantity of CSG produced (i.e., approximately 23%). The majority of the emissions generated will now be associated with electricity consumption from the grid as opposed to gas combustion, resulting in Arrow presenting its alternative power supply option (connection to Queensland's electricity grid) as its preferred option in the SREIS.

The scope 1 and scope 2 emissions associated with worst-case year 2029 are expected to contribute approximately 0.012% to Global 2009 emissions[e]. These emissions also represent approximately 0.89% of Australia's 2009 emissions for the energy sector and around 0.69% of the Australian Government's 2020 emissions target. Australia's total emission inventory in 2009 represents approximately 1.3% of global greenhouse emissions (UNSD, 2012).

Combined scope 1 and scope 2 emissions are minor (approximately 13% of the life cycle emissions) in comparison with scope 3 emissions, which will primarily be due to greenhouse emissions associated with the end use of the product fuel.

[e] The EIS compared emissions to Global 2007 emissions. Comparisons are made to Global 2009 emissions in the SREIS as more recent Global greenhouse gas emission estimates are now available (UNSD, 2012).

The refined project design results in estimated cumulative scope 1 and scope 2 emissions for the life of the project of 81 Mt CO_2-e, which is 16% lower than the estimated cumulative emissions of 96 Mt CO_2-e associated with the design at the time of the EIS.

The changes in design for the project, in particular the change in permanent power supply (i.e., self-generation using CSG was assessed in the EIS while electricity from the grid is now assessed in the SREIS), were expected to materially affect the annual and cumulative scope 1 and scope 2 emissions. However, lower refined annual power requirements for the facilities and wells were provided for the SREIS. Consequently, despite the difference in contribution from scope 1 and scope 2 emissions, the revised annual total scope 1 and scope 2 emissions for worst-case year 2029 are comparable to the emissions presented in the EIS for worst-case year 2030. There was however, a substantial reduction in cumulative emissions due to lower annual power requirements, in particular for the ramp-up and ramp-down phases.

Based solely on the emissions for worst-case year 2029, it is predicted that the potential impacts from the project will be slightly higher than those predicted in the EIS, for a higher forecast quantity of CSG produced. The impacts associated with the project, with respect to climate change, will be in proportion with the project's contribution to global greenhouse gas emissions. Therefore, the potential impacts associated with climate change directly attributable to the project on a global scale can be expected to be negligible.

Table 5.3: Comparison of Forecast Worst-Case Emissions from the Project with Large Scale Emissions

Geographic Coverage	Source Coverage	Timescale	Emissions (Mt CO_2-e)
Global [a]	Consumption of fossil fuels	2009	30,086
Australia [b]	Energy sector	2009	420.3
Australia [c]	All sectors	2020 (Australian Government's target)	530
Queensland [d]	Total GHG emissions including Land Use, Land Use Change and Forestry (LULUCF) activities	2009	155.1
Surat Gas Project [f]	**Scope 1 emissions (Year 2029) [e]**	**Estimated annual**	**1.1**
	Scope 2 emissions (Year 2029) [e]	**Estimated annual**	**2.6**
	Scope 1 & 2 emissions (Year 2029)	**Estimated annual**	**3.6**

a UNSD (2012).
b DCCEE (2011) - Energy sector includes stationary energy, transport and fugitive emissions.
c Based on 2000 Australian emissions levels for all sectors = 558 Mt CO_2-e (DCCEE, 2010). The Government has committed to reduce carbon pollution by 5 per cent from 2000 levels by 2020 (Australian Government, 2011).
d DCCEE (2011) - Emissions including land use change.
e Refer to Table 4.5.
f The figures are presented using one decimal place for comparison with the large scale emissions; as a result, the combined scope 1 and scope 2 emissions might not correspond to the individual scope 1 and scope 2 emissions presented.

6 REVISED BENCHMARKING OF COAL SEAM GAS

6.1 Life Cycle Emissions of Coal Seam Gas

Table 6.1 presents the life cycle emissions of the gas produced by the project per unit of thermal energy produced (e.g., GJ) in comparison to other typical fuels. The site-specific scope 1 and scope 3 emissions factors were derived for the worst-case year of the project (i.e., Year 2029).

The site-specific scope 1 emission factor, which is only associated with the direct combustion of the product CSG by end-users, was estimated based on the expected composition of the gas. Emissions from the combustion of the product gas from the project correspond to approximately half of the emissions generated by black coal combustion per unit of thermal energy; e.g., 49.63 kg CO_2-e/GJ versus 88.43 kg CO_2-e/GJ (for black coal).

The site-specific scope 3 emission factor accounts for all indirect emissions induced by any associated upstream activities; such as the extraction, processing and transport of the gas. CSG upstream activities generate 26 times more emissions than brown coal upstream activities, and almost two times more emissions than black coal upstream activities per unit of thermal energy. The process of producing coal seam gas leads to higher emissions than producing the same quantity on a thermal basis of black or brown coal.

The life cycle emissions of CSG per unit of thermal energy (i.e., combined scope 1 and scope 3 emission factors) is, however, lower than the life cycle emissions of brown coal, black coal and natural gas per unit of thermal energy (refer to Figure 3). This shows that the CSG that will be produced by the project is the least emission intensive of all the fossil fuels considered; i.e., overall, its use will produce less direct and indirect emissions for a given quantity of gas in GJ. For example, the life cycle emissions associated with the combustion of CSG from this project will be approximately 38% lower than the life cycle emissions associated with the combustion of brown or black coal.

Table 6.1: Life Cycle Emissions of Common Fuels in Comparison to the CSG Product from the Project

Fuel	Emission Factor		Life Cycle Emissions per Unit of Energy of the Fuel [c]
	Scope 1	Scope 3	
	(kg CO_2-e/ GJ)		
Brown coal	93.11 [a]	0.3 [d]	**93**
Black coal	88.43 [a]	4.6 [d]	**93**
Natural gas	51.33 [b]	7.8 [e]	**59**
Coal seam gas - Surat Gas Project (worst-case year 2029)	49.63 [f]	8.4	**58**

a Table 1 DCCEE (2012a).
b Table 2, DCCEE (2012a).
c Sum of direct scope 1 emission factor and indirect scope 3 emission factor.
d Table 36, DCCEE (2012a).
e Table 37, DCCEE (2012a) – non-metro factor (Queensland) selected. Metro is defined as located on or east of the dividing range in NSW, including Canberra and Queanbeyan, Melbourne, Brisbane, Adelaide or Perth. Otherwise, the non-metro factor should be used.
f The site-specific scope 1 emission factor was estimated based on the CSG composition (refer to Table 1.1) using method 2 of division 2.3.3 of the *NGER Technical Guidelines* (DCCEE, 2012b). However, scope 1 emissions associated with the project were calculated based on the default emission factor provided in the NGA factors (DCCEE, 2012a) as a conservative approach.

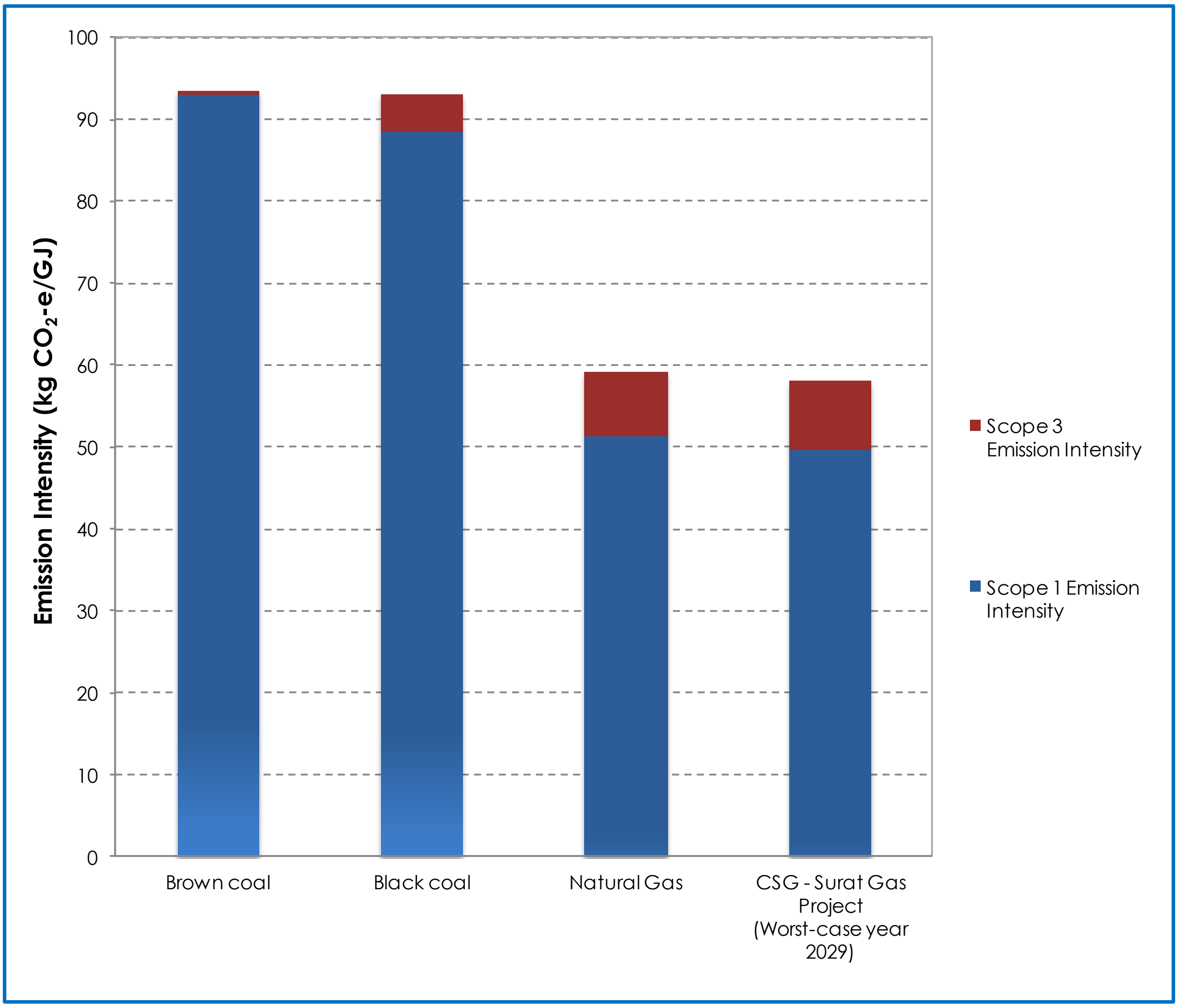

Figure 3: Emission Intensity of CSG Produced for the Surat Gas Project versus Common Fuels

6.2 Emissions per MWh of Exported Electricity

Table 6.2 presents full-cycle emissions per MWh of exported electricity, which incorporate scope 1 and scope 3 emission factors and the thermal efficiency of the power cycle used to convert the heat produced from fuel combustion to electricity. Based on Best Available Technology (BAT) standards for power cycle efficiencies (AGO, 2006), a gas-fired combined cycle gas turbine (GT) power configuration (in the absence of BAT standards for gas engines) produces emissions per MWh exported equal to (refer to Figure 4):

- 39% of those produced by a brown coal-fired ultra super critical power station
- 50% of those produced by a black coal-fired ultra super critical power station.

Table 6.2: Scope 1 and Scope 3 Emissions per MWh of Electricity Generated

Power cycle	Fuel	Efficiency [a] (%)	Scope 1 EF (kg CO_2-e/ GJ)	Scope 3 EF (kg CO_2-e/ GJ)	Emissions per MWh of Electricity [b] (kg CO_2-e /MWh)
USC - wet cooled	Brown coal	32.3	93.11 [c]	0.3 [e]	**1,041**
USC - wet cooled	Black coal	41.2	88.43 [c]	4.6 [e]	**813**
Open cycle GT	Gas	33.1	51.33 [d]	7.8 [f]	**643**
Combined cycle GT - wet cooled	Gas	51.6	51.33	7.8 [f]	**413**
Open cycle GT	CSG - Surat Gas Project	33.1	49.63 [g]	8.4	**631**
Combined cycle GT - wet cooled	CSG – Surat Gas Project	51.6	49.63 [g]	8.4	**405**

Note: USC – Ultra Super Critical; GT – Gas Turbine;

a Thermal efficiencies based on BAT standards sourced from the Australian Greenhouse Office (AGO, 2006).

b Based on 1 MWh = 3.6 GJ.

c Table 1 DCCEE (2012a).

d Table 2, DCCEE (2012a).

e Table 36, DCCEE (2012a).

f Table 37, DCCEE (2012a) – non-metro factor (Queensland) selected. Metro is defined as located on or east of the dividing range in NSW, including Canberra and Queanbeyan, Melbourne, Brisbane, Adelaide or Perth. Otherwise, the non-metro factor should be used.

g The site-specific scope 1 emission factor was estimated based on the CSG composition (refer to Table 1.1) using method 2 of division 2.3.3 of the *NGER Technical Guidelines* (DCCEE, 2012b). However, scope 1 emissions associated with the project were calculated based on the default emission factor provided in the NGA factors (DCCEE, 2012a) as a conservative approach.

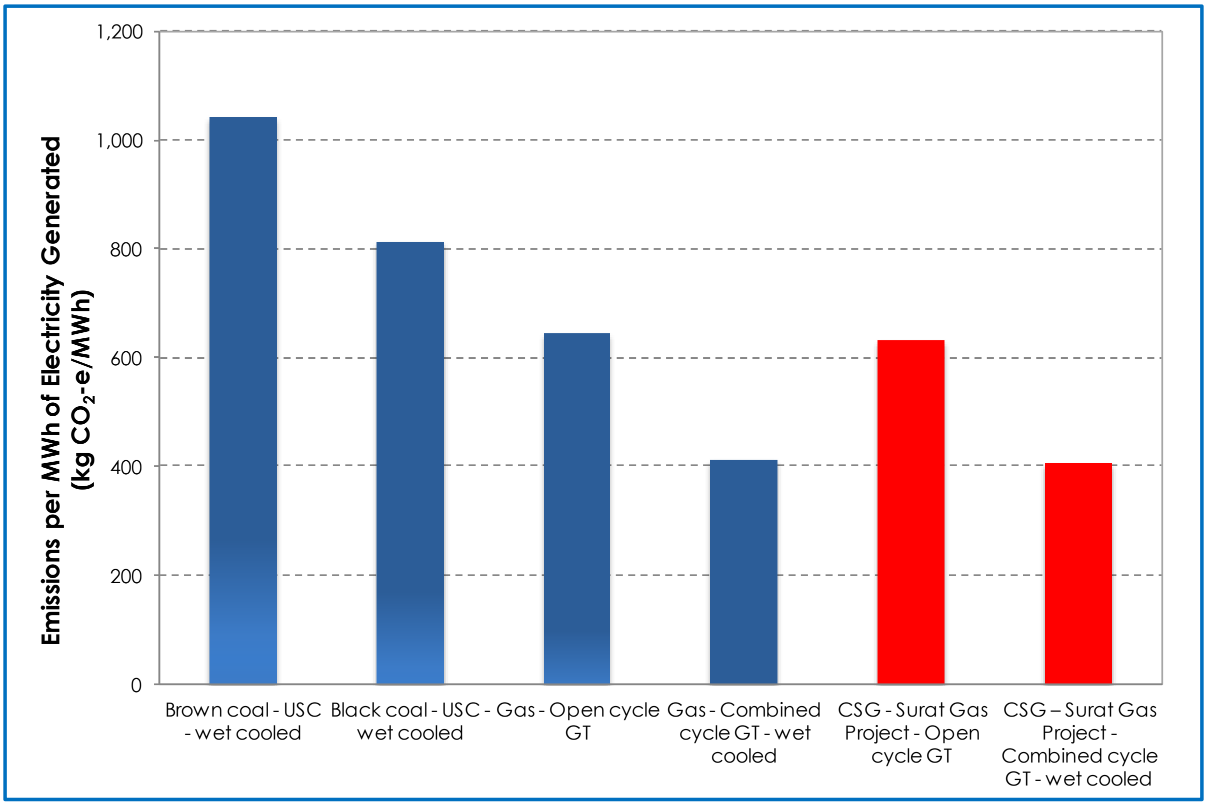

Figure 4: Comparison of Emissions per MWh of Electricity Generated

7 MANAGEMENT MEASURES

The mitigation measures adopted for the EIS presented in Appendix D of the EIS are still valid; such as minimising flaring and eliminating venting of gas where possible.

