COPPERSTRING 2.0

CopperString 2.0

Greenhouse gas assessment

Volume 3 Appendix V

CuString Pty Ltd

CopperString Project EIS
Greenhouse Gas Assessment

November 2020

Executive Summary

CuString Pty Ltd (CuString) propose to construct and operate a high voltage transmission line that will connect the North West Power System (NWPS), and foundation customers at isolated mine sites along the Project route, to the state electricity grid, allowing participation in the National Electricity Market (NEM) (the Project). The Project involves the construction and operation of approximately 1,000 km of extra high voltage overhead electricity transmission line.

The 330-kilovolt (kV) core alignment will extend from a new substation at Woodstock, on the existing Strathmore to Ross Transmission Line south of Townsville, to the Dajarra Road Substation, approximately 10 km southwest of Cloncurry, Queensland. From the Cloncurry Substation, a 200 kV transmission line will divert west to Mount Isa. An additional 220 kV transmission line will also extend south from the Cloncurry Substation to the Selwyn Substation, with spurs to the Phosphate Hill and Cannington mines.

Electricity is currently supplied to the NWMP from local generation sources, with standalone diesel or gas generation at mine sites. The Project will provide a reliable low cost supply to existing customers in the NWMP, and enable new industrial facilities and large agricultural and renewable energy projects in the region to enter the NEM.

CuString is referring this Proposal under the provisions of the *State Development Public Works Organisation Act 1971* (SDPWO Act). GHD Pty Ltd were engaged to prepare a Greenhouse Gas (GHG) assessment which is required to address an item of the Terms of Reference (ToR) for an environmental impact assessment, as required by the Queensland Government.

This assessment includes the following:

- Characterisation of GHG emission sources from the Project and an estimation of expected Scope 1 (direct) and Scope 2 (energy indirect) GHG emissions in accordance with the *National Greenhouse and Energy Reporting Act 2007* (NGER Act), considering both the construction and operation of the Project.
- Comparison of total GHG emissions between the Project and State emissions.
- Provide a high level summary of the GHG abatement opportunities and management measures for the Project.

This report will provide the basis for the development of Greenhouse Gas Management Plans and Carbon Dioxide Abatement Plans as may be required by the Construction Contractor or Operations and Maintenance Service Provided.

The GHG emissions inventory is prepared on the basis of knowledge of the Project design, construction and operations current at the time of assessment. Emission sources and estimated emissions calculated in this assessment are outlined in Table ES 1.

Table ES 1 Greenhouse gas emissions by source during construction and operation (as tCO_2-e)

Activity	Average annual GHG emissions by source		Total GHG emissions by source	
	Construction	Operation	Construction	Operation
Scope 1				
Land clearing	143,764	-	431,293	
Diesel combustion in mobile engines	3,804	179	11,413	8,071
Diesel combustion in stationary engines	2,529	13	7,587	574
Aviation fuel in mobile engines	948	26	2,843	1,183
Gas insulated electrical components (SF_6)	-	314	-	14,118
Scope 2				
Electricity consumed	34	486	102	21,870
Transmission losses (AC)	-	210,704	-	9,481,695
Total	151,079	211,722	453,238	9,527,510

GHG emissions during construction are largely comprised of Scope 1 emissions, with average annual for Scope 1 and Scope 2 emissions of 151,078 tCO_2-e per year.

During operation, average annual Scope 1 and Scope 2 GHG emissions are 248,146 tCO_2-e. Total Scope 1 and Scope 2 emissions over the life of the Project is 9,980,748 tCO_2-e. Utilising the operation only emissions, the GHG intensity (the emissions intensity to transmit the electricity) is equal to 0.60 tCO_2-e per GWh.

A comparison of publicly available data reported under the National Greenhouse and Energy reporting Scheme indicates that the Scope 1 and 2 emissions from the Project equate to an increase in emissions of 0.36%. At a national level, the Project contributes an increase of 0.10% for emissions relating to public electricity, heat production and generation of purchased electricity.

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1. Introduction

1.1 Project overview

CuString Pty Ltd (CuString) proposes to construct and operate an extra high voltage transmission line that will connect the North West Power System (NWPS), and foundation customers at isolated mine sites along the Project route, to the state electricity grid, allowing participation in the National Electricity Market (NEM). The CopperString 2.0 Project (the Project) involves the construction and operation of approximately 1,060 kilometres (km) of extra high voltage overhead electricity transmission line. The 330-kilovolt (kV) transmission lines will extend from a new substation south of Woodstock, on the existing Strathmore to Ross Transmission Line south of Townsville, to the Dajarra Road Substation, approximately 10 km southwest of Cloncurry. From the Dajarra Road Substation, a 220 kV transmission line will divert west to Mount Isa. An additional 220 kV transmission line will also extend south from the Dajarra Road Substation to the Selwyn Substation, with spurs to the Phosphate Hill and Cannington mines.

Electricity is currently supplied to the NWPS from local generation sources, with standalone diesel or gas generation at mine sites. The Project will provide a reliable low cost supply to existing customers in the NWPS, and will enable development of new industrial facilities and large agricultural projects in the region, and will facilitate participation of renewable energy projects in the region to enter the NEM.

Development of the Project will commence early 2021, subject to the securing of required government approvals and agreements with relevant landholders and Native Title groups. Capital expenditure is estimated at approximately $1.5 billion over the construction period.

1.2 Project background

The Project was initially proposed in 2010 and designated as a significant project under the *State Development and Public Works Act 1971* (SDPWO Act). A draft Environmental Impact Statement (EIS) for CopperString 1.0 was published in November 2010. The Project was determined a ‘controlled action’ under the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act) in 2010 (EPBC 2010/5581). This previous determination lapsed, and following re-referral under the EPBC Act in early 2019, CopperString 2.0 was deemed a ‘controlled action’ in May 2019 (EPBC 2019/8416).

CuString has referred the Project with the Queensland Department of State Development, Manufacturing, Infrastructure and Planning under the provisions of the SDPWO Act, for recognition as a coordinated action (noting that the term ‘coordinated action’ has replaced the previous designation ‘significant project’). This emissions assessment is required to address the Terms of Reference (ToR) for an environmental impact assessment, as required by the Queensland Government. Item 12.51 of the ToR requests the following:

“Provide a Greenhouse Gas Management Plan and Carbon Dioxide (CO_2) abatement plan and an inventory of project annual emissions for the life of the project for each relevant greenhouse gas, with total emissions expressed in ‘CO_2 equivalent’ terms for the following categories as per the National Greenhouse and Energy Reporting scheme:

(a) scope 1 emissions – means direct emissions of greenhouse gases from sources within the boundary of the facility and as a result of the facility’s activities (including emission from vegetation clearing).

(b) scope 2 emissions – means emissions of greenhouse gases from the production of electricity, heat or steam that the facility will consume, but that are physically produced by another facility.”

1.3 Purpose of this report

GHD was engaged by CuString to prepare this GHG assessment for the Project. This GHG assessment includes:

- Characterisation of GHG emission sources from the Project and an estimation of expected Scope 1 (direct) and Scope 2 (indirect) GHG emissions in accordance with the *National Greenhouse and Energy Reporting Act 2007* (NGER Act), considering both the construction and operation phases of the Project.
- An inventory of projected annual emissions of GHGs for tonnes of carbon dioxide equivalents (tCO_2-e).
- Provide a high level summary of GHG abatement opportunities and measures for the Project.

This report will provide the basis for the development of Greenhouse Gas Management Plans and Carbon Dioxide Abatement Plans as may be required by the Construction Contractor or Operations and Maintenance Service Provided.

1.4 Defined terms

The following terms are utilised throughout the GHG Assessment.

Project area - The 120 m or 60 m wide easement and associated infrastructure (including laydown areas, substations, CEV huts, access tracks, brake and winch sites and construction camps) and works referred to in the EIS ToR (these include off-easement components).

