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WOODSIDE ENERGY LIMITED

Greenhouse Gas Emissions Study of Australian LNG

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Notes by WorleyParsons relating to public release of this document

1. *This report is a modified version of the original report prepared for Woodside Energy Limited in August 2008. The modifications relate to the removal of any proprietary information or commercially confidential information relating to the technology or operations at the North West Shelf Project. The modifications do not in any way affect the results or conclusions of the study, as set out in this report.*
2. *The scope of this study was limited to conducting an independent comparison covering two typical extraction and processing cases and a range of combustion technologies and efficiencies in China. It does not include a full impact assessment of the respective industries or every possible operational or other scenario.*
3. *The study was conducted and reviewed by qualified personnel to established standards for life cycle assessment and greenhouse gas accounting. The results of the study were reviewed again as part of this 2011 public release and found to remain robust within the range of assumptions stated.*
4. *The information, data and research in this report reflects the assumptions, data, methodology and policy environment as at August 2008 (the date of the original report).*
5. *The conclusions expressed within this report are those of WorleyParsons and were drawn from the results contained within this report. They are based on the policy environment during 2008 and were prepared as advice for Woodside.*

CONTENTS

ABBREVIATIONS

AGO	Australian Greenhouse Office
AGRU	Acid Gas Removal Unit
ANFO	Ammonium Nitrate and Fuel Oil
CH_4	Methane
CO_2	Carbon Dioxide
CO_2-e	Carbon Dioxide Equivalents
ETS	Emissions Trading Scheme
GHG	Greenhouse Gas
GJ	Gigajoules (10^9 Joules)
Gt	Gigatonnes (10^9 Tonnes)
Kt	Kilotonnes (10^3 Tonnes)
LNG	Liquefied Natural Gas
N_2O	Nitrous Oxide
NGAF	National Greenhouse Account Factors
NGER	National Greenhouse and Energy Reporting
NWS	North West Shelf Project
PJ	Petajoules (10^{15} Joules)
TJ	Terajoules (10^{12} Joules)

1. BACKGROUND

With the upcoming introduction of the Australian Emissions Trading Scheme (ETS), the potential impacts on the Australian LNG industry are significant. Whilst the specific framework of the Australian ETS are yet to be disclosed, this study has been commissioned in order to better understand the unique position of Australian LNG under a future ETS in comparison to Australia's other major energy source export, Australian black coal.

The study provides a comparison of Australian LNG versus Australian black coal in terms of lifecycle greenhouse gas emissions: from extraction and processing in Australia through to an end use of combustion in China for power generation.

2. LIFECYCLE GREENHOUSE ASSESSMENT

2.1 Background – China Energy Market

For this assessment, China has been chosen as the destination for both LNG and black coal, for combustion in power plants. China has been chosen as it represents a current importer of both coal and LNG – and more importantly, imports of coal and LNG are growing substantially each year due to the rapidly increasing energy market in China.

A summary of China's energy market is as follows:

a) Since 2001, due to rapid economic growth, China has no longer been able to meet its energy demand from domestic energy supplies alone. Prior to 2001, the country supplied 96% of its energy needs (ROSEN, 2007), however China's account of global energy demand has increased from 10% in 2001 to 15% in 2006 (BP, 2007). Between 1990 and 2005, due to the doubling of China's manufacturing energy demand, the tripling of transport energy use and increase of the service sector consumption of energy by three and a half times, the overall energy use in China has increased by 69% over the 15 year period (IEA, 2008).

b) Oil currently provides 21% of China's energy needs (7.2 million barrels per day in 2006), whereas natural gas provides 3% of the country's energy consumption (ROSEN, 2007). The majority of China's energy's needs are derived from coal at 70%. The remainder of energy is supplied from hydro-electrical (5.8%) and nuclear (less than 1%) (BP, 2007).

c) China exported oil until 1993, mainly to East Asia but limited reserves suggests that annual oil output is near its peak at the current 3.7 million barrels per day (IEA, 2007). China now meets half of its oil requirements through imports and is the second largest oil consumer after the United States accounting for 8.7% of global demand (ROSEN, 2007).

d) Whilst China still exports coal, it also imports coal (predominantly to coastal provinces, due to access restrictions from the locations of coal reserves and the areas where coal is required for energy consumption within China). Coal imports are largely from Vietnam, which supplies 46%, followed by Indonesia at 29% and Australia at 11% (CCR, 2007).

e) China currently imports 3.9 billion m^3 of LNG per year but future supplies are contracted in 2009 by Indonesia (Tangguh LNG), Malaysia (Petronas) and Australia (the North West Shelf Project) (ROSEN, 2007). The demand for LNG by China is forecast to grow to 12 billion m^3 by 2015 (CPE, 2006), which represents a 210% increase in LNG imports from 2005 levels.

f) Whilst efforts are being made by China to reduce the country's energy intensity by setting a target of reducing energy intensity by 20% and air pollution by 10% as part of the 11th Five-Year Plan, this target is unlikely to be achieved (ROSEN, 2007).

2.2 Scope Definition & Methodology

An assessment of the greenhouse gas emissions for the lifecycles of both LNG from the North West Shelf Project (NWS) and Australian black coal from the Hunter Valley was carried out to determine the total emissions attributable to each fuel source throughout its lifecycle, including the following stages, as indicated in Table 2-1.

Table 2-1: Life Stages of Fuel for Greenhouse Emissions Assessment.

