Technical report N

Greenhouse gas and energy efficiency assessment report

Cleanaway & Macquarie Capital

Western Sydney Energy and Resource Recovery Centre

Greenhouse Gas and Energy Efficiency Assessment Report

WSERRC-ARU-SYD-SAEM-RPT-0001

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Contents

Environmental assessment requirements

The below table lists the Secretary's environmental assessment requirements (SEARs) relevant to greenhouse gas and where they are addressed in this report.

Assessment Requirements	Reference in this technical paper
A quantitative analysis of Scope 1, 2 and 3 greenhouse gas emissions from the development and an assessment of potential impacts on the environment in accordance with relevant guidelines	Section 4
A description of construction and operational control measures to be implemented to ensure the development is energy efficient and minimises greenhouse gas generation	Section 5
A greenhouse gas assessment, including an assessment of the potential scope 1, 2 and 3 greenhouse gas emissions from the project and an assessment of the potential impacts of these emissions on the environment.	Section 4
A detailed description of the measures that would be implemented on site to ensure that the project is energy efficient.	Section 5

Abbreviations and glossary

Abbreviations	
BoM	Bureau of Meteorology
CFC	Chlorofluorocarbons
CH_4	Methane
CO_2	Carbon Dioxide
CO_2-e	Carbon dioxide equivalent
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DoEE	Department of the Environment and Energy
ECL	East coast low
EfW	Energy from waste
ERF	Emissions reduction fund
GHG	Greenhouse gases (also commonly referred to as Carbon)
HFC	Hydrofluorocarbons
IPCC	Intergovernmental Panel on Climate Change
Kg CO_2-e	Kilograms of carbon dioxide equivalent
kwH	Kilowatt hours
MSW	Municipal solid waste
MW	Megawatts
MWh	Megawatt Hours
N_2O	Nitrous Oxide
NARCliM	NSW and ACT Regional Climate Modelling
NGA	National greenhouse account
NGERS	National Greenhouse Energy Reduction Scheme
Proposal (the)	The purpose of the proposal is to build an energy-from-waste (EfW) facility that can generate up to 55 megawatts (MW) of power by thermally treating up to 500,000 tonnes per year of residual municipal solid waste (MSW) and residual commercial and industrial (C&I) waste streams that would otherwise be sent to landfill.
tCO_2-e	Tonnes of carbon dioxide equivalent
SEARs	Secretary Environmental Assessment Requirements
UNFCC	United Nations Framework Convention on Climate Change
VSD	Variable Speed Drive

1 Introduction

This Chapter introduces the proposal and applicant while describing the purpose and structure of this report.

1.1 Proposal description

The purpose of the proposal is to build an energy-from-waste (EfW) facility that can generate up to 55 megawatts (MW) of power by thermally treating up to 500,000 tonnes per year of residual municipal solid waste (MSW) and residual commercial and industrial (C&I) waste streams that would otherwise be sent to landfill. The proposal will also recover metals from the ash and these metals will be recycled. The proposal would include a visitor centre to help educate and inform the community on the circular economy, recycling, resource recovery and EfW.

The proposal would be supported by the construction of site infrastructure including:

- Internal roads.
- Weighbridges.
- Parking and hardstand areas.
- Stormwater infrastructure.
- Fencing.
- Landscaping.

The site is located at 339 Wallgrove Road, Eastern Creek, in the Blacktown local government area (LGA) and on the western part of the Western Sydney Parklands (WSP). The area immediately surrounding the site is characterised by industrial and transport infrastructure.

The application is categorised as State significant development (SSD) as it is electricity generating works with a capital investment value (CIV) greater than $30 million for the purposes of Schedule 1 of the State and Regional Development (SRD) State Environmental Planning Policy (SEPP) (SRD SEPP) 2011. It will be assessed and determined by the Minister for Planning and Public Spaces or the Independent Planning Commission (IPC). To comply with the NSW Energy from Waste Policy Statement, unless there is sufficient source separation in the waste streams, resources in the waste streams will first be recovered at a resource recovery facility, with the residual waste providing the waste feedstock for the EfW facility.

1.2 Document purpose

The purpose of this technical report is to provide an outline of the Scope 1, 2 and 3 greenhouse gas emissions relating to the construction, operation and maintenance of the proposed EfW facility based on known available information at this early stage of design development.

This report also considers energy reduction measures during both constructions and operations to be implemented to ensure the development is energy efficient and minimises greenhouse gas generation.

A high level review of climate change impacts on the local environment and resulting potential impacts on the proposal and subsequent evaluation of the proposal against climate change factors in light of current policy and targets has also been considered.

2 Existing environment

In 2014, the Intergovernmental Panel on Climate Change (IPCC) released its fifth assessment report (AR5) which confirms that human influence on the climate system is clear and growing, with recent emissions of greenhouse gases the highest in history.

Greenhouse gases are defined as any of the gases whose absorption of solar radiation is responsible for the greenhouse effect[1]. The atmospheric concentrations of some greenhouse gases are being affected directly by human activities, namely carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and ozone O_3 and synthetic gases such as chlorofluorocarbons (CFCs) and hydrofluorocarbons (HFCs).

Identifying the likely greenhouse gas emissions associated with a project has the benefit of determining the scale of the emissions and providing a baseline from which to develop and deliver greenhouse gas reduction measures

2.1 Background climate change considerations

There is a wide body of scientific evidence indicating that warming of the climate system is occurring at a steady rate. Studies, reports and evidence demonstrate climate warming trends over the past century, and in particular the last 50 years, have led to an increase in extremes in weather conditions and hazards impacting infrastructure.

Climate change, in particular extreme weather conditions and severe climate extremes, can lead to costly impacts in terms of maintenance and repairs to critical operational components of an asset. The ability of an asset to adapt to current and changing climate will assist in reducing vulnerability and ensure resilience, functionality and longevity of the asset.

The State of the Climate report produced by CSIRO in conjunction with the Bureau of Meteorology (2018) indicates recent key climate trends in Australia observing:

- Temperature – Australia's climate has warmed in both mean surface air temperature and surrounding sea surface temperature by around 1 °C since 1910
- Oceans around Australia have warmed by around 1 °C since 1910, contributing to longer and more frequent marine heatwaves
- Sea levels are rising around Australia, increasing the risk of inundation

[1] CSIRO, Climate Change in Australia https://www.climatechangeinaustralia.gov.au/en/climate-campus/climate-system/greenhouse-gases/ accessed 6 February 2020

- The oceans around Australia are acidifying (the pH is decreasing)
- April to October rainfall has decreased in the southwest of Australia. Across the same region, May-July rainfall has seen the largest decrease, by around 20 percent since 1970
- There has been a decline of around 11 percent in April-October rainfall in the southeast of Australia since the late 1990s
- Rainfall has increased across parts of northern Australia since 1970s
- Streamflow has decreased across southern Australia and increased in northern Australia where rainfall has increased
- There has been a long-term increase in extreme fire weather, and in the lengths of the fire season, across large parts of Australia.

Long term planning and management is required to reduce the potential risk of climate change and potential impacts that climate change may have on assets such as the EfW facility to ensure long term functionality and resilience to changing climate conditions.

2.2 Regional Weather influences and effects

2.2.1 East Coast Lows

An East Coast Low (ECL) is the term used for a low-pressure weather system which forms off the east coast of Australia and can result in dangerous weather to coastal and adjoining areas. An ECL can form under a variety of circumstances at any time of the year, although historically have been more frequent during Autumn and Winter months.

An ECL can result in the following conditions and hazards:

- Gale or storm force winds along the coast and adjoining areas
- Heavy widespread rainfall leading to flash and/or major river flooding
- Very rough seas and prolonged heavy swells over coastal and ocean waters which can cause damage to the coastline.

BoM has been tracking ECLs since 1973 and found that between 1973 and 2004 there were about ten significant maritime lows each year.

Projection modelling indicates there will likely be a decrease in the number of winter storms and a small increase in the number of summer storms forming part of the ECL[2].

[2] Adapt NSW 2016, *East coast lows research program synthesis for NRM stakeholders*

2.2.2 Heat island effect

Localised warming due to large areas of paved and dark coloured surfaces, such as roads, buildings and car parks, and low tree coverage is known as the Urban Heat Island Effect. Its impact occurs as the sun's heat is absorbed by the environment and not reflected, resulting in an increase of ambient temperatures.

In Sydney, the coastal sea breeze reaches to around the Strathfield area. Locations further west of this, such as the Eastern Creek area, are particularly at risk of the heat island effect as cooling breezes are limited. The sparse nature of the surrounding environment and reduced vegetation cover in the surrounding region can potentially result in the heat island effect being amplified. This can have an impact of raising background ambient temperatures by up to 5-10 Degrees Celsius. Increasing the risk is rapid development increasing paved surfaces, heat from buildings and human activities, and further loss of tree cover.

2.3 Past climate hazards and weather events

The site is located within the broader Sydney basin and is subject to a broad range of climatic hazard events such as severe storms and heatwaves.

2.3.1 Severe storms

Over the 12 months, a number of severe storm events causing significant damage and impact to the greater western Sydney region have occurred. These have comprised the following events:

- February 2019 – severe storms event across the greater Sydney region, bringing heavy rain, damaging winds and large hailstones, cutting power to over 5,000 homes in the western Sydney area
- February 2020 – series of megastorms which brought flash flooding, heavy rain, hail and damaging winds to the greater Sydney and Blue Mountains region, causing severe damage rain.

