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PEEL ENVIRONMENTAL MANAGEMENT UK LTD & BILSTHORPE WASTE LTD

BILSTHORPE ENERGY CENTRE

CARBON ASSESSMENT

Fichtner Consulting Engineers Limited
Kingsgate (Floor 3), Wellington Road North,
Stockport, Cheshire, SK4 1LW, United Kindom
t: +44 (0)161 476 0032 f: +44 (0)161 474 0618 www.fichtner.co.uk

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Document Production & Approval Record				
ISSUE NO. 3	**NAME**	**SIGNATURE**	**POSITION**	**DATE**
Prepared by:	Timothy Overton		Project Engineer	28/10/2013
Checked by:	Stephen Othen		Technical Director	28/10/2013

Document Revision Record		
ISSUE NO.	**DATE**	**DETAILS OF REVISIONS**
1	16/10/2013	First issue to client
2	17/10/2013	Changes from client feedback
3	28/10/2013	Changes due to client alteration of input figures

Management Summary

Peel Environmental Management UK Ltd ("Peel") proposes to seek planning permission for the Bilsthorpe Energy Centre, a material recovery facility (MRF) and plasma gasification (PG) facility at Bilsthorpe. The facility is intended to process up to 117,310 tonnes/annum of waste. Of this waste, 22,310 tonnes/annum is removed prior to entering the gasifier in a materials recovery facility. Hence up to 95,000 tonnes per annum enters the plasma gasifier and is used to produce syngas which in turn is used to produce electricity.

In order to support the planning application, Fichtner Consulting Engineers has been commissioned to estimate the impact of the facility on carbon emissions.

The purpose of the carbon assessment is to determine the relative carbon impact of the proposed plasma gasification facility compared to the base case of sending 95,000 tonnes/annum of waste to landfill. We have also considered the carbon impacts of the overall facility compared to diverting 117,310 tonnes/annum to landfill.

The overall results show that the plasma gasification facility would lead to a carbon benefit of about **2,000 tonnes CO_2/annum** over the landfill base case. The combined plasma gasification and MRF facility would lead to a carbon benefit of about **8,000 tonnes CO_2/annum** over the landfill base case.

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1 INTRODUCTION

1.1 Background

Peel Environmental Management UK Ltd ("Peel") proposes to seek planning permission for a plasma gasification (PG) facility at Bilsthorpe. As part of the planning application, Peel have commissioned Fichtner Consulting Engineers Ltd to assess the effects of the proposals on greenhouse gas emissions. Peel is working with Waste2tricity on the development of this site.

This carbon assessment reviews two alternative cases in comparison to a base case.

The first case is when the waste is processed at a materials recovery facility (MRF) before transport to Bilsthorpe Energy Centre. In this case the Bilsthorpe Energy Centre will process up to 95,000 tonnes/annum of waste. The carbon releases from this case are compared with a base case where 95,000 tonnes/annum of waste is deposited in landfill.

The second case is when the waste is processed at a MRF at the Bilsthorpe Energy Centre. In this case the facility is intended to process up to 117,310 tonnes/annum of waste, with 22,310 tonnes/annum of recyclables being removed from the waste stream before the remaining 95,000 tonnes/annum is processed through the plasma gasifier. The base case for this second case is that 117,310 tonnes/annum of waste is deposited in landfill. For this second case it is assumed that of this waste 22,310 tonnes/annum is recyclable and does not contribute towards the production of landfill gas. This is a conservative base case, as it assumes that the non-metallic components of the recyclables will be mostly glass aggregates and as such will not create landfill gas or contribute to a substantial carbon benefit if recycled.

1.2 Objective

The purpose of the carbon assessment is to determine the relative carbon impact of the proposed PG and PG/MRF facility compared to base cases of sending 95,000 and 117,310 tonnes/annum of waste to landfill respectively.

2 CONCLUSIONS

The following table shows the results of our analysis. The results are broken into 4 cases:

- **Base case for PG only**: 95,000 tonnes/annum of waste sent to landfill.
- **PG only**: this case does not include an on-site MRF and so all waste is previously sorted. 95,000 tonnes/annum of waste is imported to site and enters gasifier.
- **Base case for PG with MRF**: 117,310 tonnes/annum of waste including recyclables sent to landfill.
- **PG with MRF**: 117,310 tonnes/annum of waste is sorted on site and recyclables are exported. 95,000 tonnes/annum of residual waste enters gasifier.