North West Shelf Project LNG	Australian Black Coal
Extraction, Processing & Liquefaction in Australia	Mining & Processing in Australia
Transport / Shipping to China	Transport / Shipping to China
Regasification in China	Combustion / Power Generation in China
Combustion / Power Generation in China	

a) Australian black coal was chosen for the comparison, in place of brown coal, as black coal is exported whereas brown coal is not. Black coal is the cleaner burning of the two coals, and produces less greenhouse emissions, per unit of energy generated.

b) For the extraction and processing and subsequent shipping emissions, the NWS was used as the baseline for LNG, while average factors were used for Hunter Valley coal mining and processing, with default shipping values estimated using the NGAF methodology.

c) Processing/liquefaction emissions associated with LNG production have been calculated based on historic performance of the North West Shelf Project. Typical facilities have been included in the LNG supply chain emission profile, including relevant offshore production, dehydration and compression and on-shore processing. However, annual production from the Karratha Gas Plant was not representative, as a fifth LNG train is being commissioned in 2008, which will increase production. As such, the emissions intensity of this process has been calculated based on historic performance, applied to the future Train 1 to 5 scenario.

d) As this study is considering only LNG (and not LPG, domestic gas or condensates, which are also produced at Karratha Gas Plant), only the LNG-related emissions have been included in the analysis.

e) Emissions associated with transport and shipping to China have been derived from historic performance of the NWS LNG carrier fleet.

f) Total greenhouse emissions released in the production of coal is affected by the release of coal seam gas (predominantly methane found within the coal seams). Coal seam gas releases from black coal mines do vary significantly, however the most recent data (National Greenhouse and Accounts Factors 2008) averaged for the NSW region, has been used to estimate the coal seam gas emissions associated with the black coal mining activities, as detailed in Appendix 2.

g) Construction–related emissions have been excluded from the analysis for both coal and LNG. Previous studies have shown these are negligible relative to operating phase emissions.

h) For the end-use of each fuel, which involves combustion in a power station in China, a range of current practices and standards of power generating facilities were assessed based on a combination of current standards and practices in the construction of new power plants in China at present, and the current standard practice, and short-term best practices, available in Australia. The list of power generating technologies assessed, and the varying thermal efficiencies (where low represents established practice, mid represents the current standard for new plants being constructed, and high represents best practice), are shown in Table 2-2.

Table 2-2: Power Generation Technologies and Efficiencies Used.

Fuel Source - North-West Shelf LNG				**Fuel Source - Australian Black Coal**			
Technology	Thermal efficiency (%)			Technology	Thermal efficiency (%)		
	Low	Mid	High		Low	Mid	High
Open-Cycle Gas Turbine	36[11]	41[1]	46[2]	Sub-Critical Pulverised Coal Power Station	30[5]	34[6,7]	38[5,11]
Combined-Cycle Gas Turbine	46[3]	53[1]	60[4]	Super-Critical Pulverised Coal Power Station	42[7]	44[1]	46[8]
				Ultra Super-Critical Pulverised Coal Power Station	45[9]	48[10]	50[8]

Notes:

1. ISA, 2006.
2. GE LMS 100.
3. Baushan Combined-Cycle Power Plant.
4. Futtso Combined Cycle Plant / Baglan Bay Power Station.
5. BSC, 2007.
6. CLP Power Group Asia / China Huaneng Group.
7. Fangchenggang Power Station.
8. WCI, 2008.
9. Huaneng-Yuhuan Power Plant.
10. AGO, 2006b.
11. AGO, 2000.

i) It should be noted that the open-cycle gas turbine plants are not generally used for large-scale baseload power generation. They are generally used as small-scale or peak shaving power plants.

j) The combustion emissions associated with the fuel end-use of power generation at China have been assessed based on methodologies of the National Greenhouse and Accounts Factors, 2008. Black coal combustion emissions factors present in this source are based on averaged coal compositions and energy contents of the fuel for the New South Wales area, including the Hunter Valley (which tends to represent the practice of blending coals from differing operations to obtain suitably consistent coal types).

2.3 Greenhouse Lifecycle Emissions Data

The greenhouse emissions for each fuel, LNG and black coal, were assessed in terms of the greenhouse gases emitted for every tonne of fuel passed through its lifecycle. This data is shown graphically, with the emissions split by emission sources for LNG and black coal, in Figure 2-1 and Figure 2-2 respectively.

The greenhouse emissions for the different lifecycles for black coal and LNG (based upon the differing end-use power generation technology) are shown in Table 2-3. This data shows that LNG has a substantially lower greenhouse emissions footprint over its lifecycle compared to black coal, due to the different energy contents of each fuel, and the corresponding differences in power generation efficiencies available to each fuel, which both favour LNG. These factors mean that less LNG is required to be produced, transported and subsequently combusted in order to produce the same amount of electricity as black coal.

The aim of the assessment is to consider the difference in lifecycle greenhouse emissions between LNG and black coal for the purposes of electricity generation in China, hence an appropriate measure of comparison is the greenhouse emissions generated per MWh of electricity generated. For this comparison, the varying power generation technologies shown in Table 2-2 have been used, with the mid efficiency considered as the baseline. The corresponding emissions-to-electricity generation intensities are shown in Table 2-3, and graphically in Figure 2-3, with the low and high values being represented by the error bars shown.

Table 2-3: Greenhouse Emissions / Electricity Generation Intensities for LNG and Black Coal.

North-West Shelf LNG	**Lifecycle Greenhouse Intensity**	**Electricity Generation Intensity**	**Greenhouse-to-Electricity Intensity**
	t CO_2-e / t LNG	MWh / t LNG	t CO_2-e / MWh
Open-Cycle Gas Turbine	3.12	5.21	0.60
Combined-Cycle Gas Turbine	3.12	7.08	0.44
Australian Black Coal	**Lifecycle Greenhouse Intensity**	**Electricity Generation Intensity**	**Greenhouse-to-Electricity Intensity**
	t CO_2-e / t Coal	MWh / t Coal	t CO_2-e / MWh
Sub-Critical Pulverised Coal Power Station	2.16	2.13	1.02
Super-Critical Pulverised Coal Power Station	2.16	2.81	0.77
Ultra Super-Critical Pulverised Coal Power Station	2.16	3.00	0.72

The emissions generating activities have been separated by the location of their emissions in Table 2-4.