2.3.2 Extreme heat and heatwaves

Heatwaves across the greater Sydney region are becoming more regular, with five significant heatwaves recorded since January 2013. The longest heat spell recorded in Sydney occurred in March 2016, with over 36 days in a row of temperatures above 26 degrees Celsius. Night temperatures have also been very warm, with a record of 21 nights in a row above 20 degrees Celsius. Without the coastal sea breeze, the prolonged heat had an amplified impact in Western Sydney.

Statistics from the 2018-19 summer indicates the hottest day recorded of 42.2 0C recorded at Penrith Lakes in January 2019. A record run of consecutive hot days of 35^{0}C or higher was experienced at Penrith Lakes, recording 9 days in December/January 2019. The Greater Sydney Commissions recent dashboard shows the number of days with temperatures over 35^{o}C during 2018-19.

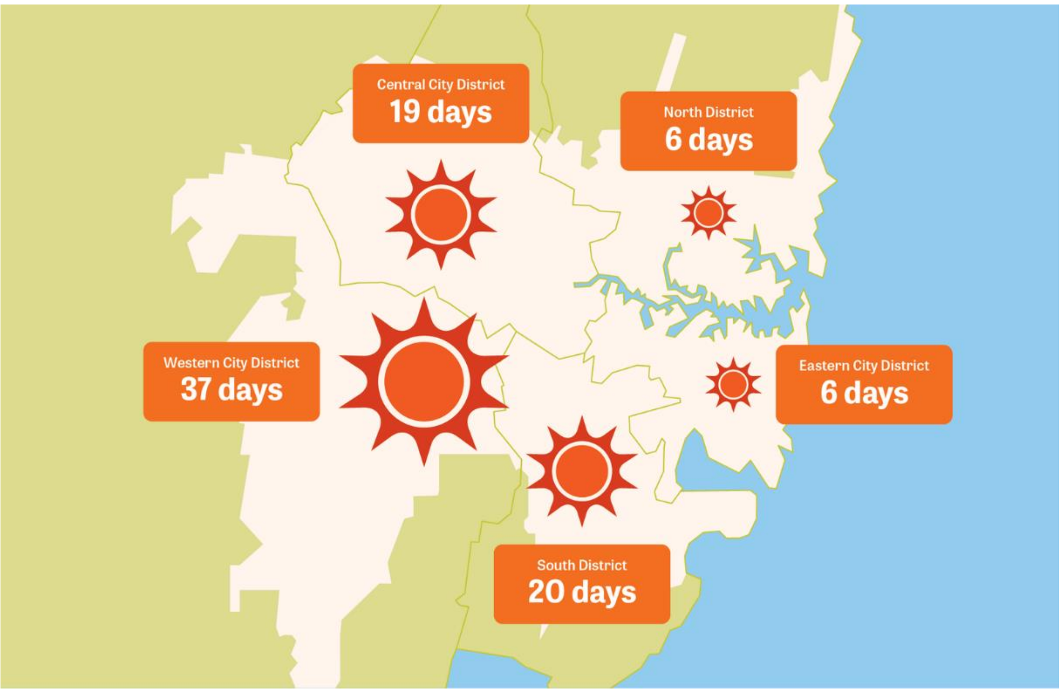

Figure 1: Number of days over 35 degrees between July 2018 and June 2019 Source: Bureau of Meteorology, 2019 https://www.greater.sydney/dashboard/resilient-city

A study undertaken by Greening Australia[3] using data from BoM shows that over the last 40 years Western Sydney weather stations have observed a rise in annual temperatures over and above what is expected from climate change and the number of extreme temperature events has risen sharply.

2.3.3 Climate projections

The NSW and ACT Regional Climate Modelling (NARCliM) project is a multi-agency research partnership between the NSW and ACT governments and the Climate Change Research Centre at the University of NSW. The project has developed twelve regional climate projections for south-east Australia spanning the range of likely future changes in climate. The snapshot for the Sydney Region is shown in summarised in Table 1 and shown in Figure 2.

[3] *The Urban Heat Island Effect and Western* Sydney, Greening Australia https://www.parliament.nsw.gov.au/committees/DBAssets/InquirySubmission/Summary/39702/08%20-%20Greening%20Australia.pdf

Table 1: Projected changes in Sydney climate

Projected **temperature** changes	
Maximum temperatures are projected to increase in the near future by 0.3–1.0°C	Maximum temperatures are projected to increase in the far future by 1.6–2.5°C
Minimum temperatures are projected to increase in the near future by 0.4–0.8°C	Minimum temperatures are projected to increase in the far future by 1.4–2.5°C
The number of hot days will increase	The number of cold nights will decrease
Projected **rainfall** changes	
Rainfall is projected to decrease in spring and winter	Rainfall is projected to increase in summer and autumn
Projected **Forest Fire Danger Index (FFDI)** changes	
Average fire weather is projected to increase in spring by 2070	Severe fire weather days are projected to increase in summer and spring by 2070

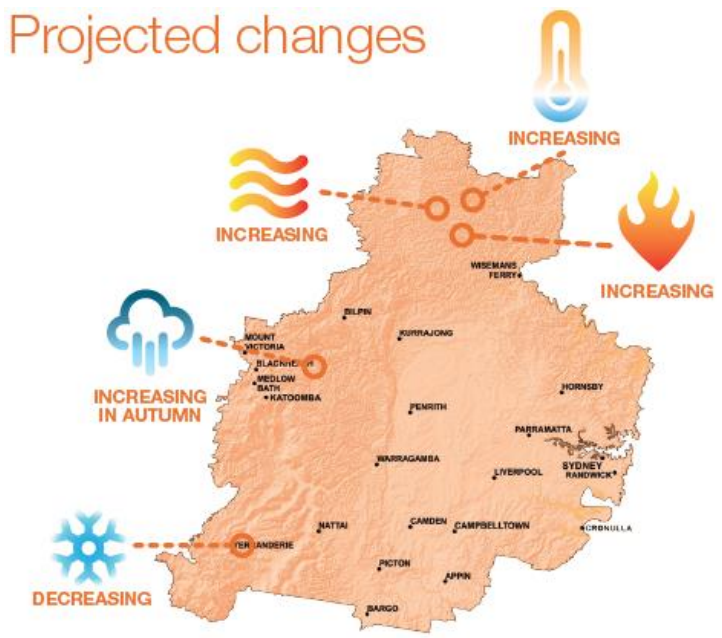

Figure 2: Region Snapshot of Sydney (NSW OEH, 2014)

3 Greenhouse Gas Context

This Chapter outlines the context and inputs used to develop the greenhouse gas assessment, including definition of the boundaries and assessment exclusions.

3.1 GHG intensity baseline assumptions

This report has been prepared in general accordance with:

- *National Greenhouse Accounts (NGA) Factors* DoEE, (August 2019)
- *Greenhouse Gas Protocol*, World Business Council for Sustainable Development and World Resources Institute
- *AGO Factors and Methods Workbook,* Australian Greenhouse Office (August 2004)
- *National Greenhouse and Energy Reporting Scheme Measurement, Technical Guidelines for the estimation of emissions by facilities in Australia* Department of the Environment and Energy (2017)

This Chapter also presents relevant regulation, legislation and policy governing management of greenhouse gas emissions as it relates to the proposal.

3.2 Legislative context

3.2.1 International Context

Paris Agreement

In December 2015 at the 21st Conference of the Parties (COP21) in Paris, an historic global climate agreement was agreed under the United Nations Framework Convention on Climate Change (UNFCCC). The Paris Agreement sets in place a framework for all countries to take climate action from 2020, building on existing international efforts in the period up to 2020. Key outcomes include:

- A global goal to hold average temperature increase to well below 2^{0} C and pursue efforts to keep warming below 1.5^{0} C above pre-industrial levels
- All countries to set mitigation targets from 2020 and review targets every 5 years to build ambition over time, informed by a global stocktake
- Robust transparency and accountability rules to provide confidence in countries actions and track progress towards targets
- Promoting action to adapt and build resilience to climate impacts

- Financial, technological and capacity building support to help developing countries implement the Agreement

In response to the Australian ratification of the Paris Agreement in 2016, the Australian Government has agreed a target of 26-28 percent reduction in greenhouse gas emissions below 2005 levels by 2030. This target is a step up from the current target to reduce emissions by five percent below 2000 levels by 2020.

Intergovernmental Panel on Climate Change

The Intergovernmental Panel on Climate Change (IPCC) is the United Nations body for assessing the science related to climate change and provides regular assessment of the scientific basis of climate change, its impacts and future risks and options for adaptation and mitigation.

The IPCC's assessment reports provide a comprehensive summary of climate change, from the physical science to its impacts and how to tackle it. The IPCC's latest report, the fifth assessment report (AR5) is the latest report (released in 2014). The sixth assessment report is currently in development and due for release in 2021.

These assessment reports inform Australia's understanding of climate change and its associated implications.