Table 1 – Carbon Assessment Results in tonnes CO2e/annum

	Base case Landfill disposal PG only	Base case Landfill disposal PG with MRF	PG only	PG with MRF
Landfill gas releases	50,497	50,497		
Transport – waste and PG outputs	125	154	595	1,052
Emissions offset by recycling				-7,344
Electricity offset – landfill gas	-7,687	-7,687		
Electricity offset – gasifier production			-30,844	-29,772
Emissions from PG			71,088	71,088
Total	**42,936**	**42,965**	**40,838**	**35,024**
Benefit compared to base case	**N/A**	**N/A**	**2,097**	**7,941**

The overall results show that the PG only solution represents a carbon benefit of **2,097 tonnes CO_2/annum** over the landfill base case. The PG and MRF solution represents a carbon benefit of **7,941 tonnes CO_2/annum** over the landfill base case.

3 Discussion

3.1 Grid Offset

Electricity is generated in both the base case of sending waste to landfill and in the proposed PG facility. In order to calculate the carbon benefit associated with this electricity generation, it is necessary to calculate the displacement factor of the grid, which represents the carbon emissions associated with power generation at other facilities.

Our analysis assumes that both landfill gas and PG electricity generation will offset electricity produced by natural gas only. While natural gas makes up only a portion of the UK electricity mix, it is considered to be the marginal technology which is most likely to be displaced by renewable generation. The following table shows the assumptions used to calculate the grid displacement factor.

Table 2 – UK Grid Assumptions

Item	Value	Comment
Total natural gas used in electricity production – 2012	182,409 GWh	Value from *Digest of UK Energy Statistics 2013 (DUKES)*, Table 5.6
Total electricity supplied by natural gas facilities – 2012	84,755 GWh	Value from *Digest of UK Energy Statistics 2013 (DUKES)*, Table 5.6
Natural gas CO_2 emissions factor	0.185 kg CO_2/kWh_{th}	Value from *Guidelines to Defra / DECC's Greenhouse Gas Conversion Factors for Company Reporting,* July 2012, Table 10

Using the above values, the grid displacement factor for natural gas production can be calculated as **0.40 tonnes CO_2/MWh generation**.

3.2 Recyclables Offset

In the second case, in which there is a MRF on site, recyclables are exported from the facility. These recyclables will offset emissions incorporated with the production of virgin material. Only the offset of metals has been calculated as this is likely to be the largest contributor to emissions. The following table shows the ratio of the metallic components of the recyclables in terms of ferrous and non-ferrous metals. It has been assumed that all non-ferrous metal is aluminium. This assumption has been made in previous studies.

Table 3 - Recyclables Emissions Factors

Item	Value	Comment
Emissions from virgin ferrous metal production	1.6 tonnes CO2/te	Value from WRATE
Emissions from production using recycled ferrous metal	0.93 tonnes CO2/te	Value from the Bureau of International Recycling
Emissions from virgin non-ferrous metal production	10.7 tonnes CO2/te	Value from WRATE

Item	Value	Comment
Emissions from production using recycled non-ferrous metal	1 tonnes CO2/te	Value from Carbon Trust, International Carbon Flows, Aluminium.

Using the above values, the total emissions offset from the recyclables is calculated as **7,344 tonnes CO_2/annum**.

Transportation of recyclables is considered in Section 3.6.3.

3.3 Waste

The proposed facility at Bilsthorpe is intended to process 95,000 tonnes/annum of waste through the gasifier. The analysis assumes a chemical composition of the waste based on the expected waste input. This breakdown is shown in the table below.

Transportation of waste is considered in Section 3.6.1.

Table 4 - Composition of Waste Entering Gasifier

Waste component	Percentage (dry, ash-free)	Percentage (as received)
Carbon	51.43%	42.17%
Hydrogen	6.69%	5.49%
Oxygen	40.06%	32.85%
Nitrogen	1.07%	0.88%
Sulpher	0.15%	0.12%
Chlorine	0.60%	0.49%
Ash		4.00%
Moisture Content		14.00%

3.4 Landfill

3.4.1 Greenhouse Gas Emissions

Waste in landfill will degrade and release landfill gas which is partially made up of methane, a powerful greenhouse gas. The following table shows the assumptions used to calculate the carbon impact of sending waste to landfill.

