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PEEL ENVIRONMENTAL

HOUGHTON MAIN ENERGY CENTRE

CARBON ASSESSMENT

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1 INTRODUCTION

1.1 Background

Peel Environmental is proposing to change the planning consent for the Houghton Main Energy Centre (the Energy Centre) from generating energy from waste derived from wood to generating energy derived from refuse derived fuel (RDF). The Energy Centre will process up to 260,000 tonnes of RDF per year to generate electricity. The Energy Centre has been designed to export up to 22 MW_{e}.

1.2 Objective

The purpose of the Carbon Assessment is to determine the relative carbon impact of processing the RDF in the Energy Centre compared to disposal in a landfill. The sensitivity of the results to changes in grid displacement factors and landfill gas recovery rates has also been assessed.

2 Conclusions

(1) The carbon emissions have been calculated for the proposed Energy Centre. This takes account of:

a) carbon dioxide released from the combustion of fossil-fuel derived carbon in the Energy Centre;

b) releases of other greenhouse gases from the combustion of waste;

c) combustion of gas oil in auxiliary burners;

d) carbon dioxide emissions from the transport of waste and residues; and

e) emissions offset from the export of electricity from the Energy Centre.

(2) These emissions have been compared with the carbon emissions from sending the same waste to landfill, taking account of:

a) the release of methane in the fraction of landfill gas which is not captured; and

b) emissions offset from the generation of electricity from landfill gas.

(3) In the base case, the Energy Centre is predicted to lead to a net reduction in greenhouse gas emissions of over 52,000 tonnes of CO_2-equivalent (CO_2e) per annum compared to the landfill counterfactual.

(4) The sensitivity of this calculation to different grid displacement factors and different landfill gas recovery rates has also been considered. The results of the sensitivities provide a net reduction of greenhouse gas emissions within a range of 20,000 to 106,000 tonnes of CO_2e emissions per annum. In all cases, processing waste in the Energy Centre is predicted to lead to a net reduction in greenhouse gases.

3 CALCULATION

3.1 Energy from waste

The combustion of waste generates direct emissions of carbon dioxide. It also produces emissions of nitrous oxide and methane, which are potent greenhouse gases. However, exporting energy to the grid offsets greenhouse gas emissions from the generation of power in other ways.

The following sections provide detail of the calculation of the carbon burdens and benefits associated with the Energy Centre. Unless otherwise specified, all values presented are on an annual basis.

3.1.1 Waste throughput and composition

Although the planning application states that the capacity of the Energy Centre would be up to 260,000 tonnes/year, the actual waste throughput would vary depending on the calorific value of the waste and the operating hours.

The design case for the Energy Centre would be an average of 240,522 tonnes/year of waste with a net calorific value (NCV) of 10 MJ/kg, assuming that the plant operates for 7,829 hours a year.

The design specification for the RDF, with this NCV, is shown below. The biogenic content of the RDF is anticipated to be 60-65%, so we have assumed 60% in this assessment to be conservative.

Table 1 - Waste characteristics

	% w/w dry	% w/w ar
Carbon	38.07	25.89
Hydrogen	5.16	3.51
Nitrogen	1.05	0.71
Sulphur	0.45	0.31
Oxygen	28.89	19.65
Chlorine	0.75	0.51
F + Br (combined)	0.07	0.05
Ash	25.56	17.37
Moisture	-	32.00

“dry" is on a dry-solids basis; "ar" is as received

3.1.2 Direct Emissions

The combustion of waste generates direct emissions of carbon dioxide, with the tonnage determined using the carbon content of the waste.

For the Carbon Assessment, only carbon dioxide emissions from fossil sources need to be considered, as carbon from biogenic sources has a neutral carbon burden.

It has been assumed that all of the carbon in the fuel is converted to carbon dioxide in the combustion process as, according to Volume 5 of the Intergovernmental Panel on Climate Change (IPCC) Guidelines for Greenhouse Gas Inventories, it can be assumed that waste incinerators have combustion efficiencies of close to 100%. The mass of fossil derived carbon dioxide produced is determined by multiplying the mass of fossil carbon in the fuel by the ratio of the molecular weights of carbon dioxide (44) and carbon (12) respectively as shown in the equation below

$$\text{Mass of CO}_2\text{ out} = \text{Mass of C in} \times \frac{\text{Mr CO}_2}{\text{Mr C}}$$

The total fossil derived carbon emissions are presented in Table 2.