Table 2-4: Electricity Generation GHG Intensities for LNG and Coal by Emission Location.

Process Area	**Coal Power Generation**			**LNG Power Generation**	
	Sub-Critical	**Super-Critical**	**Ultra Super-Critical**	**OCGT**	**CCGT**
	t CO_2-e / MWh	t CO_2-e / MWh	t CO_2-e / MWh	t CO_2-e / MWh	t CO_2-e / MWh
Australian Extraction & Processing Activities	0.04	0.03	0.03	0.08	0.06
Product Transport – International Activities	0.03	0.02	0.02	0.02	0.02
External Processing & Power Generation in China	0.95	0.71	0.67	0.50	0.37
Total	**1.02**	**0.77**	**0.72**	**0.60**	**0.44**
% of Emissions in Australia	**4%**	**4%**	**4%**	**13%**	**13%**

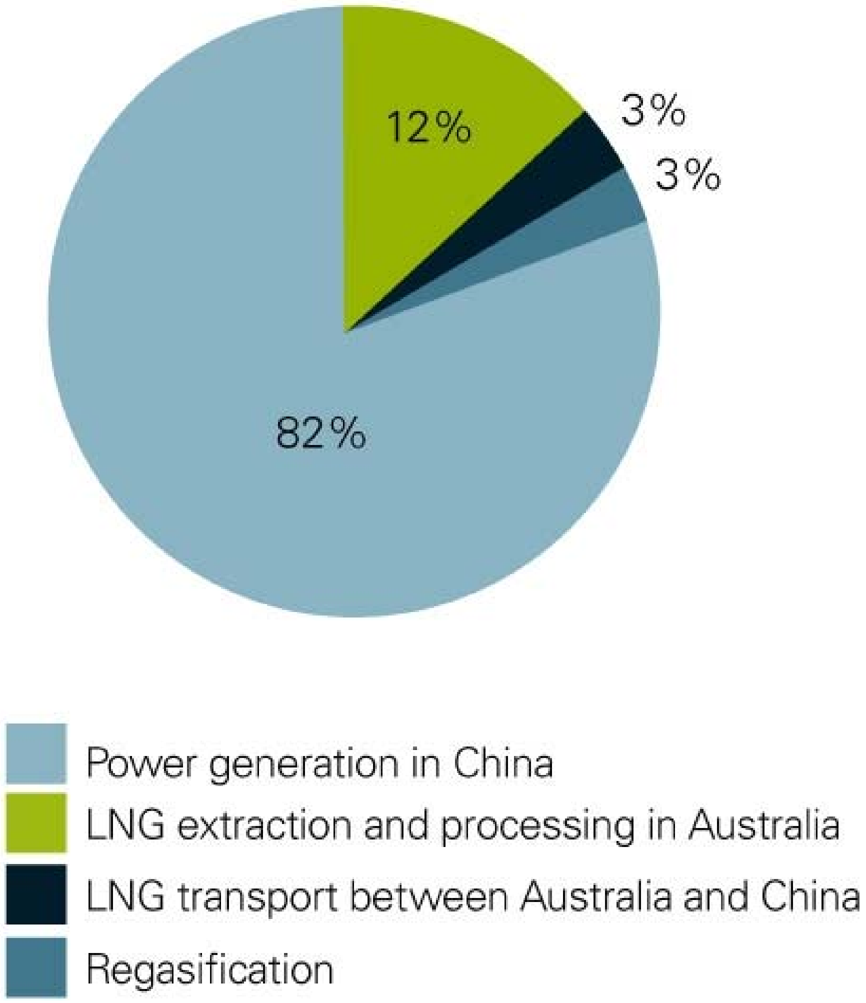

Figure 2-1: LNG Electricity Generation Emissions at Each Lifecycle Stage.

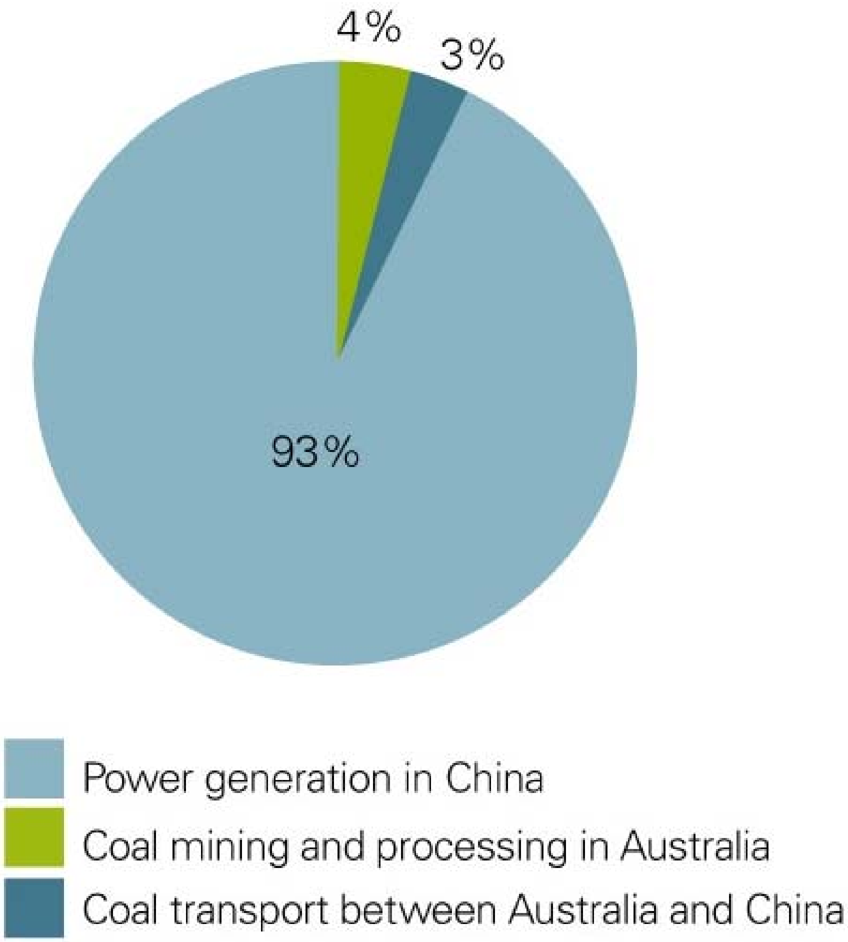

Figure 2-2: Black Coal Electricity Generation Emissions at Each Lifecycle Stage.

