8 GREENHOUSE GAS

8.1 INTRODUCTION

This chapter provides an estimate of the greenhouse gas (GHG) emissions that are likely to be emitted by the Project, as related to the issue of climate change. GHGs are assessed in order to provide an indication of what a Project's GHG emissions will be, and to find ways to mitigate them early on in the development process.

8.2 ASSUMPTIONS AND LIMITATIONS

As per Equator Principles III definitions, quantification of GHG emissions includes Scope 1 emissions (direct emissions from the facilities owned or controlled within physical Project boundary) and Scope 2 (indirect emissions associated with the off-site production of energy used by the Project).

Scope 1 assumptions are as follows:

- Construction phase
  - General use construction equipment for the Project is medium size load and average horsepower of 200hp.
  - The type of fuel used for all equipment is diesel.
  - Fuel used was estimated to be 21.86 litres of diesel fuel per hour (based on the estimated liters of fuel used per machine hour of FAO [1]).
- Operation phase
  - Gas turbine generator as it is the main source of emissions.

Scope 2 assumptions are as follows:

- Construction phase
  - During peak construction period, the energy requirement for each hour is approximately 16,000 kW. To represent the worst case scenario, the maximum electricity requirement for construction phase is used in assessment in which 86,400,000 kWh will be required, based on the 540 working days and 10 working hours per day.
  - The electricity will be sourced off-site from an external provider in Myanmar.
  - Due to the lack of emission factor from electricity supplier, national grid emission factor was used to calculate the Scope 2 emissions.
- Operation phase
  - No power requirement from external providers.

(1) Estimated following FAO's formula http://www.fao.org/docrep/t0579e/t0579e05.htm#3. calculation of machine rates

8.3 SCOPE OF ASSESSMENT

8.3.1 Project Activities

Based on the Scoping and the Project Description, the key potential impacts on greenhouse gas identified arise from the following combustion sources:

Construction Phase

During construction, the Project will involve Scope 1 and Scope 2 emissions as follows;

- Scope 1 direct emission mainly from construction site equipment and site vehicles and vessel transportation; and
- Scope 2 indirect emission from purchased electricity from external provider in Myanmar.

Operation Phase

Once operational, electricity for the Power Plant will be supplied by the Plant itself, so there would be no Scope 2 emissions to consider. Scope 1 emissions of GHG from the plant operation will mainly come from the following source:

- Scope 1 direct emission from gas turbine generators.

8.4 LEGISLATION REQUIREMENTS

Myanmar participated at the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro and signed the United Nations Framework Convention on Climate Change (UNFCCC) in June 1992.[(1)] It has embarked as one of the 12 participating countries on the Asian Least Cost Greenhouse Gas Abatement Strategy (ALGAS) Myanmar ratified the United Nations Framework Convention on Climate Change (UNFCCC) on 25 November, 1994 as a non-Annex I Party.

International guidelines i.e. the Equator Principles and IFC Performance Standards applicable to the Project in term of GHG emissions and requirements are provided in ***Chapter 3.***

8.5 SUMMARY OF RELEVANT BASELINE CONDITIONS

According to data from the World Resources Institute (2014), Myanmar's total GHG emissions (excluding land use change and forestry) in 2012 were 98.93 million tons of CO_2 equivalent ($MtCO_2$)[2]. The major sectors producing CO_2 emissions are agriculture (67.8%) and energy (20.4%).

(1) MOECF (2012) Myanmar's Initial National Communication under the United Nations Framework Convention on Climate Change (UNFCCC) available at http://www.burmalibrary.org/docs18/Myanmar's_1st_%20report_to_UNFCCC-2012-red.pdf

(2) http://cait.wri.org/profile/Myanmar

8.6 ASSESSMENT METHODOLOGY

For Scope 1, GHG emissions calculation is based on the international guidelines. The main document used is Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories, 2006 (2006 IPCC Guidelines). Other applicable guidelines and approaches come from a variety of sources, including American Petroleum Institute (API) and the World Business Council for Sustainable Development, World Resources Institute (WBCSD/WRI).

For Scope 2, GHG emissions calculation is based on tools provided by the GHG Protocol. The tool allows entering information into the spreadsheet (e.g. country, electricity requirement) along with the fuel and automatically calculates the resulting CO_2 released. The GHG Protocol is the most widely used international accounting tool for government and business leaders to understand, quantify, and manage greenhouse gas emissions. It has been developed jointly by WBCSD and WRI.