2. Regulatory framework for greenhouse gas emissions

2.1 International framework

The emission of GHGs is governed internationally through several mechanisms including the Intergovernmental Panel on Climate (IPCC), United Nations Framework Convention on Climate Change (UNFCCC), the Paris Agreement, and the Kyoto Protocol. The function of each of these is as follows:

- The IPCC was established in 1988 and operate to provide decision makers and others interested in climate change with an objective source of information. The IPCC prepare assessment reports based on available scientific evidence and produce guidance documents and recommended methodologies for GHG emission inventories.
- The UNFCCC were established in 1994 following the release of the first technical report written by the IPCC. It comprises 172 countries (parties), having ratified the Kyoto Protocol. The UNFCCC sets the overall framework for efforts to manage climate change on an international scale.
- The Kyoto Protocol was in force as of 16 February 2005 and commits member states to individual, legally binding targets to limit or reduce GHG emissions. Australia, amongst others, forms part of the Annex I Parties, and was required to meet national targets for GHG emissions between 2008 and 2012. To achieve their targets, Annex I Parties had to implement domestic policies and measures. A second commitment period was agreed in 2012 for between 2013 and 2020, where Australia, as well as 36 other countries, were bound to further reduce GHG emissions by at least 18 percent below 1990 levels by 2020.
- The Paris Agreement was established in 2015 and sets in place a durable and dynamic framework for all countries to take action on climate change from 2020. Australia ratified the Paris Agreement in November 2016 and is committed to reducing GHG emissions by 26-28 percent below 2005 levels by the year 2030.

2.2 Australia

In Australia, there are several regulatory frameworks for management and reduction of GHG emissions. This includes the *National Greenhouse and Energy Reporting Act 2007* (NGER Act), under which Safeguard Mechanism is established, and the Emissions Reductions Fund. The function of each of these is as follows:

- The NGER Act established a single national framework for reporting and disseminating company information about GHG emissions, energy production, and energy consumption. A rule made under this Act and enacted in 2015 established the Safeguard Mechanism, which operates in tandem with the ERF. Emitters must report annually all Scope 1 and Scope 2 emissions, and results are presented on the Clean Energy Regulator website.
- The Safeguard Mechanism applies to facilities with direct scope 1 emissions of more than 100,000 tonnes of carbon dioxide equivalent per year. This framework establishes a baseline against which their emissions reported under the NGER Act are compared. If a facility exceeds its baseline, they have the options to: establish a new baseline if the additional emissions related to a change in production variables; surrender Australian carbon credit units (ACCUs) to offset emissions; apply for a multi-year monitoring period to allow additional time to reduce net emissions; or apply for an exemption where emissions are due to exceptional circumstances.

- The Emissions Reduction Fund (ERF) is a scheme that aims to provide incentives for a range of organisations and individuals to adopt new practices and technologies to reduce their emissions, and provides a legal obligation for Australia's top emitters to maintain their emissions below their emissions limit (or baseline) (defined by the Safeguard Mechanism established under the NGER Act). The ERF is enacted through the *Carbon Credits (Carbon Farming Initiative) Act 2011*, and allows for the generation of ACCUs. ACCUs can be sold to the ERF or sold on the secondary market and purchased by emitters who exceed their baseline to offset their emissions.

Whilst not a regulatory body, the Climate Change Authority (CCA) provides independent, expert advice on climate change policy. The CCA assist in the development of mitigation policies, undertake reviews and make recommendations on the Carbon Farming Initiative (now part of the ERF) and the NGER Act reporting scheme.

2.3 Queensland

The Queensland Government has established a number of strategies aimed at reducing the States GHG emissions and transitioning to a lower carbon economy. These include the *Queensland Climate Transition Strategy* (2017) and the complementary *Queensland Climate Adaptation Strategy* (2017). The function of these are as follows:

- The *Queensland Climate Transition Strategy* (2017) outlines the States three key climate commitments: zero net emissions by 2050, an interim target of at least a 30% reduction in emissions on 2005 levels by 2030, and powering Queensland with 50% renewable energy by 2030.
- The *Queensland Climate Adaptation Strategy* (2017) outlines an approach for ongoing climate adaptation policy development and implementation, including using best practice climate science to update regulations and procedures.

The *Greenhouse Gas Storage Act 2009* regulates the storage of GHGs in Queensland, however does not regulate the emission of GHGs from industry. In Queensland, GHG emissions are regulated under the *Environmental Protection Act 1994* (EP Act) and *Environmental Protection (Air) Policy 2019*.

3. Emissions calculations methodology

3.1 Overview

The GHG emission quantities and sources were estimated based on activity data representative of the proposed activities, and in reference to the following documents:

- Greenhouse Gas Protocol, the World Resources Institute/ World Business Council for Sustainable Development (WRI/WBCSD 2004) (Section 2.2).
- *National Greenhouse Accounts Factors* (2020), Commonwealth Department of Environment and Energy. This determination deals with Scope 1 and Scope 2 emissions.
- *National Greenhouse and Energy Reporting Regulations 2008*, under the NGER Act, Australian Government. (Section 2.3) These outline the detailed reporting requirements under the NGER framework and provide a basis for estimating emissions.
- *NGER (Measurement) Determination 2008* (as amended) under subsection 10(3) of the NGER Act, Australian Government (Section 2.5.1).

3.2 Project specific data sources

The following data sources were utilised in the preparation for this assessment:

- *Greenhouse Gas Assessment for CopperString Project (1.0)* (URS 2010). Report prepared for CuString Pty Ltd.
- *Impact on CopperString of Corona on 220 kV and 330 kV Networks* (Hill Michael 2010). Report prepared for CuString Pty Ltd.
- Economic Assessment Report. North West Queensland Energy Delivery Options. (ROAM 2009). Report prepared for Queensland Government and Queensland Resources Council.

This assessment has been conducted during the concept and planning phase of the Project. Information not available has been assumed by appropriately qualified people, and all assumptions have been provided and endorsed by CuString.

3.3 Greenhouse gases and global warming potentials

The GHGs considered in this assessment and the corresponding global warming potential (GWP) for each gas are listed in Table 3-1. GWP is a metric used to quantify and communicate the relative contributions of different substances to climate change over a given period (usually 100 years). GWP accounts for the radiative efficiencies of various gases and their lifetimes in the atmosphere, allowing for the impacts of individual gases on global climate change to be compared relative to those for the reference gas, carbon dioxide. The GWP values referenced in this assessment are adapted from Section 7, regulation 2.02 of the National Greenhouse and Energy Reporting (NGER) Regulations 2008 (Cwlth).

Table 3-1 GHGs and 100 year global warming potential

Greenhouse Gas	Global Warming Potential (GWP)
Carbon dioxide (CO_2)	1
Methane (CH_4)	28
Nitrous oxide (N_2O)	265
Sulfur hexafluoride (SF_6)	23,500

3.4 Scope of greenhouse gas assessment

The GHG emissions considered for this assessment are consistent with the characterisation of GHGs as outlined in the Greenhouse Gas Protocol (WRI/WBCSD 2004), which establishes an international standard for reporting of greenhouse gas emissions. The GHG Protocol has been adopted by the International Organisation for Standardisation (ISO 14064-2).

The GHG Protocol defines three emissions 'Scopes' for greenhouse gas accounting and reporting purposes. This GHG assessment boundary focuses on direct (Scope 1) and indirect (Scope 2) emissions associated with the Project. Scope 3 emissions were identified; however, they were not subject to assessment.

Scope 1: Direct greenhouse gas emissions

Scope 1 emissions are direct greenhouse gas emissions from operations or activities exclusively from within the physical boundary of the Project area. Table 3-2 outlined the Scope 1 (direct) GHG emissions that are predicted to result from the Project:

Table 3-2 Scope 1 emissions during construction and operation

Construction	Operation
Combustion of diesel used in site vehicles and mobile construction equipment. The main GHG generated by the combustion of fossil fuels for energy is carbon dioxide (CO_2), while small quantities of methane (CH_4) and nitrous oxide (N_2O) are also produced.	
Combustion of diesel in stationary equipment.	
Combustion of aviation fuel in helicopter for inspection and maintenance activities.	
Land clearing. When vegetation is cleared, the carbon stored within the woody biomass is lost to the atmosphere as carbon dioxide (CO_2)	Leakage of synthetic gases (SF_6) from gas insulated electrical components during maintenance.

Scope 2: Energy product use indirect greenhouse gas emissions

Scope 2 emissions are indirect emissions emitted from the use of purchased or acquired electricity brought into the Project area.