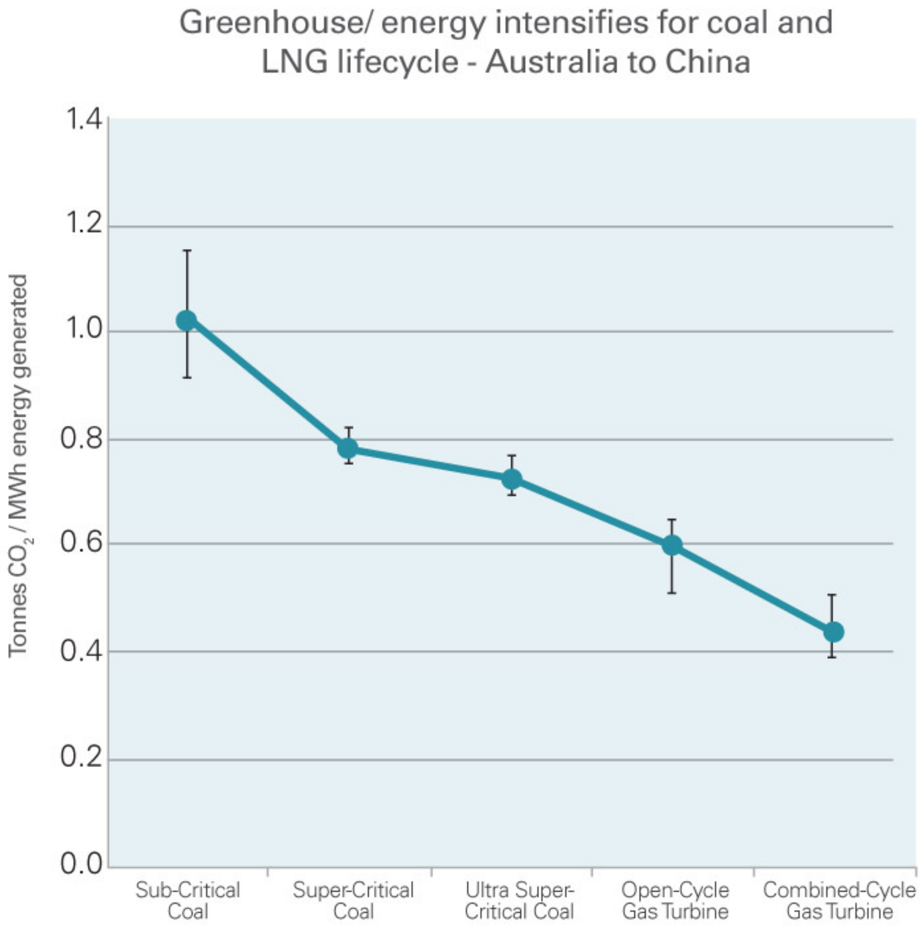

Figure 2-3: Lifecycle Greenhouse Emissions Intensities for NWS LNG and Australian Black Coal from Extraction to Combustion in China.

Figure 2-3 shows that, per unit of electricity generated, NWS LNG has a substantially lower greenhouse footprint than Australian black coal over the total lifecycle considered.

2.4 Conclusions for an Australian Emissions Trading Scheme

Figure 2-1 and Figure 2-2, in the previous section, shows the emissions for each electricity generation option at each life cycle stage of the fuel. This figure shows that the power generation process itself is the major source of greenhouse emissions, attributable to 82% and 93% of the total lifecycle greenhouse emissions for LNG and black coal respectively. It should be noted, though, that the power generation emissions themselves will, for the purposes of this assessment, be generated in China. China does not have a greenhouse emissions tax or permit scheme in place, nor are there any current plans to establish one. China is also not committed to any emissions reductions under the Kyoto Protocol, being a developing country. As such, in terms of the upcoming Australian Emissions Trading Scheme (ETS), these downstream power generation emissions will not be directly affected. In terms of impact of the upcoming Australian ETS on the two fuels, it is necessary to consider only the Australian portion of the greenhouse emissions. Figure 2-4 shows the total greenhouse emissions for LNG and black coal, and Figure 2-5 concentrates on the Australian-only proportion of the total greenhouse emissions.

