REPORT

Boston Alternative Energy Facility

Climate Change – Further Greenhouse Gas Emissions Analysis and Consideration of Waste Composition Scenarios

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Subject: **Boston Alternative Energy Facility Examination Technical Note: Climate Change – Further Greenhouse Gas Emissions Analysis and Consideration of Waste Composition Scenarios**

1 Introduction

This note has been produced to further investigate potential greenhouse gas (GHG) emissions from the operation of the proposed Boston Alternative Energy Facility (BAEF), hereby referred to as the 'Facility', when compared to the landfill disposal route for Refuse Derived Fuel (RDF) waste.

The aim of this additional assessment was to establish the potential for changes in the RDF waste composition to influence the level of GHG emissions arising from the Facility. In addition, this analysis was also undertaken to test the methodology adopted in the Environmental Statement (ES) with regard to calculating GHG emissions from the Facility compared with the landfill disposal route for RDF waste, and also to incorporate other GHGs as part of the assessment.

1.1 Background

A GHG assessment for the Facility was undertaken as part of Chapter 21 Climate Change of the ES (document reference: 6.2.21, APP-059). The assessment quantified emissions associated with activities at the Facility, including the release of GHGs from the three main stacks, transportation of RDF waste, road vehicle movements and the combustion of fuel from on-site plant. The assessment also accounted for the 'net effect' of the provision of electricity to the national grid, by displacing GHG emissions arising from Combined Cycle Gas Turbine (CCGT) electricity generation.

Emissions from the Facility were compared to two other scenarios which represent 'existing' disposal routes for the RDF waste that would be processed at the Facility, including landfill within the UK, and export to similar facilities in Europe.

The largest source of emissions from the operational phase of the Facility was predicted to be emissions associated with processing of RDF waste (see Table 21-23 of Chapter 21 'Climate Change' of the ES, document reference: 6.2.21, APP-059). Emissions from the Facility are dependent on the composition of the RDF waste that is processed, which is subject to a variety of factors including changing legislation, types of waste sources and streams, and market and consumer trends.

The GHG emissions assessment for the ES (Chapter 21 Climate Change document reference: 6.2.21, APP-059) was carried out using information and assumptions available at the time of assessment. This included the proportion of carbon dioxide (CO_2) emissions in the exhaust gas, which was provided by technology providers using an expected waste composition at the time of assessment. In addition, the effect of the provision of two CO_2 recovery plants, whereby a total of 5,000 kg of CO_2 per hour was assumed to be recovered across two lines was also incorporated into the assessment.

It was acknowledged that the GHG assessment was scenario-based, given that RDF feedstock supply will not originate from a specific source, and is subject to fluctuations depending on the factors aforementioned. One of the matters raised by the Relevant Representations to the Development Consent Order (DCO) application was the impact of changes to the composition of waste processes in Energy from Waste (EfW) facilities, with reference to a Zero Waste Scotland report (Zero Waste Scotland, 2020).

Further studies have therefore been carried out to determine the potential effect of changes to the composition of RDF waste on GHG emissions arising from the Facility. This includes the consideration of an additional methodology to calculate emissions from RDF waste processed at the Facility, and also from landfilled waste.

2 Methodology

2.1 Waste Composition

The exact sources of RDF waste that will be processed at the Facility and its composition is unknown. However, the waste provider has advised it is likely that a combination of the following waste sources will be used to supply the Facility:

- Public sector tenders;
- Commercial / industrial waste supplied by national and regional waste collection operations; and
- Residual waste from waste treatment facilities such as transfer stations and mechanical biological treatment (MBT) plants.

There has been a noticeable change in the composition of UK waste over the recent years, which is likely to continue as recycling services develop and the quantity of plastic waste reduces. Both Municipal and Commercial waste volumes are subject to separate food waste collections and this trend is likely to grow. Separate food waste collections are mainly limited to urban areas, however, it is expected that coverage will extend as infrastructure and market demands develop. The UK Government has committed to mandatory municipal food waste collections by 2023, but this could be delayed as district and borough councils are resisting due to cost concerns, particularly in rural areas.

