

Appendix C. Greenhouse gas assessment – additional information

This appendix provides detailed workings and assumptions related to the calculation of GHG emissions presented in the GHG Assessment. The methods used for the workings and calculations of GHG emissions accord with:

- EPA Victoria Publication 1658 Works approval application guideline (June 2017)
- The Greenhouse Gas Protocol (GHG Protocol) issued by the World Business Council for Sustainable Development (WBCSD) and the World Resources Institute (WRI)
- ISO 14064-1:2006 Greenhouse gases - Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals

C.1 Construction

This chapter outlines the calculations for energy consumption and greenhouse gas emissions resulting from construction of the EfW plant.

C.1.1 Construction fuel consumption

Construction fuel has been identified for the following sources:

- Site vehicles used in management of construction (e.g. utility vehicles)
- Generators used to power site offices
- Construction plant and equipment (e.g. earth movers, drill rigs, cranes etc.)
- Trucks and trailers used for haulage of cut and fill material

C.1.1.1 Site vehicle fuel consumption

The Transport Authorities Greenhouse Group (TAGG) 2013 provides a methodology for determination of fuel consumption associated with site management vehicles. This provides fuel consumption projections for utility vehicles for small (<\$2m), medium (\$2-10m) and large (>\$10m) projects. These correspond to usage of 2, 4 or 10 Toyota Hilux vehicles per month respectively. Although the project value will be greater than that for a 'large' project it is assumed that a factor for 4 Hilux vehicles would be appropriate (given that this is not a road project, and so vehicles will not be needed to traverse long distances). As such, consumption of petrol only vehicles, at a rate of 2.05 kL per month is assumed. Multiplied by an expected construction duration of 36 months, this results in total petrol fuel consumption of 74 kL.

This results in the following emissions projections:

- 176 tCO_{2e} (Scope 1 – direct emissions from combustion)
- 9 tCO_{2e} (Scope 3 – emissions associated with production of the fuel)

C.1.1.2 Site office power

TAGG (2013) provides a methodology for determination of fuel consumption from generators used to power site offices, on the assumption that diesel powered generators are required. It is not clear at this stage whether power will be provided from an Australian Paper feeder on site, and as such this has been calculated separately.

The TAGG (2013) value for diesel consumption for an office (assuming a 500 m² of office space, equivalent of 2 star NABERS rating, operating 12 hours a day, Monday to Friday) is 3.1kL diesel per month of construction. Multiplied by an expected construction duration of 36 months, this results in total diesel fuel consumption of 112 kL.

This results in the following emissions projections:

- 302 tCO₂e (Scope 1 – direct emissions from combustion)
- 14 tCO₂e (Scope 3 – emissions associated with production of the fuel)

C.1.1.3 Construction plant and equipment

Construction scheduling is likely to be approximately 3 years in total, with 3 months allocated to earthworks and ground preparation, 9 months to piling and concrete pouring, and 2 years allocated to civil construction. Assumptions were made regarding the plant and equipment used for the construction phases, with fuel consumption factors derived from TAGG (2013) with proxy figures used where an appropriate figure was not available. The equipment projected and projected fuel consumption is shown in Table C.1.

Table C.1: Construction Equipment – Diesel Fuel Consumption

Equipment	Number	Time in Use (months)	Consumption Rate (kL / month)	Diesel Consumption (kL)
Site Wide Works / Preparation (3 months)				
Graders	1	3	5.1	15.3
Large Excavator	2	3	5.1	30.6
Bulldozer	1	1	5.7	5.7
Earth hauling vehicles	4	3	12.5	150
Rollers	2	2	4.8	19.2
Bulk Earthworks and civil foundations (11 months)				
Large Cranes	1	11	7.9	86.9
Large Excavator	3	9	5.1	137.7
Earth hauling vehicles (Assumed 40t)	4	11	12.5	550
Piling Rig	1	7	7.9	55.3
Rollers	2	6	4.8	57.6
Mechanical Erection (14 months)				
Large Cranes	2	14	7.9	221.2
Frannas	4	14	5.1	285.6
Small excavator	3	8	5.1	122.4
Total				1737.5