Table 3-3 outlines the Scope 2 (indirect) GHG emissions that are predicted to result from the Project:

Table 3-3 Scope 2 emissions during construction and operation

Construction	Operation
Electricity consumed to power the CuString head office in Townsville, Queensland	
Electricity consumed in temporary site offices.	Electricity consumed in permanent offices across the Project area.
	Electricity consumed due to transmission line losses. Transmission losses are the losses in electricity due to resistive losses (in the form of heat when electric currents pass through conductors) and corona losses (power losses because of ionisation of the air immediately surrounding the conductor). Transmission losses also occur from leakage of currents through the insulation.

Scope 3: Other indirect greenhouse gas emissions

Emissions within Scope 3 are indirect emissions from sources not owned or controlled by the Project. Some expected Scope 3 emissions that were identified as resulting from the following activities associated with the Project are outlined in Table 3 4. These emissions were not subject to assessment under the ToR for the Project but have been listed for completeness.

Table 3-4 Scope 3 emissions during construction and operation

Construction	Operation
Off-site extraction, processing and transport of diesel fuel	
Combustion of fuels used in transportation of material on site by suppliers	Off-site extraction, processing and transport of fuels used in production of electricity consumed
Manufacturing, transportation and disposal of materials used in the construction of the transmission line including steel poles and cables, plastics, and other resources	Offsite consumption of the electricity distributed through the network
Manufacturing, transportation and disposal of transformer insulation gases	
Transportation and disposal of waste materials	Offsite consumption of the electricity distributed through the network
Employee travel	

3.5 Calculation procedure

The calculation procedures used to create the emissions inventory utilise the methods of the *NGER (Measurement) Determination* 2008, and were as follows:

- A scope for the GHG inventory was defined, considering possible emission sources of GHGs, including carbon dioxide, nitrous oxides, methane and sulfur hexafluoride.
- Relevant instances of energy use and emissions from construction and operations were identified. These instances were classified as either Scope 1 or Scope 2.

- For GHG emissions during the construction and operation phase:
  - Estimates of the carbon emissions from vegetation clearing were undertaken with the *National Carbon Accounting System* (NCAS) FullCAM model (DoEE 2015). The models provide an output of tonnes of carbon per hectare. To calculate tonnes of carbon lost per hectare, total on site carbon mass was subtracted from initial onsite carbon mass (prior to clearing). This is converted to carbon dioxide equivalent emissions by multiplying by a factor of 44/12. This represents the ratio of molecular weight of carbon dioxide and elemental carbon.
  - Relevant activity data for vehicle and stationary equipment plant use was identified or assumed for construction and operation, and emissions factors were determined. Estimates of emissions from the combustion of diesel are made by multiplying the physical quantities of fuel combusted, by a fuel-specific energy content factor and fuel specific emission factor. This calculation was performed for each relevant greenhouse gas. Total greenhouse gases are calculated by summing the emissions of each greenhouse gas
  - Estimates of Scope 2 emissions from consumption of purchased electricity were obtained by multiplying the estimated electricity consumed including transmission losses (MW) by the estimated operating hours, and the emission factor for electricity consumption in Queensland
  - The emissions from gas insulated electrical components were determined by multiplying the stock of SF_6 by the default leakage rate and GWP.
  - Emissions related to transmission loss from the infrastructure is detailed in Section 3.5.1 for alternating current (AC).
- The total and annual GHG emissions for the Proposal during construction and operation phases were determined.

3.5.1 AC transmission loss methodology

The original EIS transmission segment lengths and configurations (URS 2010) were broadly maintained, with some minor changes. The transmission segment lengths sum to 1047 km. Therefore the analysis is based on:

- For the core portion from Woodstock to Dajarra Substation (Cloncurry): 732 km of 330 kV double circuit twin sulphur conductor;
- For the portions from Dajarra Substation (Cloncurry) to both Mount Isa and the Selwyn Substation: 189 km of 220 kV double circuit twin sulphur; and
- For the portions from the Selwyn Substation to both Cannington and Phosphate Hill: 126 km of 220 kV single circuit single sulphur

AC resistive (Joule) losses

For a three phase transmission line, with a power factor assumed to be unity, transmission line resistive losses can be calculated as:

$$P_{loss,AC} = 3\left(\frac{P_{phase}}{V_{phase}}\right)^2 \cdot R_{eq}$$

For a three phase system each phase will carry one third of the total power. Voltages specified in practice always refer to RMS line voltages. Therefore to convert to phase voltage (line to neutral):

$$V_{phase} = \frac{V_{line}}{\sqrt{3}}$$

The resistance of a bare overhead sulphur conductor (ac) is given as 0.056 Ohms/km (Prysmian 2018). This includes the skin effect and the magnetic effect.

For a twin conductor circuit, each subconductor will carry half of the circuit phase current. In addition, for the double circuit configuration, each single circuit will carry half of the double circuit phase current. Therefore these two effects can be combined to calculate R_{eq} as ¼ of the single conductor resistance assuming a balanced current flows through all three equivalent conductors. Alternatively, the current can be divided across the 12 conductors (three phases, two subconductors each and two circuits), each with the impedance of a single conductor.

For the full length of the 330 kV double circuit twin conductor line segments, with a power flow of 450 MW (URS 2010):

$$P_{loss,1} = 3\left(\frac{\frac{450}{3}}{\frac{330}{\sqrt{3}}}\right)^2 \cdot R_{eq} = 3\left(\frac{150}{190.53}\right)^2 \cdot \frac{\frac{0.056}{2}}{2} \cdot 732 = 19.06\ MW$$

For the full length of the 220 kV double circuit twin conductor line segments, with a power flow of 250 MW (URS 2010):

$$P_{loss,2} = 3\left(\frac{\frac{250}{3}}{\frac{220}{\sqrt{3}}}\right)^2 \cdot R_{eq} = 3\left(\frac{83.33}{127.02}\right)^2 \cdot \frac{\frac{0.056}{2}}{2} \cdot 189 = 3.42\ MW$$

For the full length of the 220 kV single circuit single conductor line segments, with a power flow of 150 MW (URS 2010):

$$P_{loss,3} = 3\left(\frac{\frac{150}{3}}{\frac{220}{\sqrt{3}}}\right)^2 \cdot R_{eq} = 3\left(\frac{50}{127.02}\right)^2 \cdot \frac{\frac{0.056}{1}}{1} \cdot 126 = 3.28\ MW$$

These combine to give:

$$P_{loss,AC} = 25.75\ MW$$

The methodology applied above is consistent with several publically available reports, one such example being (El-Marsafawy 1995).

AC corona losses

The *Impact on CopperString of Corona on 220 kV and 330 kV Networks* (Hill Michael 2020) report has been used to determine the AC corona losses. This report provides detailed engineering and the corona losses have been provided for each line segment in units of kW/m depending on voltage level, conductor bundling and the number of circuits. The figures used were:

- For the 732 km segment of 330 kV double circuit twin sulphur, 2.54 kW/km in fair weather and 22.57 kW/km in stormy weather;
- For the 189 km segment of 220 kV double circuit twin sulphur, 1.47 kW/km in fair weather and 13.65 kW/km in stormy weather; and
- For the 126 km segment of 220 kV single circuit single sulphur, 0.55 kW/km in fair weather and 3.65 kW/km in stormy weather

Considering a ratio of 90-10 for fair to stormy conditions (previously assumed) and multiplying out the corona losses by the line lengths, the total corona loss for the AC case becomes:

$$P_{loss,1} = 732 \cdot 2.54 \cdot 90\% + 732 \cdot 22.57 \cdot 10\% = 3.33 \text{ MW}$$

$$P_{loss,AC} = P_{loss,1} + P_{loss,2} + P_{loss,3} = 3.94 \; MW$$

Total AC losses

The total AC transmission losses are the sum of the resistive and corona losses, or 29.70 MW.

3.6 GHG emissions factors utilised

The emission factors for each of the emissions sources that have been used in the assessment are summarised in Table 3-5.