Typically, municipal waste has a calorific value (CV) of 7 – 9 MJ/kg, but the CV rises to 8 - 10 MJ/kg with effective separate food waste collections. Uptake of recycling services is largely dependent on demographics, as recycling rates in inner city and less affluent areas are typically lower than suburban, rural and more affluent areas.

It is likely that the rise in CV directly linked to separate food waste collections will be offset to some extent by a reduction in plastic content driven by a reduction in consumption and increase in recycling. The net result of future reductions in food waste and plastic content is currently unknown, and compositional impacts are just starting to be modelled by experts in the sector.

Commercial waste average CVs have also increased in recent years. Historically, low CV Commercial Waste collected from offices, retail and the hospitality sector has been in the range of 8 - 12 MJ/kg;

however, this has increased alongside the development of commercial food waste collections and paper/card recycling. It is now reasonable to assume a CV range across this waste type of 10 – 14 MJ/kg.

Due to uncertainties in the future CV values of the waste, the additional GHG analysis has determined emissions from likely fossil and biogenic carbon contents of RDF waste, using Defra guidance, as explained in more detail in Section 2.2**Error! Reference source not found.**.

2.2 GHG Emissions from Waste Compositions in the Waste Treatment Process

The methodology adopted to calculate GHG emissions in the Climate Change chapter of the ES used information specific to the Facility, which was sourced from the technology providers. The design case for the Facility assumed a waste composition with a CV of 10.1 MJ/kg.

However, this methodology is not applicable for comparing emissions from a range of waste compositions and carbon contents. Therefore, the methodology for the additional analysis was derived from an approach detailed in Defra guidance (Defra, 2014a), which is summarised below.

The combustion of RDF waste results in the release of GHGs, the quantity of which is influenced by the carbon content of the fuel mix. The process releases both fossil and biogenic sources of carbon. In carbon calculation terms biogenic carbon sources are considered differently, and is considered to have a neutral carbon burden.

The mass of fossil derived CO_2 produced is undertaken by multiplying the mass of fossil carbon in the fuel by the ratio of the molecular weights (Mr) of CO_2 and carbon, which are 44 and 12 respectively, in accordance with the equation below:

$$CO_2\ Emisisons = Mass\ of\ C\ in * \frac{Mr\ CO_2}{Mr\ C}$$

As previously mentioned, the carbon content of waste can be derived from a range of factors, and is sensitive to the composition of the RDF waste. Therefore, to provide an overview of the potential range in GHG emissions depending on changes to the waste sector in the future, a number of different scenarios were tested.

The parameters for the assessment were obtained from Defra guidance (Defra 2014a), where waste streams with a 20 – 30% carbon content were assumed. Studies carried out for other EfW facilities assumed carbon contents within this range, including:

- Medworth EfW facility – carbon content 26.95%, of which 42.98% is fossil carbon (Medworth CHP Limited, 2021);
- Alton Advanced Energy Recovery Facility – carbon content 25.58%, of which 50.89% is fossil carbon (Alton Advanced Energy Recovery Facility, 2021)
- Cory Riverside Facility – carbon content 27%, no fossil content provided (Carbon Trust, 2017); and
- Zero Waste Scotland – carbon content 25.6%, no fossil content provided (Zero Waste Scotland, 2021).

In addition, a range of fossil and biogenic carbon proportions were tested, in accordance with the sensitivity analysis (Section 5.1) of the Defra 2014 study (Defra, 2014a). This included the following scenarios:

- A baseline composition with a 60% biogenic content;
- A composition containing around 50% biogenic content developed by halving the mass of paper, food, garden waste and wood; and
- A composition containing 40% biogenic content, developed by reducing the mass of paper, food, garden waste and wood by 25%.

Therefore, the tested scenarios aimed to account for a wide range of waste compositions (by fossil carbon content) to predict the likely minimum and maximum GHG emissions from the waste treatment options considered in the assessment. The scenarios tested as part of this assessment were therefore:

- Scenario 1 – carbon content of waste 20%, of which 40% is fossil carbon;
- Scenario 2 – carbon content of waste 20%, of which 50% is fossil carbon;
- Scenario 3 – carbon content of waste 20%, of which 60% is fossil carbon;
- Scenario 4 – carbon content of waste 30%, of which 40% is fossil carbon;
- Scenario 5 – carbon content of waste 30%, of which 50% is fossil carbon; and
- Scenario 6 – carbon content of waste 30%, of which 60% is fossil carbon.