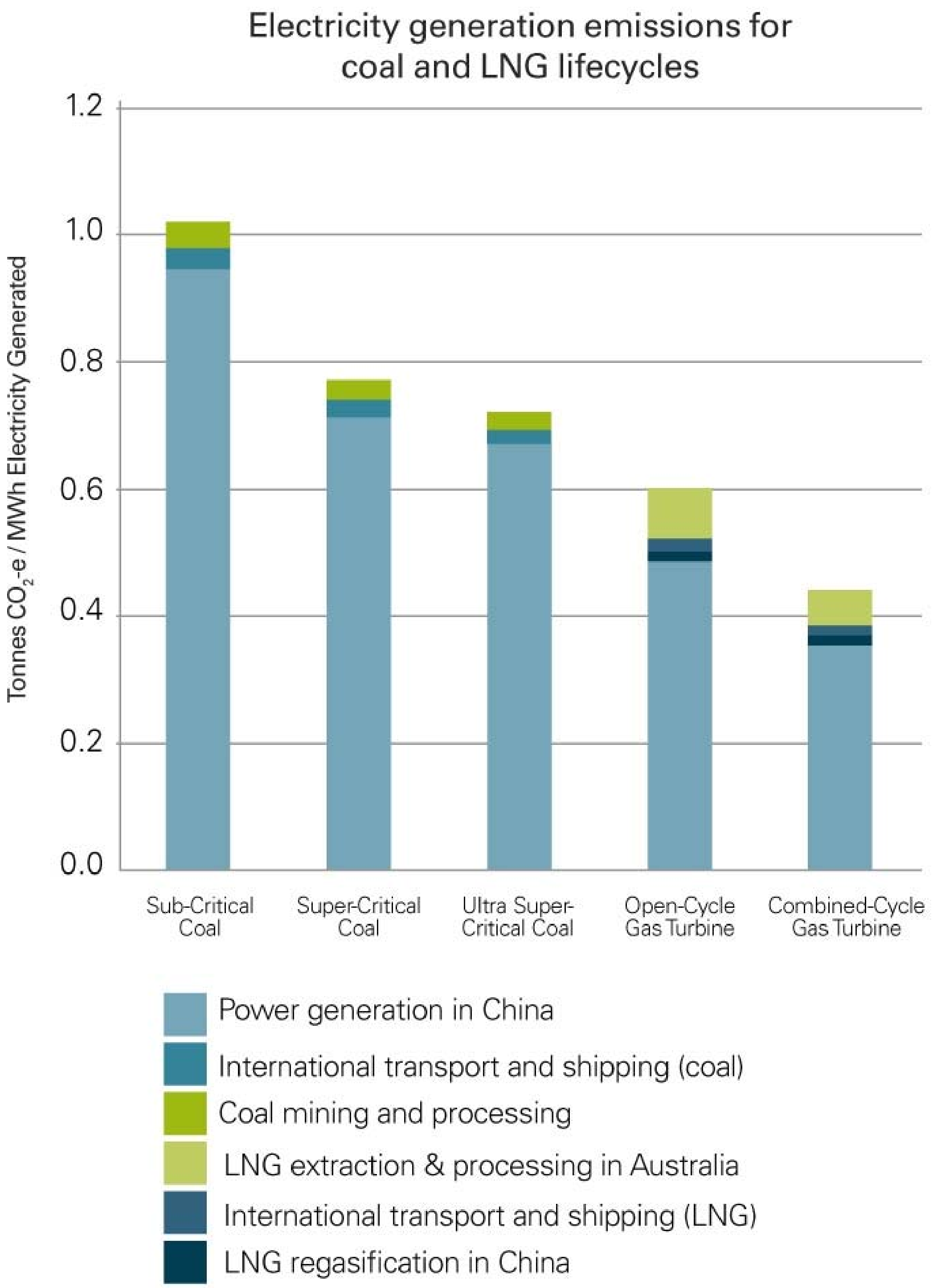

Figure 2-4: Lifecycle of Greenhouse Emissions from Electricity Generation, by Technology.