Table 3-5 Emission factors for GHG emissions sources

Emissions source	Source	Unit	Emission factor (tCO_2-e per unit)			
			CO2	CH4	N2O	Total
Diesel engines (stationary)	NGER 2019-2020 Schedule 1, Part 3	kL	69.9	0.1	0.2	70.2
Diesel engines (mobile)	NGER 2019-2020 Schedule 1, Part 4	kL	69.9	0.2	0.4	70.4
Gasoline for use as fuel in an aircraft	NGER 2019-2020 Schedule 1, Part 4	kL	67.0	0.6	0.6	68.2
Electricity consumption (Queensland)	NGER 2019-2020 Schedule 1, Part 6	kWh	-	-	-	0.81
Sulfur hexafluoride (leakage rate)	NGER 2019-2020 Schedule 1, Part 4	tCO_2-e				0.0089

3.7 Assumptions

Assumptions used in estimating GHG emissions for the construction and operation of the project are listed in Table 3-6. This assessment was based on the emission factors and Project design current at the time of assessment. Future changes in emissions factors or an expansion of network connections were not considered. The Project is expected to be operational for 8760 hours per year.

3.7.1 Land clearing

The Project will involve the clearing of native vegetation (within state landscape times) to create a clear buffer to ensure the safe operation of the transmission network. Land clearing may remove vegetation that has grown or may grow to a height greater than 5 m tall. For the purposes of this assessment is was assumed that clearing for the Project will be required for the length of the alignment traversing these landscapes which is approximately 680 km (or 55%) for a width of 60 m, totalling a proposed 4,081 ha of woody vegetation. This is considered to be a conservative estimate of clearing for the transmission line as clearing the full 60 m width of the easement across the length of the corridor is not required. To minimise the clearing required, tower heights would be increased to allow the transmission line to span sections of vegetation and minimise clearing.

During the operation phase of the Project, there may be vegetation management but no additional clearing.

The Full Carbon Accounting Model (FullCAM) was used to estimate greenhouse gas emissions from land clearing during the construction phase. FullCAM is the model used to construct Australia's national greenhouse gas emissions account for the land sector. FullCAM deals with both the biological and management processes which affect carbon pools and the transfers between pools in forest and agricultural systems. The exchanges of carbon, loss and uptake between the terrestrial biological system and the atmosphere are accounted for in the full/closed cycle mass balance model which includes all biomass, debris and soil pools.

A mixed (forest and agricultural) plot type was used to model vegetation along the alignment, with the township of Charters Towers being used as a spatial reference point. A simple model was generated, measuring only plant and above ground biomass. This includes the carbon stored in plants, roots and debris. The following forestry plots were modelled:

- Eucalypt Woodlands
- Eucalypt Open Woodlands
- Melaleuca Forests and Woodlands
- Acacia Open Woodlands
- Other Forests and Woodlands.

For each vegetation type, a conservative forest cover percentage was applied, and it is assumed that forest cover is reduced to 0% post-clearing.

3.7.2 Diesel combustion

Diesel combustion will result in Scope 1 emissions during construction and operation from stationary engines (generators) used to generate electricity for site facilities, laydowns, and batch plants. An estimated 2,800 kL of diesel is estimated to be combusted during construction, based on information provided by CuString across all nine construction zones. During operation, an estimated 212 kL of diesel fuel is proposed to be consumed.

Diesel will also be combusted in mobile engines such as construction equipment and site vehicles. During construction, an estimated 4,200 kL of diesel fuel is proposed to be consumed. During operation, an estimated 2,970 kL of diesel is proposed to be combusted, based on information provided by CuString.

3.7.3 Aviation fuel

A helicopter is proposed to be utilised during construction and operation to provide remote and aerial surveillance. An estimated 1,259 kL of aviation fuel is estimated to be combusted during construction, and 524 kL during operation. These estimates were provided by CuString.

3.7.4 Gas-insulated electrical components

The Project proposes to use sulfur hexafluoride (SF_6) as the dielectric fluid to insulate the circuit breakers installed as part of the Project. Up to 1,500 kg of SF_6 would be used in electrical components. However, emissions of SF_6 would only result from leakage and top-ups, and is expected to be approximately 600 kg during operation (45 years) (based on the applied leakage rate). The initial quantity of SF_6 used forms the basis for the estimated emissions, as the leakage rate assumes replenishment of the original quantity.

3.7.5 Transmission loss

Scope 2 emissions will result from the off-site combustion of fuel to generate electricity consumed across the network. There is also a component associated with electricity consumption at the head office during construction and the site buildings during operation. The largest component of emissions during the Project life are transmission losses across the network.

In this assessment, it has been conservatively assumed that the emissions associated with electricity usage remain constant throughout the projected life of the Project. In reality, the Scope 2 emissions are likely to reduce over time as the emissions intensity of the electricity in Queensland changes.

The following assumptions informed the transmission loss emissions estimate:

- Conductor operation at 75 degrees Celsius
- All numbers have been scaled to reflect a 1,047 km length transmission line.
- Transmission losses are active power losses only i.e. the line will operate at a power factor of 1. Reactive losses are not considered.
- Assume the 330 kV line sections will be transposed at 1/3, 2/3 locations etc. such that the system will be balanced.
- Assume the main portion of the AC line is 330 kV double circuit twin sulphur and the other segments are 220 kV double circuit twin sulphur and single circuit single sulphur as per information available at time of writing and described in Section 3.7.5.
- GHD has not considered losses related to substations. This estimate is purely for the transmission line.
- Power flow is assumed to be 450 MW based on information available at the time of writing (URS 2010). GHD has assumed a steady state conditions for load flow (constant load) and any benefits or detriments to the network under different (dynamic) scenarios via the addition of the line have not been assessed.
- Assume all systems comprise of twin bundled and single sulphur conductors.
- 45 year line operation at 8760 hours per year.

3.7.6 Summary of assumptions by source

Table 3-6 Summary of assumptions by source

Parameter	Assumptions
Construction	
Land clearing – lost carbon sink	4,081 ha Areas for access tracks, laydown areas, construction camps, concrete batching plants would be located within entirely cleared areas. All trees greater than 5 m will be cleared during construction and removed throughout operation. Township of Charters Towers used as spatial reference point as this represented a suitable location for the FullCAM assessment.
Diesel combustion – Stationary	2,800 kL. This value was provided by CuString.
Diesel combustion – Transport purposes	4,200 kL This value was provided by CuString.
Aviation Fuel	1,259 kL (Assuming 20 months x 6h/d x 3 helicopters x 115L/h
Consumption of purchased electricity in site buildings (Head office)	It is anticipated that the CuString head Office in Townsville will consume approximately 42,000 kWh per year.
Operation	
Diesel combustion – Stationary	212 kL

Parameter	Assumptions
	Stationary engines will be installed at substation and maybe some CEV huts, and tested regularly.
Diesel combustion – Transport purposes	66 kL/yr
Aviation Fuel in mobile engines	524 kL/yr
Consumption of purchased electricity in site buildings (site offices, substations)	600,000 kWh/yr
Resistive transmission losses (AC)	Refer to Calculations in Appendix A
Gas insulated (Sulfur hexafluoride) electrical components (installation, maintenance, destruction)	1,500 kg

3.8 Exclusions from this assessment

Exclusions from the assessment included:

- Emissions associated with fugitive emissions from refrigeration and/or air-conditioning. These emissions were considered negligible compared with the total emissions for the Project.

4. Greenhouse gas emissions assessment

4.1 Scope 1 emissions estimation

4.1.1 Land clearing

A total of 4,081 ha is proposed to be cleared for the construction of the transmission infrastructure, equating to total GHG emissions of 431,293 tCO_2-e (Table 4-1). No additional clearing will occur during operation, as such, there are no operational emissions relating to land clearing.

Table 4-1 Emissions relating to land clearing during construction and operation

Variable	Construction	Operation
Total clearing area (ha)	4,081	-
Total carbon mass (t)	117,625	-
Total clearing emissions (tCO_2-e)	431,293	-
Average annual clearing emissions (tCO_2-e)	143,764	-

4.1.2 Diesel combustion

A total of 7,000 kL and 3,182 kL of diesel is estimated to be combusted in mobile and stationary engines during construction and operation respectively, equating to total GHG emissions of 27,645 tCO_2-e over both phases of the Project (Table 4-2).