This results in the following emissions projections:

- 4,708 tCO₂e (Scope 1 – direct emissions from combustion)
- 215 tCO₂e (Scope 3 – emissions associated with production of the fuel)

C.1.1.4 Haulage of cut and fill material

Material that is cut from site will be reused on site wherever possible. It is expected that there will be a net positive amount of cut material, and hence this will need to be transported off site for disposal. A material cut and fill balance was derived from 3-dimensional site modelling. From this, the net amount cut material to be exported was 178,537 m³. This value was converted into tonnes using a medium density factor from the EPA (EPA, 2017). Factors from the UK (DBEIS, 2017) were used to determine emissions associated with haulage of the material to a local disposal point. This outlet has yet to be identified, but the proponent will be seeking local beneficial reuse or disposal, hence a 25km haulage distance was assumed.

This results in the following emissions projections:

- 345 tCO₂e (Scope 3)

C.1.2 Construction materials

Construction materials for the EfW plant include aggregate and concrete used in site establishment and foundations (including hard stand areas), steel used for the majority of process equipment and a range of other smaller materials used throughout the EfW plant.

To provide an indication of the embedded emissions associated with construction, emissions associated with major uses of aggregate, concrete and steel only was conducted. At this stage of the project, the preferred design has not been selected, so this is deemed appropriate. Estimations of the quantities of these materials were made by engineers working on the project feasibility study. These material quantities were multiplied by emissions factors derived from ISCA (2016). Table C.2 provides details of the construction material quantities assumed for this project.

Table C.2: Construction Material Quantities

Material	Quantity (tonnes)
Aggregate	7,050
Concrete – 40MPa	23,100
Steel	6,100
Total	36,250

The relevant emissions factors used in the IS Materials Calculator were as follows:

- Aggregate – referenced to 'Gravel, crushed, at mine/CH U/AusSD U'
- Concrete – referenced to 'ISCA Calculator 40MPa concrete 0%SCM' (with the higher strength grade used as a conservative assumption)
- Steel – referenced to 'Worldsteel data, global Plate, C2G, GLO S & Welding, arc, steel/RER U/AusSD U'

This resulted in a total of 9,790 tCO₂e GHG emissions:

- Aggregate – 40 tCO₂e (Scope 3)
- Concrete – 4,611 tCO₂e (Scope 3)
- Steel – 14,177 tCO₂e (Scope 3)

C.1.3 Construction material transport

Transport of construction materials to site was determined by assuming the following transport distances:

- Aggregate – 60 km (one way) by road (assumed local supply)
- Concrete – 60 km (one way) by road (assumed local supply)
- Steel – 9,617 km by ship from China (assumed Shanghai) to Melbourne, and 150 km by road from Melbourne to site

Emissions factors for material transport were derived from DBEIS (2017) for the following transport types:

- Articulated truck (>33t) 100% Laden
- General Cargo Ship (Average)

Emissions factors referencing transport in tonne kilometres (i.e. scaling the emissions to transport of one tonne one kilometre) and multiplying by the tonnage carried and distance were used from this source. This resulted in the following Scope 3 emissions:

- Aggregate Transport – 25 tCO₂e (Scope 3)
- Concrete Transport – 83 tCO₂e (Scope 3)
- Steel Transport – 831 tCO₂e (Scope 3)
- A total of 940 tCO₂e GHG emissions (Scope 3)

C.1.4 Vegetation clearance (loss of carbon sink)

Vegetation clearance was calculated using the vegetation removal calculation method provided in TAGG (2013). This tool assigns default values for loss of carbon sink for regions of Australia based on tonnes dry matter per hectare, and specific vegetation classes. As the land the project will be constructed upon was previously cleared, no vegetation clearance will occur as a part of the project.