The assessment of impact magnitude and significance related to GHG is based on the methodology described in ***Chapter 4***. The mitigation measures are based on international good practice (as recommended under the IFC EHS Guidelines), and good practice relevant to GHG emissions.

8.7 ASSESSMENT OF IMPACTS

8.7.1 Construction Phase

Scope 1 Direct Emissions

During construction, the Project will involve the movement of equipment in the construction areas such as crawler crane, hydraulic crane, excavators, trucks and barges.

GHG emissions are estimated using emission factors for the three (3) main greenhouse gases (CO_2, CH_4 and N_2O), and converted to CO_2 equivalent using global warming potential (GWP). ***Table 8.1*** presents the GWPs on a 100-year time horizon relative to CO_2 for ozone-depleting substances and their replacements (*IPCC, 2007*).

Table 8.1 Greenhouse Gas and Global Warming Potentials

Designation or Name	Chemical formula	100 yr GWP (AR4)[1]
Carbon dioxide	CO_2	1
Methane	CH_4	28
Nitrous oxide	N_2O	265

Source: [1] IPCC Fifth Assessment Report (AR5) (2013)

GHG emissions are estimated in terms of CO_2 equivalent (CO_2e) according to the following equation:

$$\text{Emissions}_{GHG,\,fuel} = \text{Fuel Consumption}_{fuel} \times \text{Emission Factor}_{GHG,\,fuel}$$ ***Equation 8.1***

Where:

Emissions $_{GHG,fuel}$ = z
Fuel Consumption $_{fuel}$ = amount of fuel combusted (TJ)
Emission Factor $_{GHG,fuel}$ = default emission factor of a given GHG by type of fuel (kg of greenhouse gas/TJ).

The type of fuel used for all equipment is diesel. To convert the consumption of diesel in volume (liters) to energy (TJ), the following conversion factors can be applied:

- 1 kg = 10^{-3} tonne = 10^{-6} Gg,
- 1 liter = 10^{-3} m^3
- Default net calorific value for gas/diesel oil = 43.0 TJ/Gg[(1)]
- Density of Diesel = 874.31 kg/m^3 [(2)]

Fuel consumption for diesel (in terms of TJ of energy) can therefore be calculated as follows:

Fuel Consumption (TJ) = Diesel Use (l) x Diesel Density (kg/m^3) x Net Calorific Value (TJ/Gg) x 10^{-9} (Gg/kg)
= Diesel Use (l) x 43.0 (TJ/Gg) x 874.31 (kg/m^3) x 10^{-9} (Gg/kg)
= Diesel Use (l) x 3.67 x 10^{-5} (TJ/l)

General-use construction equipment for the Project, assuming they are medium size load and average horsepower of 200hp, will consume approximately 21.86 liters of diesel fuel per hour.

It is expected that construction activities will be completed in 22.5 months. Construction hours are anticipated to be 10 hours per day, 6 days per week. Therefore, total days for construction are approximately 540 days.

GHG emissions from construction equipment are estimated following the approach of the IPCC (***Equation 8.1***) and converted to CO_2e using GWP (***Table 8.1***), with fuel consumption of 21.86 liters/hr and emission factor for diesel mobile combustion (***Table 8.2***).

Table 8.2 Default Emission Factors (kg of greenhouse gas per TJ on a Net Calorific Basis)

Sources/Fuel	CO_2	CH_4	N_2O
Stationary Combustion			
Gas/Diesel Oil	74100	3.0	0.6
Natural Gas	56100	1	0.1
Mobile Combustion			
Road Transport - Gas/Diesel Oil	74100	3.9	3.9
Water-Borne Navigation - Gas/Diesel Oil	74100	7	2

Source: IPCC Chapter 2 - Stationary Combustion and Chapter 3 Mobile Combustion of Volume 2

(1) Table 1.2 in Chapter 1 of Volume 2, IPCC (2006)
(2) Table 3-8 Density of distillate oil (Diesel), API (2009)

For a total of 540 days of construction, the release of Scope 1 emissions in CO_2 equivalent is estimated to be at 9,123.48 tonnes, as shown in ***Table 8.3***.