The mass of RDF waste processed in each scenario was 1,200,000 tonnes, which is the maximum annual throughput at the Facility. The results of the additional analysis of GHG emissions from different RDF waste compositions are presented in **Table 1**.

Table 1: Waste Composition Emissions Analysis

Parameter	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
Total carbon (% by weight)	20	20	20	30	30	30
Fossil carbon (% of total carbon)	40	50	60	40	50	60
Mass of fossil carbon in waste (tonnes)	96,000	120,000	144,000	144,000	180,000	216,000
Fossil derived CO_2 emissions (tonnes)	352,000	440,000	528,000	528,000	660,000	792,000

The results in **Table 1** highlight that differing carbon contents and fossil / biogenic ratios of the RDF waste results in a wide variety of fossil derived CO_2 emissions, ranging from 352,000 to 792,000 tonnes per annum. In the ES, it was predicted that GHG emissions from the thermal treatment process at the Facility would result in 609,649 tonnes of CO_2, which included a removal of 80,000 tonnes from the CO_2 recovery plants. Therefore, predicted emissions from the Facility sits within the range of scenarios presented in this analysis.

2.3 Addition of other GHGs

The combustion of RDF waste may also generate small volumes other GHGs, namely methane (CH_4) and nitrous oxide (N_2O). These emissions are reported in units of carbon dioxide equivalent (CO_2e), which recognises that different gases have notably different global warming potential (GWP)[1]. Emissions of CH_4

[1] GWP of a GHG is a measure of how much heat is trapped by a certain amount of gas in the atmosphere relative to carbon dioxide.

and N_2O were not considered in the ES assessment, but are considered as part of this additional analysis to determine if they would have a material impact on the outcome of the assessment.

The volume of CH_4 and N_2O emissions arising from the thermal treatment process depends on combustion conditions, and additionally for N_2O, flue gas treatment procedures. This information is not specifically available for the final design of the Facility. Therefore, default emission factors were used to determine emissions of these gases, based on the volume of waste processed. CH_4 and N_2O emissions from biogenic and non-biogenic sources are considered to be a carbon burden, and therefore are added to the carbon budget.

The results in this assessment were expressed in carbon dioxide equivalent (CO_2e) which recognises that different gases have notably different global warming potential (GWP). The GWP of a GHG is a measure of how much heat is trapped by a certain amount of gas in the atmosphere relative to CO_2.

The approach to deriving emissions of CH_4 and N_2O for the 1,200,000 tonnes of RDF waste that would be processed at the Facility is presented in **Table 2**.

Table 2: CH_4 and N_2O Emissions

Parameter	Value	Units	Source
CH_4 Emission Factor	0.3	Kg CH_4 / tonne waste	IPCC Guidelines for GHG Inventories (IPCC, 2006)
N_2O Emission Factor	0.04	Kg N_2O / tonne waste	
CH_4 GWP	28	Kg CO_2e / kg CH_4	Intergovernmental Panel on Climate Change (IPCC) Guidelines, Volume 5 (IPCC, 2014)
N_2O GWP	310	Kg CO_2e / kg N_2O	
Facility CH_4 Emissions	10,880	CO_2e	Calculated Values
Facility N_2O Emissions	14,880	CO_2e	
Total CH_4 and N_2O Emissions	**24,960**	**CO_2e**	

CO_2e emissions arising from the release of CH_4 and N_2O from the thermal treatment process were predicted to be approximately 25,000 tonnes per annum. The results presented in **Table 21-25** of Chapter 21 of the ES show that annual GHG emissions from the 'Do Something' scenario in the ES were predicted to be less than the two 'Do Nothing' scenarios considered in the assessment, once the effect of providing electricity to the grid had been accounted for, as shown in **Table 3**.