Table 2 – Fossil CO_2 emissions

Item	Unit	Result
Fossil carbon in input waste	t C	24,906
Fossil derived carbon dioxide emissions	**t CO_2**	**91,323**

The process of recovering energy from waste releases a small amount of nitrous oxide and methane, which contribute to climate change. The impact of these emissions is reported as CO_2e emissions and is calculated using the Global Warming Potential (GWP) multiplier. In this assessment the GWP for 100 years has been used.

Emissions of nitrous oxide and methane depend on combustion conditions. Nitrous oxide emissions also depend on flue gas treatment. These details are based on the final design of the Energy Centre, which is not available at this stage. Therefore, at this stage default emissions factors from the IPCC have been used to determine the emissions of these gases, as shown in Table 3.

Table 3 – N_2O and CH_4 assumptions

Item	Unit	Value	Source
N_2O default emissions factor	kg N_2O/tonne waste	0.04	IPCC Guidelines for Greenhouse Gas Inventories, Vol 2, table 2.2 Default Emissions Factors for Stationary Combustion in the Energy Industries, Municipal Wastes (non-biomass) and Other Primary Solid Biomass, using a NCV of 10 MJ/kg
CH_4 default emissions factor	kg CH_4/tonne waste	0.3	
GWP - N_2O to CO_2	kg CO_2e/kg N_2O	310	United Nations Framework for Climate Change Global Warming Potentials
GWP– CH_4 to CO_2	kg CO_2e/kg CH_4	25	

Nitrous oxide and methane emissions from both the biogenic and non-biogenic fractions are considered as a carbon burden. Both the biogenic and non-biogenic fractions of waste have the same default emissions factor. Table 4 shows the emissions of nitrous oxide and methane and the equivalent carbon dioxide emissions.

Table 4 – N_2O and CH_4 emissions		
Item	**Unit**	**Results**
N_2O emissions	t N_2O	9.6
Equivalent CO_2 emissions	**t CO_2e**	**2,982**
CH_4 emissions	t CH_4	72.2
Equivalent CO_2 emissions	**t CO_2e**	**1,804**

The Energy Centre would be equipped with auxiliary burners which would burn gasoil and would have a capacity of about 60% of the boiler capacity, or 51.2 MWth. These would only be used for start-up and shutdown. We have assumed that there would be 10 start-ups a year, which is a conservative assumption, and that the burners would operate for 16 hours for each start-up and 1 hour for shut down. Hence, the total fuel consumption would be:

$$55.1 \times 10 \times 17 = 8,704.55 \text{ MWh.}$$

Each MWh of gasoil releases 0.25 tonnes of carbon dioxide, so the emissions associated with auxiliary firing would be 8,704.55 x 0.25 = 2,176 t CO_2e.

Table 5 shows the total direct equivalent carbon dioxide emissions for the combustion of waste in the Energy Centre.

Table 5 – Total equivalent CO_2 emissions from combustion of waste		
Item	**Unit**	**Results**
CO_2 emissions	t CO_2	91,323
N_2O emissions	t CO_2e	2,982
CH_4 emissions	t CO_2e	1,804
Burner emissions	t CO_2e	2,176
Total emissions	**t CO_2e**	**98,285**

3.1.3 Grid offset

Sending electricity to the grid offsets the carbon burden of producing electricity using other methods. In the case of an energy from waste plant, such as the Energy Centre, the displaced electricity would be the marginal source which is currently gas-fired power stations, for which the displacement factor is 0.35 t CO_2e/MWh.

The effect of changing the grid offset has been considered as a sensitivity in section 4.2.

The amount of carbon dioxide offset by the electricity generated by the Energy Centre is calculated by multiplying the net electricity generated by the grid displacement factor. The Energy Centre will export up to **22 MW**, including export via private wire, and the Energy Centre availability is 7,829 hours/year. The carbon dioxide offset by electricity generation is counted as a carbon benefit and is shown in Table 6.