The overall estimated emissions intensity (kg CO_2-e/GJ of CSG) was shown to be the lowest amongst fossil fuels that are commonly used. In addition, Arrow has committed to the ongoing measurement and monitoring of the project's emissions, and energy consumption and production, through a range of schemes, including:

- the National Greenhouse and Energy Reporting (NGER) System
- the Energy Efficiency Opportunities Program (EEO).

It is also recommended that Arrow continues to investigate GHG abatement measures for ongoing monitoring and maintenance programs at the site-level, reducing fugitive emissions from equipment leaks, and high-level investigations into new technologies as they become available.

In addition to those measures, as consumption of electricity is an important contributor to life cycle emissions, it is recommended that electrical equipment (e.g. particularly engines, turbines, pumps and compressors) is regularly monitored and maintained, as part of a comprehensive energy efficiency improvement program for the project. These measures should be consistent with EEO program activities.

Arrow is also a direct participant in the carbon price mechanism. This means that, in accordance with the *Clean Energy Act 2011,* Arrow must, annually, report its emissions and submit permits to acquit its liability. The availability and price of these permits are dictated by Australia's emission targets. As such, the project's activities will be consistent with Australia's current policy to reduce greenhouse gas emissions.

8 CONCLUSIONS

The supplementary greenhouse gas impact assessment describes the revised estimated greenhouse emissions from the construction, operation and decommissioning/rehabilitation of the project, based on the recent refinements made to the project description, and predicts the potential impacts associated with these emissions.

The revised direct (scope 1) and indirect (scope 2) greenhouse emissions for worst-case year 2029 were estimated to be approximately 3.6 Mt CO_2-e/annum. These emissions are approximately 4.5% higher than the estimated emissions for worst-case year 2030 in the EIS, for a higher forecast quantity of CSG produced (i.e., approximately 23%). The majority of the emissions generated will now be associated with electricity consumption from the grid as opposed to gas combustion, as a result of Arrow presenting its alternative power supply option (connection to Queensland's electricity grid) as its preferred option in the SREIS.

The scope 1 and scope 2 emissions associated with worst-case year 2029 are expected to contribute approximately 0.012% to Global 2009 emissions. These emissions also represent approximately 0.89% of Australia's 2009 emissions for the energy sector and around 0.69% of the Australian Government's 2020 emissions target.

Combined scope 1 and scope 2 emissions are minor (approximately 13% of the life cycle emissions) in comparison with scope 3 emissions, which will primarily be due to greenhouse emissions associated with the end use of the product fuel.

The refined project design results in estimated cumulative scope 1 and scope 2 emissions for the life of the project of 81 Mt CO_2-e, which is 16% lower than the estimated cumulative emissions of 96 Mt CO_2-e associated with the design at the time of the EIS.

Based on the worst-case year (2029) of this assessment, it was determined that combusting coal seam gas for heating or electricity generation purposes emits overall significantly less greenhouse gas emissions over the life cycle (scope 1 and scope 3) per unit of thermal energy produced in comparison with other fossil fuels, particularly coal. For example, the life cycle emissions associated with the combustion of CSG from this project will be approximately 38% lower than the life cycle emissions associated with the combustion of brown or black coal.

The changes in design for the project, in particular the change in permanent power supply (i.e., self-generation using CSG was assessed in the EIS while electricity from the grid is now assessed in the SREIS), were expected to materially affect the annual and cumulative scope 1 and scope 2 emissions. However, lower refined annual power requirements for the facilities and wells were provided for the SREIS. Consequently, despite the difference in contribution from scope 1 and scope 2 emissions, the revised annual total scope 1 and scope 2 emissions for worst-case year 2029 are comparable to the emissions presented in the EIS for worst-case year 2030. There was however, a substantial reduction in cumulative emissions due to lower annual power requirements, in particular for the ramp-up and ramp-down phases.

Based solely on the emissions for worst-case year 2029, it is predicted that the potential impacts from the project will be slightly higher than those predicted in the EIS, for a higher forecast quantity of CSG produced. The impacts associated with the project, with respect to climate change, will be in proportion with the project's contribution to global greenhouse gas emissions. Therefore, the potential impacts associated with climate change directly attributable to the project on a global scale can be expected to be negligible.

Arrow has, however, committed to the ongoing measurement and monitoring of the project's emissions, and energy consumption and production, through a range of schemes, including:

- the National Greenhouse and Energy Reporting (NGER) System
- the Energy Efficiency Opportunities Program (EEO).

It is also recommended that Arrow continues to investigate GHG abatement measures for ongoing monitoring and maintenance programs at the site-level, reducing fugitive emissions from equipment leaks, and high-level investigations into new technologies as they become available.

In addition to those measures, as consumption of electricity is an important contributor to life cycle emissions, it is recommended that electrical equipment (e.g., particularly engines, turbines, pumps and compressors) is regularly monitored and maintained, as part of a comprehensive energy efficiency improvement program for the project. These measures should be consistent with EEO program activities.

Arrow is also direct participant in the carbon price mechanism. This means that, in accordance with the *Clean Energy Act 2011,* Arrow must, annually, report its emissions and submit permits to acquit its liability. The availability and price of these permits are dictated by Australia's emission targets. As such, the project's activities will be consistent with Australia's current policy to reduce greenhouse gas emissions.

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Appendix A ESTIMATION OF EMISSIONS

A.1 WELLS AND GAS PRODUCTION DATA

Data were provided for the time period 2014 – 2048 for the number of wells commissioned and decommissioned in each year, as well as cumulative gas production. The data used for the assessment are provided in Table A.1.

Table A.1: Cumulative Total Gas Production and Cumulative Number of Wells On-Line

Year	Single Wells [a, b]		Cumulative Single Wells [a]	Number of Wells in Multi-well Pads [a]	Multi-well Pads [a]		Cumulative Multi-well Pads [a]	Total Wells [a]		Cumulative Number of Wells [a]	Cumulative Total Gas Production (including domestic gas)	
	(+)	(-)			(+)	(-)		(+)	(-)		(TJ/d) [c]	(TJ/a) [d]
2014	6	0	6	15	2	0	2	21	0	21	80	29,220
2015	7	0	13	16	2	0	3	23	0	44	100	36,525
2016	48	0	61	111	12	0	16	159	0	203	120	43,830
2017	111	0	172	260	29	0	45	371	0	574	130	47,483
2018	122	0	295	286	32	0	76	408	0	982	390	142,448
2019	113	0	408	265	29	0	106	378	0	1,360	797	291,104
2020	123	0	531	288	32	0	138	411	0	1,771	880	321,420
2021	126	0	657	294	33	0	170	420	0	2,191	1,010	368,903
2022	126	0	784	295	33	0	203	421	0	2,612	1,110	405,428
2023	126	0	910	294	33	0	236	420	0	3,032	1,150	420,038
2024	125	0	1,035	293	33	0	268	418	0	3,450	1,215	443,779
2025	101	0	1,136	235	26	0	294	336	0	3,786	1,215	443,779
2026	76	0	1,212	177	20	0	314	253	0	4,039	1,215	443,779
2027	55	0	1,267	129	14	0	328	184	0	4,223	1,215	443,779
2028	64	6	1,325	149	17	2	343	213	21	4,415	1,200	438,300
2029	59	7	1,376	137	15	2	357	196	23	4,588	1,190	434,648
2030	78	48	1,407	183	20	12	365	261	159	4,690	1,150	420,038
2031	71	111	1,367	166	18	29	354	237	371	4,556	1,040	379,860
2032	58	122	1,303	136	15	32	338	194	408	4,342	910	332,378
2033	50	113	1,240	118	13	29	321	168	378	4,132	810	295,853

Year	Single Wells [a, b]		Cumulative Single Wells [a]	Number of Wells in Multi-well Pads [a]	Multi-well Pads [a]		Cumulative Multi-well Pads [a]	Total Wells [a]		Cumulative Number of Wells [a]	Cumulative Total Gas Production (including domestic gas)	
	(+)	(-)			(+)	(-)		(+)	(-)		(TJ/d) [c]	(TJ/a) [d]
2034	49	123	1,165	114	13	32	302	163	411	3,884	680	248,370
2035	36	126	1,075	84	9	33	279	120	420	3,584	600	219,150
2036	36	126	985	84	9	33	255	120	421	3,283	510	186,278
2037	36	126	895	84	9	33	232	120	420	2,983	430	157,058
2038	36	125	806	84	9	33	209	120	418	2,685	370	135,143
2039	36	101	741	84	9	26	192	120	336	2,469	330	120,533
2040	36	76	701	84	9	20	182	120	253	2,336	300	109,575
2041	30	55	676	70	8	14	175	100	184	2,252	280	102,270
2042	8	64	619	18	2	17	161	25	213	2,064	260	94,965
2043	0	59	560	0	0	15	145	0	196	1,868	240	87,660
2044	0	78	482	0	0	20	125	0	261	1,607	230	84,008
2045	0	71	411	0	0	18	107	0	237	1,370	220	80,355
2046	0	58	353	0	0	15	91	0	194	1,176	210	76,703
2047	0	50	302	0	0	13	78	0	168	1,008	200	73,050
2048	0	49	254	0	0	13	66	0	163	845	190	69,398

a Provided by Arrow – Schedule of wellhead and facility commissioning. (+) represents the commissioning of a well/well pad and (-) represents decommissioning of a well/well pad. Note that wells identified in drainage areas (DA) 4, 6 and 12 in the project description were allocated to these areas for modelling purposes only. The location of wells does not affect the outcome of the GHG assessment.

b The number of single wells commissioned correspond to 30% of the total number of wells commissioned each year. As a result, the number of wells presented in this table is a rounded figure.

c Provided by Arrow – Schedule of gas production.

d Pacific Environment's estimation - based on 365 operating days a year.

A.2 CSG MASS BALANCE

As the quantity of processed gas (i.e., gas extracted) was not provided, a mass balance of gas flows which includes gas production, gas usage and fugitive emissions was completed to determine the facility-level fugitive emissions and venting emissions (refer to section A.6.3). The equations presented below were used to estimate all the gas flows used in the mass balance. The associated parameters are presented in Table A.2 and the resulting gas flows for each year are presented in Table A.3.

$$CSG_{in} = \frac{\{CSG_{out} + CSG_{FG} + CSG_{V} + CSG_{Fu} + CSG_{Fl}\} \times \mathrm{EC_{ss}}}{\rho_{\mathrm{CSG}}}$$

where:

CSG_{in}	=	Total amount of processed CSG in the year	(TJ/a)
CSG_{out}	=	Total amount of CSG produced for export or domestic use in the year	(t/a)
CSG_{FG}	=	Total amount of fuel gas used on-site in the year	(t/a)
CSG_{V}	=	Total amount of CH_4 vented in the year	(t/a)
CSG_{Fu}	=	Total leaks of CH_4 from processing and gas field facilities in the year	(t/a)
CSG_{Fl}	=	Total amount of CSG flared (excluding ramp-up flaring) in the year (refer to Table A.28)	(t/a)
EC_{ss}	=	Site-specific energy content of CSG at standard conditions	(GJ/Sm^3 CSG)
ρ_{CSG}	=	Site-specific CSG density at standard conditions	(kg CSG/ Sm^3 CSG)

$$CSG_{out} = \frac{CSG_{out,E} \times \rho_{\mathrm{CSG}}}{\mathrm{EC_{ss}}}$$

where:

CSG_{out}	=	Total amount of CSG produced for export or domestic use in the year	(t CSG/a)
$CSG_{out,E}$	=	Total amount of CSG produced (energy) for export or domestic use in the year (refer to Table A.1)	(TJ/a)
ρ_{CSG}	=	Site-specific CSG density at standard conditions	(kg CSG/Sm^3 CSG)
EC_{ss}	=	Site-specific energy content of CSG at standard conditions	(GJ/Sm^3 CSG)

$$CSG_{V} = \frac{CSG_{V,\,CO_2-e}}{GWP_{CH_4}}$$

where:

CSG_{V}	=	Total amount of CH_4 vented in the year	(t/a)
$CSG_{V,\,CO_2-e}$	=	Vented emissions of CH_4 in the year (refer to Table A.33)	(t CO_2-e/a)
GWP_{CH_4}	=	Global warming potential of CH_4	(t CO_2-e /t CH_4)

$$CSG_{Fu} = \frac{CSG_{Fu,\,CO_2-e}}{\mathrm{GWP}_{\mathrm{CH_4}}}$$

where:

CSG_{Fu}	=	Total leaks of CH_4 from processing and gas field facilities in the year	(t CH_4/a)
$CSG_{Fu,\,CO_2-e}$	=	Total leaks in tonnes CO_2-e from processing and gas field facilities in the year (refer to Table A.31)	(t CO_2-e /a)
GWP_{CH_4}	=	Global warming potential of CH_4	(t CO_2-e/t CH_4)

$$CSG_{FG} = \frac{CSG_{FG,GJ}}{\mathrm{EC_{ss}}} \times \frac{\rho_{\mathrm{CSG}}}{1000}$$

where:

CSG_{FG}	=	Total amount of fuel gas used on-site in the year	(t/a)
$CSG_{FG,GJ}$	=	Total amount of fuel gas in GJ used on-site in the year (refer to Table A.23)	(GJ/a)
ρ_{CSG}	=	Site-specific CSG density at standard conditions	(kg CSG/Sm^3 CSG)
EC_{ss}	=	Site-specific energy content of CSG at standard conditions	(GJ/Sm^3 CSG)

Table A.2: Parameters Associated with the Estimation of the Quantity of Processed Gas

Data Required	Value	Units
Site-specific coal seam gas density at standard conditions [a]	0.70	kg/Sm^3
Site-specific energy content factor [a]	0.03660	GJ/m^3
Global warming potential of CH_4 [b]	21	t CO_2-e/ t CH_4
Site-specific CH_4 facility-level average fugitive emission factor associated with gas processing plants [c]	0.0346	t CO_2-e/ t coal seam gas processed

a Refer to Table 1.1.

b Appendix C, DCCEE (2012b).

c Pacific Environment's estimation based on the emission factors sourced from the American Petroleum Institute (API) Compendium 2009 (API, 2009) – refer to Table A.30.

