This appendix presents calculations used to estimate greenhouse gas (GHG) emissions in Section 5 and 6.

Generator Emissions

GHG emissions from generator use during the operational stage were estimated based on the Department of Climate Change and Energy Efficiency's *Technical Guidelines for the estimation of GHG emissions by facilities in Australia July 2011* (the guidelines; DCCEE, 2011), using anticipated fuel consumption.

$$E = \frac{Q \times EC \times EF}{1000}$$

Where:

E is the total emissions released measured in $tonnes\ CO_2\text{-}e$,

Q is the quantity of fuel combusted in kL,

EC is the energy content factor of the fuel in GJ/kL, and

EF is the emission factor for the fuel in $kg\ CO_2\text{-}e/GJ$.

Rationale for selection and calculation of input values for the above equation is provided below.

Q

The amount of fuel combusted to run the generator was estimated based on anticipated use of the generator and typical fuel consumption rates for diesel powered generators, as described below:

- The generator is expected to be used at full capacity approximately 10 hours per week, and at 10% capacity at all other times (158 hours per week).
- Fuel consumption of a generator varies depending on the size of the generator and the load at which it is operated. Data for various sized diesel generators operating at 25%, 50%, 75% and 100% capacity is presented in Figure 1.

It is noted that fuel consumption data for generators above 2.5 MW was not readily available at the time of this assessment. However, as the figure indicates that fuel consumption is generally more efficient for large generators compared with small ones, it was considered reasonable to use fuel consumption rates for a 2.5 MW generator to obtain a conservative (that is, high) estimate of GHG emissions from use of a 5 MW generator during the port's operational stage.

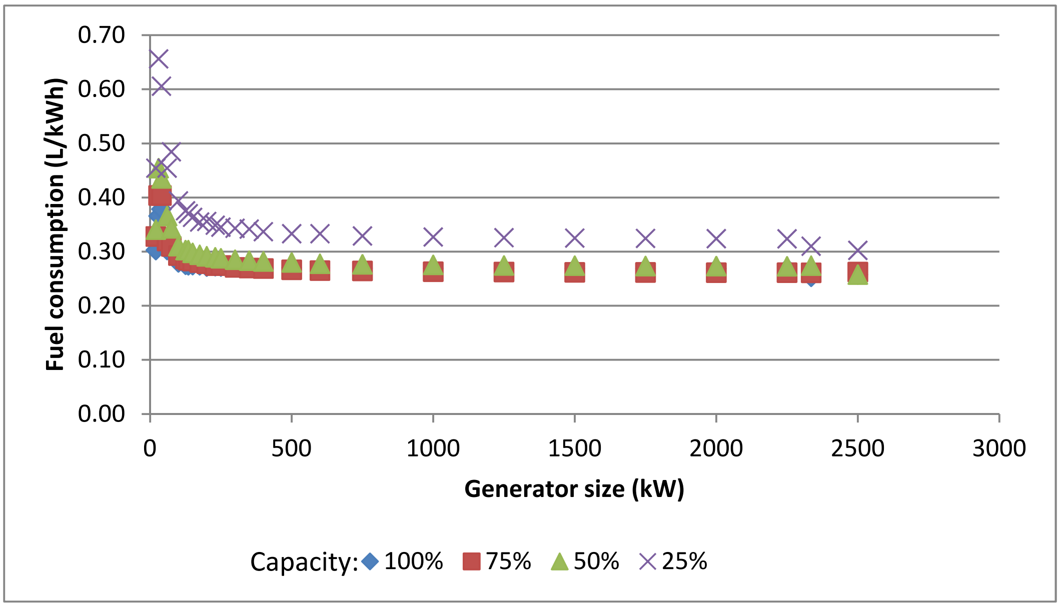

Figure 1: Fuel consumption by generator size and load (source: Cummins Power Generation 2007, Diesel Service & supply 2011):

Fuel consumption rates by generator load are presented below. A logarithmic relationship between fuel consumption and load was assumed; the equation is indicated on the figure below. Based on this data, fuel consumption of the site generator is estimated at **0.26 L/kWh** when operating at full capacity, and **0.32 L/kWh** when operating at 10% capacity (extrapolated from the figure below).

