VOLUME 2 APPENDICES JULY 2011

AGL Dalton Power Project Environmental Assessment

MP10-0035

Appendix E

Greenhouse Gas Assessment

Switched on Business.

Report

Greenhouse Gas Assessment

AGL Gas-Fired Power Station at Dalton, NSW

1 JULY 2011

Prepared for

AGL Energy Limited

Level 22, 101 Miller Street
North Sydney NSW 2060

43217973

URS

Project Manager:	Nicole Brewer		
	Senior Associate Environmental Engineer	**URS Australia Pty Ltd** **Level 4, 407 Pacific Highway** **Artarmon NSW 2064** **Australia** **T: 61 2 8925 5500** **F: 61 2 8925 5555**	
Project Director:	Michael Chilcott Principal Environmental Scientist		
Author:	James Grieve Air Quality Engineer		
Reviewer:	Stephen Bowly Associate Air Quality Scientist	Date: Reference: Status:	**1 July 2011** 43217973/GHGA/3 V1

Document delivery

URS Australia provides this document in either printed format, electronic format or both. URS considers the printed version to be binding. The electronic format is provided for the client's convenience and URS requests that the client ensures the integrity of this electronic information is maintained. Storage of this electronic information should at a minimum comply with the requirements of the Commonwealth Electronic Transactions Act (ETA) 2000.

Where an electronic only version is provided to the client, a signed hard copy of this document is held on file by URS and a copy will be provided if requested.

Table of Contents

Executive Summary v

1 Introduction 7

2 Greenhouse Gas Policy 9

2.1 International Policy 9

2.2 Australia's Climate Change Policy 9

2.3 Carbon Pollution Reduction Scheme (CPRS) 9

2.4 National Greenhouse and Energy Reporting Act 2007 (NGER Act) 10

2.5 Energy Efficiency Opportunities (EEO) 10

2.6 State-based Policy 11

2.6.1 NSW Greenhouse Plan (2005) 11

2.6.2 The NSW Greenhouse Gas Reduction Scheme 11

3 Inventory Methodology 13

3.1 Accounting and Reporting Principles 13

3.2 Inventory Organisational Boundaries 14

3.3 Inventory Operational Boundaries 14

3.3.1 Scope 1: Direct greenhouse gas emissions 14

3.3.2 Scope 2: Electricity indirect greenhouse gas emissions 14

3.3.3 Scope 3: Other indirect greenhouse gas emissions 14

3.4 Greenhouse Gas Inventory 14

3.4.1 Activity Data 15

3.4.2 Emission Factors 15

3.4.3 Annual Project Emissions 16

3.4.4 Project Lifetime Emissions 16

3.5 Generator Performance 17

3.6 Comparison to National and NSW Greenhouse Gas Inventories 19

4 Greenhouse Gas Abatement 21

4.1 AGL's Approach to Greenhouse Gas Management 21

4.2 Evaluation of Greenhouse Gas Mitigation Measures 22

4.2.1 Mitigation Measures 22

4.2.2 Technology Selection for the Project 24

4.2.3 Carbon Capture and Sequestration (CCS) 24
4.2.4 Evaporative Inlet Cooling 25
4.2.5 Influence of a Carbon Price on the Project 26
4.2.6 Summary 27

5 Conclusions 29

6 References 31

7 Limitations 33

Tables

Table 3-1 Estimated gas consumption and electricity sent out and consumed 15
Table 3-2 Emission factors used in the assessment 15
Table 3-3 Estimated greenhouse gas emissions on an annual basis 16
Table 3-4 Estimated greenhouse gas emissions on a project lifetime basis 16
Table 3-5 Full fuel cycle emissions intensity of various generator technology types 17
Table 3-6 Comparison of proposal to state and national greenhouse gas inventories 20
Table 4-1 Evaluation of potential Greenhouse mitigation measures available to the Project 23
Table 4-2 Market Cap for Carbon Price as Detailed in CPRS White Paper (COA, 2008) 25

Figures

Figure 3-1 Full Fuel Cycle Emissions intensity of various generator technology types 18
Figure 3-2 NSW and national greenhouse gas emissions 19
Figure 4-1 AGL Energy – Installed Capacity Generation 21

Abbreviations

Abbreviation	Description
AGL	AGL Energy Limited
AGO	Australian Greenhouse Office
BAT	Best Available Technology
CCS	Carbon Capture and Sequestration
CH_4	Methane
CO_2	Carbon Dioxide
CO_2-e	Carbon Dioxide Equivalent
CPRS	Carbon Pollution Reduction Scheme
DCC	Department of Climate Change
DGR’s	Director General’s Requirements
EA	Environmental Assessment
EEO	Energy Efficiency Opportunities
GHGA	Greenhouse Gas Assessment
GHG	Greenhouse gas
GJ	Gigajoule (10^9 joules)
GWh	Gigawatt Hour (3,600 GJ)
GWP	Global Warming Potential
IPCC	Intergovernmental Panel on Climate Change
MW	Megawatt (10^6 watts)
MWh	Megawatt Hour (3.6 GJ)
N_2O	Nitrous Oxide
OCGT	Open Cycle Gas Turbine
OCGTCCS	Open Cycle Gas Turbine with Carbon Capture and Sequestration
PJ	Petajoule (10^{15} joules)
TJ	Terajoule (10^{12} joules)

Executive Summary

AGL Energy Limited (AGL) proposes the development of an open cycle gas turbine peaking power station to the north of Dalton, NSW (the Facility). It is proposed that the Facility will have a total generation capacity of up to nominally 1500 MW, consisting of up to six gas turbine generators. AGL proposes to construct the Facility in a staged approach, and for it to be fuelled by natural gas supplied via an off-take from the Moomba to Sydney gas pipeline. AGL estimates the Facility would operate for up to 15 % of the year, (approximately 1300 hours), during periods of peak demand when additional energy is required by the electricity grid.

A greenhouse gas assessment has been performed for the Facility, and has included scope 1, scope 2 and scope 3 emissions associated with natural gas combustion in the open cycle gas turbine generators, and the consumption of electricity from the electricity grid. The principal greenhouse gas emission from the Facility is carbon dioxide (CO_2), which is a product of natural gas combustion. Minor quantities of other greenhouse gases may be emitted and have been represented in this assessment, as carbon dioxide equivalent (CO_2-e).

The assessment has considered four potential plant configurations, each with an operating duty of 15 % of the year (the proposed upper limit of operation). Given that AGL's current peaking experience indicates that that on a long term average, plant operation would occur for approximately 3% of the year, analysis based on the upper limit of proposed operation is considered conservative.

Total annual emissions were estimated to be in the range of 0.67 to 1.47 Million tonnes of carbon dioxide equivalent (Mt CO_2-e). The associated (full fuel cycle) emissions intensity of generation was calculated to be approximately 800 kilograms of carbon dioxide equivalent per megawatt hour of electricity generated (kg CO_2-e/MWh).

Based on a project life of 30 years, the total lifetime emissions were estimated to be between 20.1 and 44.0 Mt CO_2-e.

A comparison of emissions from the Facility to state and national greenhouse gas inventories was also made. Emissions from the project were estimated to be in the range of 0.41-0.90% and 0.11-0.25% of the state and national inventories, respectively. In addition, emissions from the project were estimated to be in the range of 0.85-1.85% and 0.23-0.49% of stationary energy emissions from the state and national inventories, respectively.

AGL proposes to implement generator technology that is consistent with current best available technology for peaking operation. Beyond the greenhouse gas reduction measures inherent in the technology choice for the Project, this has largely precluded the identification of further greenhouse gas mitigation measures, with the exception of Carbon Capture and Sequestration (CCS). However, an evaluation of the implementation of CCS for the Project indicates that CCS is unlikely to represent a technically or commercially feasible greenhouse mitigation measure for the Project.

AGL anticipates that greenhouse gas mitigation strategies will become more relevant with ongoing operation of the Facility, and are likely to be based around efficiency improvements associated with the adoption of improved technologies and componentry that are developed. Such improvements could then be implemented during routine maintenance and refurbishment. In line with the intention of the introduction of a carbon price by the Federal Government, AGL proposes to investigate the feasibility of such measures as and when they become commercially available.

1 Introduction

AGL Energy Limited. (AGL) proposes the development of an Open Cycle Gas Turbine (OCGT) peaking power station (hereafter referred to as the Facility) to the north of Dalton, NSW. It is proposed that the Facility will have a total generation capacity of up to nominally 1500MW, consisting of up to six turbines, to be constructed in a two-staged approach:

- **Stage 1**: Power generation of between 250 MW and 780 MW comprising:
  - two to four E Class generators ranging from 125 MW to 2000 MW (total power generation of 250 MW – 780 MW); or
  - two to three F Class generators ranging from 200 MW to 320 MW (total power generation of 400 MW – 780 MW).
- **Stage 2**: Power generation of up to a total of 1500 MW comprising:
  - Any underbuild of Stage 1 plus additional E or F class turbines taking the maximum number of turbines to 6 with a total maximum generating capacity to nominally 1500 MW.