Table A.3: CSG Mass Balance Inputs and Outputs for Time Period 2014-2048

Year	CSG Out	CSG Out	CSG Venting	CSG Combusted	CSG General Leaks	CSG Flaring	CSG In	CSG In
	(TJ/a) [a]	(t/a)	(t/a) [b]	(t/a) [c]	(t/a) [d]	(t/a) [e]	(t/a) [d]	(TJ/a) [f]
2014	29,220	558,852	1,278	706	925	0	561,762	29,372
2015	36,525	698,566	1,598	1,478	1,158	0	702,800	36,746
2016	43,830	838,279	1,918	6,115	1,396	0	847,708	44,323
2017	47,483	908,135	2,077	257,440	2,010	50,722	1,220,385	63,809
2018	142,448	2,724,406	6,232	305,286	5,114	63,402	3,104,440	162,318
2019	291,104	5,567,568	12,736	111,614	9,539	88,763	5,790,219	302,746
2020	321,420	6,147,377	14,062	149,919	10,582	101,443	6,423,383	335,851
2021	368,903	7,055,512	16,139	92,064	11,988	101,443	7,277,147	380,491
2022	405,428	7,754,078	17,737	7,073	13,003	101,443	7,893,334	412,709
2023	420,038	8,033,504	18,376	7,056	13,465	101,443	8,173,845	427,375
2024	443,779	8,487,572	19,415	7,022	14,216	101,443	8,629,668	451,208
2025	443,779	8,487,572	19,415	5,645	14,214	101,443	8,628,289	451,136
2026	443,779	8,487,572	19,415	4,250	14,212	101,443	8,626,892	451,063
2027	443,779	8,487,572	19,415	3,091	14,210	101,443	8,625,731	451,003
2028	438,300	8,382,787	19,175	3,578	14,037	101,443	8,521,021	445,528
2029	434,648	8,312,930	19,016	3,293	13,921	101,443	8,450,603	441,846
2030	420,038	8,033,504	18,376	6,401	13,464	101,443	8,173,189	427,341
2031	379,860	7,265,082	16,619	10,029	12,199	101,443	7,405,373	387,195
2032	332,378	6,356,947	14,541	7,291	10,693	101,443	6,490,915	339,382
2033	295,853	5,658,381	12,943	2,822	9,530	101,443	5,785,120	302,479
2034	248,370	4,750,246	10,866	2,738	8,028	101,443	4,873,322	254,805
2035	219,150	4,191,393	9,588	2,016	7,103	101,443	4,311,543	225,432
2036	186,278	3,562,684	8,150	2,016	6,063	101,443	3,680,356	192,430
2037	157,058	3,003,832	6,871	2,016	5,139	101,443	3,119,301	163,095
2038	135,143	2,584,693	5,912	2,016	4,445	101,443	2,698,510	141,094
2039	120,533	2,305,266	5,273	2,016	3,983	101,443	2,417,982	126,426
2040	109,575	2,095,697	4,794	2,016	3,637	101,443	2,207,587	115,425
2041	102,270	1,955,984	4,474	1,680	3,342	63,402	2,028,882	106,082
2042	94,965	1,816,270	4,155	420	3,067	38,041	1,861,954	97,354
2043	87,660	1,676,557	3,835	0	2,836	38,041	1,721,269	89,998
2044	84,008	1,606,701	3,675	0	2,657	0	1,613,033	84,339
2045	80,355	1,536,844	3,515	0	2,542	0	1,542,901	80,672
2046	76,703	1,466,988	3,356	0	2,426	0	1,472,770	77,005
2047	73,050	1,397,131	3,196	0	2,311	0	1,402,638	73,338
2048	69,398	1,327,275	3,036	0	2,195	0	1,332,506	69,671

a Refer to Table A.1.
b Refer to Table A.33.
c Refer to Table A.23.
d Refer to Table A.31.
e Refer to Table A.28.
f Pacific Environment's estimation - based on site-specific density and energy content factor (refer to Table A.2).

A.3 SCOPE 1 EMISSIONS – CONSTRUCTION

A.3.1 Fugitive Emissions – Ramp-Up Flaring

Ramp-up flaring will occur for a period of three months until the associated CGPF is operational to process the extracted gas. It is assumed that wells will not be brought online adjacent to FCFs until it is commissioned, hence no gas will be flared at an FCF during field ramp up.

Emissions of CO_2, CH_4 and N_2O were estimated using Method 1 (Division 3.44, *Method 1- oil or gas exploration* of the *Technical Guidelines* (DCCEE, 2012b)):

$$E_j = Q \times EF_j$$

where:

E_j	=	Emissions of gas type (j) from coal seam gas flared in the gas exploration in the year	(t CO_2-e/a)
Q	=	Quantity of coal seam gas flared in the year	(t CSG flared/a)
EF_j	=	Scope 1 default emission factor for gas type (j)	(t CO_2-e/t CSG flared)

The site-specific energy content was estimated based on the gas composition and the default emission factor for each gas were sourced from Section 3.44 of the *Technical Guidelines.* These are listed in Table A.4. The equation below was used to calculate the quantity of gas flared and the required parameters are presented in Table A.5. The activity data associated with ramp-up flaring and the resulting greenhouse gas emission estimates are presented in Table A.6 and Table A.7.

All the estimates are presented to the nearest tonne, in accordance with Australian greenhouse reporting convention, but should only be considered reliable to two significant figures.

Table A.4: Energy Content Factor and Emission Factors Associated with Ramp-Up Flaring

Method Used	Constant	Value	Units
-	Site-specific energy content factor at STP [a]	0.03660	GJ/Sm^3
Method 1	Scope 1 default CO_2 emission factor [b]	2.8	t CO_2-e/t gas flared
Method 1	Scope 1 default CH_4 emission factor [b]	0.7	
Method 1	Scope 1 default N_2O emission factor [b]	0.03	
Method 1	Scope 1 overall emission factor [c]	3.53	

a Refer to Table 1.1.
b Section 3.44, DCCEE (2012b).
c Pacific Environment's estimation.

$$Q = \frac{Q_E \times \rho_{CSG}}{EC_{ss}}$$

where:

Q	=	Quantity of gas flared in the year	(t CSG flared/a)
Q_E	=	Quantity of gas (energy) flared in the year	(TJ/a)
ρ_{CSG}	=	Gas density at standard conditions	(kg CSG/Sm^3 CSG)
EC_{ss}	=	Site-specific energy content of gas at standard conditions	(GJ/Sm^3 CSG)

Table A.5: Parameters Associated with the Estimation of the Quantity of Gas Flared

Data Required	Value	Units
Coal seam gas density at standard conditions [a]	0.700	kg/Sm^3

a Refer to Table 1.1.

Table A.6: Activity Data Associated with Gas Ramp-Up Flaring

Year	Total amount of gas flared (TJ/annum) [a]	Total amount of gas flared (t/annum) [b]
2016	1,077	20,598
2017	5,224	99,913
2018	0	0
2019	1,227	23,467
2020	360	6,885

a As advised by Arrow.

b Pacific Environment's estimation based on the energy content factor and the density of the gas.

Table A.7: Greenhouse Gas Emissions Associated with Gas Ramp-Up Flaring

Year	Scope 1 Emissions (t CO_2-e/annum)			
	CO_2	CH_4	N_2O	Total CO_2-e
2016	57,675	14,419	618	**72,712**
2017	279,755	69,939	2,997	**352,691**
2018	0	0	0	**0**
2019	65,708	16,427	704	**82,839**
2020	19,279	4,820	207	**24,305**

A.3.2 Vegetation Clearing

Clearing existing vegetation for the purposes of constructing project infrastructure will release an amount of stored carbon within the vegetation's biomass.

Construction activities occur throughout the project at a rate that aligns with the gas production requirements. The main infrastructure components of project include:

- production wells
- gas and water gathering systems
- gas processing facilities
- water and salt treatment and storage facilities
- power transmission and distribution facilities
- high pressure gas pipeline connections to the Arrow Surat Pipeline
- supporting infrastructure such as depots, roads and operations accommodation.

Table A.8 provides the emission factor used to calculate greenhouse gas emissions from this activity, sourced from the Australian Greenhouse Office (AGO).

Table A.8: Emission Factor Associated with Vegetation Clearance

Constant	Value	Units
Default emission factor for vegetation clearance [a]	3.67	t CO_2-e/t carbon

a AGO (1999, 2000, 2002 and 2003).

Greenhouse gas emissions due to vegetation clearance are calculated on a per hectare basis. For the purposes of this assessment, some assumptions were made to obtain approximate emission factors for the vegetation clearance component of the project. This information was drawn from various technical reports (AGO, 1999, 2000, 2002 and 2003). One important assumption is that 50% of the biomass in any given area is carbon. In reality, this value differs between each species in the range of 40-50% (AGO, 2000).

As the precise locations for clearing of vegetation cannot be determined at this stage of the project, it is difficult to generate site-specific emission factors. If the areas to be cleared were known, the FullCAM model from the *National Carbon Accounting Toolbox* could be used to determine vegetation clearing emission factors. Instead, the general biomass densities that have been used by AGO for land clearing inventory purposes will be used in this assessment. Of the three forest classes provided in Table 2.5 of "*Synthesis of Allometrics, Review of Root Biomass and Design of Future Woody Biomass Sampling Strategies*" (AGO, 2000), Open Forest has been deemed the most appropriate for this assessment. The biomass density presented (90 t/ha) corresponds well with values determined with the FullCAM model using benchmark plots modified with spatial data for the region.

Table A.9 summarises the estimated emissions from land clearing associated with different project activities. The resulting greenhouse gas emission estimates are presented in Table A.10. Over the life of the project, these emissions were estimated to be approximately 610,452 t CO_2-e. These values do not take into account the planned rehabilitation of all areas cleared for project purposes and were conservatively estimated. The bulk of these land clearing emissions are due to well installation; however, Arrow is committed to rehabilitate the well areas once drilling is complete.

Table A.9: Activity Data Associated with Vegetation Clearance

Project Activity	Total Area Cleared per Activity (ha) [a]	Biomass [b] (t/ha)	Carbon [c] (t/ha)	Total Carbon per Activity (t)	Total Emission per Activity [d] ($t\ CO_2$-e)
Single well construction	1	90	45	45	165
Multi-well pad construction	2			90	330
FCF construction	0.5			22.5	82.5
CGPF construction	18.2			819	3,003
CGPF + water treatment facility construction	220			9,900	36,300
Construction camp sites construction	25			1,125	4,125

a As advised by Arrow.
b Table 2.5, AGO (2000).
c Assuming 50% of biomass is carbon.
d Pacific Environment's estimation – based on the emission factor listed in Table A.8.

Table A.10: Estimated Greenhouse Gas Emissions Associated with Vegetation Clearance

Year	Single Wells	Multi-well Pads	FCFs	CGPFs	CGPF + water treatment facilities	Construction Camp Sites	Total
	(t CO_2-e/a)						
2014	1,040	539	0	0	0	0	**1,579**
2015	1,139	590	0	0	0	12,375	**14,104**
2016	7,871	4,081	0	12,012	72,600	4,125	**100,689**
2017	18,365	9,522	0	3,003	0	4,125	**35,015**
2018	20,196	10,472	0	6,006	0	4,125	**40,799**
2019	18,711	9,702	0	3,003	0	0	**31,416**
2020	20,345	10,549	0	0	0	0	**30,894**
2021	20,790	10,780	0	0	0	0	**31,570**
2022	20,840	10,806	0	0	0	0	**31,645**
2023	20,790	10,780	165	0	0	0	**31,735**
2024	20,691	10,729	83	0	0	0	**31,502**
2025	16,632	8,624	165	0	0	0	**25,421**
2026	12,524	6,494	83	0	0	0	**19,100**
2027	9,108	4,723	0	0	0	0	**13,831**
2028	10,544	5,467	0	0	0	0	**16,011**
2029	9,702	5,031	0	0	0	0	**14,733**
2030	12,920	6,699	0	0	0	0	**19,619**
2031	11,732	6,083	0	0	0	0	**17,815**
2032	9,603	4,979	0	0	0	0	**14,582**
2033	8,316	4,312	0	0	0	0	**12,628**
2034	8,069	4,184	0	0	0	0	**12,252**
2035	5,940	3,080	0	0	0	0	**9,020**
2036	5,940	3,080	0	0	0	0	**9,020**
2037	5,940	3,080	0	0	0	0	**9,020**
2038	5,940	3,080	0	0	0	0	**9,020**
2039	5,940	3,080	0	0	0	0	**9,020**
2040	5,940	3,080	0	0	0	0	**9,020**
2041	4,950	2,567	0	0	0	0	**7,517**
2042	1,238	642	0	0	0	0	**1,879**
2043	0	0	0	0	0	0	**0**
2044	0	0	0	0	0	0	**0**
2045	0	0	0	0	0	0	**0**
2046	0	0	0	0	0	0	**0**
2047	0	0	0	0	0	0	**0**
2048	0	0	0	0	0	0	**0**
Cumulative emissions for time period 2014 - 2048	**321,750**	**166,833**	**495**	**24,024**	**72,600**	**24,750**	**610,452**

A.3.3 Fuel Combustion – Diesel Combusted for Drilling Activities

Diesel is combusted in drilling rigs during well construction. Emissions of CO_2, CH_4 and N_2O were estimated using Method 1 (Division 2.4.2, *Method 1- emissions of carbon dioxide, methane and nitrous oxide from liquid fuels other than petroleum based oils or greases* of the *Technical Guidelines* (DCCEE, 2012b)):

$$E_j = \frac{Q \times EC \times EF_{joxec}}{1000}$$

where:

E_j	=	Estimated emissions of gas type (j) from diesel combustion	(t CO_2-e/a)
Q	=	Estimated quantity of diesel combusted in drill rigs in the year	(kL/a)
EC	=	Energy content factor of diesel	(GJ/kL)
EF_{joxec}	=	Emission factor for each gas type (j)	(kg CO_2-e/GJ)

The default energy content factor for diesel and the default emission factor for each gas were sourced from Table 2.4.2B of the *Technical Guidelines* and are listed in Table A.11. The equation below was used to calculate the quantity of diesel used in drill rigs and the associated parameters are listed in Table A.12. The activity data associated with diesel combusted in drill rigs are presented in Table A.13 and the resulting greenhouse gas emission estimates are presented in Table A.14.