Table 4-2 Emissions relating to diesel combustion during construction and operation

Variable	Construction	Operation
Total diesel consumed mobile engines (kL)	4,200	2,970
Total diesel consumed stationary engines (kL)	2,800	212
Total emissions (tCO_2-e)	19,000	8,644
Average annual emissions (tCO_2-e)	6,333	216

4.1.3 Aviation fuel

A total of 1,259 kL and 524 kL of aviation fuel is estimated to be consumed in during construction and operation respectively, equating to total GHG emissions of 4,025 tCO_2-e over both phases of the Project (Table 4-3).

Table 4-3 Emissions relating to aviation fuel combustion during construction and operation

Variable	Construction	Operation
Total aviation fuel consumed (kL)	1,259	524
Total emissions (tCO_2-e)	2,843	1,183
Average annual emissions (tCO_2-e)	948	26

4.1.4 Gas-insulated electrical compounds

A total of 1.5 t of sulphur hexafluoride will be used during the operation phase of the project. Emissions relating to the use of this gas are estimated using an established leakage rate for gas-insulated electrical compounds, which assumes that the original quantity of gas will be replenished throughout operation, equating to total emissions of 14,118 tCO_2-e over the life of the Project (Table 4-4). This equates to a total loss of 600 kg of SF_6 throughout the operation phase.

At the end of the operation phase, the gas will be captured during decommissioning and not vented to atmosphere. There will be no SF_6 utilised on site during construction, and as such no emissions from this phase.

Table 4-4 Emissions relating to gas insulated electrical compounds during construction and operation

Variable	Construction	Operation
Total sulphur hexafluoride used (t)	-	1.5
Total emissions (tCO_2-e)	-	14,118
Average annual emissions (tCO_2-e)	-	314

4.2 Scope 2 emissions estimation

4.2.1 Electricity consumption

A total of 126 MWh and 27,000 MWh of electricity is estimated to be consumed during construction and operation respectively, equating to total GHG emissions of 21,970 tCO_2-e (Table 4-5).

Table 4-5 Emissions relating to electricity consumption during construction and operation

Variable	Construction	Operation
Total energy consumed (MWh)	126	27,000
Total emissions (tCO_2-e)	102	21,870
Average annual emissions (tCO_2-e)	34	486

4.2.2 Transmission loss

A total of 12,203,855 MWh of electricity is estimated to be lost during the operational phase of the project. These are expected to result in total GHG emissions of 9,885,123 tCO_2-e (Table 4-6).

Table 4-6 Emissions relating to electricity transmission loss during construction and operation

Variable	Construction	Operation
Total energy consumed (MWh)	-	12,203,855
Total emissions (tCO_2-e)	-	9,885,123
Average annual emissions (tCO_2-e)	-	247,128

4.3 Greenhouse gas intensity

GHG intensity was estimated utilising the quantity of electricity transmitted through the infrastructure and the total estimated GHG emissions. Total electricity transmitted during operation was 14,016,000 MWh, with total GHG equating to 9,965,694 tCO_2-e.

GHG intensity (the emissions relating to solely delivering the electricity) equates to 0.71 tCO_2-e per GWh transmitted (Table 4-7).

Table 4-7 GHG intensity of the Proposal

Variable	Operation
Total emissions during operation (tCO_2-e)	9,526,482
Energy transmitted during operation (GWh)	15,768,000
GHG intensity (tCO_2-e per GWh transmitted)	0.60

4.4 Emissions summary

The Scope 1 and 2 greenhouse gas emissions sources from the Project included in this inventory are:

- Land use change (Scope 1)
- Diesel combustion in mobile engines (Scope 1)
- Diesel combustion for stationary engines (i.e. generators) (Scope 1)
- Aviation fuel combustion in mobile engines (Scope 1)
- Use of synthetic gases in electrical components (Scope 1); and
- Consumption of purchased electricity, including transmission losses around the network (Scope 2).

An estimate of GHG emissions from the Project are summarised in Table 4-8. The projected average annual emissions are presented as well as the total greenhouse gas emissions over the construction and operational phases of the Project.

The average annual GHG emissions equate to 151,079 tCO_2-e per year (excluding Scope 3 emissions) during construction and 248,146 tCO_2-e per year during operation (excluding Scope 3 emissions).

Table 4-8 Greenhouse gas emissions by source during construction and operation (as tCO_2-e)

Activity	Average annual GHG emissions by source		Total GHG emissions by source	
	Construction	Operation	Construction	Operation
Scope 1				
Land clearing	143,764	-	431,293	
Diesel combustion in mobile engines	3,804	179	11,413	8,071
Diesel combustion in stationary engines	2,529	13	7,587	574
Aviation fuel in mobile engines	948	26	2,843	1,183

Activity	Average annual GHG emissions by source		Total GHG emissions by source	
	Construction	Operation	Construction	Operation
Gas insulated electrical components (SF_6)	-	314	-	14,118
Scope 2				
Electricity consumed	34	486	102	21,870
Transmission losses (AC)	-	210,704	-	9,481,695
Total	151,079	211,722	453,238	9,527,510

5. Discussion

5.1 Overview

GHG emissions during construction are largely comprised of Scope 1 emissions, with average annual for Scope 1 and Scope 2 emissions of 151,078 tCO_2-e per year.

During operation, average annual Scope 1 and Scope 2 GHG emissions are 248,146 tCO_2-e. Total Scope 1 and Scope 2 emissions over the life of the Project is 9,980,748 tCO_2-e. Utilising the operation only emissions, the GHG intensity (the emissions intensity to transmit the electricity) is equal to 0.60 tCO_2-e per GWh

5.2 Emissions comparison

The National Greenhouse Gas Inventory (DISER 2020) was used to present Project emissions in comparison to Australian and Queensland emissions.

Prepared in accordance with the 2019 Refinement to the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC 2019) and under the United Nations Framework Convention on Climate Change (UNFCCC) and Kyoto Protocol, the National Greenhouse Gas inventory (DISER 2020) is the latest available national account for Australia's GHG emissions. The National Inventory defined six sectors for reporting greenhouse gas emissions:

1. Energy (including combustion and fugitive)
2. Industrial processes
3. Solvent and other product use
4. Agriculture
5. Waste
6. Land use, Land use change and forestry.

Australia's net greenhouse gas emissions across all sector totalled 537 million tonnes (Mt) CO_2- e in 2018 (DISER 2020). The direct (Scope 1) GHG emissions for public electricity and heat production totalled 183.2 Mt CO_2-e, with total indirect (Scope 2) emissions from the generation of purchased electricity totalled 21 Mt CO_2-e.

In Queensland, total annual emissions equated to 171 $MtCO_2$-e in 2018 (DISER 2020).

Total annual direct (Scope 1) GHG emissions contributed 52.9 Mt CO_2-e (28.3%) to the total 183 .2 MtCO2-e annual emissions of Australia related to public electricity and heat production. Total annual indirect (Scope 2) emissions related to the generation of purchased electricity contributed 6.2 $MtCO_2$-e (29.5%) to the total annual GHG emissions in Australia.

Within the context of Queensland emissions relating to public electricity and heat production, the Scope 1 and 2 emissions from the Project equate to an increase in emissions of 0.36%. At a national level, the Project contributes an increase of 0.10% for emissions relating to public electricity, heat production and generation of purchased electricity.

5.3 Alternative scenarios

The alternative to the proposed transmission network is continued standalone power generation in the NWQ region. This standalone power generation may continue to be supplied by typical small and medium scale installations or alternatively involve construction of an additional gas-fired power station and fuel supply.

5.4 Project benefits

The Project is intended to provide access to competitively priced electricity to both the large-energy users in the NWMP and regional communities. The following benefits are anticipated to result from the Project:

- Increased reliability and capacity of electricity supply in NWMP and regional communities, resulting in prolonged economic development of the region, with considerable social benefit for local communities.
- Direct employment opportunities during construction and operation. It is anticipated that it will provide jobs for approximately 400 people during construction and 30 people will be required to operate and maintain the infrastructure.
- Indirect employment opportunities will arises as a result of the construction and commissioning of the Project by means of further regional development because of the provision of competitive and reliable electricity.
- Provide regulatory certainty for future users; and create flexibility for users and generators.
- The infrastructure will facilitate the development and utilisation of renewable energy sources in northern Queensland (e.g. wind, solar thermal, biomass, geothermal), which cannot be developed in the absence of transmission capacity and connection to the NEM.