C.2 Operation

This chapter outlines the calculations for energy consumption and greenhouse gas emissions resulting from operation of the EfW plant.

C.2.1 Facility emissions – waste combustion

Emissions associated with the operation of the EfW plant include:

- Direct emissions from combustion of the waste. Waste includes both fossil and biogenic source carbon, and only fossil source carbon dioxide is accounted, but fossil and biogenic source methane and nitrous oxide
- Emissions associated with ancillary fuel consumption (natural gas)

C.2.1.1 Waste combustion – carbon dioxide

For this project, the carbon dioxide emissions associated with combustion of waste are determined according to the following equation:

$$E_{\text{Com}} = C_{\text{Fossil}} \times C \rightarrow \text{CO}_2$$

Where:

- E_{Com} means the facility emissions in tCO₂e, which for this project is 184,260 tCO₂e (Scope 1)
- C_{Fossil} means the total carbon content of the waste combusted in the facility of fossil origin, in tonnes
- $C \rightarrow \text{CO}_2$ is the conversion factor for carbon to carbon dioxide (and is equal to '(1/12) * 44')

The total fossil carbon content of the waste combusted in the facility is summed from the fossil carbon content of the individual compositional parts of the waste feedstock compositional fraction 'w' and determined using the following formula:

$$C_{\text{Fossil},w} = W_{\text{MW}} \times \text{FCF} \times \text{TCF}$$

Where:

- $C_{\text{Fossil},w}$ means the total carbon content, for waste compositional fraction 'w' combusted in the facility, of fossil origin, in tonnes. The sum of this value for all compositional fractions in this project is 50,253 tonnes
- W_{MW} means the quantity of waste compositional fraction 'w' present in the waste feedstock, in tonnes. This figure has been derived from modelling undertaken and as presented in Table C.3). For this energy use and GHG assessment, it has been assumed that a split of 80% municipal solid waste (MSW) and 20% C&I waste has been targeted. The waste categories present in the compositional modelling have been amended to fit the definitions in the NGER (Measurement) Determination and the IPCC categories for waste carbon, and fossil carbon content, and are shown in Table C.3 and Table C.4
- FCF means the fossil carbon factor, which is expressed as a decimal, and represents the fossil carbon proportion of the incoming waste for waste compositional fraction 'w'. This is derived from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (Chapter 2 Waste Generation, Composition and Management Data) as shown in Table C.4. The factors used for each waste compositional fraction are shown in Table C.3. The average fossil carbon content (or total carbon content) in this assessment, across all waste compositional fractions, is approximately 43%
- TCF means the total elemental carbon proportion (by mass) of the waste compositional fraction 'w' (both fossil and biogenic origin carbon, expressed as a decimal. This is derived from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (Chapter 2 Waste Generation, Composition and Management Data) as shown in Table C.4. Appropriate values for each material were derived from the 'total carbon content in % of dry weight', and the 'dry matter content in % wet weight'. The results of this are shown in Table C.3. It should be noted that Where 'miscellaneous combustible' and 'fines' materials were categorised from the waste composition data, these have been re-categorised as 'plastics' to give a conservative estimation of the fossil carbon present. Hazardous and waste electronic materials have been categorised as 'inert' – and it should be noted that these would represent contamination only, and are not accepted feedstock to the plant

Table C.3: Waste Composition (80% MSW 20% C&I split) with total carbon and fossil carbon factors

Waste Compositional Fraction	Waste Feedstock (tonnes)	Total Carbon Factor	Fossil Carbon Factor	Fossil Carbon in Feedstock (tC / year)
Food	143,200	0.152	0	0
Paper and paper board	64,400	0.414	0.01	267
Garden and park	48,400	0.196	0	0
Wood and wood waste	3,600	0.425	0	0
Textiles	800	0.4	0.2	64
Sludge	25,200	0.239	0	0
Nappies	0	0.28	0.1	0
Rubber and Leather	0	0.5628	0.2	0
Inert Material	17,663	0.027	1	477
Plastics	65,957	0.75	1	49,445
Metals	9,670	0	0	0
Glass	20,554	0	0	0
Total	400,000			50,253