Table A.11: Energy Content Factor and Emission Factors Associated with Diesel Combusted in Drill Rigs

Constant	Value	Units
Default energy content factor [a]	38.6	GJ/kL
Scope 1 default CO_2 emission factor [a]	69.2	kg CO_2-e/ GJ
Scope 1 default CH_4 emission factor [a]	0.2	
Scope 1 default N_2O emission factor [a]	0.5	
Scope 1 overall emission factor [b]	69.9	

a Table 2.4.2B, DCCEE (2012b).
b Pacific Environment's' estimation.

$$Q = W \times R_C$$

where:

Q	=	Estimated quantity of diesel combusted in drill rigs in the year	(kL/a)
W	=	Total number of wells commissioned in the year	(well/a)
R_C	=	Average quantity of diesel consumed per well drilled	(kL/well)

Table A.12: Parameters Associated with Diesel Combusted in Drill Rigs

Data Required	Value	Units
Average quantity of diesel consumed per well drilled [a]	18	kL/well

a EIS data used – PAEHolmes (2011).

Table A.13: Activity Data Associated with Diesel Combusted in Drill Rigs

Year	Total Wells Commissioned for Year [a]	Total Fuel Consumption for Year (kL) [b]
2014	21	378
2015	23	414
2016	159	2,862
2017	371	6,678
2018	408	7,344
2019	378	6,804
2020	411	7,398
2021	420	7,560
2022	421	7,578
2023	420	7,560
2024	418	7,524
2025	336	6,048
2026	253	4,554
2027	184	3,312
2028	213	3,834
2029	196	3,528
2030	261	4,698
2031	237	4,266
2032	194	3,492
2033	168	3,024
2034	163	2,934
2035	120	2,160
2036	120	2,160
2037	120	2,160
2038	120	2,160
2039	120	2,160
2040	120	2,160
2041	100	1,800
2042	25	450
2043	0	0
2044	0	0
2045	0	0
2046	0	0
2047	0	0
2048	0	0
Total for time period 2014 - 2048	**6,500**	**117,000**

a As advised by Arrow.
b Pacific Environment's estimation.

Table A.14: Greenhouse Gas Emissions Associated with Diesel Combusted in Drill Rigs

Year	Scope 1 Emissions (t CO_2-e/annum)			
	CO_2	CH_4	N_2O	Total CO_2-e
2014	1,010	3	7	**1,020**
2015	1,106	3	8	**1,117**
2016	7,645	22	55	**7,722**
2017	17,838	52	129	**18,018**
2018	19,617	57	142	**19,815**
2019	18,174	53	131	**18,358**
2020	19,761	57	143	**19,961**
2021	20,194	58	146	**20,398**
2022	20,242	59	146	**20,447**
2023	20,194	58	146	**20,398**
2024	20,098	58	145	**20,301**
2025	16,155	47	117	**16,318**
2026	12,164	35	88	**12,287**
2027	8,847	26	64	**8,936**
2028	10,241	30	74	**10,345**
2029	9,424	27	68	**9,519**
2030	12,549	36	91	**12,676**
2031	11,395	33	82	**11,510**
2032	9,328	27	67	**9,422**
2033	8,077	23	58	**8,159**
2034	7,837	23	57	**7,916**
2035	5,770	17	42	**5,828**
2036	5,770	17	42	**5,828**
2037	5,770	17	42	**5,828**
2038	5,770	17	42	**5,828**
2039	5,770	17	42	**5,828**
2040	5,770	17	42	**5,828**
2041	4,808	14	35	**4,857**
2042	1,202	3	9	**1,214**
2043	0	0	0	**0**
2044	0	0	0	**0**
2045	0	0	0	**0**
2046	0	0	0	**0**
2047	0	0	0	**0**
2048	0	0	0	**0**
Cumulative emissions for time period 2014 - 2048	**312,521**	**903**	**2,258**	**315,682**

A.4 SCOPE 1 EMISSIONS – CONSTRUCTION AND DECOMMISSIONING

A.4.1 Fuel Combustion – Diesel Combusted in Stationary Engines

Diesel will be combusted in generators to supply power to construction and decommissioning/rehabilitation activities.

Emissions of CO_2, CH_4 and N_2O were estimated based on the stationary diesel combustion emissions calculated for construction of the LNG facility in Gladstone, as part of the Arrow LNG Project:

$$E_j = \frac{WF_{SGP} \times E_{j,LNG}}{WF_{LNG}}$$

where:

E_j	=	Estimated emissions of gas type (j) from diesel combustion	(t CO_2-e/a)
WF_{SGP}	=	Workforce associated with the Surat Gas Project in a year	(workers/a)
WF_{LNG}	=	Workforce associated with the construction of the LNG facility	(workers/a)
$E_{j,LNGc}$	=	Emission of each gas type (j) from diesel combustion for construction of the LNG facility.	(t CO_2-e/a)

The activity data associated with diesel combustion for construction purposes are presented in Table A.15.The workforce of the Surat Gas Project and the resulting greenhouse gas emission estimates are presented in Table A.16.

Table A.15: Activity Data Associated with Diesel Combustion in Stationary Engines for Construction and Decommissioning/Rehabilitation Activities

Data Required	Value [a]	Unit
Emissions of CO_2 for LNG facility	48,750	t CO_2-e/a
Emissions of CH_4 for LNG facility	70	t CO_2-e/a
Emissions of N_2O for LNG facility	141	t CO_2-e/a
Peak number of workers for LNG construction	3,700	workers/day

a As advised by Arrow, based on the revised greenhouse assessment done by Pacific Environment in November 2012 (formerly PAEHolmes) Brisbane (PAEHolmes, 2012).

Table A.16: Greenhouse Gas Emissions Associated with Diesel Combustion in Stationary Engines for Construction and Decommissioning/Rehabilitation Activities

Year	Surat Gas Project Workforce [a]	CO_2 Emissions	CH_4 Emissions	N_2O Emissions	Total Emissions
		(tonnes CO_2-e/a)			
2014	300	3,953	6	11	**3,970**
2015	770	10,145	15	29	**10,189**
2016	1,300	17,128	25	50	**17,203**
2017	1,700	22,399	32	65	**22,496**
2018	900	11,858	17	34	**11,909**
2019	1,200	15,811	23	46	**15,879**
2020	900	11,858	17	34	**11,909**
2021	600	7,905	11	23	**7,940**
2022	700	9,223	13	27	**9,263**
2023	700	9,223	13	27	**9,263**
2024	700	9,223	13	27	**9,263**
2025	700	9,223	13	27	**9,263**
2026	500	6,588	9	19	**6,616**
2027	700	9,223	13	27	**9,263**
2028	600	7,905	11	23	**7,940**
2029	700	9,223	13	27	**9,263**
2030	300	3,953	6	11	**3,970**
2031	300	3,953	6	11	**3,970**
2032	300	3,953	6	11	**3,970**
2033	300	3,953	6	11	**3,970**
2034	300	3,953	6	11	**3,970**
2035	300	3,953	6	11	**3,970**
2036	300	3,953	6	11	**3,970**
2037	300	3,953	6	11	**3,970**
2038	300	3,953	6	11	**3,970**
2039	300	3,953	6	11	**3,970**
2040	300	3,953	6	11	**3,970**
2041	300	3,953	6	11	**3,970**
2042	300	3,953	6	11	**3,970**
2043	300	3,953	6	11	**3,970**
2044	300	3,953	6	11	**3,970**
2045	300	3,953	6	11	**3,970**
2046	300	3,953	6	11	**3,970**
2047	300	3,953	6	11	**3,970**
2048	300	3,953	6	11	**3,970**

a As advised by Arrow. For Year 2014 and Year 2036 – Year 2048: it was assumed the same average workforce as 2035 would apply.

A.5 SCOPE 1 EMISSIONS – CONSTRUCTION, OPERATION, DECOMMISSIONING

A.5.1 Fuel Combustion – Diesel Used in Vehicles for Transport and Construction Energy

As the production wells, processing plants and other infrastructure required to be constructed for the extraction of gas are spread over large areas of land, the construction workforce will have to travel large distances. As a result, a significant quantity of diesel is expected to be used in passenger vehicles (i.e., light vehicles) for transport. Diesel will also be consumed in industrial vehicles (i.e., heavy vehicles) for construction, operation, decommissioning and rehabilitation activities of the facilities and associated infrastructure.

Based upon Arrow's existing operations and strategic planning, the key traffic generating activities likely to be associated with the project are as follows (Section 2 of the *Transport Assumptions Report* within the *Road Impact Assessment* (Cardno, 2013):

- construction activities:
  - production well installation
  - gathering infrastructure installation
  - production facility construction
- operation activities:
  - production well operation and maintenance including well workovers
  - gathering infrastructure operation and maintenance
  - production facility operation and maintenance
- decommissioning activities:
  - production well decommissioning and rehabilitation
  - gathering infrastructure decommissioning and rehabilitation
  - production facility decommissioning and rehabilitation.

Light vehicles have been classified as sedans, wagons, vans, utilities, 4WDs and motorcycles while anything other type of vehicle has been considered a HV (heavy vehicle) for the purposes of this estimate (Cardno, 2013). It was assumed that only diesel was consumed in light and heavy vehicles.

Emissions of CO_2, CH_4 and N_2O were estimated using Method 1 (Division 2.4.2, *Method 1- emissions of carbon dioxide, methane and nitrous oxide from liquid fuels other than petroleum based oils or greases* of the *Technical Guidelines* (DCCEE, 2012b)):

$$E_j = \frac{Q \times EC \times EF_{joxec}}{1000}$$

where:

E_j	=	Estimated emissions of gas type (j) from diesel combustion	(t CO_2-e/a)
Q	=	Estimated quantity of diesel combusted in light and heavy vehicles in the year	(kL/a)
EC	=	Energy content factor of diesel	(GJ/kL)
EF_{joxec}	=	Emission factor for each gas type (j)	(kg CO_2-e/GJ)

The default energy content factor for diesel and the default emission factor for each gas were sourced from Table 2.4.2B of the *Technical Guidelines* and are listed in Table A.17. The equation below was used to calculate the quantity of diesel used in light and heavy vehicles. The associated parameters are listed in Table A.18. The activity data associated with diesel combusted in light and heavy vehicles are presented in Table A.19 and the resulting greenhouse gas emission estimates are presented in Table A.20.

Table A.17: Energy Content Factor and Emission Factors Associated with Diesel Combustion in Vehicles for Construction, Operation, Decommissioning/Rehabilitation Activities

Method Used	Constant	Value	Units
-	Default energy content factor [a]	38.6	GJ/kL
Method 1	Scope 1 default CO_2 emission factor [a]	69.2	kg CO_2-e/ GJ
Method 1	Scope 1 default CH_4 emission factor [a]	0.2	
Method 1	Scope 1 default N_2O emission factor [a]	0.5	
Method 1	Scope 1 overall emission factor [b]	69.9	

a Table 2.4.2B, DCCEE (2012b).
b Pacific Environment's' estimation.

$$Q = \frac{D \times R_C}{1000}$$

where:

Q	=	Estimated quantity of diesel combusted in light or heavy vehicles in the year	(kL/a)
D	=	Total kilometres travelled in the year	(km/a)
R_C	=	Average rate of diesel consumption of light or heavy vehicles	(L/km)

Table A.18: Parameters Associated with Diesel Combustion in Vehicles Estimation

Data Required	Value	Units
Average rate of diesel consumption of passenger vehicles (light vehicles) [a]	0.116	L/km
Average rate of diesel consumption of articulated trucks (heavy vehicles) [b]	0.557	L/km

a ABS (2010) – Pacific Environment's' assumption: the rate of fuel consumption for passenger vehicles was selected to represent the light vehicles. Passenger vehicles are defined as motor vehicles constructed primarily for the carriage of persons and containing up to nine seats (including the driver's seat). Included are cars, station wagons, four-wheel drive passenger vehicles, passenger vans or mini buses with fewer than 10 seats and campervans.
b ABS (2010) – Pacific Environment's' assumption: in the absence of more information about heavy vehicles (e.g. specific types), the average fuel consumption rate for articulated trucks was used. It is a conservative approach as this average fuel consumption is the highest rate provided in the ABS survey for motor vehicles.

Table A.19: Activity Data Associated with Diesel Combusted in Light and Heavy Vehicles for Construction, Operation, Decommissioning/Rehabilitation Activities

Year	Light Vehicles		Heavy Vehicles	
	Total kilometres travelled for year (km) [a]	Total fuel consumption for year (kL) [b]	Total kilometres travelled for year (km) [a]	Total fuel consumption for year (kL) [b]
2013	236,252	27	474,865	264
2014	1,736,784	201	724,525	404
2015	8,464,825	982	6,040,750	3,365
2016	14,055,165	1,630	12,366,200	6,888
2017	14,909,155	1,729	13,764,150	7,667
2018	18,498,127	2,146	17,330,200	9,653
2019	15,858,046	1,840	18,698,950	10,415
2020	16,001,016	1,856	19,279,300	10,739
2021	16,919,648	1,963	20,918,150	11,651
2022	18,160,133	2,107	19,516,550	10,871
2023	17,381,395	2,016	19,596,850	10,915
2024	16,011,035	1,857	18,417,900	10,259
2025	14,699,492	1,705	18,936,200	10,547
2026	13,673,594	1,586	17,801,050	9,915
2027	14,108,577	1,637	18,578,500	10,348
2028	14,356,888	1,665	18,344,900	10,218
2029	15,742,238	1,826	21,834,300	12,162
2030	15,944,083	1,850	21,684,650	12,078
2031	15,611,751	1,811	20,907,200	11,645
2032	15,468,043	1,794	20,191,800	11,247
2033	15,411,242	1,788	20,137,050	11,216
2034	14,448,350	1,676	19,355,950	10,781
2035	14,481,025	1,680	19,330,400	10,767
2036	14,688,710	1,704	19,534,800	10,881
2037	14,481,791	1,680	18,585,800	10,352
2038	14,307,766	1,660	18,472,650	10,289
2039	13,896,937	1,612	18,439,800	10,271
2040	13,616,821	1,580	18,133,200	10,100
2041	10,704,654	1,242	13,223,950	7,366
2042	9,749,781	1,131	12,212,900	6,803
2043	9,987,860	1,159	12,253,050	6,825
2044	9,224,280	1,070	9,924,350	5,528
2045	8,763,687	1,017	9,362,250	5,215
2046	8,757,386	1,016	9,125,000	5,083
2047	8,481,629	984	8,595,750	4,788
Total for time period 2013 - 2047	**458,838,165**	**53,225**	**552,093,890**	**307,516**

a Cardno (2013).

b Pacific Environment's estimation.