Table 3: Net Annual Emissions from the Facility Compared to the 'Do Nothing' Scenarios Considered in the ES

Scenario	Annual Emissions (Tonnes CO_2e)		
	Gross Emissions	Facility Emission Contribution	Net Emissions
Scenario 1 – All Waste to Landfill	533,834	386,556	-147,278
Scenario 2 – 50% Landfill, 50% to EfW Facilities in Europe (low range)	422,635		-36,079

Scenario	Annual Emissions (Tonnes CO_2e)		
	Gross Emissions	Facility Emission Contribution	Net Emissions
Scenario 3 – 50% Landfill, 50% to EfW Facilities in Europe (low range)	632,635		-246,079

The inclusion of an additional 25,000 tonnes CO_2e from the inclusion of CH_4 and N_2O emissions would not affect this conclusion.

Therefore, the addition of CH_4 and N_2O emissions into the calculation of GHG emissions from the 'Do Something' scenario is not predicted to have a material impact on the outcome of the assessment.

2.4 Emissions from Landfill

The ES calculated emissions arising from 1,200,000 tonnes of RDF waste that would be sent to landfill per year as one of the 'existing' waste treatment pathways in the 'Do Nothing' scenarios. The approach for the assessment is provided in paragraph 21.4.27 of the ES, and the assessment used GHG emission factors for landfilled waste from the Department for Business, Energy and Industry Strategy (BEIS). These emission factors were used in the absence of a typical waste composition that would be processed at the Facility if the waste was treated at landfill.

An additional methodology, adopted from Defra (Defra, 2014a) was used to validate the assessment of emissions from landfill in the ES.

An understanding of the carbon cycle is required to fully contextualise GHG emissions from landfill. The process results in the release of biogenic carbon, which in GHG calculation terms is considered differently to fossil-based CO2, which is released after long periods of storage underground. Biogenic carbon is emissions related to the natural carbon cycle, and therefore are considered to have a neutral carbon burden.

For waste which is disposed in landfill, the biogenic carbon content degrades and produces landfill gas, comprising both CO_2 and CH_4. Some of the CH_4 in landfill gas can be recovered and combusted to produce electricity. Therefore, the sources of gas associated with landfill gas are the following:

1. CO_2;
2. CH_4; and
3. CH_4 captured and combusted to produce electricity, producing CO_2 as a result of combustion.

Sources 1 and 3 above result in the release of CO_2 from biogenic sources in the waste, and therefore can be excluded from the calculation of additional GHG emissions from the landfilled waste treatment process. The focus of the calculation therefore concerns methane released in landfill gas, which was calculated using the assumptions and procedures listed below:

- The biogenic carbon from the waste was assumed to be 50%, in accordance with the mid-range of the scenarios presented in **Section 2.2**;
- 50% of the degraded biogenic carbon is released and converted into landfill gas, which is known as the degradable decomposable organic carbon (DDOC) content:

- This assumes a sequestration rate of 50%, which is considered to be a conservative assumption by Defra (Defra 2014b);
  - There is considerable uncertainty in literature surrounding the amount of biogenic carbon that is sequestered in landfill. The high sequestration used in this assessment (50%), combined with the use of high landfill gas capture rates (assumed 68% capture) is considered to be conservative. Therefore, it is not considered appropriate to give additional credit for sequestered carbon as this would result in an overly-conservative assessment.
- Landfill gas was assumed to comprise 57% CH_4, and 43% CO_2 (Golder Associates, 2014);
- It was assumed that 68% of the landfill gas is captured, and that 10% of the remaining 32% is oxidised to CO_2 as it passes through the landfill cover layer (Golder Associates, 2014). The unoxidized landfill gas is then released to atmosphere;
- 90.9% of the captured landfill gas was assumed to be used in gas engines to generate electricity (Golder Associates, 2014). However, 1.5% of the captured landfill gas is not combusted and is released to the atmosphere. The remainder is combusted in a flare, where it was assumed that the CH_4 is fully combusted to CO_2.
- Three carbon content waste composition scenarios were tested, which are consistent with the values detailed in **Section 2.2**, as listed below:
  - Scenario A – 20% carbon content of waste;
  - Scenario B – 25% carbon content of waste; and
  - Scenario C – 30% carbon content of waste.

The assumptions for the landfill gas assessment are summarised in **Table 4** Predicted annual GHG emissions from landfilling of the 1,200,000 tonnes of RDF waste processed at the Facility are provided in **Table 5**.