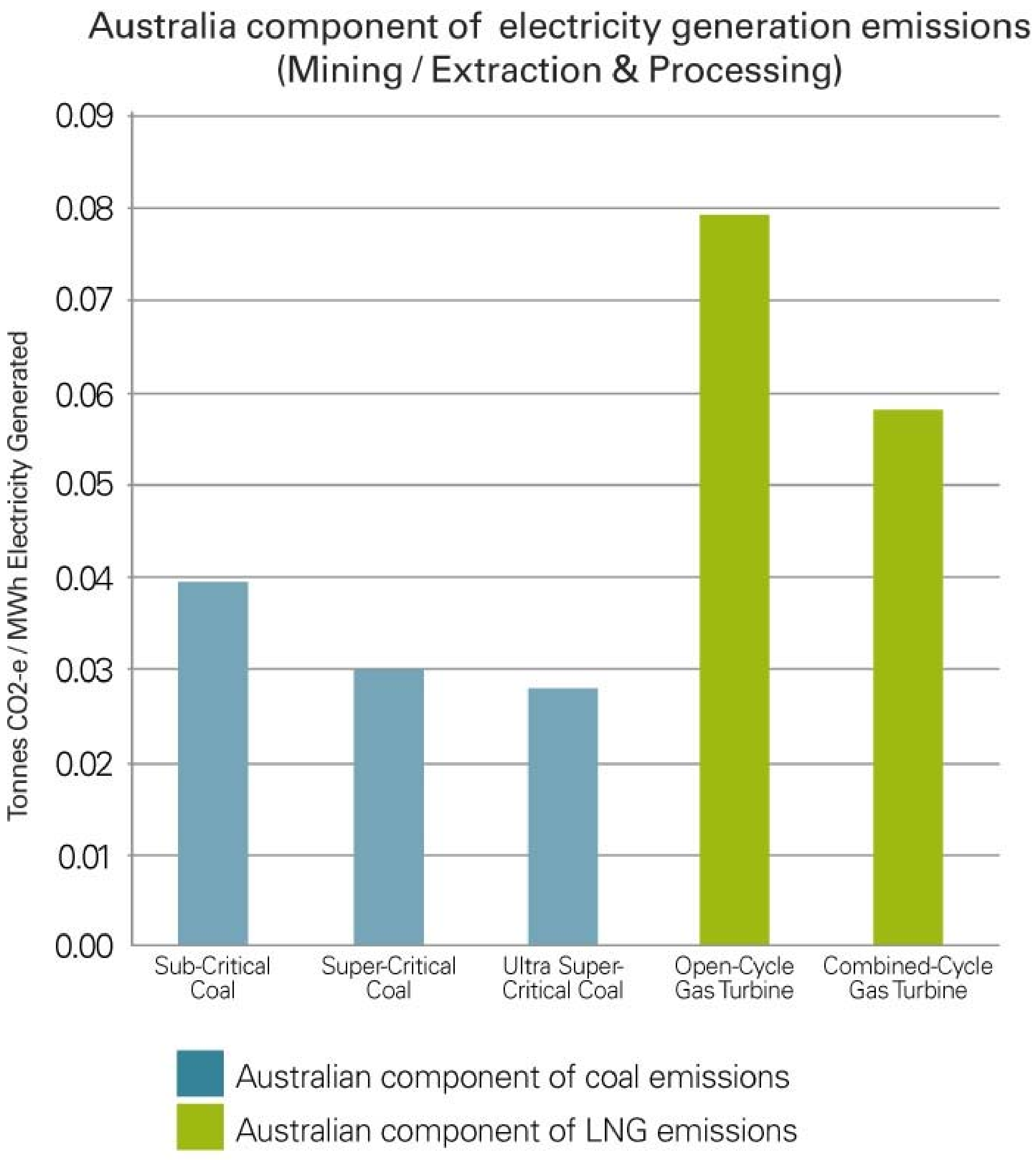

Figure 2-5: Australian Greenhouse Gas Emissions from Electricity Generation, by Technology

Figure 2-5 shows that, although LNG has been shown in the above sections to have the lowest greenhouse footprint in terms of electricity generated, it has a significantly larger portion of those greenhouse emissions originating in Australia. This is a result of the substantially more complex extraction and processing activities involved in LNG production as compared to coal production. Significantly, it is these Australian-base greenhouse emissions which will soon be considered and likely costed under the proposed Australian ETS. This implies that, while LNG is globally a less greenhouse-intensive fuel than coal, LNG is a higher polluter nationally, which will likely result in LNG extraction and processing activities being penalised heavily under an Australian ETS. This results in two significant issues:

1. LNG producers will be penalised more than coal producers based on the volume of national emissions, although globally LNG is a substantially lower emission fuel.
2. The additional costs added to LNG production based on national greenhouse emissions (and not considering global effects) will increase the cost of LNG extraction and production compared to coal mining and processing, which will increase the attractiveness of coal as compared to LNG for offshore export.

This suggests that under an Australian ETS LNG will, without protection as a trade-exposed industry, be faced with additional costs, based on carbon emissions (as shown in Figure 2-5), around 170% higher than coal in terms of potential MWh generated (depending on the combustion technologies selected).

These issues are problematic for an Australian ETS designed to result in a net reduction in global greenhouse emissions. Unless LNG extraction and processing are considered under those groups granted the status of *trade-exposed industry*, the scheme runs the risk of having the opposite effect intended, resulting in increases in global greenhouse emissions under such circumstances discussed above. Considering the issue of greenhouse gases is a global one, and not restricted to a national level, this represents a serious flaw of any non-global system in terms of carbon leakage unless protection is built into the scheme to prevent such impacts from distorting the ultimate aims of the ETS.

As an example, two scenarios have been developed in Table 2-5 below, to illustrate the relationship between Australian and global emissions for LNG replacement of coal as an energy source in China. The first scenario involves the construction of a new power generation plant in China, fuelled by LNG versus fuelled by coal. The second scenario involves the replacement of existing coal-fired power generation in China by LNG.

As highlighted in the table, the displacement of coal with LNG for use for power generation in China results in substantial reductions globally in greenhouse emissions, albeit at the expense of some additional Australian greenhouse emissions. For the scenarios addressed in Table 2-5, between 5.5 and 9.5 tonnes of CO_2-e are reduced globally by LNG replacement of coal for every 1 tonne of CO_2-e released in Australia in the LNG process.

Table 2-5: Example Scenarios of Australian-Global Emissions Relationship for LNG.

Scenario	Case	Technology	Global Lifecycle GHG Intensity	Australian Component of the GHG Intensity	Emissions Ratio (Global Change in Emissions : Australian Emissions)
		-	t CO_2-e / MWh	t CO_2-e / MWh	t CO_2-e / t CO_2-e
1. New Power Generation Plant in China	Base Case - Coal	Super-Critical	0.769	0.03	**-**
	LNG Replacement	CCGT	0.440	0.06	**-5.5 : +1** [1]
2. New Power Generation Plant in China	Base Case - Coal	Sub-Critical	1.018	0.04	**-**
	LNG Replacement	CCGT	0.440	0.06	**-9.5 : +1** [2]

Notes:

1. This shows that for the utilisation of LNG for a new power generation plant in China in place of coal, 5.5 tonnes of CO_2-e are saved globally, at the expense of every tonne of CO_2-e emitted in Australia.
2. This shows that for the replacement of a current coal-fired power generation plant in China with a LNG power plant, 9.5 tonnes of CO_2-e are saved globally, at the expense of every tonne of CO_2-e emitted in Australia.

3. CONCLUSION

The data presented in the previous sections aims to provide a better baseline for understanding the greenhouse emissions of the Australian LNG industry and the potential implications under an Emissions Trading Scheme (the Carbon Pollution Reduction System).

It is clear from the data shown in this report (which is consistent with previous studies, such as CSIRO (1996)) that LNG has a substantially lower greenhouse footprint associated with it compared to coal – not just in reference to the combustion emissions, but throughout its lifecycle. The lifecycle greenhouse intensity for LNG is approximately 50% lower than that of coal.

Importantly, however, a greater proportion of greenhouse emissions from the LNG lifecycle are released in Australia than the black coal counterpart. This has implications under the Carbon Pollution Reduction System, where only Australian emissions are considered. As it currently stands, LNG will be faced with carbon permit costs around 170% higher than coal in terms of potential MWh generated.