3.2.2 Commonwealth legislation

National Greenhouse and Energy Reporting Act 2007

The NGER scheme, established by the NGER Act 2007 is a national framework for reporting and disseminating information about greenhouse gas emissions, energy production and energy consumption specified under NGER legislation[4]. Under the current reporting year, NGERs applied to facilities that emit over 25,000 t or more of greenhouse gases ($C0_2$-e) Scope 1 and Scope 2 emissions, or produce 100 TJ or more of energy, or consume 100 TJ or more of energy.

Emissions Reduction Fund

The Emissions reduction Fund (ERF) was established in 2014, and is a voluntary scheme that aims to provide incentives for a range of organisations and individuals to adopt new practices and technologies to reduce their emissions. Funds have been committed to projects which reduce emissions to continue the momentum towards reaching Australia's 2030 emissions reduction target.

[4] National Greenhouse and Energy Reporting scheme http://www.cleanenergyregulator.gov.au/NGER/About-the-National-Greenhouse-and-Energy-Reporting-scheme accessed 4th February 2020

3.2.3 New South Wales regulations and guidance

NSW Climate Change Policy Framework

The Climate change policy framework developed by the NSW Government endorses the Paris Agreement, and complements actions consistent with the level of effort to achieve Australia's commitments to the Paris Agreement.

The framework sets policy directions to guide implementation of the framework and NSW commitments to achieving long term objectives of net zero emissions and to help NSW become more resilient to a changing climate.

The proposal will provide thermal treatment of materials which would otherwise be sent for landfill. As such, the intent of this policy would inform emissions reduction and drive greater reduction outcomes.

Net Zero Plan

The Net Zero Plan Stage 1: 2020-2030 is the foundation for NSW's action on climate change and goal to reach net zero emissions by 2050. It outlines the NSW Government's plan to grow the economy, create jobs and reduce emissions over the next decade. The key priority areas of the Net Zero plan are focused around emissions reduction technologies and the social, environmental and financial challenges posed by climate change in implementing these technologies. Development and operation of the EfW facility and its associated reduction in greenhouse gas emissions contributes to the governments goal for net zero emissions by 2030.

Western City District Plan & Central City District Plan

The site is located on the border of the Central and Western City District Plans, the Cities that make up the Greater Sydney Region. The District Plans, part of the Greater Sydney Region Plan, set out visions for the Western and Central Cities, which will be implemented through several objectives including one relating to a low-carbon city that contributes to net-zero emissions by 2050 and mitigates climate change (Objective 33).

The WSERRC will contribute to this objective by providing a sustainable energy source leading to reduced greenhouse gas emissions and capturing energy from waste materials which would otherwise be sent for disposal to landfill.

WSROC -Turn Down the Heat Strategy and Action Plan

The Turn Down the Heat Strategy, launched by the Western Sydney Regional Organisation of Councils (WSROC) in 2018, outlines a five-year plan for a cooler, more liveable and resilient future for Western Sydney in response to increasing urban heat island effects.

The aims of the Strategy are to identify best practice to develop effective actions and identify subsequent priority actions for development with a broader stakeholder group and draws on the relationship between changing climate trends and rising temperatures in urban areas.

The Proposal will contribute toward the intent of this Strategy through reduction in operational GHG emissions which would otherwise contribute towards global warming and effects of climate change.

Greater Sydney Commission - Western Parkland City

The site sits within the Western Parkland City, one of the three metropolis cities which make up the Greater Sydney Region Plan. The Western Parkland city will be established on the strength of the new international Western Sydney Airport and Badgerys Creek Aerotropolis, capitalising on the established centres of Liverpool, Greater Penrith and Campbelltown-Macarthur.

The District Plans, part of the Greater Sydney Region Plan, set out visions for the Western Parkland City, which will be informed by several directions of the plan, including those relating to an efficient and resilient city.

This overall Greater Sydney Region Plan sets out to manage growth in the context of economic, social and environmental matters to achieve the 40-year vision for Greater Sydney. The Proposal will support the continued and expected growth and provide the services required to maintain this growth, to contribute to the Greater Sydney Commissions overall objectives.

The Proposal will directly contribute to these plans by providing a facility which influences a sustainable future through provision of a renewable energy source, while also considering measures to adapt to a changing climate future.

3.3 Approach

The level of assessment required for the proposal is defined by the SEARs requirements and are classified according to the GHG Protocol[5] as follows:

Scope	Definition	Proposal Implications
Scope 1	Scope 1 emissions are the release of greenhouse gas into the atmosphere as a direct result of an activity or series of activities (including ancillary activities) that constitute the facility	• Emissions associated with thermal treatment of waste • On-site fuel combustion during construction (plant and machinery) and operations (plant and stationary and mobile on site machinery)
Scope 2	Scope 2 emissions are the release of greenhouse gases into the atmosphere as a direct result of one or more activities that generate electricity, heating, cooling or steam that is consumed by the facility but do not form part of the facilities	• Electricity imported from the grid and consumed on site
Scope 3	Scope 3 emissions are all other indirect emissions that arise as a consequence of an organisations activities, but occur outside its boundaries, from sources that it does not own or control. It is noted the GHG Protocol allows for optional reporting of Scope 3 emissions, with anything considered a significant component of the total emissions inventory can be recorded along with the Scope 1 and 2 emissions. The GHG Protocol also notes that reporting Scope 3 emissions can result in double counting between organisations and/or products.	• Transport of waste to site • Transportation of by-products from site • Employee commute to and from site • Electricity exported to the grid by the EfW facility • Avoidance of methane generation as a result of waste diversion from landfill

[5] Greenhouse Gas Protocol, The GHG Protocol for Project Accounting accessed from http://ghgprotocol.org/sites/default/files/standards/ghg_project_accounting.pdf, 6 February 2020

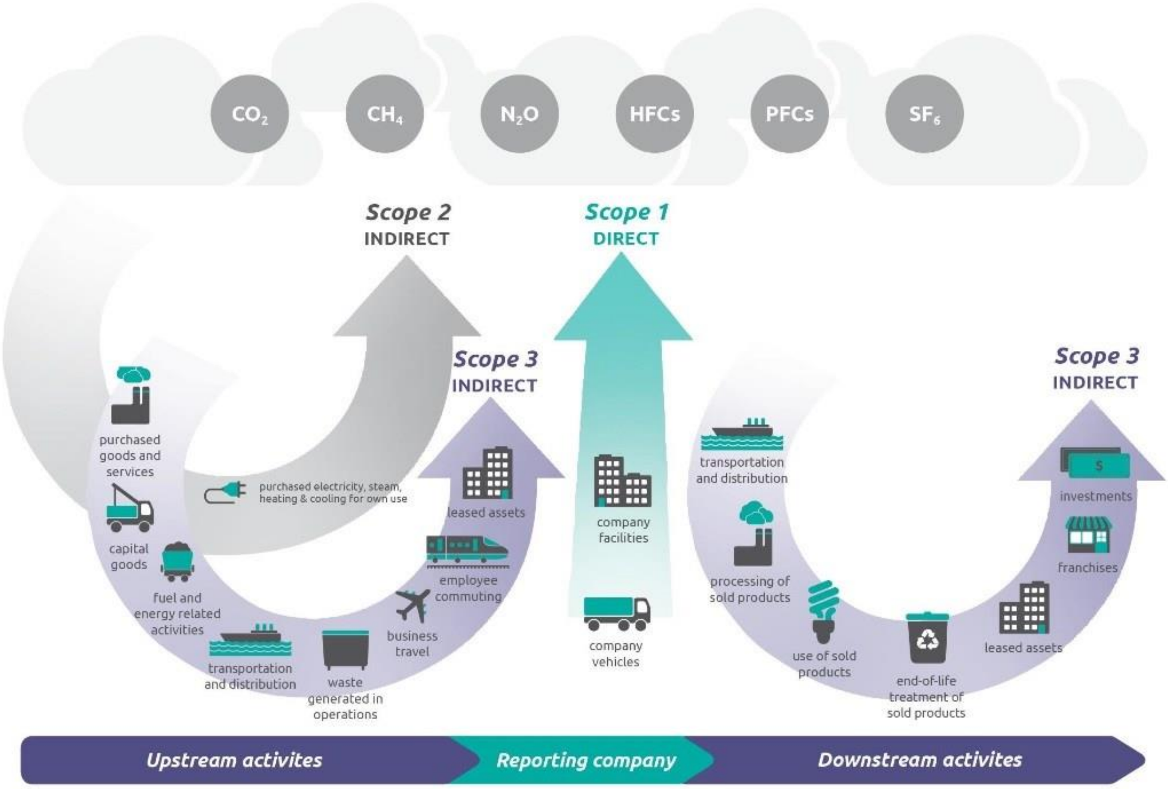

Figure 3: Generalised GHG graphic

The diagram above provides a generalised graphic of greenhouse gas emission scope and sources.

3.3.1 Exclusions

The following have not been considered as part of this greenhouse gas footprint:

- Embodied energy associated materials used for facility construction – due to the current stage of design, material quantities are currently unknown at the time of this assessment. As this is a 'one-off' emission which will not continue during operations and is considered to have a low level of materiality, this has been excluded from the assessment. In addition, it is noted the GHG Protocol allows for optional reporting of Scope 3 emissions, as there is potential for double counting between organisations and/or products when undertaking Scope 3 calculations.

