FICHTNER

Consulting Engineers Limited

Lostock Sustainable Energy Plant

Lostock Sustainable Energy Plant Ltd

EIA Report for Proposed Increase to Waste Tonnage Throughput of the Lostock Sustainable Energy Plant

Appendix 9.1 - Carbon Assessment

ENGINEERING CONSULTING

Document approval

	Name	Signature	Position	Date
Prepared by:	Hannah Lederer		Environmental Scientist	01/07/2021
Checked by:	Stephen Othen		Technical Director	02/07/2021

Document revision record

Revision no	Date	Details of revisions	Prepared by	Checked by
R0	01/07/2021	First issue	HKL	SMO
R1	26/07/2021	Update following client comments	HKL/KLH	HKL/KLH
R2	29/07/2021	Update following client comments	HKL/KLH	HKL/KLH

Contents

1 Introduction

1.1 Background

Lostock Sustainable Energy Plant Ltd ('LSEP Ltd' or 'the Applicant') is proposing to increase the annual waste fuel throughput of the Lostock Sustainable Energy Plant ('LSEP') at Lostock Works. The LSEP is a consented energy from waste ('EfW') facility and comprises a conventional, twin line, moving grate combustion plant, for the recovery of energy from residual waste.

This appendix has been written in support of Chapter 10 – Climate Change of the Environmental Impact Assessment (EIA) Report to support the section 36 ('s.36') variation application for the LSEP. The 'Proposal' will increase the current consented waste throughput of 600,000 tonnes per annum (tpa) to 728,000 tpa, as well as increasing the consented HGV movements to allow for the increase in waste throughput proposed and extending the delivery hours. The increased throughput would take the gross generating capacity from 67.3MW (58.5MW net) to 76.9MW (69.9MW net).

Where relevant in this report, the consented scheme is typically referred to as the 'LSEP scheme as consented', while the proposed scheme is typically referred to as the 'LSEP scheme with the Proposal', to help distinguish between them.

1.2 Objective

The purpose of this Carbon Assessment is to determine the relative operational carbon impact of processing the waste at the LSEP with the Proposal, compared to disposal in a landfill. The sensitivity of the results to changes in landfill gas recovery rates and waste composition including the addition of RDF, as well as a lifetime assessment considering varying grid displacement factors has also been assessed. The carbon impacts during construction have not been taken into account as these are considered minor compared to the carbon impacts over the lifetime of the LSEP.

2 Conclusions

1. The carbon emissions have been calculated for the LSEP operating with an annual waste throughput of 728,000 tonnes (i.e. the total consented capacity of the LSEP with the Proposal). This takes account of:
   a. carbon dioxide released from the combustion of fossil-fuel derived carbon in the LSEP;
   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 LSEP.
2. These emissions have been compared with the carbon emissions from sending the same volume of waste to landfill, taking account of:
   a. the release of methane in the fraction of landfill gas (LFG) which is not captured; and
   b. emissions offset from the generation of electricity from LFG.
3. The LSEP with the Proposal is predicted to lead to a net reduction in greenhouse gas emissions of approximately **159,989 tonnes of CO_2-equivalent (tCO_2e)** per annum compared to the landfill counterfactual in the base scenario.
4. If it is assumed that the LSEP has a lifespan of 25 years, taking into account conservative changes in grid displacement factors and waste compositions over the lifetime of LSEP with the Proposal (assuming a reduction in food and plastic wastes over time) the cumulative benefit of the LSEP with the Proposal over 25 years operation is estimated to be approximately 277,383 tCO_2e.
5. The sensitivity of the carbon assessment results to different LFG recovery rates, grid displacement factors and waste composition including the processing of refuse derived fuel (RDF) has also been assessed:
   a. The results of the LFG recovery rate sensitivity analysis resulted in a net benefit of between 89,650 and 320,763 t CO_2e emissions per annum for the LSEP with the Proposal as compared to landfill.
   b. The results of the grid displacement factor sensitivity analysis resulted in a net benefit of between 118,079 and 159,989 tf CO_2e emissions per annum for the LSEP with the Proposal as compared to landfill.
   c. The sensitivity of the calculation to waste composition (specifically, the removal of plastics and biodegradable waste over time) was assessed, resulting in a net benefit of the LSEP with the Proposal within a range of 143,622 to 195,356 t CO_2e emissions per annum.
6. In all cases above, processing waste in the LSEP with the Proposal is predicted to lead to a net reduction in greenhouse gases compared to disposing of the waste in landfill.
7. Finally, the carbon benefits of the LSEP with the Proposal in comparison to the carbon benefits of the recent s36 consent have been examined. The LSEP with the Proposal has a cumulative benefit of **277,383 tCO_2e**. This is a significantly greater cumulative benefit then that of the LSEP under the existing s36 consent (190,912 tCO2e).