This results in two significant issues:

1. LNG producers will be penalised more than coal producers based on the volume of national emissions, although globally LNG is a substantially lower emission fuel.
2. The additional costs added to LNG production based on national greenhouse emissions (and not considering global effects) will increase the cost of LNG extraction and production compared to coal mining and processing, which will increase the attractiveness of coal as compared to LNG for offshore export.

These factors result in an ironic situation – where LNG, which is seen globally as an important measure in the short-term reduction of global greenhouse emissions, is being subject to higher carbon costs than black coal. This will translate to increased production costs for LNG, and an increase in attractiveness in black coal mining for export, ultimately favouring an increase in global greenhouse emissions – the opposite effect intended under any emissions trading scheme.

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Appendix 1 - LNG GHG Emissions Data

Total forecast CO2-e emissions associated with LNG production at the North West Shelf Project are shown in Table A-1. This forecast is based on historic performance, applied to a projected rate of production. This was necessary because the report assumes a fifth LNG train is operational at the Karratha Gas plant. This train will be commissioned in 2008.

Table A-1 Forecast Annual Emissions and Production Rates for the North West Shelf Project (LNG only)

LNG Production Rate (t/year)	16,500,000
LNG Production rate (m^3/year)	23,165,000,000
LNG Production rate (PJ/year)	828
LNG Production allocation Trains 1 - 3	55%
LNG Production allocation Trains 4 & 5	45%
LNG production emissions (t CO_{2-e} / year)[1]	6,762,000
LNG emissions intensity (tCO2/tLNG)	0.41

The emissions estimation calculations for the subsequent lifecycle stages utilised for this assessment are shown in subsequent tables.

International Transport and shipping

Table A-2: Forecast Annual Greenhouse Emissions Data for LNG Transport1 from Karratha to China.

Product Transport – International Activities[1]	LNG Transport - Shipping	Product Loaded (tonnes LNG)[2]	Vessel Capacity (m^3)[3]	Distance: Karratha to Ghuangzhou , China return(nm)	Total distance travelled by fleet (nm/yr)[4]	*tCO2-e consumed per nm*[5]	tCO$_2$-e/yr	t CO$_2$-e / t LNG product loaded
	LNG Tankers to Ghuangzhou, China	16,511,372	150,000	8,500	1,871,289	0.938	1,755,967	0.10635

1 - Fugitive pipeline transport emissions are assumed to be negligible.

2 - Assumed LNG production for relevant period.

3 - Based on average LNG carrier size.

4 - In order to ship the specified volume of LNG.

Regasification

Table A-3: Forecast Annual Greenhouse Emissions Data for LNG Regasification at China.

					Fuel Usage		Annual Greenhouse Emissions[2]					Total	
	Source of Emissions	**Fuel Source**	**LNG Consumption**	**Operating Hours**	**Per Year**	**Per Year**	**CO_2**	**CH_4**	**N_2O**	**CO_2-e**	**CO_2-e**	**CO_2-e**	**t $CO_{2\text{-}e}$ / t LNG**
				h	kW	PJ	T/yr	T/yr	T/yr	T/yr	%	T/yr	
Re-gasification Plant	**Train 1-3 Fuelled**												
	Regasification	LNG	3%	8,410	-	12.9[1]	639,592	108	57	659,394	51.5%	698,154	0.0399
	Train 4-5 Fuelled												
	Regasification	LNG	3%	8,410	-	11.9[1]	601,096	109	57	621,122	48.5%	581,719	0.03576
TOTAL							1,240,688	217	113	1,280,516	100.0%	1,279,873	0.078

1 – Assumes 3% of end use LNG combusted is required for re-gasification, based on analysis by Jaramillo P. et al, 2007.

Open-Cycle Gas-Fired Turbine – Power Generation

Table A-4: Forecast Annual Greenhouse Emissions Data for LNG OCGT Combustion for Power Generation in China

	Source of Emissions	Model	Abatement Technology	Fuel Source	Efficiency	Power Rating	#	Operating hours	Utilisation	Power Generated Total	Power Generated Total	Fuel Usage Per Year	Fuel Usage Per Year	Annual Greenhouse Emissions CO_2	Annual Greenhouse Emissions CH_4	Annual Greenhouse Emissions N_2O	Annual Greenhouse Emissions CO_2-e	Total CO_2-e	Total CO_2-e
					%	kW		h		kW	MWh	kW	PJ	T/yr	T/yr	T/yr	T/yr	%	t $CO_{2\text{-e}}$ / t LNG
Gas- Fired Power Generation	Train 1-3 Fuelled																		
	Open Cycle Gas Turbine	OCGT	Dry Low NOX	Natural Gas	39.0%	5,535,996	1	8,410	0.96	5,535,996	46,555,515	14,194,862	429.7	22,075,991	3,328	1,743	22,686,270	54.1%	1.3740
	Train 4-5 Fuelled																		
	Open Cycle Gas Turbine	OCGT	Dry Low NOX	Natural Gas	39.0%	4,699,991	1	8,410	0.96	4,699,991	39,525,045	12,051,259	364.8	18,708,181	2,815	1,475	19,224,445	45.9%	1.1643
TOTAL											86,080,560			40,784,172	6,143	3,218	41,910,715	100%	2.538

Combined-Cycle Gas-Fired Turbine – Power Generation

Table A-5: Forecast Annual Greenhouse Emissions Data for LNG CCGT Combustion for Power Generation in China.