Table A.20: Greenhouse Gas Emissions Associated with Diesel Combusted in Light and Heavy Vehicles for Construction, Operation, Decommissioning/Rehabilitation Activities

Year	Scope 1 Emissions (t CO_2-e/annum)			
	CO_2	CH_4	N_2O	Total CO_2-e
2014	780	2	6	**788**
2015	1,616	5	12	**1,632**
2016	11,610	34	84	**11,728**
2017	22,754	66	164	**22,984**
2018	25,098	73	181	**25,352**
2019	31,516	91	228	**31,835**
2020	32,734	95	237	**33,065**
2021	33,642	97	243	**33,982**
2022	36,365	105	263	**36,733**
2023	34,664	100	250	**35,015**
2024	34,542	100	250	**34,892**
2025	32,363	94	234	**32,691**
2026	32,728	95	236	**33,059**
2027	30,721	89	222	**31,032**
2028	32,013	93	231	**32,337**
2029	31,742	92	229	**32,063**
2030	37,363	108	270	**37,741**
2031	37,203	108	269	**37,579**
2032	35,943	104	260	**36,307**
2033	34,834	101	252	**35,187**
2034	34,735	100	251	**35,087**
2035	33,275	96	240	**33,611**
2036	33,247	96	240	**33,583**
2037	33,615	97	243	**33,955**
2038	32,139	93	232	**32,465**
2039	31,917	92	231	**32,240**
2040	31,741	92	229	**32,062**
2041	31,198	90	225	**31,514**
2042	22,992	66	166	**23,224**
2043	21,191	61	153	**21,406**
2044	21,325	62	154	**21,541**
2045	17,624	51	127	**17,802**
2046	16,645	48	120	**16,813**
2047	16,290	47	118	**16,455**
2048	15,417	45	111	**15,573**
Cumulative emissions for time period 2014 - 2048	**963,584**	**2,785**	**6,962**	**973,331**

A.6 SCOPE 1 EMISSIONS – OPERATION

A.6.1 CSG Combustion for Temporary Power Generation

After commissioning of the wells and CGPFs, power will temporarily be supplied by gas-driven generators until a grid connection is made; i.e. two years after commissioning of the CGPFs and six months to two years after commissioning of the wells.

Power generation may consist of gas engine generators sized at 1.1 or 5.7 MW each for CGPFs, 60 kW for single wells and 749 kW for multi-well pads.

Emissions of CO_2, CH_4 and N_2O were estimated using Method 1 (Division 2.3.2, *Method 1- emissions of carbon dioxide, methane and nitrous oxide)* of the *Technical Guidelines* (DCCEE, 2012b)):

$$E_j = \frac{Q \times EF_{joxec}}{1000}$$

where:

E_j	=	Estimated emissions of gas type (j) from gas combustion	(t CO_2-e/a)
Q	=	Estimated quantity of gas combusted in stationary engines in the year	(GJ/a)
EF_{joxec}	=	Emission factor for each gas type (j)	(kg CO_2-e/GJ)

The default emission factor for each gas were sourced from Table 2.3.2A of the *Technical Guidelines* and are listed in Table A.21.

The equation below was used to calculate the quantity of gas combusted in stationary engines. The activity data associated with gas combusted for power generation are presented in Table A.1, Table 4.1, Table A.22 and Table A.23. The resulting greenhouse gas emission estimates are presented in Table A.24.

Table A.21: Emission Factors Associated with CSG Combusted in Stationary Engines for Temporary Power Supply during Operation

Method Used	Constant	Value	Units
Method 1	Scope 1 default CO_2 emission factor [a]	51.1	kg CO_2-e/ GJ
Method 1	Scope 1 default CH_4 emission factor [a]	0.2	
Method 1	Scope 1 default N_2O emission factor [a]	0.03	
Method 1	Scope 1 overall emission factor [b]	51.33	

a Table 2.3.2A, DCCEE (2012b).
b Pacific Environment's estimation.

$$Q = E_{req.} \times FU$$

where:

Q	=	Estimated quantity of gas combusted in stationary engines in the year	(GJ/a)
$E_{req.}$	=	Energy requirement of facility, well, or well pad	(MWh/annum)
FU	=	Fuel usage of facility, well or well pad.	(GJ/MWh)

Table A.22: Activity Data Associated with Gas Combusted in Stationary Engines for Temporary Power Supply during Operation

Facility/Well type	Energy Requirement [a]	Fuel Usage
CGPF-1	170,660 MWh/a	11.578 GJ/MWh [a,b]
CGPF-2	432,874 MWh/a	
CGPF-5	223,920 MWh/a	
CGPF-7	134,378 MWh/a	
CGPF-8	288,454 MWh/a	
CGPF-9	291,277 MWh/a	
CGPF-10	155,771 MWh/a	
CGPF-11	232,310 MWh/a	
Single well	131,400 kWh/a/well	10.840 MJ/kWh [c]
Multi-well pad	1,576,800 kWh/a/well	

a As advised by Arrow.

b Based on 3.6 GJ/MWh and using the "worst-case efficiency" between the two gas-driven generators options for the CGPFs; i.e. TAURUS 60 gas turbine generator set: 31.093% as advised by Arrow.

c As advised by Arrow, 75% load value used as it was the worst case.

Table A.23: Amount of Fuel Combusted at the CGPFs, Wells and Multi-well Pads

Year	Equivalent [a] Total Number of Wells Powered by Fuel Combustion for the Full Year	Equivalent [a] Number of Single Wells Powered by Fuel Combustion for the Full Year	Equivalent [a] Number of Multi-well Pads Powered by Fuel Combustion for the Full Year	Fuel Combustion for Single Wells	Fuel Combustion for Multi-well Pads	Fuel Combustion for CGPFs
				(GJ/year)		
2014	21	6	2	8,974	27,918	-
2015	44	13	3	18,802	58,494	-
2016	182	55	14	77,771	241,954	-
2017	426	128	33	182,035	566,332	12,712,077
2018	402	121	31	171,780	534,426	15,255,893
2019	371	111	29	158,319	492,549	5,184,970
2020	429	129	33	183,104	569,655	7,085,851
2021	210	63	16	89,736	279,178	4,444,697
2022	211	63	16	89,949	279,842	-
2023	210	63	16	89,736	279,178	-
2024	209	63	16	89,308	277,848	-
2025	168	50	13	71,789	223,342	-
2026	127	38	10	54,055	168,171	-
2027	92	28	7	39,313	122,306	-
2028	107	32	8	45,509	141,583	-
2029	98	29	8	41,877	130,283	-
2030	191	57	15	81,403	253,254	-
2031	299	90	23	127,553	396,831	-
2032	217	65	17	92,727	288,484	-
2033	84	25	7	35,894	111,671	-
2034	82	24	6	34,826	108,348	-
2035	60	18	5	25,639	79,765	-
2036	60	18	5	25,639	79,765	-
2037	60	18	5	25,639	79,765	-
2038	60	18	5	25,639	79,765	-
2039	60	18	5	25,639	79,765	-
2040	60	18	5	25,639	79,765	-
2041	50	15	4	21,366	66,471	-
2042	13	4	1	5,341	16,618	-
2043	0	0	0	-	-	-
2044	0	0	0	-	-	-
2045	0	0	0	-	-	-
2046	0	0	0	-	-	-
2047	0	0	0	-	-	-
2048	0	0	0	-	-	-

a As some wells will be self-powered for two years and others will be self-powered for six months, an equivalent number of self-powered wells for the full year is presented.

Table A.24: Greenhouse Gas Emissions Associated with Gas Combusted in Stationary Engines for Temporary Power Supply during Operation

Year	CO_2 Emissions	CH_4 Emissions	N_2O Emissions	Total Emissions
	(tonnes CO_2-e/a)			
2014	1,885	7	1	**1,894**
2015	3,950	15	2	**3,968**
2016	16,338	64	10	**16,411**
2017	687,829	2,692	404	**690,925**
2018	815,663	3,192	479	**819,335**
2019	298,211	1,167	175	**299,554**
2020	400,553	1,568	235	**402,356**
2021	245,975	963	144	**247,083**
2022	18,896	74	11	**18,981**
2023	18,851	74	11	**18,936**
2024	18,762	73	11	**18,846**
2025	15,081	59	9	**15,149**
2026	11,356	44	7	**11,407**
2027	8,259	32	5	**8,296**
2028	9,560	37	6	**9,603**
2029	8,797	34	5	**8,837**
2030	17,101	67	10	**17,178**
2031	26,796	105	16	**26,917**
2032	19,480	76	11	**19,568**
2033	7,541	30	4	**7,575**
2034	7,316	29	4	**7,349**
2035	5,386	21	3	**5,410**
2036	5,386	21	3	**5,410**
2037	5,386	21	3	**5,410**
2038	5,386	21	3	**5,410**
2039	5,386	21	3	**5,410**
2040	5,386	21	3	**5,410**
2041	4,488	18	3	**4,509**
2042	1,122	4	1	**1,127**
2043	0	0	0	**0**
2044	0	0	0	**0**
2045	0	0	0	**0**
2046	0	0	0	**0**
2047	0	0	0	**0**
2048	0	0	0	**0**

A.6.2 Fugitive Emissions – Maintenance Flaring

During operation, flaring will be performed during unplanned shutdowns for maintenance at the CGPFs.

Emissions of CO_2, CH_4 and N_2O were estimated using Method 1 (Division 3.3.9, *Method 1- gas flared from natural gas production and processing* of the *Technical Guidelines* (DCCEE, 2012b)):

$$E_j = Q \times EF_j$$

where:

E_j	=	Emissions of gas type (j) from process coal seam gas flared in the year	(t CO_2-e/a)
Q	=	Quantity of coal seam gas flared in the year	(t CSG flared/a)
EF_j	=	Scope 1 emission factor for gas type (j)	(t CO_2-e/ t CSG flared)

The site-specific energy content factor for coal seam gas was provided by Arrow and the default emission factor for each gas were sourced from Section 3.85 of the *Technical Guidelines*. These are listed in Table A.25. The equation below was used to calculate the quantity of gas flared. The activity data associated with emergency and maintenance flaring are presented in Table A.26 and Table A.27. The resulting greenhouse gas emission estimates are presented in Table A.28.

Table A.25: Energy Content Factor and Emission Factors Associated with Maintenance Flaring

Constant	Value	Units
Site-specific energy content factor [a]	0.03660	GJ/Sm^3
Scope 1 default CO_2 emission factor [b]	2.7	t CO_2-e/t CSG flared
Scope 1 default CH_4 emission factor [b]	0.1	
Scope 1 default N_2O emission factor [b]	0.03	
Scope 1 overall emission factor [c]	2.83	

a Refer to Table 1.1.
b Section 3.85, DCCEE (2012b).
c Pacific Environment's estimation.

$$Q = \frac{FR \times N_f \times \rho_{CSG}}{EC_{ss}}$$

where:

Q	=	Quantity of CSG flared during maintenance in the year	(t CSG flared/a)
FR	=	Flaring rate per CGPF per annum	(TJ/a/CGPF)
N_f	=	Number of CGPFs	(-)
ρ_{CSG}	=	Site-specific CSG density at standard conditions	(kg CSG/Sm^3 CSG)
EC_{ss}	=	Site-specific CSG energy content factor at standard conditions	(GJ/Sm^3)

Table A.26: Activity Data Associated with Maintenance Flaring (1)

Data Required	Value	Units
CSG density at standard conditions [a]	0.700	kg CSG/Sm^3 CSG
Average flaring rate per CGPF [b]	662	TJ/a/facility

a Refer to Table 1.1.
b As advised by Arrow.

Table A.27: Activity Data Associated with Maintenance Flaring (2)

Year	Operating CGPF [a]	CGPF Decommissioning	Number of CGPFs	Total Amount of Gas Flared at Processing Facilities [b] (t/a)
2014	-	-	0	0
2015	-	-	0	0
2016	-	-	0	0
2017	CGPF-9, CGPF-2, CGPF-8, CGPF-1	-	4	50,722
2018	CGPF-7	-	5	63,402
2019	CGPF-5, CGPF-11	-	7	88,763
2020	CGPF-10	-	8	101,443
2021	-	-	8	101,443
2022	-	-	8	101,443
2023	-	-	8	101,443
2024	-	-	8	101,443
2025	-	-	8	101,443
2026	-	-	8	101,443
2027	-		8	101,443
2028	-	-	8	101,443
2029	-	-	8	101,443
2030	-	-	8	101,443
2031	-	-	8	101,443
2032	-	-	8	101,443
2033	-	-	8	101,443
2034	-	-	8	101,443
2035	-	-	8	101,443
2036	-	-	8	101,443
2037	-	-	8	101,443
2038	-	-	8	101,443
2039	-	-	8	101,443
2040	-	-	8	101,443
2041	-	CGPF-9, CGPF-2, CGPF-8	5	63,402
2042	-	CGPF-1, CGPF-7	3	38,041
2043	-	-	3	38,041
2044	-	CGPF-5, CGPF-10, CGPF-11	0	0
2045	-	-	0	0
2046	-	-	0	0
2047	-	-	0	0
2048	-	-	0	0
Total for time period 2014 - 2048				**2,472,683**

a As advised by Arrow.

b Pacific Environment's estimation.

Table A.28: Greenhouse Gas Emissions Associated with Maintenance Flaring

Year	Scope 1 Emissions (t CO_2-e/annum)			
	CO_2	CH_4	N_2O	Total CO_2-e
2014	0	0	0	**0**
2015	0	0	0	**0**
2016	0	0	0	**0**
2017	136,949	5,072	1,522	**143,542**
2018	171,186	6,340	1,902	**179,428**
2019	239,660	8,876	2,663	**251,199**
2020	273,897	10,144	3,043	**287,085**
2021	273,897	10,144	3,043	**287,085**
2022	273,897	10,144	3,043	**287,085**
2023	273,897	10,144	3,043	**287,085**
2024	273,897	10,144	3,043	**287,085**
2025	273,897	10,144	3,043	**287,085**
2026	273,897	10,144	3,043	**287,085**
2027	273,897	10,144	3,043	**287,085**
2028	273,897	10,144	3,043	**287,085**
2029	273,897	10,144	3,043	**287,085**
2030	273,897	10,144	3,043	**287,085**
2031	273,897	10,144	3,043	**287,085**
2032	273,897	10,144	3,043	**287,085**
2033	273,897	10,144	3,043	**287,085**
2034	273,897	10,144	3,043	**287,085**
2035	273,897	10,144	3,043	**287,085**
2036	273,897	10,144	3,043	**287,085**
2037	273,897	10,144	3,043	**287,085**
2038	273,897	10,144	3,043	**287,085**
2039	273,897	10,144	3,043	**287,085**
2040	273,897	10,144	3,043	**287,085**
2041	171,186	6,340	1,902	**179,428**
2042	102,711	3,804	1,141	**107,657**
2043	102,711	3,804	1,141	**107,657**
2044	0	0	0	**0**
2045	0	0	0	**0**
2046	0	0	0	**0**
2047	0	0	0	**0**
2048	0	0	0	**0**
Cumulative emissions for time period 2014 - 2048	**6,676,244**	**247,268**	**74,180**	**6,997,692**

A.6.3 Fugitive Emissions – Facility-Level Fugitive Emissions from Production and Processing

Methane is the primary greenhouse gas in fugitive leak emissions from processing and compression. Three methods are available to estimate fugitive leaks (other than venting and flaring) from natural gas production or processing:

- The emission factor (in tonnes CO_2-e/ tonne gas processed) for methane from general leaks in the natural gas production or processing sourced from the *Technical Guidelines* (DCCEE, 2012b).
- The facility-level average fugitive emission factor (in tonnes CH_4/ Sm^3 gas processed) associated with gas processing plants sourced from the *API Compendium* (API, 2009) – this default emission factor was derived by combining component emission measurements and activity factors for a "typical" facility.
- The facility-level average fugitive emission factor (in tonnes CH_4/ Sm^3 gas processed) associated with onshore gas production sourced from the *API Compendium* (API, 2009).