6. Mitigation measures

6.1 Overview

This section describes the mitigation measures to reduce the potential impacts of greenhouse gas emissions from the construction and operation of the Project.

An energy conservation and GHG management plan for the construction and operation of the Project should be prepared to develop strategies to reduce GHG emissions in line with Australia's commitments under the Kyoto Protocol and the State and Commonwealth aspirations. The objectives of the plan should be:

- Reduce greenhouse gas emissions associated with the Project and all relevant emissions sources.
- Incorporate energy efficiency initiatives into Project design, procurement, engineering, construction and operation.
- Integrate greenhouse gas management and energy efficiency initiatives into business decision making at all stages of the Project.
- Provide consistent and accurate reports on greenhouse gas emission levels in compliance with relevant legislation.

6.2 Mitigation

6.2.1 Fuel combustion

The following mitigation measures should be considered for implementation to reduce the production of greenhouse gas emissions due to fuel combustion.

- Design a construction works program to minimise haul distances between construction sites and laydown areas.
- Planning activities to minimise vehicle kilometres travelled during construction and operation.
- Maintain construction equipment and vehicles in good working order to maximise fuel efficiency.
- Use appropriately-sized equipment for construction activities.
- Minimise waste from construction (therefore minimising transport of waste).

Alternative fuel types and motive technologies may also be considered to mitigate greenhouse gas emissions from construction and operation of the Project should they be readily available.

6.2.2 Electricity consumption

The design and construction of accommodation and office buildings will consider energy efficient and passive design features, including air conditioning, lighting, low-flow fitting and solar power.

6.2.3 Gas-insulated electrical components

Detailed design of the Project will endeavour to use SF_6 only where alternatives are not available. To do this, the Proponent will undertake a review of technology used in all aspects of the Project e.g. investigate oil-filled transformers as an alternative insulation solution and restricting the use of SF_6 to switchgear components.

Methods for further mitigating SF_6 gas emissions rely on appropriate selection of gasket types and best practice leakage detection monitoring during operation, maintenance and end of life dismantling procedures. The management of the end of life gas-insulated equipment will follow industry best practice guidelines i.e. recycling SF_6 gas or safe disposal if contamination due to arc switching is high.

6.2.4 Offsets

The following offset strategies are proposed for the Project where in line with State and Commonwealth legislation and policy:

- Produce a GHG Offset Plan that provides an offset for the Scope 1 and Scope 2 greenhouse gas emission generated during the construction and operation of the Project.
- Options to be considered include the use of GreenPower sources from a renewable source or contributions to another credited offset program.
- The Proposed offset strategy will depend on Federal and State climate change policy current at the time the Project is approved.

7. Summary and conclusions

This assessment has considered potential impacts of greenhouse gas emissions associated with the Project. A summary of estimated greenhouse gas emissions from the Project over the design life is presented in Table 7-1.

During construction, the Project average annual Scope 1 and Scope 2 emissions are 151,079 tCO_2-e per year and 211,722 tCO_2-e per year during operation (Table 7-1).

Table 7-1 Summary of greenhouse gas emissions during operation from the Project

Greenhouse Gas Emissions	Operation	Operation
Total GHG emissions (tCO_2-e)	453,238	9,527,510
Annual average (tCO_2-e)	151,079	211,722

Total Scope 1 and Scope 2 GHG emissions calculated over the life of the Project (3 years construction and 45 years operation) is calculated to is 9,980,748 tCO_2-e. The GHG intensity is equal to 0.60 tCO_2-e per GWh.

7.1 References

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Appendices

Appendix A – Calculations and assumptions

Emissions/Energy Source Breakdown

Client	CuString
Project	CuString 2.0

Construction Emissions

Emission source	Activity Type	Fuel / Energy Commodity	Units	Quantity	Data Source	Energy Consumed (GJ)	Scope 1 Emissions (t CO_2 -e)	Scope 2 Emissions (t CO_2 -e)	Total Emissions (t CO_2 -e)
Construction - Stationary Engines	Liquid Fuels - Stationary	40. Diesel oil	kL	2,800	='Scope 1A'!A26	108,080	7,587	0	7,587
Construction - Mobile Engines	Liquid Fuels - Transport	54. Diesel oil	kL	4,200	='Scope 1A'!A47	162,120	11,413	0	11,413
Construction - Mobile Engines	Liquid Fuels - Transport	55. Gasoline for use as fuel in an aircraft	kL	1,259	='Scope 1A'!A44	41,681	2,843	0	2,843
Construction - Electricity Consumed	Consumption of Purchased Electricity	79. Queensland	kWh	126,000	='Scope 2'!B25	454	0	102	102
Land Clearing	Other		ha	4,081	='Scope 1B'!H26	0	431,293	0	431,293
					Totals during construction	312,335	453,136	102	453,238
					Annual total during construction	104,112	151,045	34	151,079

Operation Emissions

Emission source	Activity Type	Fuel / Energy Commodity	Units	Quantity	Data Source	Energy Consumed (GJ)	Scope 1 Emissions (t CO_2 -e)	Scope 2 Emissions (t CO_2 -e)	Total Emissions (t CO_2 -e)
Operation - Stationary Engines	Liquid Fuels - Stationary	40. Diesel oil	kL	212	='Scope 1A'!A67	8,171	574	0	574
Operation - Mobile Engines	Liquid Fuels - Transport	54. Diesel oil	kL	2,970	='Scope 1A'!A95	114,642	8,071	0	8,071
Operation - Mobile Engines	Liquid Fuels - Transport	55. Gasoline for use as fuel in an aircraft	kL	524	='Scope 1A'!A88	17,343	1,183	0	1,183
Operation - Gas insulated electrical	Other	84. Sulfur hexafluoride - leakage rate	t	1,586,250	='Scope 1A'!A115	0	14,118	0	14,118
Operation - Transmission losses (AC)	Consumption of Purchased Electricity	79. Queensland	kWh	11,705,796,783	='Scope 2'!B127	42,140,868	0	9,481,695	9,481,695
Operation - Electricity Consumed	Consumption of Purchased Electricity	79. Queensland	kWh	27,000,000	='Scope 2'!B37	97,200	0	21,870	21,870
					Total during operation	42,378,225	23,945	9,503,565	9,527,510
					Annual total during operation	1,059,456	599	237,589	238,188

NGER Factors 2019-2020

This sheet contains information for the automatic selection of factors from the NGER Measurement Determination version F2020C00600

Fuel Combustion

Type	Fuel combusted / used	Emission Factor kg CO_2-e/GJ				Energy Content Factors GJ per Unit		NGER Measurement Determination Reference (Version F2020C00600)
		CO_2	CH_4	N_2O	Total			
Liquid Fuels - Stationary	40. Diesel oil	69.9	0.1	0.2	70.2	38.6	kL	Schedule 1, Part 3
Liquid Fuels - Transport	54. Diesel oil	69.9	0.1	0.4	70.4	38.6	kL	Schedule 1, Part 4
Liquid Fuels - Transport	55. Gasoline for use as fuel in an aircraft	67.0	0.6	0.6	68.2	33.1	kL	Schedule 1, Part 4
Consumption of Purchased Electricity	79. Queensland	-	-	-	0.81	0.0036	kWh	Schedule 1, Part 6
Other	84. Sulfur hexafluoride - leakage rate	-	-	-	0.0089		t	Schedule 1, Part 4

Scope 1 Emissions : Construction and Operation Data and Assumptions

Generic information

3	Years	Construction period
45	Years	Operation period

Generic exclusions and assumptions

- All electricity used during operation is generated by others
- The full length of the proposed transmission line will be constructed in the three year construction period

Construction - Stationary Engines

Existing information: Detailed information regarding construction methodology is currently not available. Quantity for construction stationary engine fuel usage taken from URS (2010).

Methodology: Estimates of fuel usage for construction in stationary engines was provided by Beckett, J. RLMS, pers. comms. 23/08/2010 cited in URS (2010).