3 Calculation

3.1 Energy from waste

The combustion of waste generates direct emissions of carbon dioxide. It also produces emissions of nitrous oxide, which is a potent greenhouse gas. Methane may arise in minimal extents from decomposition of waste remaining in the waste bunker, however decomposition is actively avoided and so methane is not regarded to have relevant climate impacts in quantitative terms.

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 LSEP with the Proposal . Unless otherwise specified, all values presented are on an annual basis.

3.1.1 Waste throughput and composition

The design case for the LSEP with the Proposal is a throughput of 728,000 tonnes per year of waste with a design point net calorific value (NCV) of 10 MJ/kg, assuming that the plant operates for approximately 8,426 hours a year. This defines the thermal capacity of the LSEP with the Proposal.

Table 1 below shows the characteristics of the waste compositions that are relevant to the main assessment. These are the percentage carbon content; the percentage of that carbon which is derived from biogenic sources; and the NCV.

Table 1: Waste characteristics

Carbon content (% mass)	Biocarbon (% carbon)	NCV (MJ/kg)	Waste throughput (tpa)
26.12	58.38	10.0	728,000

Waste composition data has been taken from different published sources to determine a composition which best reflects the design NCV of the LSEP with the Proposal;

- "National Municipal Waste Composition, England 2017", WRAP, January 2020
  - We have used the Residual Municipal Waste composition from Table 3, which is a mixture of household and commercial waste, with some data manipulation undertaken to obtain a composition which best reflects the design NCV and recent/proposed changes in waste policy.
- "Composition analysis of Commercial and Industrial waste in Wales", WRAP Cymru, January 2020:
  - This report gives an estimate for C&I waste for 2017 and is an update of the previous 2007 report. We are not aware of a more recent report for English waste. Some data manipulation has been undertaken to obtain a composition best reflective of the design NCV and recent/proposed changes in waste policy.

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 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:

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

Table 2: Fossil CO_2 emissions

Item	Unit	LSEP with the Proposal
Fossil carbon in input waste	t C	79,124
Fossil derived carbon dioxide emissions	**t CO_2**	**290,187**

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. Default emission 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/TJ	4	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
CH_4 default emissions factor	kg CH_4/TJ	30	
GWP – N_2O to CO_2	kg CO_2e/kg N_2O	298	IPCC Forth Assessment Report (AR4) 2007 (consistent with government guidance)
GWP – CH_4 to CO_2	kg CO_2e/kg CH_4	25	IPCC Forth Assessment Report (AR4) 2007 (consistent with government guidance)

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	LSEP with the Proposal
N_2O emissions	t N_2O	29.1

Item	Unit	LSEP with the Proposal
Equivalent CO_2 emissions	**t CO_2e**	**8,678**
CH_4 emissions	t CH_4	218.4
Equivalent CO_2 emissions	**t CO_2e**	**5,460**

The LSEP with the Proposal would be equipped with auxiliary burners which would burn gasoil and would have a capacity of about 65% of boiler capacity; or approximately 156 MWth combined capacity. These would only be used for start-up and shutdown. We have assumed that there would be 10 start-ups a year and that the burners would operate for 18 hours total for start-up and shut down, which is a conservative assumption. Hence, the approximate total fuel consumption would be:

Each MWh of gasoil releases approximately 0.27[1] tonnes of carbon dioxide, so the emissions associated with auxiliary firing would be 28,080 x 0.27 = 7,671 t CO_2e.

Table 5 shows the total direct equivalent carbon dioxide emissions for the combustion of waste in the LSEP with the Proposal.

Table 5: Total equivalent CO_2 emissions from the combustion of waste

Item	Unit	LSEP with the Proposal
CO_2 emissions	t CO_2	290,187
N_2O emissions	t CO_2e	8,678
CH_4 emissions	t CO_2e	5,460
Burner emissions	t CO_2e	7,671
Total emissions	**t CO_2e**	**311,996**

3.1.3 Grid offset

The LSEP with the Proposal will generate electricity for export to the grid. Sending electricity to the grid offsets the carbon burden of producing electricity using other methods. In the case of an EfW plant, such as the LSEP with the Proposal, the displaced electricity would be the marginal source which is currently gas-fired power stations, for which the displacement factor is 0.371 t CO_2e/MWh[2]. DEFRAs *'Energy from Waste – A Guide to the Debate 2014'* (specifically, footnote 29 on page 21) states that "A gas fired power station (Combined Cycle Gas Turbine – CCGT) is a reasonable comparator as this is the most likely technology if you wanted to build a new power station today". Therefore, the assessment of grid offset uses the current marginal technology (CCGT) as a comparator.