It is proposed that the Facility be fuelled by natural gas, supplied via an off-take from the Moomba to Sydney gas pipeline.

The Facility would operate for up to 15% of the year (approximately 1300 hours), during periods of peak demand. Peak demand is generally associated with the morning and evening periods, particularly at times of extreme temperatures, however, the facility may operate at any time during the day or night, and at any time of the year.

The second stage of construction of the Facility would be initiated when the need arose, however it is anticipated that this would not occur until such time that Transgrid has upgraded its transmission system between the Bannaby and Yass substations.

The principal greenhouse gas emission from the Facility is carbon dioxide (CO_2) which is the main product of fuel combustion. Minor quantities of other greenhouse gases may be emitted and have been represented in this assessment, as carbon dioxide equivalent (CO_2-e). Greenhouse gases absorb the infrared radiation reflected from the earth's surface and trap the heat in the atmosphere. The most abundant of these gases are carbon dioxide (CO_2) and water vapour (H_2O). Other greenhouse gases such as methane (CH_4) and nitrous oxide (N_2O) are present in much smaller amounts in the atmosphere. Naturally occurring greenhouse gases raise the Earth's global average temperature to approximately 15°C, approximately 33°C higher than without their presence.

The less abundant greenhouse gases (e.g. CH_4 and N_2O) are much more efficient in trapping infrared radiation than CO_2. The measure of how "efficient" a greenhouse gas in trapping heat is called the Global Warming Potential (GWP). GWP compares the heat absorbing ability of a greenhouse gas to that of the same mass of carbon dioxide over a given time frame. For example, over a 100 year time-frame, methane traps approximately 21 times as much infrared radiation from the earth as CO_2; and nitrous oxide approximately 310 times as much infrared radiation as CO_2. When compiling greenhouse gas inventories, this difference in Global Warming Potential is accounted for by converting one tonne of non-CO_2 greenhouse gas into a CO_2 equivalent (CO_2-e) amount using the GWP for that particular non-CO_2 gas.

1 Introduction

Since greenhouse gases trap heat in the atmosphere, scientists have suggested that there is a causal link between the rapid increases in the concentrations of greenhouse gases and the possibility of increased global temperatures. The best available scientific evidence suggests that the global average temperature has increased by approximately 0.76 $\pm$ 0.19 °C from 1850-1988 to 2001-2005 (IPCC, 2007). Because of this, the accounting and management of greenhouse gas emissions resulting from human activities are increasingly seen as an important issue by some governments and industrial companies. Furthermore, efficiencies in greenhouse gas emissions are often related to efficiencies in energy consumption.

This assessment discusses the current regulatory context of greenhouse gas emissions from the Facility and includes a quantitative model of the tonnages of greenhouse gas produced by the Facility, which is compared to state and national greenhouse gas inventories for both the energy sector, and the sum of all sectors.

Greenhouse Gas Policy

2.1 International Policy

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

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

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

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

Emissions projections contained in *Tracking Kyoto and 2020 Australia's Greenhouse Emissions Trends 1990 to 2008-2012 and 2020"* (DCC, 2009b) estimate that Australia is on track to meet its Kyoto target without the need to purchase international credits.

2.2 Australia's Climate Change Policy

The Australian policy on climate change was released in July 2007 (Department of the Prime Minister and Cabinet, 2007) and sets out the Commonwealth Government's focus on:

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

This Facility will operate in accordance with the following climate change policies: Carbon Pollution Reduction Scheme (CPRS), Energy Efficiency Opportunities (EEO), and *National Greenhouse and Energy Reporting Act 2007* (NGER Act).

2.3 Carbon Pollution Reduction Scheme (CPRS)

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

The CPRS is a trading scheme which will cap total greenhouse gas emissions and allow trading in emissions permits. It is unclear if or when CPRS will commence in Australia. Under CPRS liable entities would be required to obtain carbon pollution permits to acquit their greenhouse gas emission obligations under the scheme.

Industry sectors proposed to be covered by the CPRS are the stationary energy, transport, fugitive emissions, industrial processes, waste and forestry sectors (Australian Government, 2008). Direct scheme obligations will apply to entities with a facility that emits more than 25 kilotonnes CO_2-e of scope 1 emissions per year, subject to strategic review of the scheme. In the form described AGL expects that its operations, including the Dalton Power Project, will be required to participate in the CPRS, although official regulations and guidelines have not been published at the time of writing.

The CPRS would be supported by the NGER Act which establishes a national framework for Australian corporations to report Scope 1 and Scope 2 greenhouse gas emissions, reductions, removals and offsets, and energy consumption and production, from July 2008.

2.4 National Greenhouse and Energy Reporting Act 2007 (NGER Act)

The NGER Act establishes a national framework for Australian corporations to report Scope 1 and Scope 2 (see Section 3.3 for definitions) greenhouse gas emissions, reductions, removals and offsets, and energy consumption and production, and commenced in July 2008. It is designed to provide robust data as a foundation to a CPRS.

Current thresholds (for the 2010-2011 reporting period), corporations are required to register and report if:

- They control facilities that emit 25 kilotonnes or more of greenhouse gas (CO_2-e), or produce/consume 100 terajoules or more of energy annually; or
- Their corporate group emits 50 kilotonnes or more greenhouse gas (CO_2-e), or produces/consumes 200 terajoules or more of energy annually.

Companies must register by 31st August, and report by 31st October, following the financial year in which they trigger a threshold.

2.5 Energy Efficiency Opportunities (EEO)

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

Energy Efficiency Opportunities legislation is designed to lead to:

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

The EEO program will be incorporated into the National Framework for Energy Efficiency. AGL is a registered participant in EEO, and the Dalton Power Project will be included in AGL's efforts to meet their obligations under EEO.

2.6 State-based Policy

2.6.1 NSW Greenhouse Plan (2005)

The NSW Government Greenhouse Plan (NSW Government, 2005) was released in November 2005. The plan provides a strategic approach to combating climate change in NSW. The NSW Greenhouse Plan outlines new and ongoing actions to limit greenhouse emissions in NSW, and achieve key emission reduction targets announced by the NSW Government. Key principles and goals of the Greenhouse Plan are to:

- Raise awareness of climate issues within the broader community;
- Recognise that climate change is a global, long term and complex issue with no easy solution;
- Promote understanding of the likely impacts on NSW, and identify strategies for adaptation to the environmental, social and economic impacts of climate change;
- Limit the growth of greenhouse gas emissions and reduce these emissions in NSW. The Plan outlines targets, strategies and actions to achieve significant emission reductions;
- Promote climate change partnerships through co-operative approaches by Government, individuals, industry, business and community groups;
- Reduce business uncertainties by establishing carbon constraints in order to promote new investment and innovation; and
- Identify key strategic areas for cooperative work with other Australian jurisdictions including the development and establishment of a Kyoto compliant national emissions trading scheme.

The Greenhouse Plan was designed to cover the 2005 to 2008 period and the NSW Government is understood to be planning to supersede the NSW Greenhouse Plan with the NSW Climate Action Plan.

2.6.2 The NSW Greenhouse Gas Reduction Scheme

The NSW Greenhouse Gas Reduction Scheme (GGAS) (formally known as the NSW Greenhouse Gas Abatement Scheme) commenced on 1 January 2003 with the aim of reducing greenhouse gas emissions from the production and use of electricity. It uses a “baseline and credit” approach to abatement, where project-based activities generate offsets that can be used to abate greenhouse gas emissions.

The tradable unit in the GGAS is a New South Wales Greenhouse Abatement Credit (NGAC), which is equivalent to one tonne of abated CO_2-e. A more generic name for these credits in GGAS is Abatement Certificate. Retailers are liable for a certain number of NGACs calculated on the basis of their share of the NSW electricity market. Therefore, retailers provide the demand for NGACs, and other parties supply NGACs into the market.

The NSW government has indicated that GGAS will be superseded by the CPRS upon the commencement of the CPRS. Should the Facility be operational prior to this time, it will participate in GGAS.

Inventory Methodology

3.1 Accounting and Reporting Principles

The greenhouse gas inventory for the Facility has been based on the accounting and reporting principles detailed within the Greenhouse Gas Protocol (the Protocol) (WBCSD/WRI, 2004). The Protocol was first established in 1998 to develop internationally accepted accounting and reporting standards for greenhouse gas emissions from companies. The main principles are as follows:

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

The greenhouse gas emission inventory for the Project is based on the methodology detailed in the Protocol, and the relevant emission factors in the *National Greenhouse Accounts (NGA) Factors* (the NGA factors) (DCC, 2009a), and the relevant *Intergovernmental Panel on Climate Change (IPCC) Good Practice Guidance* (IPCC, 2000).