Table 6 – Energy Centre electricity offset		
Item	**Unit**	**Results**
Net electricity export	MW	22
Net electricity exported	MWh	172,238
Total CO_2 offset through export electricity	**tonnes CO_2**	**60,283**

3.2 Landfill

When waste goes to landfill the biogenic carbon degrades and produces landfill gas (LFG). LFG is comprised of methane and carbon dioxide, so has a significant carbon burden. Some of the methane in the LFG can be recovered and combusted in a gas engine to produce electricity.

3.2.1 Emissions

The emissions associated with LFG can be split into:

(1) carbon dioxide released in LFG;

(2) methane released in LFG; and

(3) methane captured and combusted in LFG engines and flares, producing carbon dioxide as a result of the combustion.

Since (1) and (3) result in the release of carbon dioxide derived from biogenic carbon in the waste, these should both be excluded from the calculation. Therefore, the focus of this calculation is the methane which is released to atmosphere. This is calculated as follows.

(1) The biogenic carbon in the waste comes from the waste composition, discussed in section 3.1.1 above.

(2) 50% of the degraded biogenic carbon is released and converted into LFG. The released carbon is known as the dissimable biogenic carbon content.

(3) LFG is made up of 57% methane and 43% carbon dioxide, based on a detailed report carried out by Golder Associates for DEFRA[1].

(4) Based on the same report, the analysis assumes 68% of the LFG is captured and that 10% of the remaining 32% is oxidised to carbon dioxide as it passes through the landfill cover layer. The unoxidized LFG is then released to atmosphere.

(5) Based on the same guidance, 90.9% of the captured LFG is used in gas engines to generate electricity. The remainder is combusted in a flare. We have assumed that the flares fully combust the methane.

Table 7 outlines the LFG assumptions and Table 8 shows the equivalent carbon emissions associated with landfill.

[1] Review of Landfill Methane Emissions Modelling (WR1908), Golder Associates, November 2014

Table 7 – LFG assumptions		
Item	**Value**	**Source**
Dissimable biogenic carbon content	50%	DEFRA Review of Landfill Methane Emissions Modelling (WR1908) (2014)
CO_2 percentage of LFG	43%	
CH_4 percentage of LFG	57%	
LFG recovery efficiency	68%	
Molecular ratio of CH_4 to C	1.33	Standard value
Molecular ratio of CO_2 to CH_4	2.75	Standard value
Molecular ratio of CO_2 to C	3.67	
Global warming potential - CH_4 to CO_2	25	United Nations Framework for Climate Change Global Warming Potentials

Table 8 – LFG emissions		
Item	**Unit**	**Results**
Biogenic carbon	tonnes	37,359
Total dissimable carbon	tonnes	18,680
Methane in LFG, of which:	tonnes	14,197
Methane captured	tonnes	9,654
Methane oxidised in landfill cap	tonnes	454
Methane released to atmosphere directly	tonnes	4,089
Methane leakage through gas engines	tonnes	132
Total methane released to atmosphere	Tonnes	4,223
CO_2e released to atmosphere	**tonnes CO_2e**	**105,506**

3.2.2 Grid offset

The methane in the LFG that has been recovered can be used to produce electricity. This electricity will offset grid production, and results in a carbon benefit of sending waste to landfill as per section 3.1.3. The assumptions for the amount of LFG methane captured and used in a typical LFG engine are shown in Table 9.

Table 9 – LFG grid offset assumptions		
Item	**Value**	**Source**
Landfill gas recovery efficiency	68%	DEFRA Review of Landfill Methane Emissions Modelling (Nov 2014)
Methane captured used in gas Engines	90.9%	
Methane leakage through gas engines	1.5%	
Landfill gas engine efficiency	36%	
Methane net calorific value	47 MJ/kg	Standard value

The power produced by the engine is based on the amount of methane, the heat content of methane and the engine efficiency, as per the assumptions in Table 9. The power generated by the LFG engines and carbon dioxide offset are shown in Table 10.

Table 10 – LFG grid offset

Item	Unit	Results
Methane captured, of which	tonnes	9,654
Methane flared	tonnes	878
Methane leakage through gas engines	tonnes	132
Methane used in gas engines	tonnes	8,644
Fuel input to gas engines	GJ	406,285
Power generated	MWh	40,629
Total CO_2e offset through grid displacement	**t CO_2e**	**14,220**

3.3 Transport

3.3.1 Energy Centre

There are carbon emissions associated with the transport of waste to the Energy Centre, and the transport of residues (i.e. Incinerator Bottom Ash, or IBA, and Air Pollution Control residues, or APCR) from the process to their respective treatment facilities. The assumptions for determining these emissions are presented in Table 11.