Table 8.3 Scope 1 Emission during Construction Phase

Source Type	Quantity	Activity Data			Total Fuel Consumption		GHG Emission				
							(kg CO_2e)				(ton CO_2e)
		Fuel Consumed	Working Hours	Working Day			CO_2	CH_4	N_2O	Total	Total
		(liter/hr)	(hr)	(day)	(liter)	(TJ)					
Emission Factors for Road Transport - Gas/Diesel Oil (kg of greenhouse gas per TJ)							**74100**	**3.9**	**3.9**		
Emission Factors for Water-Borne Navigation - Gas/Diesel Oil (kg of greenhouse gas per TJ)							**74100**	**7**	**2**		
Global Warming Potential for 100-year time horizon							**1**	**28**	**265**		
-Crawler Crane (100t)	1	21.86	10	540	118,044.00	4.33	321,017.12	473.08	4,477.34	325,967.54	325.97
-Crawler Crane (50t)	1	21.86	10	540	118,044.00	4.33	321,017.12	473.08	4,477.34	325,967.54	325.97
- Hydraulic Crane (50t)	2	21.86	10	540	236,088.00	8.66	642,034.23	946.16	8,954.69	651,935.08	651.94
- Hydraulic Crane (75t)	2	21.86	10	540	236,088.00	8.66	642,034.23	946.16	8,954.69	651,935.08	651.94
- Vibrating Compactor (20t)	5	21.86	10	540	590,220.00	21.66	1,605,085.58	2,365.39	22,386.72	1,629,837.69	1,629.84
- Concrete Truck ($6m^3$)	3	21.86	10	540	354,132.00	13.00	963,051.35	1,419.23	13,432.03	977,902.62	977.90
- Concrete Pump	2	21.86	10	540	236,088.00	8.66	642,034.23	946.16	8,954.69	651,935.08	651.94
- Compressor	1	21.86	10	540	118,044.00	4.33	321,017.12	473.08	4,477.34	325,967.54	325.97
- Reverse Excavator	3	21.86	10	540	354,132.00	13.00	963,051.35	1,419.23	13,432.03	977,902.62	977.90
- Bull dozer	3	21.86	10	540	354,132.00	13.00	963,051.35	1,419.23	13,432.03	977,902.62	977.90
- Dump truck	3	21.86	10	540	354,132.00	13.00	963,051.35	1,419.23	13,432.03	977,902.62	977.90
- Barge	2	21.86	10	540	236,088.00	8.66	642,034.23	1,698.23	4,592.15	648,324.61	648.32
										Total GHG emissions during construction phase	**9,123.48**

Scope 2 Indirect Emissions

The maximum electricity of 16,000 kW or of 86,400,000 kWh of the worst case might be required during the construction period. The electricity will be purchased from the national grid.

The GHG emissions are calculated using GHG protocol tools for purchased electricity. The total estimated Scope 2 emissions during construction are approximately 18,680.17 tonnes CO_2e (***Table 8.4***).

Table 8.4 Scope 2 Emissions during Construction Phase

Source	Electricity Consumption (kWh)	Emissions (tonnes CO_2e)	Source of Emission Factor
Purchased Electricity	86,400,000	18,680.17	Based on the national average of all fuel in Power Plant in Myanmar. (Source: World Resource Institute (2015). GHG Protocol Tool for Stationary Combustion. Version 4.7)

Total GHG Emissions during Construction Phase (Scope 1&2)

Combing Scope 1 and Scope 2 emissions, the total release of GHG emissions during construction phase is estimated to be 27,803.65 tonnes CO_2e as shown in ***Table 8.5***.

Table 8.5 Assessment of GHG Emissions during Construction Phase

Sources	Emissions (tonnes CO_2e)
Scope 1 direct emission from construction site equipment and site vehicles and vessel transportation	9,123.48
Scope 2 indirect emission from purchased electricity from external provider in Myanmar	18,680.17
Total	**27,803.65**

Potential Impact

Based on the calculated GHG emissions, the emissions from the construction phase (22 months) are estimated to be 27,803.65 tonnes CO_2e. This is considered insignificant emissions according to IFC.

Potential Consequence

GHG is global pollutants. The concentration of GHG in the atmosphere beyond the level of naturally occurring concentrations could result in more heat being held within the atmosphere. Although overall the atmosphere is sensitive to impacts from GHG emissions, the local atmosphere is not expected to be any more or less sensitive to potential impacts to GHG.

Existing and / or In-place Controls

No existing or in place control.

Significance of Impact

The significance of potential impacts to greenhouse gas during construction phase is assessed in ***Table 8.6***, and mitigation measures are presented. Magnitude is considered small as emissions contribution is accounted for 0.028% of national GHG emissions in 2012. Receptor sensitivity is considered low because the local atmosphere is not expected to be any more or less sensitive to potential impacts to GHG. Therefore, using impact significance matrix in ***Chapter 4***, significance of the impact is considered **negligible**.