Assumptions

- Construction will involve the establishment of the construction camps, lay downs, offices at one or more locations along the alignment

- Power consumed during construction would be generated onsite using stationary diesel fuelled generators.
- All fuel used is a non-renewable diesel product
- Electricity used will be powered by diesel generators. No import of electricity from external sources.
- Any other GHG emitting products used (such as grease) will be of insignificant quantities

2.8	ML	Consumption during construction (three year period)
933.3	kL	Average annual consumption
2,800	**kL**	**Total for Stationary Engines during Construction Period**

Construction - Mobile Engines

Existing information: A

Methodology: Estimates of diesel fuel usage for construction in mobile engines was provided by Beckett, J. RLMS, pers. comms. 23/08/2010 cited in URS (2010).
Estimates for aviation fuel use provided by Barnett, M of CuString 15/04/2020.

Assumptions

- Construction will involve use of plant typical to construction
- Construction period diesel usage in mobile engines is estimated to be 4.2 kL
- All fuel used is either non-renewable diesel product or aviation (gasoline) fuel
- Three helicopters are assumed to be used daily for 20 months (1.67 years), six (6) hours per day including Saturday and Sunday. Helicopters are assumed to use 115L/hr of aviation fuel.

20	Months	
1.7	Years	
608	Days	
6	Hours/Day	
3	Number	Helicopters
10,950	Total hours helicopter operation	
115	L/hr	Fuel efficiency
1,259	**kL**	**Aviation fuel consumed during construction (three year period)**
420	kL	Average annual aviation fuel consumption
4,200	**kL**	**Diesel consumed during construction (three year period)**
1,400	kL	Average annual diesel consumption

Scope 1 Emissions : Construction and Operation Data and Assumptions

Operation - Stationary Engines

Existing information: Quantity for operation stationary engine fuel usage sourced from CuString.

Methodology: Estimates of fuel usage for operation in stationary engines was provided by Barnett, M of CuString 15/04/2020.

Assumptions

- Operation will include the installation of stationary diesel engines at substations, and one or more CEV huts.
- All fuel used is a non-renewable diesel product
- Electricity used will be powered by diesel generators. No import of electricity from external sources.

7	Number	Sites
60	Hrs/yr	Operating hours
35	kW	Power generation capacity
14.7	MWh/yr	Total power generated per year
320	L/MWh	Fuel efficiency
45	Years	Operation
211,680	L	Diesel consumed during operation (45 year period)
212	**kL**	**Diesel consumed during operation (45 year period)**
4.7	kL	Average annual diesel consumption during operation

Operation - Mobile Engines

Existing information: Quantity for operation mobile engine diesel oil fuel usage sourced from CuString.
Hours of operation and fuel effiency for the helicopter sourced from CuString

Methodology: Estimates of diesel and aviation fuel usage for operation in mobile engines was provided by Barnett, M of CuString 15/04/2020, and as per URS (2010).

Assumptions

- Operation will include the use of 4x4 utilities and helicopters primarily, with additional assumed maintenance
- All fuel used is either non-renewable diesel product or aviation (gasoline) fuel
- One helicopter is assumed to be used to inspect all the towers (2700) along the alignment on an annual basis. One helicopter is able to inspect 160 towers per day, and operate for six (6) hours per day. Helicopters are assumed to use 115L/hr of aviation fuel.

- 4x4 utilities are assumed to drive 200 km per year
- Diesel consumed during operation was provided by CuString - 66 kL per year
- Energy content factor for diesel fuel is 38.6 kL per GJ

2700	Number	Towers
160	Number/d	Towers per day able to be inspected by a single helicopter
17	Days/yr	Days required to inspect the towers each year
6	Hours/Day	
1	Number	Helicopters
101	hrs	Total hours helicopter operation
115	L/hr	Fuel efficiency
45	Years	Operation period
524	**kL**	**Aviation fuel consumed during operation (45 year period)**
12	kL	Average annual aviation fuel consumption
2,970	**kL**	**Diesel consumed during operation**
66	kL/yr	Annual average diesel consumed during operation
440,000	km/yr	Average distance travelled per year
19,800,000	km	Distance travelled during operation
0.15	L/km	Fuel efficiency

Scope 1 Emissions : Construction and Operation Data and Assumptions

Operation - Gas insulated electrical components

Existing information: Quantity for sulfur hexafluoride sourced from URS (2010).
1,500 kg of SF6 initially installed onsite, with 600kg SF6 replenished over the life of the project (40 year).

Methodology: Estimates of sulfur hexafluoride use during operation provided by Beckett, J. RLMS, pers. comms. 23/08/2010 cited in URS (2010).
The quantity of tCO2-e emissions from SF6 leakage is estimated on the initial volume, as the NGER leakage rate takes into acccount leakage (and the need for replenishment)

Assumptions

- There is no SF_6 utilised onsite during construction
- SF_6 annual leakage rate of 0.0089 t CO_2-e per t CO_2-e stored
- Global warming potential of SF_6 is 23,500
- Mineral oil is proposed to be used in insignificant quantities
- 300 kg of SF_6 replenished during operation
- The initial quantity of SF6 (1,500 kg) will not be released to atmosphere. This quantity will be recovered, for recycling or destroyed, at end of life of the compartment.

1,500	kg	Total SF6 consumed during operation
1.5	tonnes	Total SF6 consumed during operation
23,500	t CO_2-e/t	Global warming potential of SF6
35,250	t CO_2-e	Total SF6 consumed during operation as tonnes carbon dioxide equivalent
1,586,250	**tCO_2-e**	**Total leaked SF6 during operation (45 year period)**

Scope 1 Emissions : Construction and Operation Data and Assumptions

Construction - Land clearing

Existing information: A proposed total clearing area of 4,081 ha is required along the alignment, as sourced from the EIS being prepared by GHD.

Methodology: Full Carbon Accounting Model (FullCAM) was used to estimate emissions from the following forestry plot vegetation types: — Eucalypt Woodlands, — Eucalypt Open Woodlands, — Melaleuca Forests and Woodlands, — Acacia Open Woodlands — Other Forests and Woodlands
To calculate tonnes of carbon lost per hectare, total on site carbon mass was subtracted from initial onsite carbon mass (prior to clearing).

Assumptions
- Clearing will only occur during the construction phase
- Forest cover is reduced to 0% during clearing
- Vegetation communities outlined below

		Input Data						FullCAM Outputs					Emissions	
Landscape type / Vegetation community	**BVG / FullCAM modelled tree species**	**Total Vegetation Area**	**% canopy cover (greater than 5m)**	**Estimated area cleared within the landscape type**	**Estimated area cleared within the landscape type**	**Estimated area cleared within the landscape type**	**Forest Cover**	**C mass of trees**	**C mass of grass**	**C mass of debris**	**Total Carbon mass**	**Total Carbon mass**	**Land Clearance Emissions**	**Land Clearance Emissions**
		(sqkm)	(%)	(%)	(sqkm)	(ha)	(%)	tC/ha	tC/ha	tC/ha	tC/ha	tC	tCO2-e/ha	tCO2-e
Open forest to open woodland (eucalypt / melaleuca / belah dominated) on flat to undulating plains	Eucalypt Woodlands	9.859	32.5	52.9	5.2154	521.5421	0.8	39.71	0.07	1.76	41.54	21664.85961	152.31	79,438
	Eucalypt Open Woodlands	17.3964	32.5	52.9	9.2027	920.2720	0.8	39.64	0.07	1.83	41.54	38228.09918	152.31	140,170
	Melaleuca Forests and Woodlands	0.3865	32.5	52.9	0.2045	20.4482	0.8	40.86	0.07	1.84	42.77	874.5716105	156.82	3,207
Riparian zone and fringing vegetation along ephemeral channels, watercourses and channelised floodplains	Eucalypt Open Woodlands	1.5386	32.1	52.4	0.8062	80.6204	0.8	39.64	0.07	1.83	41.54	3348.972864	152.31	12,280
	Melaleuca Forests and Woodlands	0.0953	32.1	52.4	0.0500	4.9952	0.8	40.86	0.07	1.84	42.77	213.6465107	156.82	783
	Blank, assumed to be Eucalypt Open	15.5857	32.1	52.4	8.1669	816.6907	0.8	39.64	0.07	1.83	41.54	33925.33175	152.31	124,393
Low open woodland to wooded spinifex grassland (eucalypt / acacia dominated) on slopes,	Eucalypt Open Woodlands	16.3102	9.5	32.3	5.2682	526.8202	0.5	24.77	0.18	1.29	26.24	13823.76206	96.21	50,687
	Acacia Open Woodlands	0.1251	9.5	32.3	0.0404	4.0403	0.5	34.51	0.18	2.03	36.72	148.3594013	134.64	544
Mixed low woodland with spinifex (gidgee / mulga / eucalypt dominated) on plains	Acacia Open Woodlands	1.9470	11.3	33.6	0.6542	65.4203	0.2	13.81	0.28	1.09	15.18	993.0808449	55.66	3,641
	Other Forests and Woodlands	0.8706	11.3	33.6	0.2925	29.2530	0.2	10.22	0.28	0.77	11.27	329.681808	41.32	1,209
Tussock/hummock grassland	Tussock Grasslands	38.1727	0.4	22.7	8.6652	866.5205	0.01	0.5	0.35	0.43	1.28	1109.14627	4.69	4,067
	Hummock Grasslands	0.5736	0.4	22.7	0.1302	13.0215	0.01	0.5	0.36	0.43	1.29	16.79776525	4.73	62
Cleared grazing land with scattered trees		4.9776	20.2	42.5	2.1155	211.5483	0.5	13.12	0	0.82	13.94	2948.983591	51.11	10,813
Total		**107.8**			**40.8**	**4,081.2**						**117,625**		**431,293**