Table C.4: Default dry matter content, DOC content, total carbon content and fossil carbon fraction of different MSW components (Source 2006 IPCC Guidelines for National Greenhouse Gas Inventories (Chapter 2 Waste Generation, Composition and Management Data))

TABLE 2.4
DEFAULT DRY MATTER CONTENT, DOC CONTENT, TOTAL CARBON CONTENT AND FOSSIL CARBON FRACTION OF
DIFFERENT MSW COMPONENTS

MSW component	Dry matter content in % of wet weight ¹	DOC content in % of wet waste		DOC content in % of dry waste		Total carbon content in % of dry weight		Fossil carbon fraction in % of total carbon	
		Default	Range	Default	Range ²	Default	Range	Default	Range
Paper/cardboard	90	40	36 - 45	44	40 - 50	46	42 - 50	1	0 - 5
Textiles ³	80	24	20 - 40	30	25 - 50	50	25 - 50	20	0 - 50
Food waste	40	15	8 - 20	38	20 - 50	38	20 - 50	-	-
Wood	85 ⁴	43	39 - 46	50	46 - 54	50	46 - 54	-	-
Garden and Park waste	40	20	18 - 22	49	45 - 55	49	45 - 55	0	0
Nappies	40	24	18 - 32	60	44 - 80	70	54 - 90	10	10
Rubber and Leather	84	(39) ⁵	(39) ⁵	(47) ⁵	(47) ⁵	67	67	20	20
Plastics	100	-	-	-	-	75	67 - 85	100	95 - 100
Metal ⁶	100	-	-	-	-	NA	NA	NA	NA
Glass ⁶	100	-	-	-	-	NA	NA	NA	NA
Other, inert waste	90	-	-	-	-	3	0 - 5	100	50 - 100

¹ The moisture content given here applies to the specific waste types before they enter the collection and treatment. In samples taken from collected waste or from e.g., SWDS the moisture content of each waste type will vary by moisture of co-existing waste and weather during handling.

² The range refers to the minimum and maximum data reported by Dehoust *et al.*, 2002; Gangdonggu, 1997; Gijndehou, 2004; JESC, 2001; Jager and Blok, 1993; Würdinger *et al.*, 1997; and Zeschmar-Lahl, 2002.

³ 40 percent of textile are assumed to be synthetic (default). Expert judgement by the authors.

⁴ This value is for wood products at the end of life. Typical dry matter content of wood at the time of harvest (that is for garden and park waste) is 40 percent. Expert judgement by the authors.

⁵ Natural rubbers would likely not degrade under anaerobic condition at SWDS (Tsuchii *et al.*, 1985; Rose and Steinbüchel, 2005).

⁶ Metal and glass contain some carbon of fossil origin. Combustion of significant amounts of glass or metal is not common.

C.2.1.2 Waste combustion – methane and nitrous oxide

Methane and nitrous oxide emissions associated with combustion of waste fuel feedstock are determined in line with guidance provided in IPCC (2006). This provides standard factors for estimation of these greenhouse gases based on waste throughput. The factors are identified in Chapter 11.2.3 of the Works Approval application, and when multiplied by the intended waste throughput (400,000 tonnes per year) result in emissions of:

- Methane – 2 tCO₂e / year (Scope 1)
- Nitrous oxide – 5,602 tCO₂e / year (Scope 1)

C.2.2 Facility emissions – other fuel and electricity consumption

In addition to waste as a fuel feedstock, the project will also use natural gas on occasions when the fuel mix doesn't have sufficient calorific value to allow combustion temperatures to be maintained at the correct level. This may occur when, for example, a large quantity of waste containing garden or kitchen waste enters the combustion chamber. This is not a planned scenario, and good mixing of the waste feedstock will assist to avoid it. This value cannot be accurately predicted, but an approximate figure used in this assessment is that natural gas will represent 1% of waste throughput on an energy basis.