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

The main greenhouse gases emitted during operation of the Dalton Power Project activities will be carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). To report these emissions, they are converted to carbon dioxide equivalents (CO_2-e) as specified under the Kyoto Protocol. The GWP adopted for each greenhouse gas emitted are as follows: carbon dioxide GWP of 1, methane GWP of 21; and nitrous oxide GWP of 310, as detailed in the NGA Factors.

Materiality

Materiality is a concept used in accounting and auditing to minimise the time spent verifying data that does not impact a company's accounts or inventory in a material way. The exact materiality threshold that is used in greenhouse gas emissions accounting and auditing is subjective and dependent on the context of the site and the features of the inventory. Depending on the context, the materiality threshold can be expressed as a percentage of a company's total inventory, a specific amount of greenhouse gas emissions, or a combination of both.

In the context of this assessment, emissions have been assumed to be immaterial if they are likely to account for less than 5% of the overall emissions profile. This materiality threshold has been chosen as a standard measure in greenhouse gas inventories.

3.2 Inventory Organisational Boundaries

The organisational boundary of the project is defined as the physical site boundary.

3.3 Inventory Operational Boundaries

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

3.3.1 Scope 1: Direct greenhouse gas emissions

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

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

3.3.2 Scope 2: Electricity indirect greenhouse gas emissions

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

3.3.3 Scope 3: Other indirect greenhouse gas emissions

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

3.4 Greenhouse Gas Inventory

The quantitative component of this assessment encompasses the operational stage of the Facility. Due to the relatively compact size of open cycle gas turbine infrastructure and the short construction duration, greenhouse gas emissions during construction and decommissioning are considered insignificant in the calculation of emissions over the lifetime of the project, and are thus considered to be below the materiality threshold. In addition, emissions derived from the embodied energy of construction materials are also considered to be below the materiality threshold and have not been incorporated.

The operational boundary has been defined as the boundary of the power station site. Power generated has been quantified gross power sent out, whilst electricity required to power auxiliary plant equipment has been quantified as electricity imported from the grid.

3 Inventory Methodology

In addition to this, the following emissions were not included in the assessment of operation, as they are considered to contribute negligibly to the site's greenhouse gas inventory and below the materiality threshold:

- Fuel combusted by vehicle use;
- Liquid refrigerant losses; and
- Sulphur Hexafluoride (SF_6) emissions from switchgear.

3.4.1 Activity Data

The estimated fuel consumption and power generated per year (electricity sent out) are presented in **Table 3-1**. These figures have been estimated with the following considerations:

- Capacity factor has been based on a typical operating duty of 15% of the year (all turbines operating);
- Fuel consumption has been calculated from manufacturer specifications, in accordance with the proposed operating regime, whereby the turbines will not operate at part loads;
- Generator losses and power consumed by auxiliary equipment have been accounted for in estimates of electricity imported from the grid; and
- Fuel consumption associated with startup and shutdown of the turbines has been incorporated with the assumption of three hour generation periods.

Table 3-1 Estimated gas consumption and electricity sent out and consumed

Project Stage	Amount Gas Combusted (PJ/yr)	Electricity Sent Out (GWh/yr Gross)	Electricity Consumed (GWh/yr)
Stage 1, E Class	9.8	838	12
Stage 1, F Class	10.7	927	14
Stage 2, E Class	14.7	1257	18
Stage 2, F Class	21.4	1854	27

3.4.2 Emission Factors

Project emissions have been estimated using the Scope 1, Scope 2 and Scope 3 emission factors for natural gas combustion and electricity consumption, which have been sourced from **Table 2, Table 39** and **Table 37** of DCC (2009a). These factors are shown in **Table 3-2**.

Table 3-2 Emission factors used in the assessment

Emission Type	Emission Factor
Scope 1	51.33 kg CO_2-e/GJ
Scope 2	0.89 kg CO_2-e/kWh
Scope 3	15.20 kg CO_2-e/GJ gas combusted 0.18 kg CO_2-e/kWh electricity consumed

3.4.3 Annual Project Emissions

Table 3-3 presents estimated greenhouse gas emissions from the Facility on an annual basis. These estimates have included Scope 1, Scope 2, and Scope 3 emissions which account for emissions from combustion, (indirect) emissions associated with the extraction, production and transport of the natural gas to the site, as well as emissions associated with electricity imported from the grid for use in the production of electricity.

Table 3-3 Estimated greenhouse gas emissions on an annual basis

Scenario	Activity	Emissions (Mt CO_2-e)				Full Fuel Cycle Emissions Intensity
		Scope 1	Scope 2	Scope 3	Total	kg CO_2-e/MWh
Stage 1, E Class	9.8 PJ Consumed 838 GWh Generated	0.50	0.01	0.16	0.67	801
Stage 1, F Class	10.7 PJ Consumed 927 GWh Generated	0.55	0.01	0.17	0.73	791
Stage 2, E Class	14.7 PJ Consumed 1257 GWh Generated	0.76	0.02	0.23	1.01	801
Stage 2, F Class	21.4 PJ Consumed 1854 GWh Generated	1.10	0.02	0.34	1.47	791

Note: totals may appear non-additive due to rounding.

Based on the fuel consumption and power sent out, for the four plant configurations, with operating duty of 15% (the upper limit of proposed operation), the plant was estimated to emit between 0.67 and 1.47 Mt CO_2-e, at an emissions intensity of approximately 800 kg CO_2-e/MWh.

3.4.4 Project Lifetime Emissions

Table 3-4 shows greenhouse gas emissions for the proposed plant on a project lifetime of 30 years assuming 15% operation per year. AGL's current peaking experience indicates that that on a long term average, plant operation would occur for approximately 3% of the year. Consequently, the use of the upper limit of proposed operation is considered highly conservative. Long term market trends define the operating duty, and ultimately the commercial life of the Facility, hence there exist large uncertainties in potential emissions over the project lifetime.

Table 3-4 Estimated greenhouse gas emissions on a project lifetime basis

Scenario	Project Lifetime Emissions (Mt CO_2-e)			
	Scope 1	Scope 2	Scope 3	Total
Stage 1, E Class	15.1	0.3	4.7	20.1
Stage 1, F Class	16.5	0.4	5.1	22.0
Stage 2, E Class	22.7	0.5	7.0	30.2
Stage 2, F Class	33.0	0.7	10.2	44.0

3.5 Generator Performance

The proposed use of natural gas fired OCGT technology at Dalton results in electricity production at a lower greenhouse intensity than the existing NSW average. Whilst detailed plant selection for the proposed Facility is yet to be made, **Table 3-5** shows the emissions intensities for the proposed OCGT technology, as well as a range of other generator technology types. The data in **Table 3-5** are primarily sourced from the *Technical Guidelines: Generator Efficiency Standards* (AGO, 2006) and the *Energy Directions Green Paper* (NSW Government, 2004).

The emissions intensities contained in AGO (2006) were generated for the purpose of identifying standards of performance for new plant types under the recently defunct "Greenhouse Challenge Plus" program. Within the document, the presented emissions intensities are defined as representing Best Available Technology (BAT) on the basis of reviews conducted during 2004-2005.

Renewable energy technologies have not been included in **Table 3-5** as they are unable to provide peaking power in accordance with the project requirements. Further discussion of renewable technologies is provided in the *Project Alternatives* section of the Environmental Assessment for the Facility.

When performing comparisons against the intensities presented in **Table 3-3** it should be acknowledged that the data presented in **Table 3-5** represent the instantaneous emissions intensity of each technology type operating at its peak efficiency, and do not include fuel consumption associated with startup and shutdown of the plant.

Table 3-5 Full fuel cycle emissions intensity of various generator technology types

Technology Type	Full Fuel Cycle Emissions Intensity (kg CO_2-e/MWh)
Open Cycle Gas-Fired Turbine	~600 – 700[1]
Open Cycle Gas-Fired Turbine (BAT)	710[2]
Combined Cycle Gas Turbine	~400 – 500[1]
Combined Cycle Gas-Fired Turbine (BAT)	454[2]
Coal-Fired – Best Existing Australian Plant	830[1]
Coal-Fired – World's Best Practice	~800 – 810[1]
Coal-Fired with Water Cooling (BAT)	855[2]
Coal-Fired with Air Cooling (BAT)	893[2]
Current NSW Average (NGA Scope 2 + Modified Scope 3)*	960[3]
2009 NSW GGAS Pool Coefficient[*]	967[4]

Notes: [1]NSW Government (2004) *Energy Directions Green Paper*.

[2]AGO (2006) *Technical Guidelines: Generator Efficiency Standards* - These intensities have been scaled with emission factors from DCC(2008) to incorporate the full fuel cycle (Scope 1+3) emissions and thus allow comparison with NSW Government (2004)[1] and DCC (2009a)[3]. Note that DCC(2008) factors have been used in this analysis, as DCC(2009a) does not include a Scope 3 emission factor for NSW black coal in electricity generation.