- Employee business travel (not including employee commuting to and from work) – this is considered minor in the overall emissions total and has therefore been excluded from the calculations.

3.4 Assumptions

The following outlines the relevant assumptions that have been used to determine the estimated greenhouse gas emissions for the proposal.

Table 2: Calculation Assumptions

Parameter	Variable	Value
Construction		
Construction activities	Overall construction period	39 months
	Stationary Equipment	*see list in Appendix A7
Vegetation Clearing	Site location according to maximum potential biomass class as derived from the Australian Greenhouse Office	Class 3
	Vegetation clearing as provided by ecologist based on construction footprint	- 0.45 hectares of eucalypt woodland - 1.45 hectares of exotic grasslands
	Conversion factor – assumed all carbon is emitted as CO_2	3.67
Operations		
Thermal treatment[6]	Quantity of waste	500,000 t/year
	Proportion of waste type as used for baseline[7]	MSW – 30% C&I – 70%

[6] Calculated in accordance with Method 1 of NGER Technical Guidelines for the estimation of emissions by facilities in Australia (Section 5.53)
[7] Note it is recognised the proportion of waste type may differ. The 30:70 split has been used as the basis for these calculations, with comparison calculations undertaken for the lower end of the target range of 50:50 split also presented in Section 4.1 to demonstrate comparative GHG emissions of the two scenarios

Parameter	Variable	Value
	CCi - Carbon content in waste (based on waste type)	MSW – 26% C&I – 34%
	FCCi - Proportion of carbon that is of fossil origin as derived from waste audit data[8]	MSW – 13% C&I – 19%
	OF - Oxidation factor (assumed based on default)	0.98
On-site fuel combustion - stationary	Diesel consumed by plant (front end loader) during normal operations	2,500 m^3/year
	Diesel consumed during start-up/shut down (based on 5 per year at 7 hour duration on average)	40 m3/year
On-site fuel combustion - mobile	Diesel consumed (front end loader) based on 3,120 hours operation/year (12 hours/day, 5 days/week, 52 weeks/year)	31.2 kL/year
Electricity imported from the grid[9]	Parasitic electricity consumed from grid during plant start-up/shut down	200 MWh/year
	Parasitic electricity consumed from grid when plant is offline (based on 2 weeks of shut down 24 hours/day at value of 1MW/h)	336 MWh/year
	Grid carbon factor (for year 2024 at start up)[10]	0.73

[8] As determined from actual waste audits conducted by Cleanaway at the Erskine Park landfill facility which has determined expected MSW and C&I waste composition– further details outlined in Arup's Waste and resource management assessment report WSERRC-ARU-SYD-WEWM-RPT-0001
[9] Assumed electricity import remains constant over design life (as an average)
[10] The grid carbon factor at start up was based on the estimates of projections from Table 5 of Australia's emissions projections 2019. Projection of the carbon factor beyond the published data (2030 and beyond) has been interpolated based on historic data and past decline. These interpolations are provided in Appendix A.

Parameter	Variable	Value
Electricity produced on site	Net electricity output exported back into the grid[11]	424,000 MWh/year
	Grid carbon factor (for year 2024 at start up)[12]	0.73
Transportation of waste to the site[13]	Number of daily truck movements	161 one-way trips
	Operational days per year	300 days/year
	Average fuel consumption for rigid truck	0.286 L/km
	Average distance travelled based on transportation of waste from within Greater Sydney region	30 km/one way trip
Transportation of waste/by-products from site operations	Number of daily truck movements	28 one-way
	Average fuel consumption for articulated truck (semi trailer)	0.55 L/km
	Average distance travelled based on transportation of waste from within Greater Sydney region	30 km/one way trip
Employee commute to/from the site	Average number of employees	50
	Average fuel consumption rate for a Toyota Prado or similar (unleaded petrol)	0.1 L/km

[11] This is assumed to remain constant over the design life of the facility
[12] The grid carbon factor at start up (year 2024) was based on the estimates of projections from Table 5 of Australia's emissions projections 2019. Projection of the carbon factor beyond the published data (2030 and beyond) has been interpolated based on historic data and past decline. These interpolations are provided in Appendix A.
[13] Traffic numbers and truck numbers taken from Arup traffic and transport assessment report WSERRC-ARU-SYD-TTEM-RPT-0001

Parameter	Variable	Value
	Average distance travelled of based on assumption of employment from within the Greater Sydney region	25 km one-way
	Number of work days for employees	365 days/year
Diversion of waste from landfill[14]	Assumed percentage of methane captured[15]	46.2%
	Waste volume	500,000 t/year
	Comparative waste type composition	MSW – 30% C&I – 70%
	Factor used for LFG combustion[16][17]	MSW – 0.82 tCO2e/twaste C&I – 0.79 tCO2e/twaste

[14] Based on NGER Scheme Method 1for emissions of methane from landfill
[15] based on the average Australian landfill operations (AusLCI database)
[16] Factor has been derived from multiplication of the waste composition combusted (as percentage) by the EF as outlined in Table 45 of NGA (2019), followed by application of the methane capture percentage
[17] Also refer to Waste and Resource Management assessment report for assumptions made around waste disposal and LFG capture (WSERRC-ARU-SYD-WEWM-RPT-0001)

4 Impact assessment

This Chapter details the greenhouse gas impact assessment in relation to both construction and operational impacts and provides a high-level review of potential climate impacts which are likely to affect the asset.

4.1 Construction Emissions

Table 3 summarises the individual sources of GHG emissions. Based on the calculations undertaken for this work, the construction of the proposal would result in the addition of approximately 4,073 tCO_2-e to the atmosphere. Detailed calculations are provided in Appendix A.

Table 3: Construction GHG Emissions

Emission source	Quantity	Units	Emission Factor	Total Emissions (t CO_2-e)
Construction machinery – stationary equipment	1,100	kL	2.71	2,981
Vegetation clearing	298	t C	3.67	1,092
Total construction GHG emissions				4,073

4.2 Operational Emissions

Table 4 summarises the individual sources of GHG emissions and total emissions for the first year of operations (assumed commissioning at year 2024).

Detailed calculations are provided in Appendix A.

Table 4: Gross Operational GHG Emissions

Emission source	Quantity	Units	Emission Scope	Emission Factor	Total Emissions (t CO_2-e)
Thermal treatment of waste	500,000	t /year	Scope 1	-	307,431
On-site fuel combustion (stationary)	2,700	kL	Scope 1	2.710	7,316
On-site fuel combustion (mobile)	31	kL	Scope 1	2.721	85
Electricity imported from grid	536,000	kWh	Scope 2	0.73[18]	393

[18] The grid carbon factor at start up (year 2024) was based on current factors for 2019, and taking into consideration rate of historic decline, with interpolation of estimated emission projections based on historic data and past decline. The assumptions for these interpolations are provided in Appendix A.

Employee commute to/from the site	91	kL	Scope 3	2.384	218
Transport of waste to site	1,658	kL	Scope 3	2.721	4,511
Transport of by-products from site	535	kL	Scope 3	2.721	1,455
Gross GHG emissions (indicative of first year)					**321,408**

It is noted these calculations have been undertaken based on the assumption the feedstock composition remains relatively consistent over the design life of the facility and the proportion of MSW and C&I. However, it is recognised waste trends are likely to change over time and the feedstock composition will also alter with these changing trends. These changes have been considered based on best available current information on likely trends and the direction of different waste composition projections. Indicative calculations using baseline projections and the estimated waste trend direction have been undertaken to compare the GHG emissions associated with different feedstock.

The proportion of waste type is likely to differ over the Proposal lifetime, with introduction of new technologies, change in policy and change in consumer behaviour. Subsequently, a comparison of net GHG emissions associated with changing feedstock composition between MSW:C&I (50:50 and 30:70) for representative periods in time which also reflect the target range for composition has been provided in Figure 4 (for Scope 1 and Scope 2 emissions only).

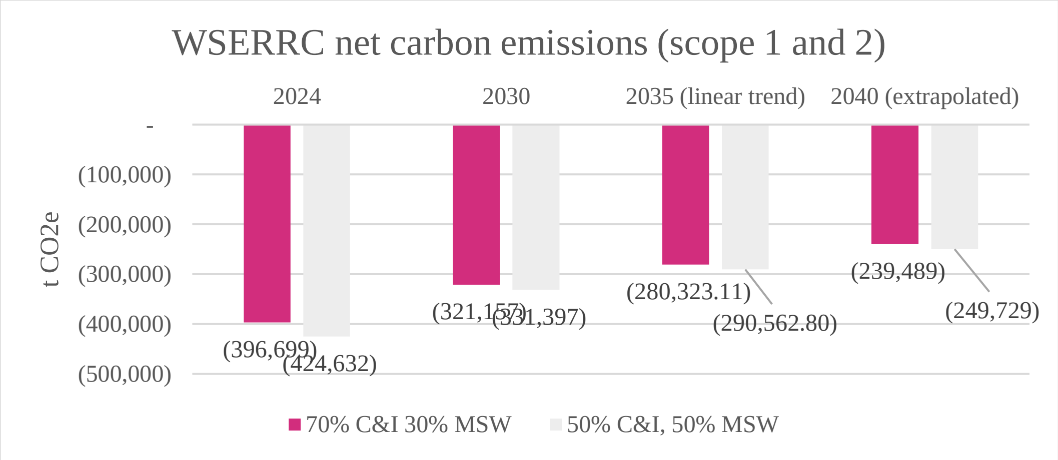

Figure 4: MSW, C&I feedstock comparison for Scope 1 and 2 carbon emissions Net greenhouse gas emissions

The above demonstrates change in feedstock composition has marginal difference in overall GHG emissions over the lifetime of the Proposal.