Assuming that the waste feedstock has an approximate calorific value of 9.5 MJ/kg, and that there is waste throughput of 400,000tpa, this would require 38,000 GJ of natural gas per year, resulting in emissions of:

- 1,953 tCO₂e / year (Scope 1)
- 148 tCO₂e / year (Scope 3)

The site will also operate a diesel generator (approximately 3-3.5 MWe output) to support operations in time of shutdown. This is not expected operation and so is maintained for non-expected periods only. The anticipated fuel consumption associated with this use is not material, and hence has been not included in the assessment.

However, it is possible that this generator will be operated during periods of peak electricity usage in the National Electricity Market to provide peaking power. The assessment assumes that this will be for approximately 24 hours per year. Based on performance statistics for a 3.6 MW CAT PRIME generator, this would result in fuel consumption of 22kL of diesel per year, resulting in the following emissions:

- 60 tCO₂e / year (Scope 1)
- 3 tCO₂e / year (Scope 3)

In addition, the generated electricity would offset emissions for the use of the electricity by others. This would be 86 MWh per year. Applying the same electricity generation emissions factor as that described in Chapter 11.2.3 of the Works Approval application for electricity generated by the EfW plant (also described later in this appendix), this would result in the following emissions offsets:

- 71 tCO₂e / year (Scope 2)

C.2.3 Logistics

Logistics modelled includes:

- Truck delivery of waste from the LGAs along the western coast of Port Phillip Bay to the facility (and return journey for trucks). Assumptions include 400,000tpa of waste delivered by truck (14,159 movements per year) of average one-way distance of 60 km. Trucks are modelled both fully laden and empty
- Truck removal of Bottom Ash (BA) to landfill in Western Melbourne – assuming that approximately 54,000 t of Bottom Ash is produced annually, with trucks travelling 65 km to landfill (and returning empty)

- Truck removal of Air Pollution Control (APC) residue to a hazardous material landfill in Dandenong South, assuming that 20,000 t APC is produced annually, and transported 115 km to landfill. Both empty outward and fully laden return is modelled
- It was assumed that no waste handling would be performed on site, with waste delivered straight to the dipping hall by truck

The results of the assessment are presented in Table C.5.

Table C.5: Logistics Operations – GHG Emissions

Stage	Total (tCO ₂ e)	Carbon Dioxide (tCO ₂ e)	Methane (tCO ₂ e)	Nitrous Oxide (tCO ₂ e)
Waste Delivery (Fully Laden) (Scope 3)	1,441	1,423	0	18
Return Journey (Empty) (Scope 3)	563	551	0	12
Transport of waste to site	2,004			
Removal of IBA to landfill (Scope 3)	211	208	0	3
Removal of APC residue / boiler ash to landfill (Scope 3)	138	136	0	2
Empty return trip for truck (Scope 3)	147	144	0	2
Transport of residues to landfill	496			
Total	2,500	2,462	0	37

C.2.4 Avoided emissions from landfill waste

Landfill baseline emissions are determined using a method adapted from the ERF *Carbon Credits (Carbon Farming Initiative—Alternative Waste Treatment) Methodology Determination 2015*

From the ERF AWT method – the following equation (*Equation 4* in the ERF AWT method) is used to determine the methane generation potential of the degradable organic carbon content in the waste feedstock to the plant:

$$M_B = \sum_w (WM_W \times DOCW \times DOCF_W) \times MCF \times WLF_{CH_4} \times FC_{\Delta CH_4}$$

Where (interpreted for this assessment):