[3]DCC (2009a) *National Greenhouse Accounts (NGA) Factors*, June 2009. *Includes standard NSW Scope 2 emission factor of 890 CO_2-e/MWh, as well as transmission network operator specific scope 3 factor from footnotes of Table 39 of DCC (2009a) of 70 kg CO_2-e/MWh. This particular Scope 3 emission factor has been used in order to avoid the inclusion emissions due to transmission and distribution losses, and thus provide a factor suitable for comparison against full fuel cycle emissions intensities.

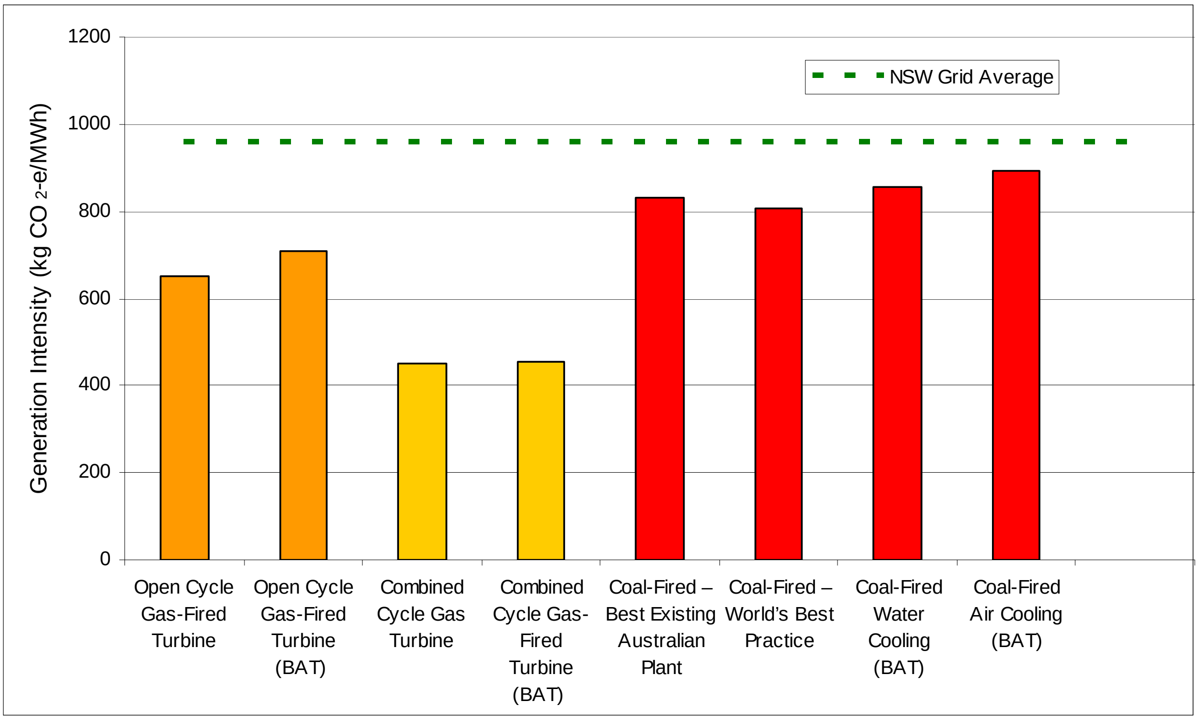
[4]NSW Government (2008) *Fact Sheet – The NSW Pool Coefficient* November 2008. **Pool Coefficient does not include full suite of Scope 3 emissions, and is also calculated from a subset of NSW based national electricity market generators.

3 Inventory Methodology

Whilst the emissions intensities presented in **Table 3-3** are commonly compared to the NSW GGAS Pool Coefficient, it is considered that the DCC (2009a) National Greenhouse Accounts (NGA) Factors provide a more relevant basis for comparison. The NSW Pool Coefficient only includes a subset of electricity generators, and does not include the full suite of Scope 3 emissions associated with fuel combustion[1].

As can be seen in **Table 3-5,** the proposed technology has a lower intensity than the grid average, which is largely defined by a balance of coal and hydroelectric generation. It should also be acknowledged that of the technology types presented in **Table 3-5,** OCGT technology is the only technology that is designed to proceed from standby to generation at full load in a timeframe consistent with the peaking regime in which AGL proposes to operate. **Figure 3-1** provides a visual representation of the data contained in **Table 3-5.**

Figure 3-1 Full Fuel Cycle Emissions intensity of various generator technology types



Note: See **Table 3-4** for data sources.

The technologies included in AGO (2006) represent mature technologies for which efficiency improvements are gradual, and have been limited in recent years. It is considered that these technologies are representative of current BAT.

[1] For example, under GGAS, coal combustion (which is a key influence on the Pool Coefficient) Scope 3 emissions are limited to fugitive methane emissions, and constitute less than half of the total Scope 3 emissions for coal combustion as defined in (DCC, 2009a). No Scope 3 emissions are included for fuel oil combustion.

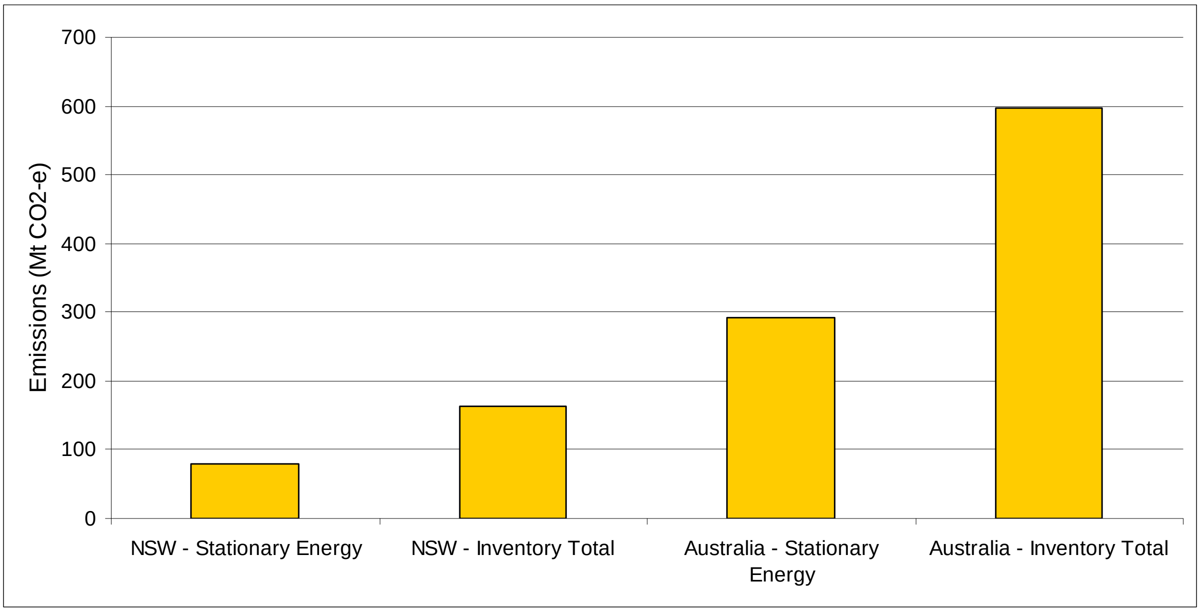
3.6 Comparison to National and NSW Greenhouse Gas Inventories

In May 2009, the Department of Climate Change published the *Australian National Greenhouse Accounts State and Territory Greenhouse Gas Inventories 2007* (DCC, 2009c) which provides detail of greenhouse gas emissions from a range of emission sectors and on a state and national basis.

Total greenhouse gas emissions in Australia for 2007 were estimated to be 597.2 million tonnes of CO_2-e. Stationary energy sources were estimated to emit 291.7 million tonnes, equating to approximately 49% of total national greenhouse gas emissions.

At a state level, NSW was estimated to emit 162.7 million tonnes CO_2-e (27% of national emissions). Stationary energy sources were estimated to be 79.4 million tonnes, equating to approximately 49% of total NSW greenhouse gas emissions. **Figure 3-2** shows the relative scale of these emission quantities.

Figure 3-2 NSW and national greenhouse gas emissions



Quantitative greenhouse gas emissions from the Facility and comparison with greenhouse gases generated from the electricity sector in NSW and Australia are provided in **Table 3-5.** For the four plant configurations considered in this assessment, at the upper limit of operating duty of 15%, the total annual emissions were estimated to be in the range of 0.67 to 1.47 Mt CO_2-e. For the sectors considered, these emissions constitute a small percentage of the inventory totals.