Table 5 – Landfill Emission Assumptions

Item	Value	Comment
% biogenic carbon sequestered	50%	Based on recommended default value in the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, Volume 5: Waste. This biogenic carbon is assumed to not degrade, and therefore not cause landfill emissions.
Landfill gas recovery efficiency	75%	Based on the *World Bank MSW Fact Sheet for landfill gas*. Recovery values stated between 40 and 80%.
CH_4 percentage of landfill gas	55%	Value from the *Environment Agency's guidance on the management of landfill gas*.
Greenhouse gas potential – CH_4 to CO_2	25	Accepted value for the conversion of the greenhouse gas impact of methane to an equivalent CO_2 impact.

In both cases, although the total tonnage being landfilled differs, the amount of waste in the landfill that contributes towards the production of landfill gas is 95,000 tonnes/annum. This is based upon the conservative assumption that all non-metallic recyclables are non-biogenic and so will not contribute towards the production of landfill gas.

Using the above assumptions, 8,080 tonnes of methane is produced by the landfill of either 95,000 tonnes/annum of waste or 117,310 tonnes/annum of waste including recyclables. Of the 8,080 tonnes of methane, **2,020 tonnes of methane** is released directly to the atmosphere. This is equivalent to **50,497 tonnes of CO_2** released directly to the atmosphere.

3.4.2 Electricity Generation

A portion of the captured landfill gas will be used to generate electricity. This electricity will offset grid production, which is a carbon benefit of sending waste to landfill. The following tables shows the assumptions used to calculate the carbon benefit of landfill electricity generation.

Table 6 – Landfill Electricity Production Assumptions

Item	Value	Comment
% of captured CH_4 used in gas engines	65%	Based on the *Environmental Services Association Annual Report 2005/06*. The remaining captured CH_4 is assumed to have been flared rather than released directly to the atmosphere.
Net calorific value of CH_4	47 MJ/kg	Standard value for CH_4 energy content.
Landfill gas engine efficiency	38%	Based on previous experience of landfill gas engine efficiencies.

Using the above values, the electricity generation from the landfilling of 95,000 tonnes/annum of waste can be calculated as **19,284 MWh/annum**. Using the grid displacement factor described in Section 3.1, this leads to a carbon benefit of **7,687 tonnes CO_2/annum**.

3.5 Plasma Gasification Facility

3.5.1 Electricity Generation

The electricity generation of the PG is the same in both cases, but the electricity consumption on site is different, so the electricity exported is different. The figures are based upon data provided by Waste2tricity.

For the first case, using the PG facility without a MRF, the electricity exported is **77,380 MWh/annum**. Using the grid displacement factor described in Section 3.1, this leads to a carbon benefit of **30,844 tonnes CO_2/annum**.

For the second case, using the PG facility with a MRF the electricity exported is **74,690 MWh/annum**. This is lower due to the parasitic load of the MRF. Using the grid displacement factor described in Section 3.1, this leads to a carbon benefit of **29,772 tonnes CO_2/annum**.

3.5.2 Facility Emissions

The tonnage of carbon in the waste is calculated based upon the waste composition as seen in Section 3.3. The additional inputs into the gasifier have associated emission factors or carbon composition as shown in Table 7. It has been assumed that 45% of the carbon in the waste is fossil carbon. This assumption is based upon previous modelling experience. Data provided by Waste2tricity states that 7,600 tonnes of limestone and 3,800 tonnes of metallurgical coke are input into the gasifier per annum.

Table 7 - Emissions Assumptions

Item	Value	Comment
Limestone Emissions Factor	0.43971 tonnes CO_2/tonne	Value from 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 3 Industrial Processes and Product Use
Metallurgical Coke Fossil Carbon Content	91% Carbon Fossil content	Value from DOFASCO, Composition and Information on Ingredients of Metallurgical Coke

Since both cases have the same tonnage of waste entering the gasifier, the emissions in both cases are assumed to be identical. The total fossil CO_2 emissions from all inputs into the gasifier is calculated to be 70,228 tonnes CO_2/annum. The total equivalent CO_2 emissions from N_2O emissions is calculated to be 860 tonnes CO_2/annum. This leads to the total CO_2 emissions from the plant being **71,088 tonnes CO_2/annum**.