- M_B means the methane generation potential of the degradable organic carbon content in the waste feedstock processed per year, in tonnes CH₄, which for this assessment is 24,247 tCH₄
- WM_W means the quantity of waste compositional fraction W present waste feedstock, in tonnes
- $DOCW$ means the degradable organic carbon value for waste compositional fraction w mentioned in section 5.12 of the NGER (Measurement) Determination
- $DOCF_W$ means the fraction of degradable organic carbon dissimilated for waste compositional fraction w mentioned in section 5.14A of the NGER (Measurement) Determination

- MCF means the methane correction factor for aerobic decomposition mentioned in section 5.14B of the NGER (Measurement) Determination (set as '1' for aerobic decomposition)
- $W_{LFG_{CH_4}}$ means the fraction, by volume of methane generated in landfill gas, mentioned in section 5.14C of the NGER (Measurement) Determination (set as '0.5' in accordance with the 2017 NGER (Measurement) Determination)
- $FC_{\rightarrow CH_4}$ means 1.336, being the factor to convert a mass of carbon to a mass of methane

The above formula was applied to the waste volumes assumed as feedstock to the plant (and identified in Table C.3).

The sum of the methane generation potential of each waste mix type is then converted to baseline landfill emissions using the following formula, also taken from (Equation 3 of) the ERF AWT method:

$$E_B = (1 - W_{LFG}) \times M_B \times (1 - OF_{LF}) \times GWP_{CH_4}$$

Where (interpreted for this assessment):

- E_B means the baseline Emissions, in tonnes CO₂-e, which for this assessment is 300,051 tCO₂-e (Scope 3)
- W_{LFG} means the average capture rate for methane emissions from landfill in the State or Territory in which the project is located (45% (or 0.45) for Victoria)
- M_B means the methane generation potential of the degradable organic carbon content in waste feedstock processed per year, in tonnes CH₄, worked out using the previous formula
- OF_{LF} means the oxidation factor for near surface methane in landfill mentioned in subsection 5.4(1) of the NGER (Measurement) Determination (set as '0.1' in accordance with the 2017 NGER (Measurement) Determination)
- GWP_{CH_4} means the value specified as the Global Warming Potential for methane in regulation 2.02 of the NGER Regulations (set as '25' in accordance with the 2017 NGER (Measurement) Determination)

C.2.5 Avoided emissions from displaced grid electricity

The displaced electricity emissions associated with supply of electricity to the project (and to the grid) is determined in accordance with the displaced electricity equations of the ERF *Carbon Credits (Carbon Farming Initiative – Coal Mine Waste Gas) Methodology Determination 2015*

Equation 28 of the CMWG method outlines the calculation for the displaced electricity emissions, which (edited for this project) is:

$$A_G = NEG_P \times EF_{Elec}$$

- A_G means the displaced electricity emissions from electricity production (determined for 1 year), in tonnes CO₂-e, which for this project is 209,288 tCO₂e (Scope 2)
- NEG_P means the net amount of electricity produced by electricity production devices as part of the project (determined for 1 year), in megawatt hours which for this assessment is which for this project = 255,229 MWh
- EF_{Elec} means:

for electricity supplied to an electricity grid that is a grid in relation to which the NGA Factors document, in force on the declaration day, includes an emissions factor—that factor, in kilograms CO₂-e per kilowatt hour (or its equivalent of tonnes CO₂e per megawatt hours).

Note that the Emissions Factors used for ERF methods (and for this assessment) differ from those used for annual emissions reporting, and for the National Electricity Market (including Victoria) is 0.82 tCO₂e / MWh.