It is considered that the construction of an EfW plant will have little or no effect on how nuclear, wind or solar plants operate when taking into account market realities, such as the phase-out of old nuclear plants and the planned construction of new plants, and the generous subsidies often associated with the development of wind and solar plants.

Current energy strategy uses nuclear power stations to operate as baseload stations run with relatively constant output over a daily and annual basis, with limited ability to ramp up and down in capacity to accommodate fluctuations in demand. Power supplied from existing nuclear power stations is relatively low in marginal cost and has the benefit of extremely low carbon dioxide

[1] DEFRA – Greenhouse gas reporting: Conversion factors 2020 (based on net CV)

[2] DEFRA – Fuel Mix Disclosure Data Table – 01/04/2019 – 31/03/2020

emissions. Wind and solar plants also have very low marginal operating costs and are supported by subsidies in many cases. This means that they will run when there is sufficient wind or sun and that this operation will be unaffected by the operation of the LSEP with the Proposal.

Combined cycle gas turbines (CCGTs) are the primary flexible electricity source. Since wind and solar are intermittent, with the electricity supplied varying from essentially zero (on still nights) to more than 16 GW (on windy or sunny days), CCGTs supply a variable amount of power. However, there are always some CCGTs running to provide power to the grid.

Gas engines, diesel engines and open cycle gas turbines also make a small contribution to the grid. These are mainly used to provide balancing services and to balance intermittent supplies. As they are more carbon intensive than CCGTs, it is more conservative to ignore these.

In addition, recent bidding of EfW plants into the capacity market mean that they are competing primarily with CCGTs, gas engines and diesel engines. It is therefore considered that CCGT is the correct comparator and may possibly be conservative.

It is acknowledged that the UK grid mix will change and decarbonise over time, and it is not disputed that the carbon benefits of the project will change over time. However, for the main assessment, it is considered reasonable to assess the benefits using the marginal technology at the time (CCGT) as the comparator. This has been confirmed by the Secretary of State on a number of recent decisions as the correct approach.

Notwithstanding the above, the effect of changing the grid offset has been considered as a sensitivity in Section 4.3. In addition, it is possible that the LSEP with the Proposal will export heat, subject to commercial and economic viability. The carbon benefits associated with the export of heat have been qualitatively considered within section **Error! Reference source not found.**

The amount of carbon dioxide offset by the electricity generated by the LSEP with the Proposal is calculated by multiplying the net electricity generated by the grid displacement factor. The LSEP with the Proposal will export approximately 69.9 MW, including export via private wire, and the availability is 8,426 hours/year. The carbon dioxide offset by electricity generation is counted as a carbon benefit and is shown in Table 6.

Table 6: LSEP with the Proposal electricity offset

Item	Unit	LSEP with the Proposal
Net electricity export	MW	69.9
Net electricity exported	MWh	588,972
Total CO_2 offset through export of electricity	**tonnes CO_2 p.a.**	**218,509**

3.2 Landfill

For waste which is disposed of in 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 Justification of baseline

Landfill has been used as the comparator as this is the primary alternative treatment route available for residual waste. This is because the UK does not have enough EfW capacity to treat all residual waste, so quite a lot of residual waste goes to landfill. This position is also relevant on a more local scale, where landfill still has a role to play in current residual waste management practice within

Cheshire, and to which the LSEP with the Proposal can offer an alternative treatment for this residual waste. If a new EfW facility is built, this means that less waste overall will be sent to landfill and therefore, at both a national and local level, the correct comparator is landfill.

In addition to the above, a report by Tolvik[3] suggests that landfill will still play a key role in providing 'balancing capacity' in the residual waste market through to 2030. In fact, the report states that it was only in 2019 that the total tonnage of residual waste sent to UK EfW facilities exceeded the tonnage sent to landfill. Therefore, it is clear that landfill still plays a large part within UK waste management practices for residual waste.

The approach to use landfill as a baseline is supported by national guidance, specifically "*Energy from Waste: A Guide to the Debate*" and "*Energy recovery for residual waste – A carbon based modelling approach*", both published by DEFRA in 2014.