The equation below was used to convert the API default facility-level average fugitive emission factors to site-specific emission factors. The required parameters are presented in Table A.29. The comparison between the three available emission factors associated with general leaks is presented in Table A.30.

$$EF_{ss(CH_4)} = \frac{EF_{d(CH_4)} \times \frac{mol\%_{ss\ (CH_4)}}{mol\%_{d\ (CH_4)}} \times GWP_{CH_4}}{\rho_{CSG}} \times 1000$$

where:

$EF_{ss(CH_4)}$	=	Site-specific CH_4 facility-level average fugitive emission factor	(t CO_2-e/t CSG processed)
$EF_{d(CH_4)}$	=	Default CH_4 facility-level average fugitive emission factor	(t CH_4/Sm^3 CSG processed)
$mol\%_{ss\ (CH_4)}$	=	Site-specific CH_4 mole percentage of gas processed	(mol%)
$mol\%_{d\ (CH_4)}$	=	Default CH_4 mole percentage of gas processed	(mol%)
GWP_{CH_4}	=	Global warming potential of CH_4	(t CO_2-e/ t CH_4)
ρ_{CSG}	=	CSG density at standard conditions	(kg CSG/ Sm^3 CSG)

Table A.29: Parameters for (Site-Specific) Facility-Level Fugitive Emission Factors Estimation

Data Description	Value	Units
Site-specific CH_4 molar percentage of CSG processed [a]	96.99	mol%
Global warming potential of CH_4 [b]	21	t CO_2-e/ t CH_4
Coal seam gas density at standard conditions [a]	0.700	kg/ Sm^3 CSG
Default CH_4 facility-level average fugitive emission factor associated with gas processing plants (at standard conditions) [c]	1.03×10^{-6}	t CH_4/ Sm^3 CSG processed
Default CH_4 mole percentage of coal seam gas processed [c]	86.8	mol%
Default CH_4 facility-level average fugitive emission factor associated with onshore gas production (at standard conditions) [c]	9.184×10^{-7}	t CH_4/ Sm^3 CSG processed
Default CH_4 molar percentage of coal seam gas processed [c]	78.8	mol%

a Refer to Table 1.1.
b Appendix C, DCCEE (2012b).
c Table 6-2, API (2009).

Table A.30: Facility-Level Fugitive Emission Factors Comparison

Data Description	Value	Units
Default CH_4 emission factor for general leaks [a]	0.0012	t CO_2-e/ t CSG processed
Site-specific CH_4 facility-level average fugitive emission factor associated with gas processing plants (at standard conditions) [b]	0.0346	
Site-specific CH_4 facility-level average fugitive emission factor associated with onshore gas production (at standard conditions) [b]	0.0339	

a Section 3.72 (1) of the *Technical Guidelines*, DCCEE (2012b).
b Pacific Environment's estimation based on emission factors sourced from the API Compendium (2009).

According to the API Compendium (API, 2009), applying average facility-level emission factors is the simplest method for estimating CH_4 emissions from oil and natural gas operation. These emission factors are considered to be the best available method for forecasting emissions from production facilities (i.e., FCFs) and processing facilities (i.e., CGPFs) for this project.

It is assumed that the API Compendium emission factor associated with gas processing plants covers all gas leakage from gas processing and compression (for sources not already characterised by other methods in this assessment).

Table A.30 shows that the facility-level average fugitive emission factor associated with gas processing plants sourced from the API Compendium is the most conservative option; i.e., its use will result in higher emissions. Therefore, this emission factor will be used to estimate emissions associated with facility-level leaks not covered elsewhere for all the facilities.

Emissions of CH_4 for processing facilities were estimated using the equation below. The activity data associated with fugitive emissions from gas processing facilities can be found in the 'CSG in' column of Table A.3. The resulting greenhouse gas emission estimates are presented in Table A.31.

$$E_{CH_4} = Q \times EF_{CH_4}$$

where:

E_{CH_4}	=	Emissions of CO_2-e from facility-level leaks of CH_4	(t CO_2-e/ a)
Q	=	Total quantity of gas processed in the year	(t CSG/a)
EF_{CH_4}	=	Site-specific facility-level average emission factor for CH_4	(t CO_2-e/ t CSG processed)

Table A.31: Greenhouse Gas Emissions Associated with Facility-Level Fugitive Emissions from Gas Production or Processing

Year	Scope 1 Emissions (t CO_2-e/annum)	
	CH_4 Emissions	Total CO_2-e
2014	19,434	**19,434**
2015	24,313	**24,313**
2016	29,326	**29,326**
2017	42,219	**42,219**
2018	107,397	**107,397**
2019	200,310	**200,310**
2020	222,214	**222,214**
2021	251,750	**251,750**
2022	273,067	**273,067**
2023	282,771	**282,771**
2024	298,540	**298,540**
2025	298,492	**298,492**
2026	298,444	**298,444**
2027	298,404	**298,404**
2028	294,781	**294,781**
2029	292,345	**292,345**
2030	282,748	**282,748**
2031	256,186	**256,186**
2032	224,551	**224,551**
2033	200,134	**200,134**
2034	168,591	**168,591**
2035	149,156	**149,156**
2036	127,320	**127,320**
2037	107,911	**107,911**
2038	93,354	**93,354**
2039	83,649	**83,649**
2040	76,371	**76,371**
2041	70,188	**70,188**
2042	64,414	**64,414**
2043	59,547	**59,547**
2044	55,802	**55,802**
2045	53,376	**53,376**
2046	50,950	**50,950**
2047	48,524	**48,524**
2048	46,097	**46,097**
Cumulative emissions for time period 2014 - 2048	**5,452,674**	**5,452,674**

A.6.4 Fugitive Emissions - Venting

In addition to the emissions sources considered in the EIS, supplementary venting emissions sources are included in this assessment based on their historical proportion to Arrow's total gas production, sourced from their 2011/2012 National Greenhouse and Energy Reporting (NGER) inventory. The venting emissions sources included in the assessment are listed in Table 3.2.

The equation below was used to estimate the CH_4 emissions associated with the project.

$$E_V = Q \times R_v$$

where:

E_V	=	Vented emissions of methane from the Surat Gas Project in the year	(t CO_2-e/a)
Q	=	Total amount of gas produced in the year	(GJ/a)
R_v	=	Ratio of vented emissions to total gas production from Arrow's 2011/12 NGER inventory.	(t CO_2-e/GJ)

The ratio used is the sum of all venting emissions across Arrow's operational facilities for the 2011/2012 reporting period (namely: Daandine, Tipton, Kogan, and Moranbah gas fields, and Daandine, Tipton and Moranbah CGPFs) and the associated total gas production. It is presented in Table A.32.

Table A.32: Data Required to Estimate Venting Emissions

Data Required	Value	Units
Ratio of vented emissions to total gas production [a, b]	0.000919	t CO_2-e/ GJ

a Pacific Environment's estimation based on Arrow's 2011-12 NGER inventory (Arrow, 2013).

b Assumed to include all dehydrator pump emissions as the highest of the available emission factors from the *API Compendium 2009* for gas dehydrators with electrically driven pumps was used for the 2011/2012 NGER inventory.

The total gas production for each year can be found in the 'CSG in' column of Table A.3. The resulting greenhouse gas emission estimates are presented in Table A.33.

Table A.33: Greenhouse Gas Emissions Associated with Venting

Year	Scope 1 Emissions (t CO_2-e/annum)	
	CH_4	Total CO_2-e
2014	26,845	**26,845**
2015	33,557	**33,557**
2016	40,268	**40,268**
2017	43,624	**43,624**
2018	130,872	**130,872**
2019	267,448	**267,448**
2020	295,300	**295,300**
2021	338,924	**338,924**
2022	372,481	**372,481**
2023	385,903	**385,903**
2024	407,715	**407,715**
2025	407,715	**407,715**
2026	407,715	**407,715**
2027	407,715	**407,715**
2028	402,682	**402,682**
2029	399,326	**399,326**
2030	385,903	**385,903**
2031	348,991	**348,991**
2032	305,367	**305,367**
2033	271,810	**271,810**
2034	228,186	**228,186**
2035	201,341	**201,341**
2036	171,140	**171,140**
2037	144,294	**144,294**
2038	124,160	**124,160**
2039	110,737	**110,737**
2040	100,670	**100,670**
2041	93,959	**93,959**
2042	87,248	**87,248**
2043	80,536	**80,536**
2044	77,181	**77,181**
2045	73,825	**73,825**
2046	70,469	**70,469**
2047	67,114	**67,114**
2048	63,758	**63,758**
Cumulative emissions for time period 2014 - 2048	**7,374,780**	**7,374,780**

A.7 SCOPE 2 EMISSIONS – OPERATION

As a permanent power supply option, electricity from the grid will be supplied to the CGPFs and the brine treatment facility from where it will be distributed to wells and water transfer stations. FCFs will be powered from a direct connection to the grid or via a CGPF. No electricity will be supplied from the grid for construction and decommissioning activities. Construction and decommissioning power will be supplied via diesel generators (refer to Section A.4.1).

The method to estimate Scope 2 emissions can be found in Chapter 7 of the *Technical Guidelines* (DCCEE, 2012b). Only one method is currently available for the estimation of emissions from electricity purchased from the grid. This method uses indirect emission factors based on the state, territory or electricity grid corresponding to the facility of interest. It should be noted that these indirect emission factors are intended to be updated each year.

Scope 2 emissions of CO_2 associated with purchased electricity were estimated using Method 1 (Division 7.2, *Method 1 – purchase of electricity from main electricity grid in a State or Territory* of the *Technical Guidelines*):

$$Y = Q \times \frac{EF_{S2}}{1000}$$

where:

Y	=	Scope 2 greenhouse gas emissions in the year	(t CO_2-e/a)
Q	=	Quantity of electricity purchased from the grid in the year	(kWh/a)
EF_{S2}	=	Default Scope 2 emission factor specific to State or Territory in which the consumption occurs	(kg CO_2-e/kWh)

The default energy content factor for electricity and the emission factor for CO_2 were sourced from Part 7.2 (3) and Table 7.2 of the *Technical Guidelines* and are listed in Table A.34. The equation below was used to estimate the total quantity of electricity consumed by the single wells in the year based on the number of wells and CGPFs on-line. The same approach was used to estimate the total quantity of electricity consumed by well pads. The activity data associated with electricity consumed are presented in Table A.35 and Table A.36. The resulting greenhouse gas emission estimates are presented in Table A.37.

$$Q = EU_{\text{single wells}} \times N_{\text{single wells}} + EU_{\text{multi-well pads}} \times N_{\text{multi-well pads}}$$

where:

Q	=	Quantity of electricity purchased from the grid in the year	(kWh/a)
$EU_{\text{single wells}}$	=	Electricity usage of single wells	(kWh/a)
$N_{\text{single wells}}$	=	Equivalent number of single wells powered by electricity during the year	(wells/a)
$EU_{\text{multi-well pads}}$	=	Electricity usage of multi-well pads	(kWh/a)
$N_{\text{multi-well pads}}$	=	Equivalent number of multi-well pads powered by electricity during the year	(wells/a)

Table A.34: Energy Content Factor and CO_2 Emission Factor of Electricity Purchased from the Grid in Queensland

Variable	Value	Units
Energy content factor [a]	0.0036	GJ/kWh
CO_2 emission factor (Qld) [b]	0.86	kg CO_2–e/kWh

a Refer to Table 1.1.

b Table 7.2, DCCEE (2012b).

Table A.35: Activity Data Associated with Electricity Purchased from the Grid (1)

Data Required [a]	Value	Unit
Total electricity usage per single wellhead	131,400	kWh/a
Total electricity usage per multi-well pad	1,576,800	kWh/a
Total electricity usage at FCFs	59,130	MWh/a
Total electricity usage at CGPF-1	170,660	MWh/a
Total electricity usage at CGPF-2	432,874	MWh/a
Total electricity usage at CGPF-5	223,920	MWh/a
Total electricity usage at CGPF-7	134,378	MWh/a
Total electricity usage at CGPF-8	288,454	MWh/a
Total electricity usage at CGPF-9	291,227	MWh/a
Total electricity usage at CGPF-10	155,771	MWh/a
Total electricity usage at CGPF-11	232,310	MWh/a

a As advised by Arrow.

Table A.36: Activity Data Associated with Electricity Purchased from the Grid (2)

Year	Equiv. [a] Total Cumulative Number of Wells Powered by Elec. for Full Year	Equiv. Cumulative Single Wells Powered by Elec. for Full Year [b]	Equiv. Cumulative Multi-Well Pads Powered by Elec. for Full Year [b]	Cum. Elec. Usage at FCFs [c, e]	Cum. Elec. Usage at CGPFs [d, e]	Cum. Elec. Usage at Wells [e]
				(kWh/annum)		
2014	0	0	0	0	0	0
2015	0	0	0	0	0	0
2016	21	6	2	0	0	3,403,260
2017	148	44	12	0	0	23,984,880
2018	580	174	45	0	0	93,994,800
2019	990	297	77	0	1,097,885,000	160,358,370
2020	1,343	403	104	0	1,317,593,000	217,565,550
2021	1,981	594	154	0	1,545,708,000	321,040,860
2022	2,402	720	187	0	1,929,594,000	389,187,090
2023	2,822	847	219	0	1,929,594,000	457,333,320
2024	3,241	972	252	118,260,000	1,929,594,000	525,236,460
2025	3,618	1,085	281	177,390,000	1,929,594,000	586,333,080
2026	3,913	1,174	304	295,650,000	1,929,594,000	634,059,750
2027	4,131	1,239	321	354,780,000	1,929,594,000	669,469,860
2028	4,309	1,293	335	354,780,000	1,929,594,000	698,235,510
2029	4,490	1,347	349	354,780,000	1,929,594,000	727,649,400
2030	4,500	1,350	350	354,780,000	1,929,594,000	729,188,970
2031	4,258	1,277	331	354,780,000	1,929,594,000	689,970,450
2032	4,125	1,238	321	354,780,000	1,929,594,000	668,497,500
2033	4,048	1,214	315	354,780,000	1,929,594,000	656,018,880
2034	3,803	1,141	296	354,780,000	1,929,594,000	616,233,150
2035	3,524	1,057	274	354,780,000	1,929,594,000	571,099,440
2036	3,223	967	251	354,780,000	1,929,594,000	522,319,380
2037	2,923	877	227	354,780,000	1,929,594,000	473,701,380
2038	2,625	788	204	354,780,000	1,929,594,000	425,407,500
2039	2,409	723	187	354,780,000	1,929,594,000	390,402,540
2040	2,276	683	177	354,780,000	1,929,594,000	368,848,560
2041	2,202	661	171	354,780,000	917,039,000	356,856,120
2042	2,052	615	160	354,780,000	612,001,000	332,466,090
2043	1,868	560	145	354,780,000	612,001,000	302,728,080
2044	1,607	482	125	354,780,000	0	260,430,420
2045	1,370	411	107	354,780,000	0	222,022,200
2046	1,176	353	91	354,780,000	0	190,582,560
2047	1,008	302	78	236,520,000	0	163,356,480
2048	845	254	66	177,390,000	0	136,940,700

a As some wells will be self-powered for two years and others will be self-powered for six months, an equivalent number of wells powered by electricity for the full year is presented.
This value was estimated using the cumulative number of wells presented in Table A.1 and the equivalent number of wells self-powered in Table A.23.

b Estimated based on the assumption that a third of the commissioned wells are single wells. The remaining wells will be part of multi-well pads.

c FCFs will be powered from the grid after commissioning as advised by Arrow.

d CGPFs will be self-powered for two years after commissioning until a grid connection is made as advised by Arrow.

e Pacific Environment's estimation.