The amount of electricity produced is determined in accordance with Equation 29 of the CMWG ERF Method:

$$NEG_p = TEG - \left(FSL + AUX + (DEG \times (1 - MLF)) \right)$$

Where (adapted for this assessment):

- NEG_p means the net amount of electricity produced by installed and existing electricity production devices as part of the project in the reporting period, in megawatt hours, which for this project = 255,229 MWh
- TEG means the total amount of electricity produced as part of the project in the reporting period, in megawatt hours, which for this project is 40.7MW x 90% availability x 7,884 hours = 288,791 MWh
- FSL means the amount of electricity produced using energy sources that are not solid waste by installed electricity production devices, in megawatt hours (assumed to be zero for this project – emissions from ancillary fuels used in the facility are captured separately and not subtracted here)
- AUX means the auxiliary loss for the project in the reporting period, in megawatt hours, which for this project is 4.73MW x 90% availability x 7,884 hours = 33,562 MWh
- DEG means the amount of electricity transmitted or distributed as part of the project in the reporting period (other than electricity used by installed and existing electricity production devices as part of the project or the local distribution network), in megawatt hours, which for this project is hours = 255,228 MWh
- MLF means the marginal loss factor for the project, as the majority of the electricity generated will be used on site, is set to '1'

C.2.6 Electricity carbon intensity

The carbon intensity of the electricity generated as part of the process are useful value for comparing the energy generated by the EfW plant with other forms of energy generation.

Based on total emissions direct emissions of 192,034tCO₂e / year (relating to waste and ancillary fuel combustion), the resulting carbon intensity factor for electricity production is:

- 0.75 tCO₂e/MWh for electricity

C.2.7 R1 value

As taken from EPA publication 1559.1 (Guideline: Energy from waste):

For thermal processes, proponents must demonstrate that the proposal targets genuine energy recovery. As most EfW technologies produce a fuel or gas instead of energy, the overall environmental benefits will depend not only on the thermal treatment step but also on the energy conversion technology (combustion) to which it is coupled and how much of the produced energy is used to run the overall process. The important factor in assessing any plant is therefore the overall efficiency net of any energy required to run the process. Depending on the type of facility, the thermal efficiency should be assessed as follows:

- Where waste or RDF is used as fuel replacement for co-combustion in an existing facility, the proponent must demonstrate through a mass balance that the traditional fuel required will be reduced.
- For dedicated EfW plants, the proponent should demonstrate the thermal efficiency of the proposed technology using the R1 Efficiency Indicator as defined in the European Union's WID 2008/98/EC. For a plant to be considered a genuine energy recovery facility, R1 will be expected to be equal or above 0.65. Alternatively, if R1 is below 0.65, proponents will be expected to provide a justification as to why this value cannot be reached.

$$R_1 = \frac{E_p - (E_f + E_i)}{0.97 \times (E_w + E_f)}$$

Where:

E_p = annual energy produced as heat or electricity. It is calculated with energy in the form of electricity being multiplied by 2.6 and heat produced for commercial use multiplied by 1.1 (GJ/year) which for this project is 2,853,254 GJ/year

E_f = annual energy input to the system from fuels contributing to the production of steam (GJ/year) which for this project is 10,175 GJ/year

E_w = annual energy contained in the treated waste calculated using the net calorific value of the waste (GJ/year) which for this project is 3,800,000 GJ/year

E_i = annual energy imported excluding E_w and E_f (GJ/year) which for this project is 12,215 GJ/year

0.97 = factor accounting for energy losses due to bottom ash and radiation.

This produces an R1 result of 0.77. Refer to Chapter 7.6 for further details of assumptions.

Detailed R1 calculation

1. E_p - annual energy produced as heat or electricity

Gross turbine power output based on average annual ambient temperature of 15°C and relative humidity of 65% is 40.7MWe

Plant availability factor, estimated based on experience of similar plants is 0.90

Plant operating hours per year based on the plant availability factor is total annual hours $8760 \times 0.9 = 7884$ hrs/annum

Plant Load Factor is the ratio between the actual energy generated by the plant to the maximum possible energy that can be generated with the plant working at its rated power and for a duration of an entire year. This takes into account some time during the year where the plant will not operate at 100% MCR and allows some extra capacity to catch up on waste treatment before and after overhauls or forced periods of reduced waste throughput. This is estimated as 0.95.