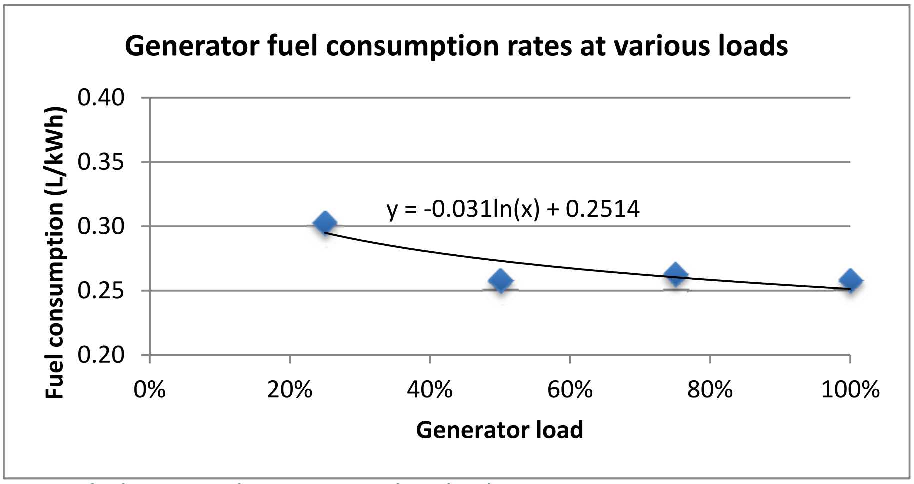

Figure 2: Generator fuel consumption rates at various loads

Using the above hours of operation at each load, and the associated fuel consumption rates, annual fuel consumption of the 5 MW generator was estimated, as outlined below.

Table 1: Estimated Annual Generator Energy Consumption

Generator Capacity Load		Annual Operation Time	Estimated Fuel Consumption	Annual Fuel Use	Annual Power Generated	Annual Diesel Consumption
%	**kW**	**hours**	**L/kWh**	**kL**	**MWh**	**GJ**
100	5,000	520	0.26	675	2,600	26,055
10	500	8,216	0.32	1,315	4,108	50,759
Total (*Q*)				**1,990**	**6,708**	**76,814**

$\boldsymbol{EC}$

The guidelines indicate the energy content factor of diesel oil used for stationary energy purposes is $\mathbf{38.6}\ \boldsymbol{GJ/kL}$.

$\boldsymbol{EF}$

The guidelines indicate the following emission factors for diesel oil used for stationary energy purposes: $69.2\ kg\ CO_2\text{-}e\ per\ GJ$ for carbon dioxide, $0.1\ kg\ CO_2\text{-}e\ per\ GJ$ for methane, and $0.2\ kg\ CO_2\text{-}e\ per\ GJ$ for nitrous oxide. This is a total of $\mathbf{69.5}\ \boldsymbol{kg\ CO_2\text{-}e\ per\ GJ}$.

GHG emissions

Based on the above parameters, GHG emissions were estimated as below:

$$E = \frac{1{,}990 \times 38.6 \times 69.5}{1000} = \mathbf{5{,}340}\ \boldsymbol{t\ CO_2e}$$

Grid Electricity Option

The annual energy consumption for the site is shown in Table 1 above (Estimated Annual Generator Energy Consumption).