3 Inventory Methodology

Table 3-6 Comparison of proposal to state and national greenhouse gas inventories

2007 Greenhouse Gas Inventory Sector	Greenhouse Gas Emissions (Mt CO_2-e)	% Contribution represented by the Dalton Power Project			
		Stage 1		Stage 2	
		E Class	F Class	E Class	F Class
NSW Stationary Energy sector	79.4	0.85%	0.92%	1.27%	1.85%
Total NSW GHG emissions	162.7	0.41%	0.45%	0.62%	0.90%
Australian Stationary Energy sector	297.7	0.23%	0.25%	0.34%	0.49%
Total Australian GHG emissions	597.2	0.11%	0.12%	0.17%	0.25%

Australia's future greenhouse gas inventory data are not possible to forecast with certainty. The 2007 inventory data shows that national emissions across all sectors rose by 9.3% from 1990 to 2007. The largest sector increase was the stationary energy sector, followed by transport, showing a rise due to population growth and electricity demand for resources. Since future trends are unknown, the greenhouse gas emissions from the Facility cannot be meaningfully compared to future emissions from other sources of greenhouse gases in Australia over the operational life of the plant.

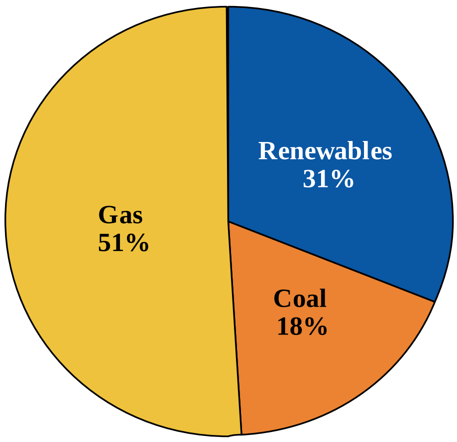
Greenhouse Gas Abatement

4.1 AGL's Approach to Greenhouse Gas Management

AGL believes that Australia should renew efforts to address the challenge of climate change. Notwithstanding current policy uncertainties relating to carbon emissions trading, AGL incorporates a cost of carbon in its current business decision making. AGL believes that a national emissions trading scheme should be implemented. This involves the national development and deployment of low emission technologies and an economy-wide approach with greenhouse gas abatement implemented on a least cost basis. AGL is the largest producer of renewable energy in Australia, with installed capacity of 1,170 MW, and an additional 928 MW currently under construction. Looking forward, AGL is committed to investing in low emission (including natural gas) technology or renewables projects.

The installed capacity of AGL power generation assets is shown in **Figure 3-1**.

Figure 4-1 AGL Energy – Installed Capacity Generation



Source: AGL 2008

AGL supports the establishment of a long-term greenhouse gas (GHG) emissions reduction target and the creation of market-based mechanisms to achieve this goal.

As part of AGL's commitment to sustainability, AGL has for a number of years had an on-going commitment to:

- at a minimum, meeting all statutory requirements relating to reducing GHG emissions;
- quantifying and publishing the greenhouse gas impacts of their investments, operations and supply chain;
- seeking to reduce the greenhouse gas intensity of energy across the supply chain by:
  - expanding investments in low emission and renewable generation, and through the development and commercialisation of technologies that assist in reducing greenhouse gas emissions; and
  - helping customers to reduce GHG emissions by providing practical and accurate information on energy use and offering and promoting green energy;
- improving the greenhouse gas efficiency of their operations, and those in which they have an influence; and

- working with customers, shareholders, governments and the community to progress policy options and initiatives to reduce GHG emissions.

AGL has, for a number of years, had an ongoing commitment to the following actions:

- Incorporating a forecast of future carbon pricing into all major business decisions.
- Publishing information about AGL's greenhouse gas impacts.
- Benchmarking AGL's performance (both using our supply chain intensity and AGL's generation intensity) against the overall industry.
- Working with all AGL's stakeholders to better understand their options for reducing greenhouse gas emissions.
- Continuing to consider a suite of opportunities to expand AGL's low emission and renewable generation interests including the Macarthur wind farm, Oaklands Hill windfarm in Victoria, Ben Lomond windfarm in NSW and two further wind farm projects surrounding Hallett in South Australia;
- Continuing to work with the Commonwealth and State Governments as they implement a price on carbon, and subsequently an emissions trading scheme (known as the Carbon Pollution Reduction Scheme) and effective Renewable Energy Target;
- Continuing to offer to forward trade in Australian Emission Units (AEUs), promoting the scheme and providing liquidity in an emerging market;
- Continuing to work with AGL's stakeholders to foster greater levels of shared understanding about the targets, pathways and costs associated with reducing greenhouse gas emissions;
- Providing expert advice on energy efficiency and carbon management services through AGL's new business offering for our major commercial and industrial customers called Carbon Management Services;
- Aiming for AGL's state electricity supply intensity to be beneath state averages; and
- Continuing to work with governments and agencies at all levels to foster understanding around energy markets and energy efficiency programs.

4.2 Evaluation of Greenhouse Gas Mitigation Measures

The DGR's for the project state that the EA must include "*an evaluation of the availability and feasibility of measures to reduce and/or offset the greenhouse emissions of the project including options for carbon capture and storage*". This section provides an evaluation of greenhouse gas mitigation measures available to the Project.

4.2.1 Mitigation Measures

AGL proposes to implement technology that is consistent with current BAT. Hence the Project design has incorporated a range of greenhouse gas mitigation measures. In addition, greenhouse gas mitigation measures have been identified for the detailed design, and operational phases of the Project. These measures are detailed in **Table 4-1**

4 Greenhouse Gas Abatement

Table 4-1 Evaluation of potential Greenhouse mitigation measures available to the Project.

Mitigation Measure	Greenhouse Gas Reduction
Incorporated at Project Design Phase	
Technology Selection: Adoption of OCGT – Plant is able to be started and stopped quickly thus minimising fuel consumption outside of periods when the generator is on line. Alternatives to OCGT include CCGT or coal-fired generation, which would have to run on standby for large proportions of the year in order to be available to the peaking market (and would have significantly higher emissions). OCGT also has lower operational emissions than alternative peaking technologies.	Not Quantified[1]
Fuel Selection: Use of Natural Gas – Natural Gas has lower emissions per GJ of heat energy than alternative fuels such as oil or coal.	~20-40%[2]
Plant Selection: Implementation of OCGT with high thermal efficiency - AGL propose plant for this Project that achieves a thermal efficiency that is consistent with Best Available Technology (BAT) as defined in the Generator Efficiency Standards (AGO,2006).	~10% (60 kg CO_2-e/MWh)
Plant Selection: Implementation of Evaporative Cooling - AGL propose evaporative cooling which will offer efficiency benefits reducing greenhouse gas emissions when operating during hot conditions.	~1.5% (10 kg CO_2-e/MWh)
Available to Project at Detailed Design, Commissioning and Operational Phases	
Efficiency Auditing – In a manner consistent with both AGL's internal directives, and regulatory requirements under the *Energy Efficiency Opportunities Act 2006* (as amended), conducting audits to ensure that plant is being operated efficiently, and to identify opportunities to improve efficiency and reduce emissions intensity e.g.: • restoring the plant to design condition – e.g. replacing filters and removing fouling; • changing operational settings – e.g. ensuring control systems are operating correctly; • investigating and implementing retrofit improvements, and other mitigation options – e.g. turbine blades capable of withstanding higher combustion temperatures, CCS and waste heat brine concentration. EEO obligations involve assessment and implementation of efficiency improvements with a payback period of four years or less on a 5 year assessment cycle.	Varied: Operational efficiency improvements would typically result in reductions in the vicinity of 1-2% (6-12 kg CO_2-e/MWh), whilst CCS may achieve reductions in the range of 90% (500 kg CO_2-e/MWh[2])
Carbon Capture and Sequestration - separation of carbon dioxide from the generator exhaust stream, with subsequent transportation and underground storage.	AGL do not anticipate CCS will prove commercially effective on the proposed OCGT technology under the proposed peaking operational regime. Further discussion provided in **Section 4.2.3**.

Notes: [1] Due to the need to maintain boilers in ready state, emissions intensity from applying CCGT or coal-fired generation to a peaking regime (as proposed by AGL) would likely be in excess of an order of magnitude higher. [2] Based on scope 1 emissions: Natural Gas: 51.3 kg CO_2-e/GJ (58% of Coal), Diesel Oil: 69.5 kg CO_2-e/GJ (79% of Coal) Coal: 88.4 kg CO_2-e/GJ.

Further discussion on the following is provided below:

- Technology Selection for the Project;
- Carbon Capture and Sequestration (CCS); and
- Evaporative Inlet Cooling.

4.2.2 Technology Selection for the Project

AGL has proposed to use Open Cycle Gas Turbine (OCGT) technology. Open cycle gas turbine units can be at full capacity within thirty minutes from a cold start, compared to a minimum of eight hours for a coal fired power station. Rapid start up and shut down provides a further benefit in the saving on greenhouse gas emissions by responding to demand as it arises. Given the relatively short start-up and shut down times for these systems, open cycle gas turbine units are ideal for operations to meet peak load demand and represent best practice technology for this type of use. In addition, AGL has focused on selecting the most efficient plant available within this technology group.