4.2.1 Export grid equivalency

Through the thermal treatment of waste that would otherwise be sent to landfill, the WSERRC will generate a nominal equivalent electrical output exported to the grid of 424,000 MWh/year. This will result in a *net reduction* in GHG emissions of -310,731 t CO_2-e as outlined in Table 5 below.

Table 5: GHG emissions resulting from export of electricity to grid

Emission source	Quantity	Units	Emission Scope	Emission Factor	Total Emissions (t CO_2-e)
Export of electricity back to grid	424,000,000[19]	kWh	Scope 2	0.73[20]	-310,731

4.2.2 Diversion of waste to landfill

The diversion of waste which would otherwise be disposed to landfill will result in the reduction of methane gases produced during the decomposition process of landfilled waste.

Calculations have been undertaken to determine the comparable emissions generated from disposal of the same volume of waste to landfill (500,000 t/year). Calculations were based on the assumption that 46.2% of methane was captured (based on the average Australian landfill operations from the AusLCI database) and a split of MSW and C&I (30:70).

Based on the alternative disposal of equivalent waste to landfill, carbon emissions were equal to **401,192 tCO_2-e/year** as outlined in Table 6.

Table 6: Equivalent GHG emissions resulting diversion of waste to landfill

Emission source	Quantity	Units	Emission Scope	Emission Factor	Total Emissions (t CO_2-e)
Diversion of waste to landfill	500,000	t/year	Scope 3	0.82 (MSW)[21] 0.79 (C&I)	123,035 278,157
Total GHG emissions from landfill diversion					401,192

A breakdown of calculations is provided in Appendix A.

[19] Based on estimated output of 53MW over 8,000 operational hours/year

[20] The grid carbon factor at start up (year 2024) was based on current factors for 2019, taking into consideration rate of historic decline, with interpolation of estimated emission projections based on historic data and past decline. The assumptions for these interpolations are provided in Appendix A.

[21] Emission factors for MSW and C&I were based on actual waste audit data conducted quarterly at Cleanaway's Erskine Park landfill facility and the average short term methane generation rate, with application of the methane capture rate – detailed outline of waste audit results provided in Arup's Waste and resource management report WSERRC-ARU-SYD-WEWM-RPT-0001.docx

4.2.3 Net carbon emissions

A summary balance of indicative GHG emissions resulting from operation of the facility during the first year of operations is provided in Table 7. Calculations indicate a *net reduction* of GHG emissions of approximately 390,515 t CO_2-e during the first year of operations.

Emissions intensity of electricity generation is expressed as the rate of emissions (tonnes or kg CO2-e) per net unit of electricity produced (MWh or kWh). The estimated emissions intensity for the Proposal is 0.72 t CO_2-e/MWh, which is slightly lower than the interpolated emissions factor for the NSW grid at the time of start up (2024) of 0.73 t CO_2-e.MWh.

Table 7: Net GHG balance

Emission source	Quantity	Units	Emission Scope	Emission Factor	Total Emissions (t CO_2-e)
Gross GHG emissions (indicative of first year)					321,408
Diversion of waste to landfill	500,000	t/year	Scope 3	0.82 (MSW) 0.79 (C&I)	-123,035 -278,157
Export of electricity back to grid	424,000,000	kWh	Scope 2	0.73	-310,731
Net indicative GHG emissions (indicative of first year of operations)					**-390,515**

A graph indicating the estimated GHG emissions avoided through generation of electricity on site over the Proposal life (30 year) is provided in Figure 5

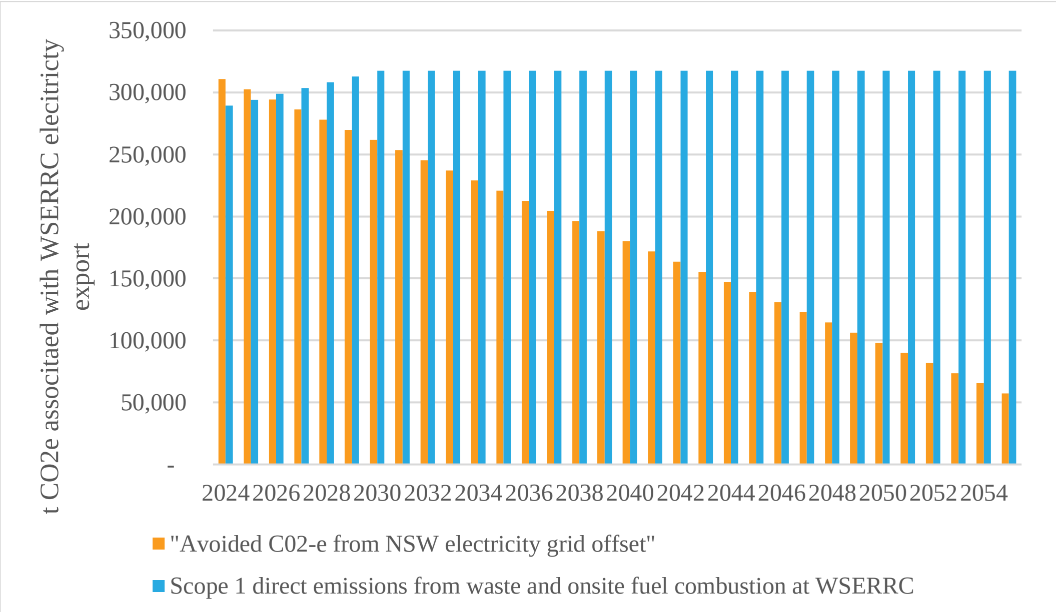

Figure 5: Estimated GHG emissions over Proposal design life

4.3 Potential climate impacts

Climate change is a significant risk and a major challenge for industry across the globe. According to the National Greenhouse Gas Inventory quarterly update, the waste sector contributed 2.2% of Australia's GHG emissions in September 2019, [22], with little to no difference in trend over the past few years. Methane gas is a greenhouse gas which is considered more potent than carbon dioxide at absorbing the sun's heat, having 25 times the effect of carbon dioxide in the medium term[23].

Reducing not only waste disposal to landfills and associated fugitive methane generation, but also reliance on non-renewable energy sources is required to move towards a net zero carbon future. There are opportunities for addressing methane emissions which aren't otherwise captured, by reducing the amount of waste that ends up in landfill, an opportunity which the WSERRC facility will facilitate The renewable nature of waste to energy and its climate change mitigation potential presents an opportunity to support the transition to a low carbon economy.

4.3.1 Climate risk review

A high-level review of potential climate risks and hazards associated with a changing climate has been undertaken as part of this assessment. This initial consideration aims to highlight potential climate risks to help improve the ability to impact and influence the final design. The most likely climate change hazards that may impact the proposal have been reviewed, with a more detailed climate change risk assessment with key design disciplines and stakeholder groups recommended to be undertaken following further design development.

Table 8: Preliminary review of potential climate impacts

Asset/service impacted	Potential climate change impact
Increase in annual mean temperature and annual number of hot days over 35^{0}C	
Plant operations	• Potential effects to plant operations and inefficiencies in electricity output • Higher use of energy associated with plant operations
Increased frequency and severity of extreme rainfall events	
Damage to infrastructure - pavement and civil infrastructure	• Localised flooding of access routes from extreme rainfall, blockage or incapacity of drainage to cope with flow or overland flow resulting in damage to infrastructure or blockage to waste bays

[22] DEE, 2019 *Quarterly update of Australia's National GHG Inventory: September 2019*
[23] https://theglobalclimate.net/methane-gas/

	• Localised flooding of access routes or entry routes from extreme rainfall, resulting in limited access to site and ability to supply waste to the site
Reduced rainfall and extended periods of drought	
Rainwater supplies	• Less rainfall recovery in process water for plant operations leading to reliance on mains water

In summary, potential impacts associated with increased severity of extreme rainfall events can lead to potential flooding, which may affect culvert and drainage design, extreme temperatures may affect plant operations and lead to inefficiencies in electricity output and extended periods of drought which may result in less rainfall recovery for process water used in the plant.

Consideration of appropriate planning and management treatment options to manage or reduce the impact of the potential impacts to critical aspects of operations will help build adaptation to future changes in climate.

5 Proposed mitigation measures

This Chapter outlines proposed mitigation and management measures that have been developed to mitigate the potential GHG impacts of the proposal during operations. During the construction stage, appropriate measures will be implemented to optimise construction machinery and fuel usage, and the clearing of vegetation will be minimised as much as practical for the construction footprint.