Operational stage GHG emissions from purchased main electricity grid supplies were estimated based on the Department of Climate Change and Energy Efficiency's *Technical Guidelines for the estimation of GHG emissions by facilities in Australia July 2011* (the guidelines; DCCEE, 2011), using anticipated electricity consumption.

$$E = \frac{Q \times EF}{1000}$$

Where:

E is the scope 2 emissions measured in $tonnes\ CO_2\text{-}e$,

Q is the quantity of electricity purchased from the electricity grid in kWh,

EF is the emission factor for the electricity in the State in which the consumption occurs $= 0.72kg\ CO_2\text{-}e/kWh$ for South Australia

GHG emissions

Based on the above parameters, GHG emissions were estimated for mains electricity supply (refer below), i.e. 6,708 MWh per annum:

$$E = \frac{6{,}708{,}000 \times 0.72}{1000} = \mathbf{4,830\ t\ CO_2e}$$

The GHG emissions for grid electricity (of 4,830 t CO2-e) are lower than the GHG emissions for electricity generated on site by a diesel generator (of 5,340 t CO2-e) by 510 t CO2-e per annum, or 9.5%. Although the GHG emissions for this project would be lower by connecting to the electricity network, project constraints require on site generation until such time as the transmission spur line is constructed.

Transport Emissions

Annual GHG emissions were estimated for the scenarios listed below to provide a quantitative comparison of transport alternatives for ore and grain. The port of Qingdao, located in eastern China, is a large deep sea port that receives inbound iron ore and bulk grain. To allow for comparison between the selected transport scenarios, annual GHG emissions were estimated based on transport of all product to the port of Qingdao.

O1. Ore transport by sea in Cape class vessels from Port Lincoln to Qingdao.

O2. Ore transport by road (O2a) or rail (O2b) to Darwin, then transport in Cape class vessels to Qingdao.

O3. Ore transport by sea in Panamax vessels from Port Lincoln.

G1. Grain transport by sea in Cape class vessels from Port Lincoln to Qingdao.

G2. Grain transport by road to Port Adelaide, then transport in Panamax vessels to Qingdao.

Annual GHG emissions from each leg of each transport scenario were calculated based on the following equation:

$$A_i = GHG_i \times P \times D$$

Where:

A_i is the annual GHG emissions for transport type *i*, in *g CO_2-e*

GHG_i is the GHG emissions for transport type *i* in $\frac{g\ CO_2}{tonne-km}$

P is the annual payload in *tonnes*, and

D is the distance of the leg of the transport route in *km*.

Rationale for selection and calculation of input values for the above equation is provided below.

GHG

Unit GHG emissions from each transport type were obtained from published data as described below:

- Ship emissions were reported by the National Technical University of Athens' Laboratory for maritime Transport (NTU Athens, 2008) in $g\ CO_2\ per\ tonne\text{-}km$ based on ship size. The report indicated emissions of $\mathbf{4.7\ g\ CO_2\ per\ tonne\text{-}km}$ for Panamax dry bulk carriers, and $\mathbf{2.7\ g\ CO_2\ per\ tonne\text{-}km}$ for Cape class dry bulk carriers[1].
- Truck emissions were reported by the Centre for International Economics (CIE, 2011) in $gigagrams\ CO_2\ per\ billion\ tonne\text{-}km$ ($g\ CO_2\ per\ tonne\text{-}km$) for various truck types. The report indicated emissions of $\mathbf{74\ g\ CO_2\ per\ tonne\text{-}km}$ for modern articulated trucks (which includes road trains and B-doubles), based on full fuel cycle (FFC) assessment[2].
- Rail energy intensity was reported by the Australasian Railway Association (ARA, 2010) in $MJ\text{-}FFC\ per\ tonne\text{-}km$, where $MJ\text{-}FFC$is the energy intensity based on FFC assessment in megajoules (MJ). The report indicated energy intensity of $0.3\ MJ\text{-}FFC\ per\ tonne\text{-}km$ for "hire and reward" rail freight.

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[1] **Note that the ships reference emissions factors are for carbon dioxide only and do not include methane and nitrous oxide. The difference to convert to carbon dioxide equivalent was less than 1%. Furthermore, it is assumed that the emissions factors are based on transport emissions only, i.e. they are not for full fuel cycle emissions.**

[2] **Note that the truck's reference emissions factor is for carbon dioxide only and does not include methane and nitrous oxide. The difference to convert to carbon dioxide equivalent was less than 1%.**

Unit GHG emissions for rail were estimated based on the guidelines (DCCEE, 2011). The guidelines indicate GHG emissions of $69.9\ g\ CO_2 - e\ per\ MJ$[3] for diesel oil used for transport purposes, including rail transport.