Table 8.6 Assessment of GHG Emissions during Construction Phase

Impact	Potential impacts on climatic condition due to GHG emissions.				
Impact Nature	**Negative**	Positive	Neutral		
	Potential impacts to climate would be considered to be adverse (negative).				
Impact Type	**Direct**	Indirect	Induced		
	Potential impacts would likely be direct impacts through the release of emissions from combustion process of construction equipment.				
Impact Duration	Temporary	Short-term	**Long-term**	Permanent	
	Many of the major greenhouse gases can remain in the atmosphere for tens to hundreds of years after being released.				
Impact Extent	Local	Regional	**International**		
	Greenhouse gases can potentially affect the Earth's climate.				
Impact Scale	The emissions from construction phase are calculated to be 27,803.65 tonnes CO_2e or 0.028 million tonnes CO_2e. Compared to Myanmar's CO_2 release of 98.83 million tons in 2012, the total GHG releases from the Project are insignificant (approximately 0.028%).				
Frequency	Emissions will be released intermittently, but repeatedly throughout the construction period.				
Impact Magnitude	Positive	Negligible	**Small**	Medium	Large
	Minor emissions of GHG will be emitted as a result of the Project, and considered insignificant emissions according to IFC. Magnitude is considered Small.				
Receptor Sensitivity	**Low**	Medium	High		
	GHG is global pollutant. The greenhouse effect is enhanced by greenhouse gas emissions of anthropogenic nature. Minor emissions of GHG will be emitted as a result of the Project, and not likely to significantly change atmospheric GHG concentrations. Receptor/resource sensitivity is rated as Low.				
Impact Significance	**Negligible**	Minor	Moderate	Major	
	As per the impact assessment methodology defined in ***Chapter 4***, the combination of a Low resource sensitivity and Small impact magnitude will result in an overall Negligible potential impact.				

Mitigation and Management Measures

The following measures will be put in place for the Project during construction to reduce GHG emissions;

- Implement the same mitigation measures to minimize impacts to Air Quality (***Chapter 7***).
- Develop and implement preventive maintenance plan for machines, and engines to ensure combustion efficiency.
- Develop vehicle maintenance plan.

Residual Impacts

If the recommended mitigation measures are implemented, residual impact significance would be **negligible**.

8.7.2 Operation Phase

Scope 1 Direct Emissions

During the operation phase of the Project, GHG emissions would be generated mainly from the gas turbine generators in the Combined Cycle Gas Turbine (CCGT) Power Plant.

The gas turbine will use natural gas as the only fuel. Net heat rate of natural gas in CCGT Power Plant is 6,606 KJ/KWH. To convert units of KJ/KWH to units of terajoules (TJ), the following conversion factors can be applied:

- 1 kJ = 10^{-9} TJ
- Total power output during combined cycle operation = 225 MW or 225,000 KW
- Daily operation hours = 24 hr

Fuel consumption for natural gas (in terms of TJ of energy) can therefore be calculated as follows:

Fuel Consumption (TJ) = Net heat rate of natural gas (KJ/KWH) x Power output (KW) x Daily operation hours (Hr/day)
= 6,606 (KJ/KWH) x 225,000 (KW) x 24 (Hr/day) x $1/10^{9}$ (TJ/KJ)
= 35.67 TJ/day

In order to calculate GHG emissions, ***Equation 8.1*** can be applied, considering the quantity of fuel consumed for combustion purposes. The result of GHG emissions calculations are shown in ***Table 8.7***.

It is anticipated that the emission of greenhouse gas is estimated to be 2,003.03 tonnes of CO_2e/day, and annual emission is 731,106.32 tonnes.

The estimated GHG emissions from the Power Plant during operation will exceed the threshold that defines significant emitters of GHGs by the ADB SPS and EP III (100,000 tonnes CO_2e per year) and IFC PS3 (25,000 tonnes CO_2e per year). Therefore, the Project is required to report annual GHG emissions as per the applicable reference framework.

Table 8.7 Estimated GHG Emissions during Operation Phase

Source	Fuel Type	Fuel Consumed	GHG Emissions (kg CO_2e/day)			
		(TJ/day)	CO_2	CH_4	N_2O	Total
Global Warming Potential for 100-year time horizon			1	28	265	
Default Emission Factor (kg of greenhouse gas per TJ)			56100	1	0.1	
Gas Turbine Generator	Natural Gas	35.67	2,001,087.00	998.76	945.26	2,003,031.02
GHG Emission (tonnes CO_2e/day)						**2,003.03**
Annual GHG Emission (365 days) (tonnes CO_2e/year)						**731,106.32**

Potential Impact

Greenhouse gas (GHG) emissions have the potential to adversely affect the environment because they contribute to global climate change.