Whilst it is recognised operation of the facility will generate GHG emissions and calculations indicate the full extent of these emissions will be offset through the generation of electricity, a number of features have been considered and implemented in the facility design to ensure operations maximise resource and energy recovery, including:

- The plant is designed to run at “high steam conditions”. High steam conditions refer to the temperature and pressure of the steam that is generated by the boiler and is used to drive the turbine to generate electricity. The European Waste Incineration Best Available Techniques Reference Document (EU WI BREF) defines high steam conditions as a steam pressure above 45bar and a steam temperature above 400 degrees Celsius. The WSERRC facility will have high steam conditions by this definition. High steam conditions maximise the recovery of energy from the flue gases and therefore maximise energy efficiency.
- Variable Speed Drives (VSD’s) will be specified for large motors driving fans and pumps to reduce energy consumption within the plant. This effectively decreases the electricity consumed by the plant and therefore increases the amount of electricity that can be exported to the electricity grid in comparison to the case where single speed drives are used.
- All plant systems and equipment will be accurately specified and sized to ensure they operate at optimal design point during normal operations. This means that equipment will operate efficiently and therefore energy efficiency of the overall facility will be increased.
- Use of energy efficient motors.
- Use of mechanical/pneumatic rapping systems to provide online cleaning to the boiler rather than soot blowers which would utilize steam which could otherwise been used for electricity generation.
- Efficient design of steam turbine with multiple steam extraction points to ensure all internal process demands can be met with extracted steam for all load conditions.
- Maximizing natural ventilation of process plant areas where possible to minimize use of forced ventilation.
- Sub-metering of all electricity distribution at a system level to monitor usage and identify high consumers and opportunities for future improvement.

In addition, a number of energy efficiency measures will be adopted in the design of the administration building and visitor centre. These include:

- Location of the Operations/Administration areas in the main facility, not a stand-alone building which reduces the overall volume of materials required for construction.
- Consideration of the orientation of the buildings and glazed facades to limit excess solar gain thus reducing the need for excessive cooling. Careful consideration of use of glazing to balance solar gain with provision of natural light will also be provided to reduce the energy usage from electrical lighting.
- Use of insulated façade materials to reduce energy consumption for heating and cooling when compared to a non-insulated facility.

During operations, the following energy efficient measures will be reviewed and implemented as part in operation of the facility:

- Identification of the most significant energy consuming plant and equipment and recognize opportunities where future technologies may further reduce energy use.
- Implementation of the site specific Environmental Management Plan (as discussed in the Best Available Techniques Appendix to this report) which will outline energy efficient procedures to ensure plant operation is optimised. Continuous review and auditing of this plan
- Optimisation of operational activities and logistics to reduce fuel usage.
- Investigation into the installation of a heat/low pressure steam offtake in the future to allow the facility to operate in a Combined Heat and Power mode. Depending on the development of the surrounding area there may be future opportunities to provide process steam, heating or cooling to nearby third-party energy consumers. The facility will be constructed such that heat/steam can be exported if it becomes viable in the future by incorporating a spare steam bleed into the low-pressure section of the steam turbine. Such opportunities will be assessed periodically. The use of low-pressure steam has the potential to increase the overall facility energy efficiency.

6 Conclusions

This report has been prepared to document anticipated greenhouse gas emissions resulting from the construction and ongoing operation of the proposed energy from waste facility located at Eastern Creek.

Scope 1, 2 and 3 emissions were estimated based on data available at the time of design and the relevant guidelines and standards. Based on calculations and assumptions as outlined in this report, assessment results indicate:

- Construction emissions are estimated to be 4,073 t CO_2-e
- Annual operational Scope 1, 2 and 3 emissions in gross are estimated to result in 321,408 t CO_2-e for the first year of operations
- Annual Scope 1, 2 and 3 emissions resulting from operations of the Proposal, taking into consideration net export of electricity back to the grid and avoidance of landfill disposal are estimated to result in a *net reduction* of 390,515 t CO_2-e for the first year of operations

The annual energy output of the proposal of 440 GWh is considered equivalent to the comparable amount of energy to power 79,000[24] homes in Western Sydney, with the net GHG reduction equivalent to taking approximately 85,000[25] cars off the road each year.

The above calculation considers changes in emission factors over time, change in the composition of feedstock over time, the reducing carbon intensity of the electricity grid over the Proposal timeframe and the avoidance of comparative waste disposal which would otherwise be sent to landfill.

Notwithstanding, a number of energy efficient measures have been considered and incorporated in design, with further measures to be implemented during operation of the facility to ensure operations maximise resource and energy recovery, thus maximising overall energy efficiency.

The WSERRC facility will not only reduce the possibility of fugitive methane emissions resulting from landfill, but also contribute to a more sustainable source of electricity generation, with a net positive GHG impact resulting from operation of the Proposal.

[24] Based on average home power consumption of 15.2 kWh/day/household = annual power consumption of 5,548 kWh/household/year
[25] Based on average CO_2 vehicle emission of 4.6 tCO_2-e/year

References

Adapt NSW 2016, *East coast lows research program synthesis for NRM stakeholders*

Australian Lifecycle Assessment Society, *Australian Lifecycle Inventory Database initiative (AusLCI database)*

Clean Energy Regulator, *National Greenhouse and Energy Reporting scheme* http://www.cleanenergyregulator.gov.au/NGER/About-the-National-Greenhouse-and-Energy-Reporting-scheme accessed 4th February 2020

CSIRO, *Climate Change in Australia* https://www.climatechangeinaustralia.gov.au/en/climate-campus/climate-system/greenhouse-gases/ *accessed* 6 February 2020

The Global Climate, *How methane gas causes climate change and what to do about it* https://theglobalclimate.net/methane-gas/, accessed 26 March 2020

Greater Sydney Commission, 2019, *Western City District Plan*

Greenhouse Gas Protocol, February 2020, *The GHG Protocol for Project Accounting* http://ghgprotocol.org/sites/default/files/standards/ghg_project_accounting.pdf, accessed 6 February 2020

Department of the Environment and Energy, 2019, *National Greenhouse Accounts (NGA) Factors*

Department of the Environment and Energy, 2017, *National Greenhouse and Energy Reporting Scheme Measurement, Technical Guidelines for the estimation of emissions by facilities in Australia*

Department of the Environment and Energy, 2019, *Australia's emissions projections 2019*

Department of the Environment and Energy, 2019 *Quarterly Update of Australia's National GHG Inventory, September 2019*

Intergovernmental Panel on Climate Change (IPCC), September 2014, *Climate Change 2014, AR5 Synthesis Report*

Department of Planning, Industry and Environment, 2019, *Net Zero Plan Stage 1: 2020 - 2030*

Office of Environment and Heritage, 2016, *NSW Climate Change Policy Framework*

Office of Environment and Heritage, 2014, *Adapt NSW, Climate Change Snapshot*

Appendix A

Greenhouse Gas Calculations Sheet

A1. Calculation Summary Spreadsheet

Emissions source - Operations	Quantity		Emission Factor		Total Annual Emissions
	Total	Units	t CO_2-e / units	Units	(t CO_2-e)
Construction					
Construction machinery - stationary equipment	1,100	kL	2.710	t CO2-e / KL	2,981
Vegetation clearing	298	t C	3.670	t C	1,092
		Total Construction GHG Emissions			**4,073**
Operations					
Transport of waste to site	1,658	kL	2.721	t CO2-e / KL	4,511
Transport of waste from site	535	kL	2.721	t CO2-e / KL	1,455
On-site fuel combustion - stationary	2,700	kL	2.710	t CO2-e / KL	7,316
On-site fuel combustion - mobile	31	kL	2.721	t CO2-e / KL	85
Electricity imported from grid	536,000	kWh	0.00073	t CO2-e/kWh	393
Employee commute to/from site	91	kL	2.384	t CO2-e / KL	218
Net export electricity back to grid	424,000,000	kWh	0.00073	t CO2-e/kWh	-310,731
Thermal treatment	500,000	t /year	-	-	307,431
Diversion of waste from landfill (MSW)	150,000	t /year	0.820	tCO2e/twaste	-123,035
Diversion of waste from landfill (C&I)	350,000	t /year	0.795	tCO2e/twaste	-278,157
Total Annual GHG Emissions - Operations (1st year					**-390,515**

A2. Input Summary Sheet

Input	Quantity	Unit	Source	Comments
Thermal treatment	500,000	t /year	See further calcs	
Transport of waste to site	1657.656	kL	https://www.budgetdirect.com.au/car-insurance/research/average-fuel-consumption-australia.html Truck movements and numbers taken from Arup Traffic and Transport report - extract included	Distance travelled is based on a radius within the greater Sydney region of 60 km round trip, based on 300 operational days/yr Based on average articulated truck fuel consumption of 28.6L/100 km
Transport of waste from site	534.6	kL	https://www.abs.gov.au/ausstats/abs@.nsf/mf/9208.0	Distance travelled is based on a radius within the greater Sydney region of 60 km round trip, based on 300 operational days/yr Based on average rigid truck fuel consumption of 55L/100 km
On-site fuel combustion - stationary	2700	kL	email dated 24/3/20 (from Euan M): 2,500m3/yr, 40m3 per start-up/shut-down based on R1 calculation.. Start-ups. Ramboll have allowed 5 per year at 7hr duration on average.	
On-site fuel combustion - mobile	31.2	kL	Email received Ramboll 25/3 (extract provided)	Based on 12 hr/day @ 5 days/week*52 weeks
Electricity imported from grid	536000	kWh	Based on 200 MWh during start up/shut down + 336 MWh when plant is offline (based on 2 weeks shut down/year (24hours/day and value of 1MW/h)	
Employee commute to/from site	91.25	kL	https://www.budgetdirect.com.au/car-insurance/research/average-fuel-consumption-australia.html	
Construction machinery - stationary equipment	1100	kL	Equipment list and hours or operations as per provided by client	Assumptions around quantity and construction timeframe as per outlined in Appendix A7
Net export electricity back to grid	424000000	kWh	Based on information received from Ramboll (extract provided)	
Vegetation clearing	297.65	t C	Greenhouse Gas Assessment workbook for Road projects, Transport Authorities Greenhouse Group, 2013	Assumed all carbon emitted as CO2 where 3.67 is constant conversion factor