Open cycle gas turbine units are also ideally placed to respond to the short term variability in the generation capacity of wind farms as a result of variable wind conditions. AGL anticipate that this will become increasingly important as more wind-generated power is introduced into the system.

This technology selection is consistent with BAT for peaking power generation and AGL's greenhouse gas management directives, including consideration of the planned introduction of a carbon price from the 1st July 2012.

4.2.3 Carbon Capture and Sequestration (CCS)

CCS involves the separation of carbon dioxide from the generator exhaust stream, with subsequent transportation and underground storage. CCS (or carbon capture readiness) is not proposed as part of the Project, as AGL do not anticipate that CCS will prove commercially effective on the proposed OCGT technology under the proposed peaking operational regime[2]. Key contributing factors include:

- Intermittent and transient operation would mean that CCS infrastructure would lie unutilised for greater than 85% of the year (AGL's current peaking experience indicates that the Project would operate for approximately 3% of a typical year);
- OCGT technology (which has been proposed for its ability to respond to market peaks) produces an exhaust stream for which CCS is less technically plausible (relative to coal-fired generation for which CCS has been proposed at a pilot scale). For example:
  - — For OCGT, CO_2 concentrations are relatively low at 3-4%, as compared to conventional coal-fired boilers in which CO_2 concentrations are in the range of 12-14%[3]. On a per megawatt capacity basis, volumetric flows are also proportionally (~3 times) higher than coal-fired plant;
  - — The exhaust stream is around 500ºC higher than conventional coal-fired plant, where intermittent and transient operation would potentially inhibit efficient process control.
- Scope 1 emissions from OCGT are relatively low at around 600 kg CO_2-e/MWh.

Energy market modelling such as ACIL Tasman (2010) *Preparation of Energy Market Modelling Data for the Energy White Paper* and others, report electricity generation costs as levelised costs (i.e. $/MWh) for a wide range of generation technologies including renewable and fossil fuel based technologies.

Cost estimates for the implementation of CCS on OCGT (OCGTCCS) were not able to be sourced from these publications, hence, for the purposes of this assessment, a coarse estimation has been performed in order to evaluate the cost effectiveness of OCGTCCS in mitigating CO_2 emissions. This

[2] AGL have also noted that CCS is unproven on OCGT, is not commercially available for implementation on the Project, and that equipment suppliers do not offer an option for CCS readiness for OCGT plant.
[3] Sourced from IPCC (2005).

estimation has been based on information provided by the Australian Government Department of Resources, Energy and Tourism (RET) in *Australian Electricity Generation Technology Costs - Reference Case* (RET,2011a) and the datasheet *Data – Fossil Fuel Plant Performance and Cost Summary 2011* (RET,2011b). The estimate has been performed by adapting data prepared for CCGT (both with and without CCS), and applying these to estimates provided for OCGT. Further detail of this analysis is provided in **Appendix A** of this report.

Based on operation for 3 % and 10 % of the year, the cost of implementing CCS on OCGT was estimated to be between approximately \$1300/t CO_2 and \$400/t CO_2 (respectively), of which the key contributor was the cost of capital investment associated with the CCS infrastructure. Given the uncertainty, and conservativeness[4] of this estimation, actual costs could potentially be significantly higher than this estimate.

In contrast, in the CPRS white paper (COA, 2008) nominated a five year price cap of \$40/tonne at the commencement of the scheme, rising at five per cent real per annum[5]. **Table 4-2** shows how the market cap would progress under this arrangement.

Table 4-2 Market Cap for Carbon Price as Detailed in CPRS White Paper (COA, 2008)

Year of Scheme	Market Cap (\$AUD/t CO_2, real at time Implementation)
1	40
5	40
10	51
15	65
20	83
25	106
30	135

Based on this coarse estimate, in order for OCGTCCS to represent a least-cost market based abatement solution, carbon prices would need to be significantly higher than those currently under consideration. Given the conservative assumptions regarding CCS energy requirements, capture rates and disposal cost, these costs likely represent an underestimation.

This is consistent with the intention of the CPRS, in which emissions are reductions are achieved in a least-cost manner, rather than pursued at any cost.

4.2.4 Evaporative Inlet Cooling

AGL proposes to use evaporative inlet cooling to increase power output when operating during high ambient temperatures and low humidity. As air temperature increases, the density of air decreases. During hot weather, this reduces the amount of air that can be drawn into the turbines, resulting in a reduction in power output, and marginal reduction in the thermal efficiency.

[4] Assumptions include 90% CO_2 capture rate, 3% penalty in sent-out thermal efficiency for CCS operation, and that CO_2 disposal costs are relatively low, despite the absence of an identified storage reservoir.
[5] Whilst it is acknowledged that the CPRS white paper differs from the specific scheme arrangements which are currently under consideration by the Federal Government, this data has been included for the purpose of showing the scale of carbon prices under consideration.

Under evaporative cooling, the inlet air is passed through wet porous media. Water is evaporated into the air stream, where the heat of vaporisation acts to cool the air. This results in a cooler and denser inlet air stream, which permits a higher mass flow rate of air to be drawn into the turbine compressor.

AGO (2006) notes improvements in Higher Heating Value (HHV) thermal efficiency of up to 0.5% from the implementation of evaporative cooling[6]. For the technology proposed by AGL, this equates to a change in (instantaneous full load) emissions intensity of approximately 1.5%, or approximately 10 kg CO_2-e/MWh.

Given that evaporative cooling would not be suitable during all operating conditions (e.g. cooler and/or humid conditions), and would not reduce fuel consumption associated with startup and shutdown, the impact on the overall emissions intensity of the facility would likely be lower than 10 kg CO_2-e/MWh.

The source of water to be used in the evaporative cooling system is yet to be finalised. However, options include sourcing from Upper Lachlan Shire Council, from groundwater, and trucking water to the Site. The emissions intensity of trucking water to the Site has been estimated[7] at approximately 0.6 kg CO_2-e/MWh. However, the impact on the overall emissions intensity of the facility would likely be lower when startup and shutdown are also considered.

4.2.5 Influence of a Carbon Price on the Project

This section provides an "*evaluation of the Project in the light of various carbon emission prices with and without proposed mitigation measures*" as required by the DGRs.

At a (Scope 1) emissions intensity of 0.6t/MWh[8], and a carbon price of between \$20/t and \$60/t, the effect of a carbon price on the Project would be between \$12/MWh and \$36/MWh generated. When the proposed peaking operation is considered in the context of the cost of power generation, and the typical wholesale electricity prices at which peaking power plants enter the generating market (which are typically in the order of several hundreds of dollars per megawatt hour), the scale of a carbon cost is small relative to revenue associated with electricity generation. Unlike base load generators (which enter the generating market at far lower wholesale prices e.g. \$40/MWh, and operate at higher emissions intensities and higher capacity factors) the sensitivity of peaking plants to a carbon price is relatively low. This lower sensitivity is considered to reflect the following factors:

- The primary role of peaking power plants to ensure the security of electricity supply; and
- The small quantity of emissions associated with highly infrequent operation at a lower than average emissions intensity.

[6] This is in agreement with values provided in GE(2000), which for a range of meteorological conditions, notes a heat rate change of between 0.5 and 2.5% (which is equivalent to between 0.2 and 0.8% HHV).

[7] Assuming a 30kL truck, completing a round trip of 200 km, and consuming diesel at a rate of 0.54 L /km, fuel consumption is 3.6L/kL of water delivered. Assuming a fuel calorific value of diesel fuel of 38.6 GJ/kL, and a full fuel cycle (Scope 1+3) emission factor of 74.8 kg CO_2-e/GJ, the emissions intensity of water delivery is 10.4 kg CO_2-e/kL of water delivered. When coupled with evaporative cooling water consumption which has been estimated at 0.057 kL/MWh*, emissions intensity of transporting water to site would be approximately 0.6 kg CO_2-e/MWh.
*Value sourced from Figure 34 of GE(1991) for typical summer conditions of 32ºC and relative humidity of 30%. According to with Figure 16 of GE(2000) under these conditions, evaporative cooling would result in a 0.5% HHV efficiency improvement. Figure 34 indicates water consumption of 9.6 Gal/min for an MS6001 estimated to be generating 38 MW. This equates to an evaporative cooling water consumption rate of 0.057 kL/MWh.

[8] A Scope 1 emissions intensity of 0.6 t/MWh is considered representative of the OCGT technology proposed by AGL, in accordance with allowances for the factors listed in **Section 3.4.1**.

4.2.6 Summary

AGL proposes to implement technology that is consistent with current BAT for peaking operation. This has largely precluded the identification of greenhouse gas mitigation measures beyond those that are an inherent part of the Project.

An evaluation of the implementation of CCS for the Project indicates that CCS is unlikely to represent a technically or commercially feasible greenhouse mitigation measure for the Project.