3.5.3 Other Facility Outputs

The PG facility produces up to 27,280 tonnes/annum of additional solid outputs. This consists of 23,280 tonnes/annum of slag and 4,000 tonnes/annum of other materials. These items will be inert and therefore will not produce landfill gas when landfilled. Therefore, no direct burden associated with these residues has been included.

In the case including a MRF on site, up to 22,310 tonnes/annum of recyclables are exported from the facility in addition to the above outputs.

Transportation of all outputs is considered in Section 3.6.3.

3.6 Transport

3.6.1 Waste

In the base case, the waste is transported directly to landfill. It is assumed that this transport will be in waste collection vehicles with a load size of 20 tonnes. In the base case, it is assumed that waste arising will be within 15 km of a suitable landfill site.

The carbon assessment includes two assumptions about waste transport distance.

- The first assumption is that all bulk waste travels 50 km to reach the PG facility. This is the Environmental Agency's recommended distance for in-region transport. This maximum value has been used as a conservative assumption in the carbon assessment, and it is worth noting that not all bulk waste is expected to travel this distance.
- The second assumption is that all Refuge Collection Vehicle (RCV) waste travels 50 km to reach the PG facility. This is the Environment Agency's recommended distance for in-region transport. This maximum value represents a conservative assumption, and it is worth noting that not all RCV waste is expected to travel this distance.

Waste transport differs for both of the cases in the carbon assessment.

- In the first case it is assumed that the waste has previously visited a MRF. For this reason it has been assumed that all waste transported to site is in bulk waste transport vehicles.
- In the second case it is assumed that waste is brought to the site both in bulk transport vehicles and in RCVs. The ratio of bulk waste to RCV waste was provided by Peel.

3.6.2 Additional Imports

In addition to the waste entering the facility, transport is required for the following commodities:

(1) Limestone (7,600 tonnes/annum);

(2) Metallurgical Coke (3,800 tonnes/annum); and

(3) Consumable materials (2,000 tonnes/annum).

We have assumed this transport will be in vehicles with a load size of 20 tonnes.

3.6.3 Facility Outputs

Slag and sludge from the PG facility is assumed to be transported to landfill within 50 km of the site. This distance is based on the Environmental Agency's recommended distance for regional travel. The slag is transported in articulated lorries with a load size of 20 tonnes.

The second case requires the additional output of recyclables that are removed in the MRF. The recyclables are transported in articulated lorries with a load size of 20 tonnes. The assumed export distance is 50 km. This is based on the Environmental Agency's recommended distance for in-region travel.

3.6.4 Vehicle emissions

The following table shows the emission factors used in the calculation of the transport related carbon burdens. All lorry factors have been taken from *Guidelines to Defra/DECC's Greenhouse Gas Conversion Factors for Company Reporting*, Table 7d. The car factor has been taken from *Guidelines to Defra/DECC's Greenhouse Gas Conversion Factors for Company Reporting*, Table 12.

Table 8 – Vehicle Emission Factor Assumptions

Vehicle	100% loaded CO_2 factor	0% loaded CO_2 factor
Articulated lorry (3.5 - 33 tonnes)	1.05053 kg CO_2/km	0.70359 kg CO_2/km
RCV (3.5 – 7.5 tonnes)	0.64467 kg CO_2/km	0.55011 kg CO_2/km

Vehicles transporting wastes or products are assumed to travel one direction fully loaded and make the return trip empty. Using these factors and the vehicle details described above lead to the following carbon burdens for transport of waste and outputs.

- Waste delivery – without MRF: **417 tonnes CO_2/annum**
- Waste delivery – with MRF: **776 tonnes CO_2/annum**
- Additional materials delivery: **58 tonnes CO_2/annum**
- Slag and residue transport: **120 tonnes CO_2/annum**
- Recyclables transport (with MRF): **98 tonnes CO_2/annum**

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Kingsgate (Floor 3), Wellington Road North, Stockport, Cheshire, SK4 1LW, United Kindom
t: +44 (0)161 476 0032 f: +44 (0)161 474 0618 www.fichtner.co.uk