A3. Thermal Treatment Calculations

	MSW				
Lab test average results	**Solid content (1-measured moisture content)**	**Carbon content (% dry mass)**	**Fossil carbon content (1-measured biogenic carbon)**	**Initial composition of waste combusted (% wet weight)**	**Long term composition of waste combusted (% wet weight)**
Paper/cardboard	0.776	43%	0%	16%	19%
Food and garden organics	0.301333333	42%	0%	48%	33%
Wood & building materials	0.834666667	49%	0%	2%	2%
Textile materials	0.796666667	56%	24%	5%	6%
Plastics	0.791333333	73%	100%	17%	21%
Potentially hazardous	0.546666667	49%	100%	7%	9%
Other/inert materials	0.902333333	0%	0%	6%	10%
				100%	100%
				Cci x FCC	**12%**
				Cci x FCCi x OFi (0.98 assumed	**0.437177452**

	C&I			
Lab test average results	**Solid content (1-measured moisture content)**	**Carbon content (% dry mass)**	**Fossil carbon content (1-measured biogenic carbon)**	**Expected composition of waste combusted (% wet weight)**
Paper/cardboard	0.719333333	44%	0%	26%
Food and garden organics	0.377333333	49%	0%	25%
Wood & building materials	0.883	49%	0%	6%
Textile materials	0.781333333	55%	37%	5%
Plastics	0.898666667	81%	100%	23%
Potentially hazardous	0.745	36%	100%	7%
Other/inert materials	0.942333333	0%	0%	8%
			Cci x FCC	**19%**
		Cci x FCCi x OFi (0.98 assumed) x 3.664		**0.691011667**

A4. LF Avoidance Calculations

National Greenhouse Accounts factors 2019 Table 45

Waste material	Degradable organic carbon (DOC)	Conversion factor to tonnes CO2e	Short term combosition waste combusted	Long term composition waste combusted	Short term CH4gen	Long term CH4 gen	
Paper and card	0.4	2.9	15.50%	18.80%	0.45	0.55	
Plastic film	0	0	10.40%	11.40%	0.00	0.00	
Dense plastic	0	0	6.30%	9.80%	0.00	0.00	
Textiles	0.24	1.8	5.30%	6.40%	0.10	0.12	
Glass	0	0	2.40%	2.90%	0.00	0.00	
Inert material (concrete, rock, ceramics etc)	0	0	2.50%	3.00%	0.00	0.00	
Food and Kitchen waste	0.15	1.9	35.10%	23.40%	0.67	0.44	
Garden waste	0.2	1.4	9.20%	5.50%	0.13	0.08	
Other Organics	0.15	1.9	3.40%	4.10%	0.06	0.08	
Ferrous metal	0	0	0.40%	2.90%	0.00	0.00	
Non-ferrous metal	0	0	0.20%	0.70%	0.00	0.00	
Electronic equipment, household chemicals and pharmaceuticals	0	0	1.10%	1.30%	0.00	0.00	
Fine material <10mm	0	0	0.40%	0.50%	0.00	0.00	
Absorbent hygiene products	0.24	1.8	6.10%	7.40%	0.11	0.13	
Wood	0.43	0.6	1.60%	1.90%	0.01	0.01	
			99.90%	**100.00%**	**1.52**	**1.40**	**t CO2e/t waste accepted for combustion**
				Apply methane capture (53.8%)	**0.82**	0.76	**t CO2e/t waste accepted for combustion**

	Degradable organic carbon (DOC)	Conversion factor to tonnes CO2e	Composition of waste combusted	CH4 gen	
Paper and card	0.4	2.9	26.00%	0.754	
Plastic film	0	0	15.20%	0	
Dense plastic	0	0	7.70%	0	
Textiles	0.24	1.8	3.50%	0.063	
Glass	0	0	2.00%	0	
Inert material (concrete, rock, ceramics etc)	0	0	2.10%	0	
Food and Kitchen waste	0.15	1.9	24.00%	0.456	
Garden waste	0.2	1.4	0.90%	0.0126	
Other Organics	0.39	2.9	1.60%	0.0464	
Ferrous metal	0	0	2.50%	0	
Non-ferrous metal	0	0	0.30%	0	
Electronic equipment, household chemicals and pharmaceuticals	0	0	0.70%	0	
Fine material <10mm	0	0	1.40%	0	
Absorbent hygiene products	0.24	1.8	6.10%	0.1098	
Wood	0.43	0.6	5.90%	0.0354	
			99.90%	**1.48**	**t CO2e/t waste accepted for combustion**
			Apply methane capture	**0.79**	**t CO2e/t waste accepted for combustion**

MSW proportion	50%	
C&I proportion	50%	
Total equivalent waste volume	500,000	tonnes/year
MSW taken	250,000	tonnes/year
C&I taken	250,000	tonnes/year

Landfill avoided emissions

MSW emissions factor in landfill	0.82	tCO2e/twaste
C&I emissions factor in landfill	0.79	tCO2e/twaste
Fugitive emissions after methane recovery (1-R)	53.80%	
MSW emissions	205,059	tCO2e/yr
C&I emissions	198,683	tCO2e/yr
Total emissions from landfill	**403,742**	**tCO2e/yr**

A5. EF calculations - export of electricity

Year	Mt CO2-e	Grid Carbon Factor	Power Gen MWh	Total Avoided tCO2e/year	
2020	52	0.81	424,000	343,440	*Actual*
2021	49.6	0.79	424,000	335,263	***Estimated based on past decline x6*
2022	47.2	0.77	424,000	327,086	*Estimated based on past decline x6*
2023	44.8	0.75	424,000	318,909	*Estimated based on past decline x6*
2024	42.4	0.73286	424,000	**310,731**	*Estimated based on past decline x6*

Rationale for elec projection

2018	**0.81**
1990	**0.9**
28	**-0.090**
	-0.003
	-0.019

**These estimates have been multiplied by a factor of 6 - based on working backwards from a 2050 scenario where the grid has been decarbonised.
However, it is assumed grid would not be fully decarbonised, therefore factor of 6 is assumed. which sees decarbonsisation of grid - but unlikely - interpreted as a linear decline

A6. EF Calculations - import of electricity

Year	Mt CO2-e	Grid Carbon Factor	Elec imported MW	Total tCO2e/year
2020	52	0.81	536	434
2021	49.6	0.79	536	424
2022	47.2	0.77	536	413
2023	44.8	0.75	536	403
2024	**42.4**	**0.73**	**536**	**393**

	Rationale for elec projection	
Actual	**2018**	**0.81**
***Estimated based on past decline x6*	**1990**	**0.9**
Estimated based on past decline x6	**28**	**-0.090**
Estimated based on past decline x6		**-0.003**
Estimated based on past decline x6		**-0.019**

**These estimates have been multiplied by a factor of 6 - based on working backwards from a 2050 scenario where the grid has been decarbonised.
However, it is assumed grid would not be fully decarbonised, therefore factor of 6 is assumed. which sees decarbonsisation of grid - but unlikely - interpreted as a linear decline