R1 calculation factor for energy in the form of electricity is a multiplication by 2.6

Conversion factor to convert from MWhrs to GJ/annum is 3.6

E_p = Gross turbine power * R1 calculation factor * plant load factor * annual operating hours * conversion from MWhrs to GJ/annum

$$= 40.7 \times 2.6 \times 0.95 \times 7884 \times 3.6 \quad E_p = 2,853,254 \text{ GJ/annum}$$

2. E_w - annual energy contained in the treated waste

Total waste processed at the plant is 400,000 tonnes/annum

LHV of waste design value is 9.5GJ/tonne

Total heat energy derived from waste is waste throughput * LHV = $400,000 \times 9.5$ $E_w = 3,800,000 \text{ GJ/annum}$

3. E_f - annual energy input to the system from fuels contributing to the production of steam

Percentage of auxiliary fuel consumed as a proportion of total LHV heat waste, estimated based on experience of similar plants is 0.5355% (0.005355 in the equation)

EU Waste Framework guidelines on the R1 calculation advise to assume fuel consumption at the burner during start-up and shut down periods is roughly 50% without steam being produced (E_i) and 50 % with steam production (E_f) (0.5 used in the equation for E_f)

E_f = total waste heat energy*percentage of auxiliary fuel consumed* proportion consumed with steam being produced

$$= 3,800,000*0.005355*0.5 \quad E_f = 10,175\text{GJ/annum}$$

4. E_j - annual energy imported excluding E_w and E_f

Number of plant starts and stops is estimated based on experience of similar plants to be 6 per annum with an estimated duration of 5 hours for each event.

Operating hours when energy is being imported without steam production = $6*5 = 30\text{hrs/annum}$

Percentage of auxiliary fuel consumed as a proportion of total LHV heat waste, estimated based on experience of similar plants is 0.5355% (0.005355 in the equation)

EU Waste Framework guidelines on the R1 calculation advise to assume fuel consumption at the burner during start-up and shut down periods is roughly 50% without steam being produced (E_i) and 50 % with steam production (E_f) (0.5 used in the equation for E_i).

Gas fuel energy imported when steam is not being produced = total waste heat energy*percentage of auxiliary fuel consumed* proportion consumed without steam being produced = $3,800,000*0.005355*0.5 = 10,175\text{GJ/annum}$

Electrical energy imported to the plant is estimated by the plant supplier as 15 to 17% of gross power generated. We have decided to use a conservative value of 17% in the R1 calculation. Energy imported is thus $40.7*0.17 = 6.919\text{MWe}$

R1 calculation factor for energy in the form of electricity is a multiplication by 2.6

Conversion factor to convert from MWhrs to GJ/annum is 3.6

Electrical energy imported when steam is not being generated = energy imported*hrs when steam is not being generated*R1 calculation factor*conversion from MWhrs to GJ/annum = $6.919*30*2.6*3.6 = 1,943\text{GJ/annum}$.

Fuel gas will be consumed for soot blowing of the boiler surfaces and an allowance for this can be made in the E_i calculation. The plant supplier estimates the annual consumption to be $2,825\text{Sm}^3/\text{annum}$ with a density of 0.74kg/Sm^3 and calorific value of 0.04647GJ/kg .

Fuel gas for soot blowing = consumption (Sm^3)*density (kg/Sm^3)*calorific value(GJ/kg) = $2,825*0.74*0.04647 = 97\text{GJ/annum}$

E_i = Gas fuel energy imported when steam is not being produced plus electrical energy imported when steam is not being generated plus fuel gas consumed for soot blowing

$$= 10,175+1,943+97 \quad E_i = 12,215\text{GJ/annum}$$

5. R1 – Efficiency Indicator

$$R_1 = \frac{E_p - (E_f + E_i)}{0.97 \times (E_w + E_f)}$$

$$R_1 = 2,853,254 - (10,175 + 12,215) / 0.97 * (3,800,000 + 10,175) \quad R_1 = 0.766$$