AGL anticipates that greenhouse gas mitigation strategies will become more relevant with ongoing operation of the Facility, and are likely to be based around efficiency improvements associated with the adoption of improved technologies and componentry that are developed. Such improvements could then be implemented during routine maintenance and refurbishment. In line with the intention of the introduction of a carbon price by Government, AGL proposes to investigate the feasibility of such measures as and when they become commercially available.

Conclusions

A greenhouse gas assessment has been performed for the Dalton Power Project. The greenhouse gas inventory has included scope 1, scope 2 and scope 3 emissions associated with natural gas combustion in the open cycle gas turbine generators and the consumption of electricity from the electricity grid. The principal greenhouse gas emission from the Facility is carbon dioxide (CO_2), which is a product of natural gas combustion. Minor quantities of other greenhouse gases may be emitted and have been represented in this assessment, as carbon dioxide equivalent (CO_2-e).

The assessment has considered four potential plant configurations, each with an operating duty of 15% of the year. Given that AGL's current peaking experience indicates that that on a long term average, plant operation would occur for approximately 3% of the year, analysis based on the upper limit of proposed operation is considered conservative.

Total annual emissions were estimated to be in the range of 0.67 to 1.47 Million tonnes of carbon dioxide equivalent (Mt CO_2-e). The associated emissions intensity of generation was calculated to be approximately 800 kilograms of carbon dioxide equivalent per megawatt hour of electricity generated (kg CO_2-e/MWh).

Based on a project life of 30 years, the total lifetime emissions for the four plant configurations considered were estimated to be between 20.1 and 44.0 Mt CO_2-e.

A comparison of emissions from the Facility to state and national greenhouse gas inventories was also made. Emissions from the project were estimated to be in the range of 0.41-0.90% and 0.11-0.25% of the state and national inventories, respectively. In addition, emissions from the project were estimated to be in the range of 0.85-1.85% and 0.23-0.49% of stationary energy emissions from the state and national inventories, respectively.

AGL proposes to implement technology that is consistent with current best available technology for peaking operation. This has largely precluded the identification of greenhouse gas mitigation measures beyond those that are an inherent part of the Project. An evaluation of the implementation of CCS for the Project has indicates that CCS is unlikely to represent a technically or commercially feasible greenhouse mitigation measure for the Project.

AGL anticipate that greenhouse gas mitigation strategies will become more relevant with ongoing operation of the Facility, and are likely to be based around efficiency improvements the adoption of improved technologies and componentry that are developed. Such improvements could then be implemented during routine maintenance and refurbishment. In line with the intention of the introduction of a carbon price by Government, AGL proposes to investigate the feasibility of such measures as and when they become commercially available.

References

- ACIL Tasman (2010), *Preparation of Energy Market Modelling Data for the Energy White Paper*, ACIL Tasman Pty Ltd, 13 September, 2010, http://www.aemo.com.au/planning/0400-0019.pdf
- Australian Government (2008), *Carbon Pollution Reduction Scheme Australia's Low Pollution Future, White Paper*, December 2008.
- Australian Government (2009), Media Release: *New measures for the Carbon Pollution Reduction Scheme,* Senator the Hon. Penny Wong Minister for Climate Change and Water, May 2009.
- AGO (2006), *Technical Guidelines: Generator Efficiency Standards*, Australian Greenhouse Office, December 2006.
- COA (2008), *Carbon Pollution Reduction Scheme: Australia's Low Pollution Future, White Paper*, Volume 1, Commonwealth of Australia, December 2008, http://www.climatechange.gov.au/publications/cprs/white-paper/cprs-whitepaper.aspx
- DCC (2008), *National Greenhouse Accounts (NGA) Factors*, Department of Climate Change, January 2008.
- DCC (2009a), *National Greenhouse Accounts (NGA) Factors*, Department of Climate Change, June 2009.
- DCC (2009b), *Tracking Kyoto and 2020 Australia's Greenhouse Emissions Trends 1990 to 2008-2012 and 2020,* Department of Climate Change, August 2009.
- DCC (2009c), *Australia's National Greenhouse Accounts, State and Territory Greenhouse Gas Inventories,* Department of Climate Change, August 2009.
- Department of the Prime Minister and Cabinet (2007), *Australia's Climate Change Policy*, Australian Government, July 2007.
- GE (1991) GER-3419A - *Gas Turbine Inlet Air Treatment,* GE Power Generation, June 1991.
- GE (2000) GER-3567H *GE Gas Turbine Performance Characteristics,* GE Power Systems, October 2000.
- IPCC (2000), *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*, Intergovernmental Panel on Climate Change, 2000, http://www.ipcc.ch
- IPCC (2005), *IPCC Special Report on Carbon Dioxide Capture and Storage*, Intergovernmental Panel on Climate Change, 2000, http://www.ipcc.ch
- IPCC (2007), *IPCC Fourth Assessment Report (AR4) Climate Change 2007:The Physical Science Basis, Summary for Policymakers, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Intergovernmental Panel on Climate Change, 2007, http://www.ipcc.ch
- NSW Government (2004), *Energy Directions Green Paper*, December 2004.
- NSW Government (2005), *New South Wales Greenhouse Plan*, New South Wales Greenhouse Office, NSW Government, November 2005.
- NSW Government (2008), *Fact Sheet – The NSW Pool Coefficient,* November 2008.

- RET(2011a), *Fact Sheet - Australian Electricity Generation Technology Costs - Reference Case*, Department of Resources, Energy and Tourism, May 2011, http://www.ret.gov.au/energy/Documents/facts-stats-pubs/2011/AEGTC-2011-Fact-Sheet.pdf
- RET(2011b), *Data – Fossil Fuel Plant Performance and Cost Summary 2011*, Department of Resources, Energy and Tourism, May 2011, http://www.ret.gov.au/energy/Documents/facts-stats-pubs/2011/Fossil-Fuel-Plant-Performance-and-Cost-Summary-2011.pdf
- WBCSD/WRI (2004), *The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard*. World Business Council for Sustainable Development & World Resources Institute, 2004.

7 Limitations

URS Australia Pty Ltd (URS) has prepared this report in accordance with the usual care and thoroughness of the consulting profession for the use of AGL Pty Ltd and only those third parties who have been authorised in writing by URS to rely on the report. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the Proposal dated 19th December, 2008.

The methodology adopted and sources of information used by URS are outlined in this report. URS has made no independent verification of this information beyond the agreed scope of works and URS assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to URS was false.

This report was prepared between March 2009 and July 2011, and is based on the conditions encountered and information reviewed at the time of preparation. URS disclaims responsibility for any changes that may have occurred after this time.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

Appendix A Levelised Costs for Application of CCS on OCGT

Appendix A

A.1 Levelised Costs for Application of CCS on OCGT

This Appendix section provides a summary of the calculation performed to estimate the cost effectiveness of CCS on OCGT technology (OCGTCCS). Data released on the Australian Government Department of Resources, Energy and Tourism (RET) website[9] provides 2011 reference costs for a wide range of power generation technologies, which include:

- Open Cycle Gas Turbine (OCGT);
- Combined Cycle Gas Turbine (CCGT); and
- Combined Cycle Gas Turbine with Carbon Capture and Sequestration (CCGTCCS).

Given the role of peak power generation in the electricity market[10], the application of CCS on OCGT is typically not considered feasible. It is expected that this constitutes the reason for which technology costs for OCGT are not commonly available in reviews and forecasts of generator costs. In absence of such data, URS has performed an estimation, based on an adaptation of existing, publically available RET data, namely:

- (RET,2011a) Australian Electricity Generation Technology Costs - Reference Case; and
- (RET,2011b) Data – Fossil Fuel Plant Performance and Cost Summary 2011.

A.2 OCGTCCS Estimation Assumptions

This estimation has assumed that:

- The CCGT plant is composed of an OCGT plant (i.e. gas turbine generator), with the addition of a Heat Recovery Steam Generator (HRSG) and steam turbine;
- CCS is another independent plant component, for which the energy requirements are proportional to the exhaust stream processed; and
- For a given (gas turbine generator) heat input, CCS energy requirements are the same for both OCGTCCS and CCGTCCS.

On this basis that quantities of heat input (gas combusted) would be the same for OCGT, CCGT, CCGTCCS, and OCGTCCS, the following parameters have been normalised against heat input:

- Capital Cost;
- Fixed Capital Cost; and
- Variable O&M Cost.

OCGTCCS values have then been calculated from the normalised values assuming that:

$$\text{OCGTCCS} = \text{OCGT} + (\text{CCGTCCS} - \text{CCGT})$$

and subsequently converting back to required bases by dividing by the efficiency (gross or net, as appropriate). OCGTCCS thermal efficiency has been estimated by subtracting the difference between the CCGT and the CCGTCCS values from the OCGT value, whilst also assuming that two thirds of the CCS energy requirement can be sourced from the OCGT exhaust waste heat[11]. Given the transient nature of gas turbine operation, this assumption is considered conservative. Whilst it is also noted that the CCGT data may reflect technical or commercial factors which imply that plant components are not independent (e.g duct firing after the gas turbine), such simplification is considered appropriate to the intended purpose of this estimation, and the level of uncertainty inherent in the estimates.