										Power Generated		Fuel Usage		Annual Greenhouse Emissions				Total	
	Source of Emissions	**Model**	**Abatement Technology**	**Fuel Source**	**Efficiency**	**Power Rating**	**#**	**Operating hours**	**Utilisation**	**Total**	**Total**	**Per Year**	**Per Year**	**CO2**	**CH_4**	**N_2O**	**CO_2-e**	**CO_2-e**	**CO_2-e**
					%	kW		h		kW	MWh	kW	PJ	T/yr	T/yr	T/yr	T/yr	%	t $CO_{2\text{-}e}$ / t LNG
Gas- Fired Power Generation	Train 1-3 Fuelled																		
	Combined Cycle Gas Turbine	CCGT	Dry Low NOX	Natural Gas	53.0%	7,523,277	1	8,410	0.96	7,523,277	63,267,751	14,194,862	429.7	22,075,991	3,328	1,743	22,686,270	54.1	1.3740
	Train 4-5 Fuelled																		
	Combined Cycle Gas Turbine	CCGT	Dry Low NOX	Natural Gas	53.0%	6,387,167	1	8,410	0.96	6,387,167	53,713,523	12,051,259	364.8	18,708,181	2,815	1,475	19,224,445	45.9	1.1643
TOTAL											116,981,274			40,784,172	6,143	3,218	41,910,715	100%	2.538

Appendix 2 - Australian Black Coal GHG Emissions Data

The greenhouse emissions estimations for black coal have been based on black coal from the Hunter Valley region, NSW, Australia. The emission factors utilised are sourced from the National Greenhouse Accounts Factors 2008 (NGAF, 2008) for NSW black coal mines, and the associated combustion emissions associated with black coal. A summary of the emission factors used is presented in A-6. For the coal emissions estimations, total reportable emissions have been used (similarly for LNG), consisting of both direct (scope 1) and indirect (scope 2 only) emissions.

Table A-6: Summary of Emission Factors used for Black Coal Greenhouse Estimations.

Emission Source	**NGAF 2008 Emission Factors**	
	Direct (Scope 1) Greenhouse Emissions	**Indirect (Scope 2) Greenhouse Emissions**
	kg/GJ	kg/GJ
Diesel Combustion	69.5	0
Fuel Oil Combustion (Shipping)	73.5	0
Black Coal Combustion (for Electricity)	89.3	0
Grid Electricity (NSW)	0	249
	kg/t ANFO	
ANFO Explosives	170	0
	kg/t raw coal	
Fugitive Coal Seam Gas Emissions (NSW Open Cut Mine)	45.5	0

For the mining activities emissions, the Clermont coal mine has been used for the baseline. Fuel usage projections from the Clermont Coal EIS* have been used to prepare the emissions estimations (CCMP, 2008), in conjunction with the above emissions factors for the mining activities. One exception lies in the use of the average NSW black coal NGAF 2008 emissions factor for the fugitive coal seam gas emissions, rather than the site-specific Clermont Coal mine coal seam gas emissions. Emissions associated with vegetation removal / revegetation have not been considered for this assessment.

The emissions estimation calculations for the coal combustion technologies for power generation utilised for this assessment are shown in the following tables.

* Although the mine is in Queensland, this EIS presented good quality operational emissions data for a typical open cut mine in NSW or Queensland. Such data was not readily available for NSW mines at the time.

Sub-Critical Coal-Fired Power Generation

Table A-7: Forecast Annual Greenhouse Emissions Data for Coal Sub-Critical Plant Power Generation in China.

										Power Generated		Fuel Usage		Annual Greenhouse Emissions				
	Source of Emissions	**Model**	**Abatement Technology**	**Fuel Source**	**Efficiency**	**Power Rating**	**#**	**Operating hours**	**Utilisation**	**Total**	**Total**	**Per Year**	**Per Year**	**CO2**	**CH_4**	**N_2O**	**CO_2-e**	**Total**
					%	kW		h		kW	MWh	kW	PJ	T/yr	T/yr	T/yr	T/yr	t $CO_{2\text{-}e}$ / t LNG
Coal Fired Power Generation	Subcritical Pulverised Coal Power Station	Subcritical PV	Dry Low NOX	Natural Gas	34.0%	1,345,418	1	8,410	0.96	1,345,418	11,314,431	3,957,113	119.8	-	-	-	10,698,127	2.0093

Super-Critical Coal-Fired Power Generation

Table A-8: Forecast Annual Greenhouse Emissions Data for Coal Super-Critical Plant Power Generation in China.

										Power Generated		Fuel Usage		Annual Greenhouse Emissions				
	Source of Emissions	Model	Abatement Technology	Fuel Source	Efficiency	Power Rating	#	Operating hours	Utilisation	Total	Total	Per Year	Per Year	CO2	CH_4	N_2O	CO_2-e	Total
					%	kW		h		kW	MWh	kW	PJ	T/yr	T/yr	T/yr	T/yr	t $CO_{2\text{-}e}$ / t LNG
Coal Fired Power Generation	Supercritical Pulverised Coal Power Station	Super critical PV	Dry Low NOX	Natural Gas	45.0%	1,780,701	1	8,410	0.96	1,780,701	14,974,982	3,957,113	119.8				10,698,127	2.0093

Ultra Super-Critical Coal-Fired Power Generation

Table A-9: Forecast Annual Greenhouse Emissions Data for Coal Ultra Super-Critical Plant Power Generation in China.

	Source of Emissions	Model	Abatement Technology	Fuel Source	Efficiency	Power Rating	#	Operating hours	Utilisation	Power Generated		Fuel Usage		Annual Greenhouse Emissions				Total
										Total	Total	Per Year	Per Year	CO2	CH_4	N_2O	CO_2-e	
					%	kW		h		kW	MWh	kW	PJ	T/yr	T/yr	T/yr	T/yr	t $CO_{2\text{-}e}$ / t LNG
Coal Fired Power Generation	Ultra-Supercritical Pulverised Coal Power Station	Ultra-Super critical PV	Dry Low NOX	Natural Gas	48.0%	1,899,414	1	8,410	0.96	1,899,414	15,973,314	3,957,113	119.8				10,698,127	2.0093