Table A.37: Emissions of Scope 2 CO_2 and Energy Consumption from Electricity Purchased from the Grid in Queensland

Year	Energy Consumption	Wellheads	FCFs	CGPFs	Total Emissions
	(PJ/annum) [a]	Scope 2 CO_2 Emissions (t CO_2-e/annum)			
2014	0.0	0	0	0	**0**
2015	0.0	0	0	0	**0**
2016	0.0	2,927	0	0	**2,927**
2017	0.1	20,627	0	0	**20,627**
2018	0.3	80,836	0	0	**80,836**
2019	4.5	137,908	0	944,181	**1,082,089**
2020	5.5	187,106	0	1,133,130	**1,320,236**
2021	6.7	276,095	0	1,329,309	**1,605,404**
2022	8.3	334,701	0	1,659,451	**1,994,152**
2023	8.6	393,307	0	1,659,451	**2,052,757**
2024	9.3	451,703	101,704	1,659,451	**2,212,858**
2025	9.7	504,246	152,555	1,659,451	**2,316,253**
2026	10.3	545,291	254,259	1,659,451	**2,459,001**
2027	10.6	575,744	305,111	1,659,451	**2,540,306**
2028	10.7	600,483	305,111	1,659,451	**2,565,044**
2029	10.8	625,778	305,111	1,659,451	**2,590,340**
2030	10.8	627,103	305,111	1,659,451	**2,591,664**
2031	10.7	593,375	305,111	1,659,451	**2,557,936**
2032	10.6	574,908	305,111	1,659,451	**2,539,469**
2033	10.6	564,176	305,111	1,659,451	**2,528,738**
2034	10.4	529,961	305,111	1,659,451	**2,494,522**
2035	10.3	491,146	305,111	1,659,451	**2,455,707**
2036	10.1	449,195	305,111	1,659,451	**2,413,756**
2037	9.9	407,383	305,111	1,659,451	**2,371,945**
2038	9.8	365,850	305,111	1,659,451	**2,330,412**
2039	9.6	335,746	305,111	1,659,451	**2,300,308**
2040	9.6	317,210	305,111	1,659,451	**2,281,771**
2041	5.9	306,896	305,111	788,654	**1,400,661**
2042	4.7	285,921	305,111	788,654	**1,379,685**
2043	4.6	260,346	305,111	526,321	**1,091,778**
2044	2.2	223,970	305,111	0	**529,081**
2045	2.1	190,939	305,111	0	**496,050**
2046	2.0	163,901	305,111	0	**469,012**
2047	1.4	140,487	203,407	0	**343,894**
2048	1.1	117,769	152,555	0	**270,324**
Total for time period 2014 - 2048	**232**	**11,683,033**	**6,966,697**	**37,039,814**	**55,689,544**

a Pacific Environment's estimation based on data in Table A.36 and energy content factor of electricity provided in Table A.34.

A.8 SCOPE 3 EMISSIONS – CONSTRUCTION, OPERATION AND DECOMMISSIONING

A.8.1 Full Fuel Cycles

Diesel that will be used during construction, operation, decommissioning and rehabilitation activities have associated indirect emissions from its extraction, processing and transport. The consumption of purchased electricity also have associated scope 3 emissions from the extraction, production and transport of fuel combusted at generation and the indirect emissions attributable to the electricity lost in delivery in the transmission and distribution network.

Full life cycle emissions associated with the construction material (raw material extraction though to manufacturing) are not considered in this study.

The equations below were used to calculate the scope 3 emissions from the consumption of diesel and electricity from the main grid.

$$\mathrm{E_{CO_2-e}} = \frac{\mathrm{Q} \times \mathrm{EC} \times \mathrm{EF_{S3}}}{1000}$$

where:

$\mathrm{E_{CO_2-e}}$	=	Scope 3 emissions of greenhouse gases from diesel combustion in the year	(t CO_2-e/a)
Q	=	Quantity of diesel combusted in the year	(kL/a)
EC	=	Energy content factor of diesel	(GJ/kL)
$\mathrm{EF_{S3}}$	=	Scope 3 emission factor	(kg CO_2-e/GJ)

$$\mathrm{E_{CO_2-e}} = \frac{\mathrm{Q} \times \mathrm{EF_{S3}}}{1000}$$

where:

$\mathrm{E_{CO_2-e}}$	=	Scope 3 emissions of greenhouse gases from electricity consumption in the year	(t CO_2-e/a)
Q	=	Quantity of electricity purchased from the grid in the year	(kWh/a)
$\mathrm{EF_{S3}}$	=	Default Scope 3 emission factor specific to State or Territory in which the consumption occurs	(kg CO_2-e/ kWh)

The default energy content factor of diesel was sourced from Table 2.4.2B of the *Technical Guidelines* (DCCEE, 2012b). The default scope 3 emission factors of diesel and electricity were sourced from Table 39 and Table 40, of the *National Greenhouse Account Factors* (DCCEE, 2012a), and are listed in Table A.38. The activity data associated with the full fuel cycle of diesel are presented in Table A.39 and the resulting greenhouse gas emission estimates are presented in Table A.40. The activity data associated with the full fuel cycle of electricity are presented in Table A.41 and the resulting greenhouse gas emission estimates are presented in Table A.42.

Table A.38: Energy Content Factor and Scope 3 Emission Factors Associated with Full Fuel Cycles

Variable	Value	Units
Energy content factor of diesel [a]	38.6	GJ/kL
Scope 3 emission factor of diesel [b]	5.3	kg CO_2–e/GJ
Scope 3 emission factor of electricity (Qld) [c]	0.12	kg CO_2–e/kWh

a Table 2.4.2B, DCCEE (2012b).
b Table 39, *NGA Factors* DCCEE (2012a).
c Table 40, *NGA Factors* DCCEE (2012a) – latest estimate for Queensland.

Table A.39: Activity Data Associated with Full Fuel Cycle of Diesel

Year	Total Fuel Consumed for Year [a] (kL/annum)
2014	2,150
2015	4,817
2016	13,621
2017	23,582
2018	21,179
2019	24,522
2020	24,092
2021	23,114
2022	24,645
2023	23,990
2024	23,909
2025	21,617
2026	19,273
2027	18,266
2028	18,778
2029	18,864
2030	20,166
2031	19,674
2032	18,428
2033	17,545
2034	17,418
2035	16,097
2036	16,087
2037	16,225
2038	15,672
2039	15,589
2040	15,523
2041	14,960
2042	10,537
2043	9,413
2044	9,463
2045	8,078
2046	7,711
2047	7,578
2048	7,251
Total fuel consumed for time period 2014 - 2048	**569,833**

a This includes diesel used in:
- light and heavy vehicles (refer to Table A.19)
- drills (refer to Table A.13)
- diesel generators for construction power (refer to Table A.16).

Table A.40: Scope 3 Greenhouse Gas Emissions from Full Fuel of Diesel

Year	Scope 3 Emissions ($t\ CO_2$-e/annum)
2014	440
2015	985
2016	2,787
2017	4,824
2018	4,333
2019	5,017
2020	4,929
2021	4,729
2022	5,042
2023	4,908
2024	4,891
2025	4,422
2026	3,943
2027	3,737
2028	3,842
2029	3,859
2030	4,125
2031	4,025
2032	3,770
2033	3,589
2034	3,563
2035	3,293
2036	3,291
2037	3,319
2038	3,206
2039	3,189
2040	3,176
2041	3,060
2042	2,156
2043	1,926
2044	1,936
2045	1,653
2046	1,578
2047	1,550
2048	1,484
Cumulative emissions for time period 2014 - 2048	**116,576**

Table A.41: Activity Data Associated with Full Fuel Cycle of Electricity

Year	Total Electricity Used for Year [a] (kWh/annum)
2014	0
2015	0
2016	3,403,260
2017	23,984,880
2018	93,994,800
2019	1,258,243,370
2020	1,535,158,550
2021	1,866,748,860
2022	2,318,781,090
2023	2,386,927,320
2024	2,573,090,460
2025	2,693,317,080
2026	2,859,303,750
2027	2,953,843,860
2028	2,982,609,510
2029	3,012,023,400
2030	3,013,562,970
2031	2,974,344,450
2032	2,952,871,500
2033	2,940,392,880
2034	2,900,607,150
2035	2,855,473,440
2036	2,806,693,380
2037	2,758,075,380
2038	2,709,781,500
2039	2,674,776,540
2040	2,653,222,560
2041	1,628,675,120
2042	1,299,247,090
2043	1,269,509,080
2044	615,210,420
2045	576,802,200
2046	545,362,560
2047	399,876,480
2048	314,330,700
Total electricity used for time period 2014 - 2048	**64,450,245,590**

a Refer to Table A.36.

Table A.42: Scope 3 Greenhouse Gas Emissions from Full Fuel Cycle of Electricity

Year	Scope 3 Emissions ($t\ CO_2$-e/annum)
2014	0
2015	0
2016	408
2017	2,878
2018	11,279
2019	150,989
2020	184,219
2021	224,010
2022	278,254
2023	286,431
2024	308,771
2025	323,198
2026	343,116
2027	354,461
2028	357,913
2029	361,443
2030	361,628
2031	356,921
2032	354,345
2033	352,847
2034	348,073
2035	342,657
2036	336,803
2037	330,969
2038	325,174
2039	320,973
2040	318,387
2041	195,441
2042	155,910
2043	152,341
2044	73,825
2045	69,216
2046	65,444
2047	47,985
2048	37,720
Cumulative emissions for time period 2014 - 2048	**7,734,029**

A.9 SCOPE 3 EMISSIONS – OPERATION

A.9.1 End Use of Gas

Scope 3 emissions associated with the end use of gas refer to the full combustion of product gas and as a result scope 1 emission factors will be used. End use of the product gas will be the most significant scope 3 emission associated with the project.

In order to estimate the greenhouse gas emissions from the end use of CSG, it was assumed that no fugitive losses will occur after the product gas leaves Arrow Surat Gas facilities. The equation used to calculate the Scope 3 emissions associated with the end use of gas is as follows:

$$E_{CO_2-e} = \frac{Q \times EF_{S1}}{1000}$$

where:

E_{CO_2-e}	=	Emissions of greenhouse gases from end use of produced gas in the year	(t CO_2-e/a)
Q	=	Quantity of gas produced in the year	(GJ/a)
EF_{S1}	=	Greenhouse gas scope 1 emission factor for CSG combustion	(kg CO_2-e/GJ)

The default scope 3 emission factors (i.e., scope 1 emission factors used as scope 3 emission factors) of CSG were sourced from Table 2.3.2A of the *Technical Guidelines* (DCCEE, 2012b) and are listed in Table A.43. The activity data associated with the end use of gas are presented in Table A.44 and the resulting greenhouse gas emission estimates are presented in Table A.45.

Table A.43: Energy Content Factor and Scope 3 Emission Factors Associated with the End-Use of CSG

Method Used	Variable	Value	Units
Method 1	Scope 1 CO_2 emission factor of coal seam gas [a]	51.1	kg CO_2–e/GJ
Method 1	Scope 1 CH_4 emission factor of coal seam gas [a]	0.2	
Method 1	Scope 1 N_2O emission factor of coal seam gas [a]	0.03	
Method 1	Scope 1 overall emission factor of coal seam gas [b]	51.33	

a Table 2.3.2A, DCCEE (2012b).
b Pacific Environment's estimation.

Table A.44: Activity Data Associated with the End-Use of CSG

Year	Cumulative total gas production [a]	Cumulative quantity of gas available to end-users [b]
	(TJ/a)	
2014	29,220	29,220
2015	36,525	36,525
2016	43,830	43,830
2017	47,483	47,465
2018	142,448	142,430
2019	291,104	291,087
2020	321,420	321,403
2021	368,903	368,885
2022	405,428	405,410
2023	420,038	420,020
2024	443,779	443,762
2025	443,779	443,762
2026	443,779	443,762
2027	443,779	443,762
2028	438,300	438,283
2029	434,648	434,630
2030	420,038	420,020
2031	379,860	379,843
2032	332,378	332,360
2033	295,853	295,835
2034	248,370	248,353
2035	219,150	219,133
2036	186,278	186,260
2037	157,058	157,040
2038	135,143	135,125
2039	120,533	120,515
2040	109,575	109,558
2041	102,270	102,253
2042	94,965	94,948
2043	87,660	87,643
2044	84,008	83,990
2045	80,355	80,338
2046	76,703	76,685
2047	73,050	73,033
2048	69,398	69,380

a Refer to Table A.1.
b This excludes the quantity of gas lost through transmission to the Arrow LNG Plant (refer to Table A.50).