Table 11 – Transport assumptions			
Parameter	**Unit**	**Value**	**Source**
Articulated lorry load size	tonnes	25	Assumption based on information from the client
Articulated lorry CO_2 factor - 100% loaded	kg CO_2/km	1.02676	BEIS "Greenhouse gas reporting: conversion factors 2017" HGV (all diesel) Articulated (>3.5- 33t)
Articulated lorry CO_2 factor - 0% loaded	kg CO_2/km	0.67711	
RDF distance to landfill (one way)	km	10	EA guidance for default WRATE (lifecycle analysis) assumptions
RDF waste distance to Energy Centre (one way)	km	50	Assumption based on information from the client
IBA distance to disposal	km	50	Provided by client
APCR distance to disposal	km	50	Provided by client
Mass of RDF	tonnes	240,522	
Mass of IBA	tonnes	47,030	Based on ash content and assuming 90% of ash content is in IBA and 25% moisture is added in the ash quench.
Mass of APCR	tonnes	8,361	

The carbon burden of transporting the waste is determined by calculating the total number of loads required and multiplying it by the transport distance to generate an annual one-way vehicle distance. This is multiplied by the respective empty and full carbon dioxide factor for HGVs to determine the overall burden of transport. It is recognised that this is conservative, as it may be possible to coordinate HGV movements to reduce the number of trips.

We have also included additional vehicle trips to transport reagents to the Energy Centre. The number of loads has been selected so that the total HGV movements per operational week is 546, which is consistent with the transport assessment.

Table 12– Transport emissions

Parameter	Unit	RDF to landfill	RDF to Energy Centre	IBA to disposal	APCR to disposal	Reagents
Waste	tonnes	240,522	240,522	46,000	8,178	-
Number of loads required		9,621	9,621	1,882	335	884
One-way distance	km	10	50	50	50	50
One-way total vehicle distance per year	km	96,210	481,050	94,100	16,750	44,200
Total CO_2 emissions	**t CO_2**	**164**	**820**	**160**	**29**	**75**

4 Results

4.1 Base Case

The results of the assessment are shown below. It can be seen that there is a net benefit of **52,364 carbon dioxide equivalent emissions per annum.**

Table 13– Summary		
Parameter	**Units**	**Results**
Releases from landfill gas	t CO_2e	105,506
Transport of waste and outputs to landfill	t CO_2e	164
Offset of grid electricity from landfill gas engines	t CO_2e	-14,220
Total landfill emissions	**t CO_2e**	**91,450**
Transport of waste to and outputs from Energy Centre	t CO_2e	1,084
Offset of grid electricity with Energy Centre generation	t CO_2e	-60,283
Emissions from Energy Centre	t CO_2e	98,285
Total Energy Centre Emissions	**t CO_2e**	**39,086**
Net Benefit of Energy Centre	**t CO_2e**	**52,364**

4.2 Sensitivities

The two key assumptions in the Carbon Assessment are the grid displacement factor for electricity and the landfill gas capture rate.

- There is some debate over the type of power which would be displaced and so we have considered the effect of using lower figures, which would only be relevant if the Energy Centre were to displace other renewable sources of electricity.
- The Golders Associates report for DEFRA states that the collection efficiency for large, modern landfill sites was estimated to be 68% and the collection efficiency for the UK as a whole was estimated to be 52%. There have been suggestions in other guidance that a conservative figure of 75% should be used. The sensitivity of the results to this assumption has also been assessed below.

Table 14 below shows the estimated net benefit of the Energy Centre, in tonnes of carbon dioxide equivalent emissions per annum, for different combinations of grid displacement factor and landfill gas capture rate. The base case is highlighted in bold. It can be seen that there is a benefit in all cases.

Table 14– Sensitivity Cases				
Grid Displacement Factor (t $CO2_e$/MWh	**LFG Capture Rate**			
	75%	**68%**	**60%**	**52%**
0.35	28,880	**52,364**	79,204	106,043
0.32	25,057	48,416	75,112	101,808
0.28	19,960	43,152	69,656	96,161

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