Scope 2 : Construction and Operation Data and Assumptions

Generic information

3	Years	Construction period
45	Years	Operation period

Generic exclusions and assumptions

- All electricity used during operation is generated by others
- The transmission line will operate at full capacity/voltage throughout the during of the operation phase
- All electricity used during operation is generated by others
- The full length of the proposed transmission line will be constructed in the three year construction period

Construction - Electricity Consumed

Existing information: Quantity for purchased electricity consumed taken from URS (2010).
Economic Assessment Report – North West Queensland Energy Delivery Options (ROAM 2009)
Impact on Copperstring of Corona on 220 kV and 330 kV Networks (Hill Michael 2010).

Methodology: Estimates of electricity consumed in the head office in Townsville, Queensland was provided by Beckett, J. RLMS, pers. comms. 23/08/2010 cited in URS (2010).

Assumptions

- Electricity consumption per annual period at the head office is assumed to be the same for both the construction and operation phases

42,000	kWh/yr	Annual electricity consumed in the Townsville head office
126,000	**kWh**	**Electricity consumed during construction (three year period)**

Operation - Electricity Consumed

Existing information: Quantity for purchased electricity consumed taken from URS (2010).
Economic Assessment Report – North West Queensland Energy Delivery Options (ROAM 2009)
Impact on Copperstring of Corona on 220 kV and 330 kV Networks (Hill Michael 2010).

Methodology: Estimates of electricity consumed in the head office in Townsville, Queensland was provided by Beckett, J. RLMS, pers. comms. 23/08/2010 cited in URS (2010). Estimates of electricity consumed in the site office, substations and CEVs provided by Barnett, M. of CuString 15/04/2020.

Assumptions

- Electricity consumption per annual period at the head office is assumed to be the same for both the construction and operation phases

600,000	kWh/yr	Annual electricity consumed in the site office, substations and CEVs
27,000,000	**kWh**	**Electricity consumed during operation (40 year period)**

Scope 2 : Construction and Operation Data and Assumptions

Operation - Transmission losses (AC)

Existing information: Quantity for purchased electricity consumed taken from URS (2010).
Economic Assessment Report – North West Queensland Energy Delivery Options (ROAM 2009)
Impact on Copperstring of Corona on 220 kV and 330 kV Networks (Hill Michael 2010).
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Methodology: Resistive (joule) loss AC: $(P_{loss}) = 3*(P_{phase}/V_{phase})^2 * R_{eq}$.
Corona loss AC: Hill Michael report for loss values in kV/km for each conductor configuration in fair and stormy weather. These numbers are multiplied by line distances and weighted in a fair-stormy weather ratio of 90%-10% and summed to obtain a total loss.

Assumptions

- All numbers have been scaled to reflect a 1047km length transmission line
- Conductor operation at 75 degrees celcius for both AC
- Transmission losses are active power losses only i.e. line will operate at a power factor of 1 (unity)
- Assume the line will be transposed at 1/3, 2/3 locations etc. such that the system will be balanced
- Assume the core portion of the AC line is 330kV double circuit twin sulphur as per information available
- Assume the secondary portions of the AC line are 220kV double circuit twin sulphur & single circuit single sulphur respectively as per information available

-We have not considered losses for the substation. This estimate is purely for the transmission line
- Power flow is assumed 450MW based on existing inputs to sheet
- 45 year line operation at 8760 hours per year.

AC resistive (joule) losses

330kV double circuit twin sulphur segment

450	MW	Total three phase power
330	kV RMS	Line voltage
1		Power factor
150	MW	Power per phase
190.53	kV	Phase voltage (line to neutral)
787.3	A	Phase current (line current)
0.056	Ω/km	AC resistance
2	no.	Number of circuits (e.g. 2 for double circuit)
2	no.	Number of bundles (e.g. 2 for twin conductor bundle)
0.026	MW/km	Power loss per kilometre
732	km	Distance of line segment
19.06	MW	Total loss for line segment

220kV single circuit twin sulphur segment

250	MW	Total three phase power
220	kV RMS	Line voltage
1		Power factor
83.33	MW	Power per phase
127.02	kV	Phase voltage (line to neutral)
656.1	A	Phase current (line current)
0.056	Ω/km	AC resistance
2	no.	Number of circuits (e.g. 2 for double circuit)
2	no.	Number of bundles (e.g. 2 for twin conductor bundle)
0.018	MW/km	Power loss per kilometre
189	km	Distance of line segment
3.42	MW	Total loss for line segment

Scope 2 : Construction and Operation Data and Assumptions

220kV single circuit single sulphur segment

150	MW	Total three phase power
220	kV RMS	Line voltage
1		Power factor
50.00	MW	Power per phase
127.02	kV	Phase voltage (line to neutral)
393.6	A	Phase current (line current)
0.056	Ω/km	AC resistance
1	no.	Number of circuits (e.g. 2 for double circuit)
1	no.	Number of bundles (e.g. 2 for twin conductor bundle)
0.026	MW/km	Power loss per kilometre
126	km	Distance of line segment
3.28	MW	Total loss for line segment

Sum of AC resistive losses

25.75	**MW**	**Total annual AC Transmission Resistive Losses**
10,151,912	**MWh**	**Total AC Transmission Resistive Losses during operation phase**

AC corona losses

330kV double circuit twin sulphur segment

2.54	kW/km	Corona loss for 330kV twin sulphur (double circuit): fair weather
22.57	kW/km	Corona loss for 330kV twin sulphur (double circuit): stormy weather
732	km	Distance of line segment
3.33	MW	Corona loss for line segment for fair to stormy weather ratio 90%-10%

220kV single circuit twin sulphur segment

1.47	kW/km	Corona loss for 220kV single sulphur (double circuit): fair weather
13.65	kW/km	Corona loss for 220kV single sulphur (double circuit): stormy weather
189	km	Distance of line segment
0.51	MW	Corona loss for line segment for fair to stormy weather ratio 90%-10%

220kV single circuit single sulphur segment

0.55	kW/km	Corona loss for 220kV single sulphur (single circuit): fair weather
3.65	kW/km	Corona loss for 220kV single sulphur (single circuit): stormy weather
126	km	Distance of line segment
0.11	MW	Corona loss for line segment for fair to stormy weather ratio 90%-10%

3.94	**MW**	**Total AC Transmission Corona Losses**
1,553,884	**MWh**	**Total AC Transmission Corona Losses**
29.70	**MW**	**Total annual AC Transmission Losses**
11,705,796,783	**kWh**	**Total AC Transmission Losses (during operation)**

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42-SO1-1921852678-925/https://projects.ghd.com/oc/NQOC2/copperstring2/Delivery/Documents/4221176_Rep_EIS GHG Assessment.docx

Document Status

Revision	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
A	S. Nind	T. Young		P. Bradley		31/07/2020
B	S. Nind	T. Young		P. Bradley		06/08/2020
0	S. Nind	T. Young		P. Bradley		13/11/2020

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