Table A.45: Scope 3 Greenhouse Gas Emissions Associated with the End-Use of CSG

Year	Scope 3 Emissions (t CO_2-e/annum)			
	CO_2	CH_4	N_2O	Total CO_2-e
2014	1,493,142	5,844	877	**1,499,863**
2015	1,866,428	7,305	1,096	**1,874,828**
2016	2,239,713	8,766	1,315	**2,249,794**
2017	2,425,474	9,493	1,424	**2,436,391**
2018	7,278,186	28,486	4,273	**7,310,945**
2019	14,874,546	58,217	8,733	**14,941,496**
2020	16,423,681	64,281	9,642	**16,497,603**
2021	18,850,036	73,777	11,067	**18,934,880**
2022	20,716,464	81,082	12,162	**20,809,708**
2023	21,463,035	84,004	12,601	**21,559,640**
2024	22,676,213	88,752	13,313	**22,778,278**
2025	22,676,213	88,752	13,313	**22,778,278**
2026	22,676,213	88,752	13,313	**22,778,278**
2027	22,676,213	88,752	13,313	**22,778,278**
2028	22,396,249	87,657	13,148	**22,497,054**
2029	22,209,606	86,926	13,039	**22,309,571**
2030	21,463,035	84,004	12,601	**21,559,640**
2031	19,409,965	75,969	11,395	**19,497,328**
2032	16,983,609	66,472	9,971	**17,060,052**
2033	15,117,181	59,167	8,875	**15,185,223**
2034	12,690,826	49,671	7,451	**12,747,947**
2035	11,197,684	43,827	6,574	**11,248,084**
2036	9,517,899	37,252	5,588	**9,560,739**
2037	8,024,757	31,408	4,711	**8,060,876**
2038	6,904,900	27,025	4,054	**6,935,979**
2039	6,158,329	24,103	3,615	**6,186,048**
2040	5,598,401	21,912	3,287	**5,623,599**
2041	5,225,116	20,451	3,068	**5,248,634**
2042	4,851,830	18,990	2,848	**4,873,668**
2043	4,478,545	17,529	2,629	**4,498,702**
2044	4,291,902	16,798	2,520	**4,311,220**
2045	4,105,259	16,068	2,410	**4,123,737**
2046	3,918,616	15,337	2,301	**3,936,254**
2047	3,731,974	14,607	2,191	**3,748,771**
2048	3,545,331	13,876	2,081	**3,561,288**
Cumulative emissions for time period 2014 - 2048	**410,156,567**	**1,605,309**	**240,796**	**408,441,385**

A.9.2 Emissions Associated with the Third Party Infrastructure Required to Export CSG

Scope 3 emissions associated with the third party infrastructure required to export gas as LNG refer to the gas losses through transmission to Arrow LNG Plant and the emissions associated with downstream processing of the gas.

A.9.2.1 Transmission

According to the *Technical Guidelines* (DCCEE, 2012b), additional potential emissions of methane can be a result of:

- maintenance on pipelines
- leakage.

High-pressure gas pipelines will transport gas from the outlet of the CGPFs to the main Arrow Surat Pipeline, Surat Header Pipeline or Daandine gas hub. The emissions from the transmission of the gas are considered as indirect scope 3 emissions, in line with the terms of reference, as the transmission pipeline is not within the boundaries of the Surat Gas Project.

Emissions of CO_2 and CH_4 were estimated using Method 1 (Division 3.3.7, *Method 1- natural gas transmission* of the *Technical Guidelines*):

$$E_j = Q \times EF_j$$

where:

E_j	=	Emissions of gas type (j) from natural gas transmission in the year	(t CO_2-e/a)
Q	=	Total length of pipeline system relevant to the study in the year	(km/a)
EF_j	=	Emission factor for gas type (j)	(t CO_2-e/km)

The default emission factor for each gas was sourced from Section 3.76, of the *Technical Guidelines*, and are listed in Table A.46. The activity data associated with fugitive emissions from transmission are presented in Table A.47. The resulting greenhouse gas emission estimates are presented in Table A.48.

Table A.46: Emission Factors Associated with Gas Transmission to Arrow LNG Plant (Scope 3)

Method Used	Variable	Value	Units
Method 1	Scope 1 default CO_2 emission factor [a]	0.02	t CO_2-e/ km
Method 1	Scope 1 default CH_4 emission factor [a]	8.7	
Method 1	Scope 1 overall emission factor [b]	8.72	

a Section 3.76, DCCEE (2012b).
b Pacific Environment's estimation.

Table A.47: Activity Data Associated with Gas Transmission to Arrow LNG Plant (Scope 3)

Data Required	Value	Units
Maximum length of high pressure gas pipelines from CGPFs to Arrow LNG [a, b]	760	km

a Pacific Environment's estimate: The total pipeline length include the following distances:

- Goodiwindi - Millmeran (161 kms)
- Millmeran-Dalby (99 kms)
- Dalby - Chinchilla (82 kms)
- Chinchilla - Wandoan (115 kms)
- Wandoan - Arrow LNG (Gladstone) (303 kms).

Full length of Arrow Surat Pipeline will be commissioned in 2016. However, high pressure pipeline infrastructure (as yet undefined) will be installed to ensure that gas from the facilities that are developed before 2016 can be distributed for use as advised by Arrow.

b Pacific Environment's assumption: the maximum pipeline length is used for each year (worst-case).

Table A.48: Greenhouse Gas Emissions Associated with Gas Transmission to Arrow LNG Plant (Scope 3)

Year	Scope 3 Emissions (t CO_2-e/annum)		
	CO_2	CH_4	Total CO_2-e
Annual emissions (2017 - 2048)	15	6,609	**6,624**
Cumulative emissions for time period 2017 – 2048 [a]	**486**	**211,473**	**211,959**

a No emissions associated with transmission of coal seam gas to Arrow LNG Plant occur for the period 2014 – 2017 as no CGPFs will be operational until 2017 as advised by Arrow. The Arrow LNG Plant is expected to be decommissioned by 2042; however, it was assumed that the gas will be redirected to a new LNG plant after 2042.

A.9.2.2 Emissions Associated with Downstream Processing of Coal Seam Gas

In order to estimate the emissions associated with the downstream processing of CSG to produce and export LNG, the scope 1 and scope 2 annual emissions associated with the "partial auxiliary power import case" (or "partial power mode") scenario from the Arrow LNG plant SREIS were used. This scenario was selected as it is anticipated to yield the highest emissions for the Arrow LNG Plant project (refer to Arrow LNG EIS Greenhouse Gas chapter (PAEHolmes, 2012)). The fugitive losses from gas transmission to Arrow LNG Plant were then excluded from the total scope 1 and scope 2 emissions.

Scope 3 emissions of CO_2 CH_4 and N_2O based on the Arrow LNG Plant estimated scope 1 and scope 2 annual emissions for the "partial auxiliary power import case" option for four LNG trains were scaled down to the amount of CSG delivered by the project as follows:

$$E_{j,S3} = E_{j,S1\&2} \times \frac{Q_{upstream}}{Q_{downstream}}$$

where:

$E_{j,S3}$	=	Scope 3 emissions of gas type (j) associated with downstream gas processing in the year	(t CO_2-e/a)
$E_{j,S1\&2}$	=	Scope 1 and scope 2 emissions of gas type (j) associated with gas processing at Arrow LNG Plant in the year	(t CO_2-e/a)
$Q_{upstream}$	=	Total amount of gas fed to Arrow LNG from the project	(Sm^3/a)
$Q_{downstream}$	=	Total amount of gas processed downstream for four LNG trains (Arrow LNG Plant)	(Sm^3/a)

The equation below presents the energy balance used to determine the total amount of gas fed to Arrow LNG Plant from the project. The second equation below was used to convert CO_2 equivalent emissions from gas transmission (refer to Table A.48) to a quantity of gas. The required parameters are presented in Table A.49. The activity data associated with the downstream processing of coal seam gas are presented in Table A.50, Table A.51 and Table A.52. The greenhouse gas emission estimates are presented in Table A.53.

$$Q_{upstream} = \frac{(CSG_P - CSG_T) \times 1000}{EC_{ss}}$$

where:

$Q_{upstream}$	=	Total amount of gas fed to Arrow LNG from the project	(Sm^3/a)
CSG_P	=	Cumulative total gas produced by the project in the year	(TJ/a)
CSG_T	=	Total leaks of CO_2 and CH_4 during transmission to Arrow LNG Plant in the year	(TJ/a)
EC_{ss}	=	Site-specific energy content of CSG at standard conditions	(GJ/Sm^3 CSG)

$$CSG_T = \frac{\left(\frac{CSG_{T,CO2}}{GWP_{CO2}} + \frac{CSG_{T,CH4}}{GWP_{CH4}}\right) \times EC_{ss}}{\rho_{CSG}}$$

where:

CSG_T	=	Total leaks of CO_2 and CH_4 during transmission in the year	(TJ/a)
$CSG_{T,CO2}$	=	Total leaks of CO_2 during transmission in the year (refer to Table A.48)	(t CO_2-e/a)
$CSG_{T,CH4}$	=	Total leaks of CH_4 during transmission in the year (refer to Table A.48)	(t CO_2-e/a)
GWP_{CO2}	=	Global warming potential of CO_2	(t CO_2-e /t CO_2)
GWP_{CH4}	=	Global warming potential of CH_4	(t CO_2-e /t CH_4)
EC_{ss}	=	Site-specific CSG energy content factor at standard conditions	(GJ/Sm^3 CSG)
ρ_{CSG}	=	Site-specific CSG density at standard conditions	(kg CSG/ Sm^3 CSG)

Table A.49: Parameters Associated with the Estimation of the Quantity of CSG losses during Transmission to Arrow LNG Plant

Data Required	Value	Units
Site-specific CSG density at standard conditions [a]	0.700	kg/Sm^3
Site-specific CSG energy content factor [a]	0.03660	GJ/Sm^3
Global warming potential of CO_2 [b]	1	t CO_2-e/ t CO_2
Global warming potential of CH_4 [b]	21	t CO_2-e/ t CH_4

a Refer to Table 1.1.
b Appendix C, DCCEE (2012b).

Table A.50: Activity Data Associated with Downstream Processing of CSG (Scope 3) (1)

Year	Cumulative Total Gas Produced by the Project	Amount of CSG Losses Through Transmission to Arrow LNG	Amount of Gas Fed to Arrow LNG
	(TJ/a) [a]	(TJ/a) [b]	(Sm^3/a)
2014	29,220	0	798,360,656
2015	36,525	0	997,950,820
2016	43,830	0	1,197,540,984
2017	47,483	17	1,296,864,804
2018	142,448	17	3,891,536,935
2019	291,104	17	7,953,196,771
2020	321,420	17	8,781,495,951
2021	368,903	17	10,078,832,017
2022	405,428	17	11,076,782,836
2023	420,038	17	11,475,963,164
2024	443,779	17	12,124,631,197
2025	443,779	17	12,124,631,197
2026	443,779	17	12,124,631,197
2027	443,779	17	12,124,631,197
2028	438,300	17	11,974,938,574
2029	434,648	17	11,875,143,492
2030	420,038	17	11,475,963,164
2031	379,860	17	10,378,217,263
2032	332,378	17	9,080,881,197
2033	295,853	17	8,082,930,377
2034	248,370	17	6,785,594,312
2035	219,150	17	5,987,233,656
2036	186,278	17	5,089,077,918
2037	157,058	17	4,290,717,263
2038	135,143	17	3,691,946,771
2039	120,533	17	3,292,766,443
2040	109,575	17	2,993,381,197
2041	102,270	17	2,793,791,033
2042	94,965	17	2,594,200,869
2043	87,660	17	2,394,610,705
2044	84,008	17	2,294,815,623
2045	80,355	17	2,195,020,541
2046	76,703	17	2,095,225,459
2047	73,050	17	1,995,430,377
2048	69,398	17	1,895,635,295

a Refer to Table A.1.
b Refer to Table A.48.

Table A.51: Activity Data Associated with Downstream Processing of CSG (Scope 3) (2)

Data Required	Value	Units
Total amount of gas processed downstream for four LNG trains (Arrow LNG Plant) [a]	25,566,527,729	Sm^3/a

a Sourced from Arrow LNG Greenhouse Assessment for the SREIS (PAEHolmes, 2012).

Table A.52: Arrow LNG Plant Operational Emissions (Scope 1 and Scope 2)

Year	Arrow LNG Operational Emissions (t CO_2-e/annum) [a]		
	CO_2	CH_4	N_2O
2014	123,097	12	55
2015	49,887	46	166
2016	100,292	40	151
2017	99,683	38	147
2018	2,169,776	337,397	2,475
2019	2,028,702	335,826	1,868
2020	2,028,702	335,826	1,868
2021	2,028,702	335,826	1,868
2022	2,028,702	335,826	1,868
2023	2,111,491	335,864	2,015
2024	2,111,491	335,864	2,015
2025	2,111,491	335,864	2,015
2026	4,181,584	673,224	4,342
2027	4,057,403	671,653	3,735
2028	4,057,403	671,653	3,735
2029	4,057,403	671,653	3,735
2030	4,057,403	671,653	3,735
2031	4,057,403	671,653	3,735
2032	4,057,403	671,653	3,735
2033	4,057,403	671,653	3,735
2034	4,057,403	671,653	3,735
2035	4,057,403	671,653	3,735
2036	4,057,403	671,653	3,735
2037	4,057,403	671,653	3,735
2038	4,057,403	671,653	3,735
2039	4,057,403	671,653	3,735
2040	4,057,403	671,653	3,735
2041	4,057,403	671,653	3,735
2042	4,057,403	671,653	3,735
2043	4,057,403	671,653	3,735
2044	4,057,403	671,653	3,735
2045	4,057,403	671,653	3,735
2046	4,057,403	671,653	3,735
2047	4,057,403	671,653	3,735
2048	4,057,403	671,653	3,735
Cumulative emissions for time period 2014 - 2048	**110,436,473**	**18,138,010**	**103,030**

a Emissions for period 2043-2048 were assumed to be the same as the emissions for period 2027 - 2042. Even though the Arrow LNG project is only forecast until 2042, it was assumed that the gas will still undergo downstream processing.

Table A.53: Scope 3 Greenhouse Gas Emissions Associated with Downstream Processing of CSG

Year	Scope 3 Emissions (t CO_2-e/annum)			
	CO_2	CH_4	N_2O	Total CO_2-e
2014	3,844	0	2	**3,846**
2015	1,947	2	6	**1,956**
2016	4,698	2	7	**4,707**
2017	5,056	2	7	**5,066**
2018	330,266	51,356	377	**381,999**
2019	631,085	104,468	581	**736,135**
2020	696,811	115,348	642	**812,801**
2021	799,754	132,389	736	**932,880**
2022	878,942	145,498	809	**1,025,249**
2023	947,778	150,758	904	**1,099,441**
2024	1,001,350	159,280	955	**1,161,585**
2025	1,001,350	159,280	955	**1,161,585**
2026	1,983,068	319,269	2,059	**2,304,396**
2027	1,924,177	318,523	1,771	**2,244,472**
2028	1,900,421	314,591	1,750	**2,216,761**
2029	1,884,583	311,969	1,735	**2,198,287**
2030	1,821,233	301,482	1,677	**2,124,392**
2031	1,647,021	272,644	1,516	**1,921,181**
2032	1,441,134	238,562	1,327	**1,681,023**
2033	1,282,760	212,345	1,181	**1,496,285**
2034	1,076,873	178,263	991	**1,256,127**
2035	950,173	157,289	875	**1,108,337**
2036	807,636	133,694	744	**942,073**
2037	680,936	112,720	627	**794,283**
2038	585,911	96,990	539	**683,441**
2039	522,561	86,504	481	**609,546**
2040	475,049	78,638	437	**554,125**
2041	443,374	73,395	408	**517,177**
2042	411,699	68,152	379	**480,230**
2043	380,024	62,908	350	**443,282**
2044	364,187	60,287	335	**424,809**
2045	348,349	57,665	321	**406,335**
2046	332,512	55,043	306	**387,861**
2047	316,674	52,422	292	**369,387**
2048	300,837	49,800	277	**350,914**
Cumulative emissions for time period 2014 - 2048	**28,184,075**	**4,631,539**	**26,361**	**32,841,975**