Table 4: Landfill Gas Assumptions

Parameter	Value	Source
DDOC Content	50%	DEFRA Review of Landfill Methane Emissions Modelling (WR1908) (Defra 2014c)
CO_2 Percentage of Landfill Gas	43%	
CH_4 Percentage of Landfill Gas	57%	
Landfill Gas recovery efficiency	68%	
Molecular ratio of CH_4 to C	1.33	Standard Values
Molecular ratio of CO_2 to CH_4	2.75	
Molecular ratio of CO_2 to C	3.67	
CH_4 GWP	28	IPCC Fifth Assessment Report (IPCC, 2014)

Table 5: GHG Emissions from Landfill Gas According to the Carbon Content of the Waste

Parameter	Value (Tonnes)		
	Scenario A	Scenario B	Scenario C
Biogenic Carbon	120,000	150,000	180,000
Total DDOC Content	60,000	75,000	90,000
CH_4 in LFG, of which	45,468	56,858	68,229
CH_4 captured	30,930	38,663	46,396
CH_4 oxidised in landfill cap	1,456	1,819	2,183
CH_4 released to atmosphere	14,919	18,649	22,379
CH_4 leakage through gas engines	464	580	696
Total CH_4 released to atmosphere	15,383	19,229	23,075
CO_2e released to atmosphere	**430,734**	**538,418**	**646,101**

The method adopted in the ES, using the BEIS emission factors, calculated that emissions from landfilled waste would be 533,834 tonnes CO_2e per year, which is similar to Scenario 2 presented in **Table 5**. However, the figures above have not accounted for the potential grid offset from the provision of electricity from the combustion of landfill gas, which needs to be accounted for. The assumptions for calculating the grid offset figures are presented in **Table 6**.

Table 6: Landfill Gas Grid Offset Assumptions

Parameter	Value	Source
Landfill gas recovery energy	68%	DEFRA Review of Landfill Methane Emissions Modelling (WR1908) (Defra 2014c)
CH_4 captured that is used in gas engines	90.9%	
CH_4 leakage through gas engines	1.5%	
Landfill gas engine efficiency	36%	
Net calorific value	47 MJ/kg	Standard value
Grid emission factor	0.371 g / kWh	ES and BEIS, 2020.

The grid offset values, and residual emissions for landfilled gas for each scenario are presented in **Table 7.** Residual emissions were determined by deducting the quantity of CO_2e offset by the provision of electricity from the amount released to atmosphere from landfill gas (**Table 5**) for each scenario.

Table 7: Landfill Gas Grid Offset and Residual Emissions

Parameter	Scenario A	Scenario B	Scenario C
CH_4 captured, of which (tonnes)	30,930	38,663	46,396
CH_4 flared (tonnes)	2,815	3,518	4,222

Parameter	Scenario A	Scenario B	Scenario C
CH_4 leakage through gas engines (tonnes)	464	580	696
CH_4 used in gas engines (tonnes)	27,652	34,565	41,478
Fuel input to gas engines (tonnes)	1,299,637	1,624,546	1,949,455
Power generated	129,964	162,455	194,946
Total CO_2e offset (tonnes)	**48,217**	**60,271**	**72,325**
Residual Emissions (tonnes)	**382,518**	**478,147**	**573,777**

The revised methodology for calculating GHG emissions from landfilled waste highlights that the carbon content of the waste may have an influence in the outcome of the assessment. The results presented in **Table 7** highlight that GHG emissions in the ES (533,834 tonnes CO_2e per year) were towards the upper end of the range when the Defra methodology is used to calculate GHG emissions from landfilled waste.

2.5 Comparison of Scenarios

The ES concluded that it was "*likely that GHG emissions from the Facility would be lower or similar when compared to landfilled waste streams*". To test if this conclusion remains valid following the analysis of the effect of carbon content of the RDF waste, and the additional consideration of CH_4 and N_2O emissions is still valid, a comparison of the 20% and 30% carbon waste content scenarios outlined in **Sections 2.2** and **2.4** was carried out. The results are presented in **Table 8** and **Figure 1**, which include the effects of providing electricity to the grid for both waste treatment options.