Unit GHG emissions for rail were calculated as:

$$0.3\ MJ\text{-}FFC\ per\ tonne\text{-}km \times 69.9\ g\ CO_2 - e\ per\ MJ = \mathbf{21\ g\ CO_2 - e\ per\ tonne\text{-}km}$$

P (payload)

The annual payload is **2 Mt** for ore, and **0.5 Mt** for grain, based on anticipated shipping rates.

D (distance)

Distances of each leg of the transport routes were estimated using online navigation tools. Distances of sea travel were obtained from Ports.com (2010). Distances of overland travel were obtained from Google Maps (2011). Input start locations and destinations used to obtain the distances are provided below, along with the distances provided for the routes in the navigation tools.

Table 2: Estimated Transport Option Distances*

Transport Scenario	Mode of Travel	Start Location	Destination	Distance[4] (km)
O1	Sea	Port Spencer or Port Lincoln, South Australia, Australia	Port of Qingdao, China	**11,800**
O2	Overland	Port Spencer or Port Lincoln, South Australia, Australia	Darwin, Northern Territory, Australia	**3,100**
	Sea	Port of Darwin, Australia	Port of Qingdao, China	**6,300**
O3	Sea	As for transport scenario O1		
G1	Sea	As for transport scenario O1		
G2	Overland	Port Spencer or Port Lincoln, South Australia, Australia	Port Adelaide, South Australia, Australia	**700**
	Sea	Port Adelaide (Outer Harbour), Australia	Port of Qingdao, China	**12,250**

*It was estimated that Port Spencer and Port Lincoln are separated by roughly 70 km by road or sea. The sensitivity of this distance is considered negligible compared to the estimated overland transport distances from either port to Port Adelaide and the shipping route distances to Qingdao, China. Based on this assumption the GHG and energy calculations for Port Spencer are also applied to Port Lincoln for the purposes of this assessment.

[3] This value is a total of the emission factors of $69.2\ g\ CO_2\ per\ MJ$, $0.2\ g\ CO_2\ per\ MJ$, and $0.5\ g\ CO_2\ per\ MJ$ for carbon dioxide, methane and nitrous oxide respectively.

[4] Sea distances were converted from nautical miles (nm) to kilometers (km) based on 1.852 km/nm.

GHG emissions

Based on the above parameters, GHG emissions were estimated for each transport scenario as outlined below.

Transport scenario	Route	Transport type	GHG_i (g CO_2-e per tonne-km)	Payload (P) (tonnes)	Distance (D) (km)	Annual GHG emissions (A_i) (g CO_2)	Total annual GHG emissions for scenario (kt CO_2-e)
O1	Port Lincoln to Qingdao	Cape class	2.7	2×10^6	11,800	64×10^9	**64**
O2a	Port Lincoln to Darwin	Road	74	2×10^6	3,100	460×10^9	**493**
	Darwin to Qingdao	Cape class	2.7	2×10^6	6,300	34×10^9	
O2b	Port Lincoln to Darwin	Rail	21	2×10^6	3,100	130×10^9	**164**
	Darwin to Qingdao	Cape class	2.7	2×10^6	6,300	34×10^9	
O3	Port Lincoln to Qingdao	Panamax	4.7	2×10^6	11,800	110×10^9	**111**
G1	Port Lincoln to Qingdao	Panamax	4.7	0.5×10^6	11,800	28×10^9	**28**
G2	Port Lincoln to Port Adelaide	Road	74	0.5×10^6	700	26×10^9	**55**
	Port Adelaide to Qingdao	Panamax	4.7	0.5×10^6	12,250	29×10^9	

Note: Truck and rail emissions are based on FFC assessments, however the ship assessments are based on transport emissions only. The emissions profiles for truck and rail emissions may therefore be marginally inflated compared to the ships emissions, i.e. by up to approximately 30% higher than using transport emissions only