A7. Stationary Construction Equipment Calculations

Equipment	Number of Equipment	Consumption Litres per Hour	Utilisation Factor	Total Consumption (KL)	1	2	3	4	5	6	7	8
Demolition				% use per month	25%	50%	50%					
Backhoe loader	2	7.5	0.75	3.7	730.6875	1461.375	1461.375					
Bulldozer (CATD8 to CATD10 or similar)	1	40	0.8	10.4	2078.4	4156.8	4156.8					
Diesel generator	2	1.5	1	1.0	194.85	389.7	389.7					
Excavator (<25t)	1	4	0.75	1.0	194.85	389.7	389.7					
Excavator (>25t)	1	5	0.75	1.2	243.5625	487.125	487.125					
Trucks (water cart)	1	2	1	0.6	129.9	259.8	259.8					
Misc Tools	10	1	1	3.2	649.5	1299	1299					
Sub-Total				**21.1**	**4.22175**	**8.4435**	**8.4435**					
Site Preparation and Early Works				% use per month		50%	75%	75%	75%	75%	50%	
Backhoe loader	2	7.5	0.75	11.7		1461.375	2192.0625	2192.0625	2192.0625	2192.0625	1461.375	
Bulldozer (CATD8 to CATD10 or similar)	2	40	0.8	66.5		8313.6	12470.4	12470.4	12470.4	12470.4	8313.6	
Compactors (CAT835 or similar)	2	30	0.75	46.8		5845.5	8768.25	8768.25	8768.25	8768.25	5845.5	
Diesel generator	2	1.5	1	3.1		389.7	584.55	584.55	584.55	584.55	389.7	
Excavator (>25t)	2	5	0.75	7.8		974.25	1461.375	1461.375	1461.375	1461.375	974.25	
Front End Loaders (FEL)	2	6	0.75	9.4		1169.1	1753.65	1753.65	1753.65	1753.65	1169.1	
Graders (CAT14G to CAT16G or similar)	2	10	0.75	15.6		1948.5	2922.75	2922.75	2922.75	2922.75	1948.5	
Piling Rigs (bored piles)	2	45	0.65	60.8		7599.15	11398.725	11398.725	11398.725	11398.725	7599.15	
Rollers	2	15	0.75	23.4		2922.75	4384.125	4384.125	4384.125	4384.125	2922.75	
Scrapers	2	40	0.8	66.5		8313.6	12470.4	12470.4	12470.4	12470.4	8313.6	
Trucks (water cart)	2	2	1	4.2		519.6	779.4	779.4	779.4	779.4	519.6	
Vibration roller	2	6	0.75	9.4		1169.1	1753.65	1753.65	1753.65	1753.65	1169.1	
Misc Tools	10	1	1	10.4		1299	1948.5	1948.5	1948.5	1948.5	1299	
Sub-Total				**335.4**		**41.925225**	**62.8878375**	**62.8878375**	**62.8878375**	**62.8878375**	**41.925225**	
Main Construction and Landscaping				% use per month						50%	50%	75%
Backhoe loader	1	7.5	0.75	30.7						730.6875	730.6875	1096.03125
Compactors (CAT835 or similar)	2	30	0.75	245.5						5845.5	5845.5	8768.25
Crawler Crane >200t	1	8	0.25	10.9						259.8	259.8	389.7
Diesel generator	4	1.5	1	32.7						779.4	779.4	1169.1
Fork lifts	2	5	1	54.6						1299	1299	1948.5
Front End Loaders (FEL)	2	6	0.75	49.1						1169.1	1169.1	1753.65
Graders (CAT14G to CAT16G or similar)	1	10	0.75	40.9						974.25	974.25	1461.375
Manitou	2	6	0.25	16.4						389.7	389.7	584.55
Padfoot roller	2	5	0.75	40.9						974.25	974.25	1461.375
Rollers	2	6	0.75	49.1						1169.1	1169.1	1753.65
Trucks (water cart)	1	2	1	10.9						259.8	259.8	389.7
Vibration roller	2	6	0.75	49.1						1169.1	1169.1	1753.65
Misc Tools	10	1	1	54.6						1299	1299	1948.5
Sub-Total				**685.4**						**16.3186875**	**16.3186875**	**24.47803125**
Total On-Site Fuel Usage (KL)				**1100.00**	**4.22175**	**50.368725**	**71.331338**	**62.887838**	**62.887838**	**79.206525**	**58.243913**	**24.47803125**

Equipment	9	10	11	12	13	14	15	16	17	18	19	20	21
Main Construction and Landscaping	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Backhoe loader	1461.375	1461.375	1461.375	1461.375	1461.375	1461.375	1461.375	1461.375	1461.375	1461.375	1461.375	1461.375	1461.375
Compactors (CAT835 or similar)	11691	11691	11691	11691	11691	11691	11691	11691	11691	11691	11691	11691	11691
Crawler Crane >200t	519.6	519.6	519.6	519.6	519.6	519.6	519.6	519.6	519.6	519.6	519.6	519.6	519.6
Diesel generator	1558.8	1558.8	1558.8	1558.8	1558.8	1558.8	1558.8	1558.8	1558.8	1558.8	1558.8	1558.8	1558.8
Fork lifts	2598	2598	2598	2598	2598	2598	2598	2598	2598	2598	2598	2598	2598
Front End Loaders (FEL)	2338.2	2338.2	2338.2	2338.2	2338.2	2338.2	2338.2	2338.2	2338.2	2338.2	2338.2	2338.2	2338.2
Graders (CAT14G to CAT16G or similar)	1948.5	1948.5	1948.5	1948.5	1948.5	1948.5	1948.5	1948.5	1948.5	1948.5	1948.5	1948.5	1948.5
Manitou	779.4	779.4	779.4	779.4	779.4	779.4	779.4	779.4	779.4	779.4	779.4	779.4	779.4
Padfoot roller	1948.5	1948.5	1948.5	1948.5	1948.5	1948.5	1948.5	1948.5	1948.5	1948.5	1948.5	1948.5	1948.5
Rollers	2338.2	2338.2	2338.2	2338.2	2338.2	2338.2	2338.2	2338.2	2338.2	2338.2	2338.2	2338.2	2338.2
Trucks (water cart)	519.6	519.6	519.6	519.6	519.6	519.6	519.6	519.6	519.6	519.6	519.6	519.6	519.6
Vibration roller	2338.2	2338.2	2338.2	2338.2	2338.2	2338.2	2338.2	2338.2	2338.2	2338.2	2338.2	2338.2	2338.2
Misc Tools	2598	2598	2598	2598	2598	2598	2598	2598	2598	2598	2598	2598	2598
Sub-Total	**32.637375**	**32.637375**	**32.637375**	**32.637375**	**32.637375**	**32.637375**	**32.637375**	**32.637375**	**32.637375**	**32.637375**	**32.637375**	**32.637375**	**32.637375**
Total On-Site Fuel Usage (KL)	**32.637375**	**32.637375**	**32.637375**	**32.637375**	**32.637375**	**32.637375**	**32.637375**	**32.637375**	**32.637375**	**32.637375**	**32.637375**	**32.637375**	**32.637375**

Equipment	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
Main Construction and Landscaping	50%	50%	50%	50%	50%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	50%	50%	0.25
Backhoe loader	730.6875	730.6875	730.6875	730.6875	730.6875	365.34375	365.34375	365.34375	365.34375	365.34375	365.34375	365.34375	365.34375	365.34375	365.34375	730.6875	730.6875	365.34375
Compactors (CAT835 or similar)	5845.5	5845.5	5845.5	5845.5	5845.5	2922.75	2922.75	2922.75	2922.75	2922.75	2922.75	2922.75	2922.75	2922.75	2922.75	5845.5	5845.5	2922.75
Crawler Crane >200t	259.8	259.8	259.8	259.8	259.8	129.9	129.9	129.9	129.9	129.9	129.9	129.9	129.9	129.9	129.9	259.8	259.8	129.9
Diesel generator	779.4	779.4	779.4	779.4	779.4	389.7	389.7	389.7	389.7	389.7	389.7	389.7	389.7	389.7	389.7	779.4	779.4	389.7
Fork lifts	1299	1299	1299	1299	1299	649.5	649.5	649.5	649.5	649.5	649.5	649.5	649.5	649.5	649.5	1299	1299	649.5
Front End Loaders (FEL)	1169.1	1169.1	1169.1	1169.1	1169.1	584.55	584.55	584.55	584.55	584.55	584.55	584.55	584.55	584.55	584.55	1169.1	1169.1	584.55
Graders (CAT14G to CAT16G or similar)	974.25	974.25	974.25	974.25	974.25	487.125	487.125	487.125	487.125	487.125	487.125	487.125	487.125	487.125	487.125	974.25	974.25	487.125
Manitou	389.7	389.7	389.7	389.7	389.7	194.85	194.85	194.85	194.85	194.85	194.85	194.85	194.85	194.85	194.85	389.7	389.7	194.85
Padfoot roller	974.25	974.25	974.25	974.25	974.25	487.125	487.125	487.125	487.125	487.125	487.125	487.125	487.125	487.125	487.125	974.25	974.25	487.125
Rollers	1169.1	1169.1	1169.1	1169.1	1169.1	584.55	584.55	584.55	584.55	584.55	584.55	584.55	584.55	584.55	584.55	1169.1	1169.1	584.55
Trucks (water cart)	259.8	259.8	259.8	259.8	259.8	129.9	129.9	129.9	129.9	129.9	129.9	129.9	129.9	129.9	129.9	259.8	259.8	129.9
Vibration roller	1169.1	1169.1	1169.1	1169.1	1169.1	584.55	584.55	584.55	584.55	584.55	584.55	584.55	584.55	584.55	584.55	1169.1	1169.1	584.55
Misc Tools	1299	1299	1299	1299	1299	649.5	649.5	649.5	649.5	649.5	649.5	649.5	649.5	649.5	649.5	1299	1299	649.5
Sub-Total	**16.3186875**	**16.3186875**	**16.3186875**	**16.318688**	**16.318688**	**8.1593438**	**8.1593438**	**8.1593438**	**8.1593438**	**8.1593438**	**8.1593438**	**8.1593438**	**8.1593438**	**8.1593438**	**8.1593438**	**16.318688**	**16.318688**	**8.1593438**
Total On-Site Fuel Usage (KL)	**16.318688**	**16.318688**	**16.318688**	**16.31869**	**16.31869**	**8.159344**	**8.159344**	**8.159344**	**8.159344**	**8.159344**	**8.159344**	**8.159344**	**8.159344**	**8.159344**	**8.159344**	**16.31869**	**16.31869**	**8.159344**