Table 8: Comparison of GHG Emissions from Waste Treatment and Landfill Options with the Effect of the Provision of Electricity to the Grid

Carbon Content of RDF Waste	Thermal Treatment Minimum	Thermal Treatment Maximum	Landfill
20%	139,520	315,520	382,518
30%	315,520	579,520	573,777

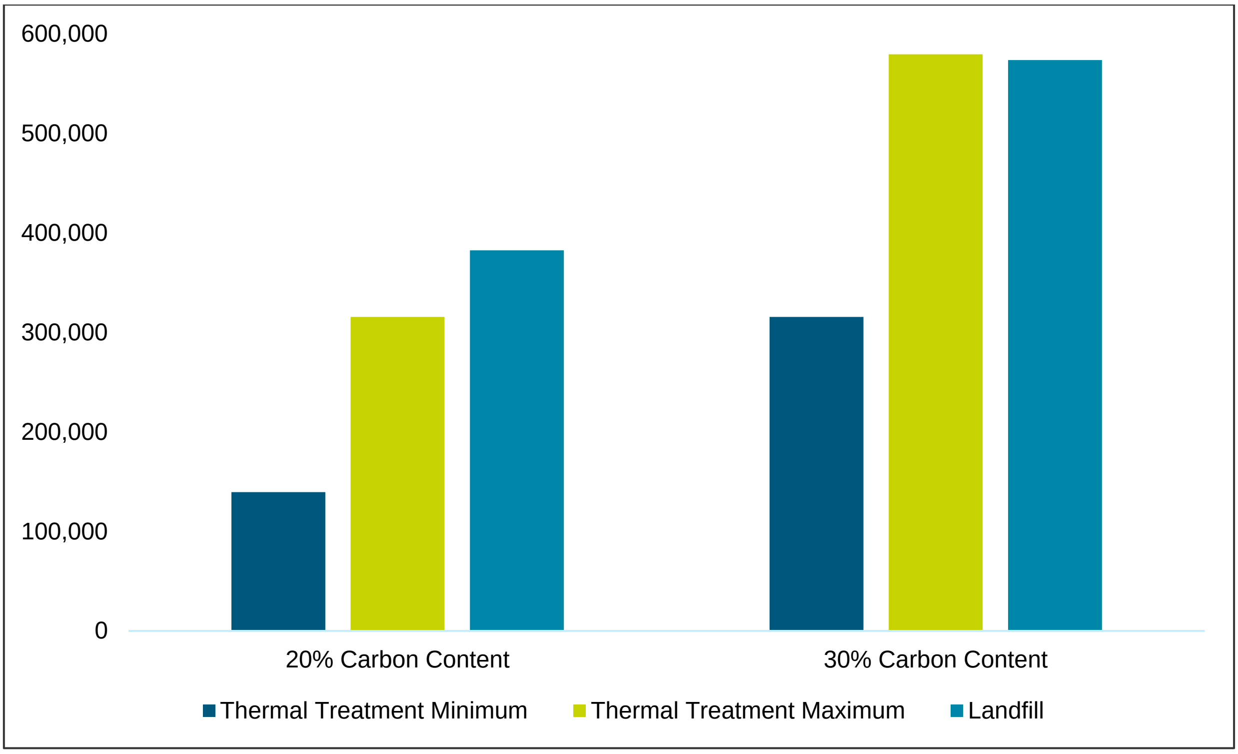

Figure 1: Comparison of GHG Emissions from Waste Treatment and Landfill Options with the Effect of the Provision of Electricity to the Grid

The results in **Table 8** highlight that the processing of waste at the proposed Facility is likely to be beneficial in GHG terms when compared to landfilling waste under most waste compositions and carbon contents.

3 Summary

This additional analysis has considered the effect of a range of carbon compositions on GHG emissions arising from the thermal treatment process for RDF waste at the Facility when compared to landfilling waste. In addition, further an additional methodology to calculate GHG emissions from both waste treatment options was adopted to determine if the conclusions presented in the ES remain valid according to differing waste compositions.

The results of the additional assessment show that the carbon composition of the waste does have a large impact on GHG emissions arising from both the thermal treatment process and landfilled waste. However, the scenarios presented in the ES sit within the range of GHG emissions presented in this additional analysis. Furthermore, the outcomes of the Climate Change chapter in the ES which states it is "*likely that GHG emissions from the Facility would be lower or similar when compared to landfilled waste streams*" remain valid.

4 References

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