Potential Consequence

GHG is global pollutants. The concentration of GHG in the atmosphere beyond the level of naturally occurring concentrations could result in more heat being held within the atmosphere. Although overall the atmosphere is sensitive to impacts from GHG emissions, the local atmosphere is not expected to be any more or less sensitive to potential impacts to GHG.

Existing and / or In-place Controls

The Project has employed a CCGT technology which was designed for high reliability and efficiency operation with lower environmental impact. CCGT plant offer lower half as much CO_2 per kWh compared to coal-fire power. Non-greenhouse gas (GHG) emissions such as SO_2, NOx, and particulate matter are also relatively low.[1] Therefore, the development of electric energy in the form of combined heat energy is considered one of the most effective GHG reduction measure.

Significance of Impact

The significance of potential impacts to greenhouse gas during operation phase is assessed in ***Table 8.8***, and mitigation measures are presented. Magnitude is considered medium as emissions contribution will exceed the threshold that defines significant emitters of GHGs. Receptor sensitivity is considered medium because significant increase of GHG concentration in the atmosphere beyond the level of naturally occurring concentrations could result in more heat being held within the

[1] Energy Technology Systems Analysis Programme (2010). Gas-Fired Power. http://www.iea-etsap.org/web/e-techds/pdf/e02-gas_fired_power-gs-ad-gct.pdf

atmosphere. Therefore, using impact significance matrix in ***Chapter 4***, significance of the impact is considered **moderate**.

Table 8.8 Assessment of GHG Emissions during Operation Phase

Impact	Potential impacts on climatic condition due to GHG emissions.				
Impact Nature	**Negative**	Positive	Neutral		
	Potential impacts to climate would be considered to be adverse (negative).				
Impact Type	**Direct**	Indirect	Induced		
	Potential impacts would likely be direct impacts through the release of emissions from Project operation.				
Impact Duration	Temporary	Short-term	**Long-term**	Permanent	
	Many of the major greenhouse gases can remain in the atmosphere for tens to hundreds of years after being released.				
Impact Extent	Local	Regional	**International**		
	Greenhouse gases can potentially affect the Earth's climate.				
Impact Scale	The emissions from Power Plant are calculated to be 731,106.32 tonnes CO_2e or 0.73 million tonnes CO_2e per annum. Compared to Myanmar's CO_2 release of 98.83 million tons in 2012, the total GHG releases from the Project is approximately 0.73%.				
Frequency	Emissions will be released continuously throughout the operation period.				
Impact Magnitude	Positive	Negligible	Small	**Medium**	Large
	GHG will be emitted as a result of the Project. The emissions from Power Plant are calculated to be 731,106.32 tonnes CO_2e per year. This is considered 'significant emissions' according to ADB SPS and EP III (100,000 tonnes CO_2e per year) and of IFC PS3 (25,000 tonnes CO_2e per year). Magnitude is therefore considered Medium.				
Receptor Sensitivity	Low	**Medium**	High		
	GHG is global pollutants. The greenhouse effect is enhanced by greenhouse gas emissions of anthropogenic nature. The concentration of GHG in the atmosphere beyond the level of naturally occurring concentrations could result in more heat being held within the atmosphere. Receptor/resource sensitivity is rated as Medium.				
Impact Significance	Negligible	Minor	**Moderate**	Major	
	As per the impact assessment methodology defined in ***Chapter 4***, the combination of a Medium resource sensitivity and Medium impact magnitude will result in an overall Moderate potential impact.				

Mitigation and Management Measures

The technology of the Project is an efficient form of CCGT power generation. In additional the Project uses natural gas as its only fuel to generate electricity that provides more efficiency than coal because of higher operating temperatures, and when used together with the more efficient combined-cycle results in even higher efficiencies (*IEA, 2006*).[1] Therefore at this stage it is considered that further design measures and control measures are not considered necessary.

It is therefore proposed to undertake an annual GHG inventory to monitor the GHG emissions according to the applicable requirements (i.e. ADB SPS, EP III and IFC):

- Conduct annual pollutant release inventory to monitor the GHG emissions from the Project. The GHGs emission shall be reported as CO_2e unit.

[1] IEA, 2006a: Energy Technology Perspectives 2006: Scenarios and strategies to 2050. International Energy Agency, Paris, 484 pp.

Residual Impacts

The Project employs the most effective GHG reduction measure. The mitigation measures above have been put in place to monitor the GHG emission. There will be no reduction in the impact level, residual impact significance would be **moderate**.