[9] http://www.ret.gov.au/energy/facts/Pages/EnergyFacts.aspx

[10] Peaking plants operate at low capacity factors, which means that they are typically characterised by high operating costs and low capital costs.

[11] It is implicit in the RET data that 1/3 of the CCS energy requirement would be serviced by CCGT exhaust heat, i.e. for the CCGT data, the application of CCS results in a 9% change in sent out thermal efficiency, compared to 6% (heat input basis) change in auxiliary loads.

Appendix A

Table A-1 Comparison of CCGT and OCGT Costs with and without CCS

Case	CCGT 85% Capacity Factor				OCGT 10% Capacity Factor				OCGT 3% Capacity Factor			
	Base Plant		CCS Plant		Base Plant		CCS Plant		Base Plant		CCS Plant	
Cost type	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
Total Plant Cost (A$/kW installed)	1,231	1,505	2,123	2,595	887	1,084	2,072	2,532	887	1,084	2,072	2,532
Unit Plant Size (MW)	600-800	600-800	600-800	600-800	160-190	160-190	160-190*	160-190*	160-190	160-190	160-190*	160-190*
Capacity Factor (%)	85%	85%	85%	85%	10%	10%	10%	10%	3%	3%	3%	3%
Auxiliary Load (% of output at generator terminals.)	2.9%	2.9%	15.4%	15.4%	1.0%	1.0%	10.0%	10.0%	1.0%	1.0%	10.0%	10.0%
Effective Capacity Factor (%)	82.5%	82.5%	71.9%	71.9%	9.9%	9.9%	9.0%	9.0%	3.0%	3.0%	2.7%	2.7%
Thermal Efficiency (% sent out)	50%	50%	41%	41%	33%	33%	30%	30%	33%	33%	30%	30%
Fuel Cost (A$/GJ)	5.2	5.5	5.2	5.5	5.2	5.5	5.2	5.5	5.2	5.5	5.2	5.5
CO_2-e generation (t/MWh sent out)	0.370	0.370	0.451	0.451	0.560	0.560	0.616	0.616	0.560	0.560	0.616	0.616
Emissions Captured (%)	0%	0%	90%	90%	0%	0%	90%**	90%**	0%	0%	90%**	90%**
CO_2-e emissions (t/MWh sent out)	0.370	0.370	0.045	0.045	0.560	0.560	0.062	0.062	0.560	0.560	0.062	0.062
CO_2 Transport and Storage (A$/t$CO_2$)	0	0	7	21	0	0	7**	21**	0	0	7**	21**
Fixed O&M (A$/kW sent out capacity-yr)	14	14	25	25	9	9	21	21	9	9	21	21
Variable O&M (A$/MWh sent out)	2	2	4.2	4.2	2.5	2.5	5.2	5.2	2.5	2.5	5.2	5.2
Plant Life (yrs)	40	40	40	40	40	40	40	40	40	40	40	40
Levelized Cost of Electricity (LCOE) - $/MWh												
Fuel Cost	37	40	46	48	57	60	62	66	57	60	62	66
Variable O&M Cost	2	2	4	4	3	3	5	5	3	3	5	5
Fixed O&M Cost	2	2	3	3	10	10	24	24	34	34	79	79
CO_2 Transport and Storage	NA	NA	3	9	NA	NA	4	12	NA	NA	4	12
Capital Charges	18	21	35	43	106	129	271	331	352	430	904	1105
TOTAL LCOE	**59**	**65**	**91**	**107**	**175**	**202**	**366**	**438**	**445**	**527**	**1054**	**1266**

Notes:

- Reference data (shaded grey) sourced from RET (2011b).
- *Whilst unit plant size for the gas turbine is 160-190MW, CCS costs have been adapted from the CCGT estimates, which are based on a 2 gas turbine + 1 steam turbine block. Given that this is within the scale of the Project, size factors are appropriate. It should be noted that all calculations are specific (i.e on a per MW basis), and do not assume any specific plant size, rather capital cost estimates ($/kW) reflect a certain scale of plant.
- **In the absence of other data, CCGT CO_2 capture rates, and transport and storage costs have been assumed. Data presented in Section 6.5 of ACIL Tasman (2010) indicate these costs selections to be conservative. In addition, given the transient operation of gas turbine operation, a 90% capture rate is considered to be conservative.

As can be seen in **Table A1**, OCGTCCS Levelised cost is elevated relative to the other costs presented, and is driven by the capital cost of the infrastructure, which is dependent upon discount rate, cost per kW installed, and capacity factor.

A.3 Associated Cost of CCS

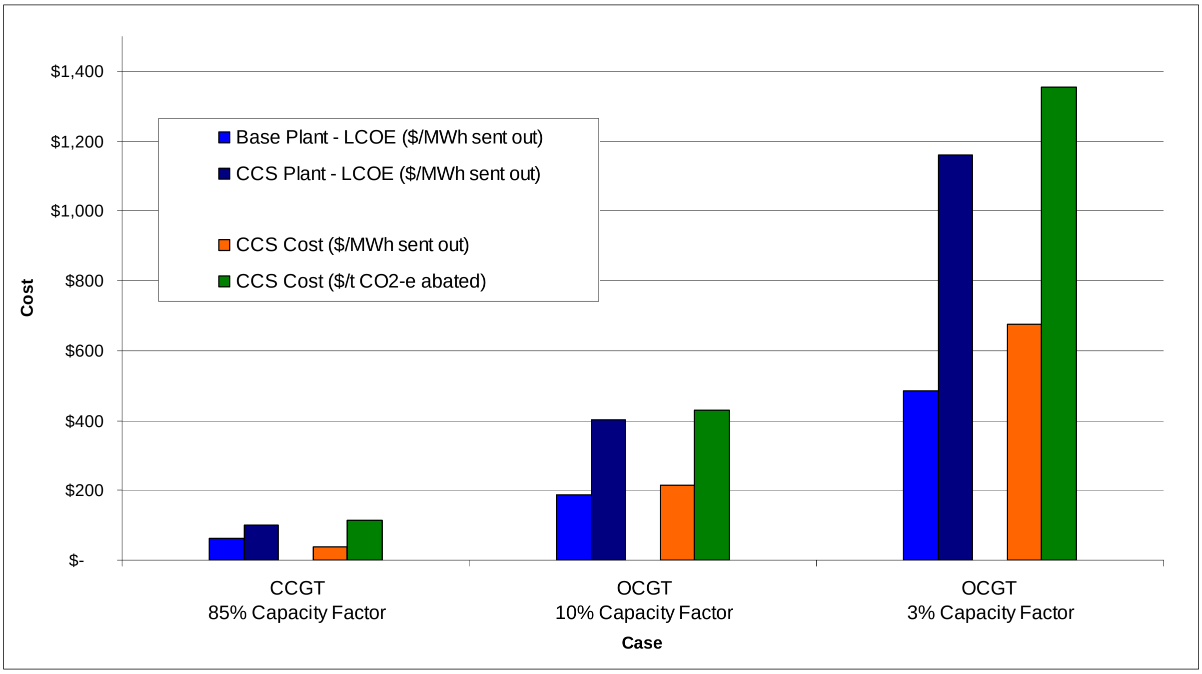
In accordance with the scenarios detailed in **Table A-1**, the cost effectiveness OCGTCCS can be estimated on the basis of cost per tonne of CO_2 removed. **Table A-2** provides this detail. Presented costs represent the average of the High and Low costs as shown in **Table A-1**.

Table A-2 Cost of Effectiveness of OCGT/CCS

Case	LCOE		CCS Cost	CO_2 removed	CCS Cost
	Base Plant	CCS Plant			
	($/MWh sent out)		($/MWh sent out)	(t CO_2/MWh)	($/t CO_2 abated)
CCGT 85% Capacity Factor	$62	$99	$37	0.325	$114
OCGT 10% Capacity Factor	$188	$402	$214	0.498	$429
OCGT 3% Capacity Factor	$486	$1,160	$674	0.498	$1,353

Based on operation for 3% and 10% of the year, CCS is estimated to reduce CO_2 emissions at a cost of approximately $1300/t and $400/t (respectively).

Figure A-1 Comparison of CCS



Based on this coarse estimate, in order for OCGTCCS to represent a least-cost market based abatement solution, carbon prices would need to be significantly higher than those currently under consideration. Given the conservative assumptions regarding CCS energy requirements, capture rates and disposal cost, these costs likely represent an underestimation.

URS Australia Pty Ltd
Level 4, 407 Pacific Highway
Artarmon NSW 2064
Australia
T: 61 2 8925 5500
F: 61 2 8925 5555

www.ap.urscorp.com