Further to the above, the draft Waste Management Plan for England (DEFRA, 2020) indicates government support for efficient energy recovery from residual waste, stating that "*energy from waste is generally the best management option for waste that cannot be reused or recycled in terms of environmental impact and getting value from the waste as a resource. It plays an important role in diverting waste from landfill*".

3.2.2 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, alongside the electricity displaced by generation in LFG engines. 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 dissimilable decomposable organic carbon (DDOC) content.
    a. This assumes a sequestration rate of 50%, which is considered to be a conservative assumption and is in accordance with DEFRAs *'Energy from Waste – A Guide to the Debate'*.
    b. There is considerable uncertainty in literature surrounding the amount of biogenic carbon that is sequestered in landfill. The high sequestration used in this assessment (i.e. 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.
        i. Although the DEFRA report "*Energy recovery for residual waste - A carbon based modelling approach*" considers the impact of sequestration on the carbon model, the report notes that there was considerable uncertainty surrounding the calculation and that further work is required.

[3] UK Residual Waste: 2030 Market Review, Tolvik (2017)

ii. Changing the level of sequestration impacts on both the amount of biogenic carbon that needs to be counted on the EfW side of the model, and the amount of methane emitted on the landfill side. The calculations are described as being "*particularly sensitive to sequestration levels, with any drop in assumed sequestration significantly favouring EfW over landfill*".

iii. In addition, the report describes an additional complicating factor regarding the effect of sequestration assumptions on the LFG capture rate. The report indicates that the assumed LFG capture rates are based on a high sequestration rate, which may not be correct, and which are based on the higher end of the rates in literature. Should the sequestration rates be lower in reality, more LFG is generated than expected, resulting in lower capture rates and making the impact of landfill considerably worse. The approach used within the report (i.e. high sequestration percentage, high LFG capture rates and no additional credit for sequestered carbon), and also within this carbon assessment, is considered to be conservative, in that it will tend to favour landfill over EfW.

iv. Therefore, it is considered that the report does not support the inclusion of credit for sequestered carbon within the assessment.

3. LFG is made up of 57% methane and 43% carbon dioxide, based on a detailed report carried out by Golder Associates for DEFRA[4].

    a. Opinion is divided as to whether to use an assumption of 50% or 57% for the methane content of landfill gas. The Golder Associates report reviewed an extensive dataset from UK landfill sites and calculated that a figure of 57% should be used, stating that this figure "is based on a substantive and representative data set, and is considered to be a very reliable calculation". This figure is then used throughout the Golder Associates report to derive the other figures. It is therefore considered that 57% is the correct figure to use within this carbon assessment. However, it is acknowledged by Golders that further review of published studies may be required to explain why 50% is more commonly used as an assumption in accordance with the IPCC (2006) default values.

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.

    a. The Golder Associates report states the estimated landfill gas collection efficiency for a subset of 43 large modern landfills as 68%. For all UK landfills, the figure would be 52%. Taking this into consideration, 68% has been used as the central figure: the landfill site in the comparison scenario is considered to represent a typical modern large UK landfill site. Nevertheless, a more conservative figure of 75% has been considered for sensitivity purposes within section 4.1.1.

5. Based on the same report, 90.9% of the captured LFG is used in gas engines to generate electricity, although 1.5% of this captured LFG passes through uncombusted and is released to atmosphere. The remainder is combusted in a flare. We have assumed that the flares fully combust the methane.

    a. The DEFRA report "*Energy recovery for residual waste - A carbon based modelling approach*" assumes that, over the life of a landfill site, about 50% of the landfill gas collected is used to generate electricity, with the remainder flared. In contrast to this, the Golder Associates report estimates that around 90.9% of the landfill gas would be used to generate electricity. This does not take account of sites which do not have gas engines, but should be

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

representative of the 43 large, modern landfills for which the collection efficiency figure was derived. The Golder Associates report was produced after the DEFRA report and is more detailed, with a clearer evidence base. Therefore, we consider that the Golder Associates report supersedes the DEFRA report, and the assumption made for the amount of landfill gas used to generate electricity within the assessment is more conservative.

b. In addition to the above, the DEFRA report uses an engine efficiency of 41%, based on the gross generation efficiency of new landfill gas engines. The Golder Associates report agrees with this figure for new engines, but takes account of parasitic loads and other losses to estimate a net export efficiency of 36%. Given that, for the LSEP with the Proposal , we are using net electricity exported, it is reasonable to use the same type of efficiency for landfill gas engines.

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

Table 7: LFG assumptions

Item	Value	Source
Calorific value of methane	50 MJ/kg	BEIS "Greenhouse gas reporting: conversion factors 2021"
DDOC content *(dissimilable decomposable carbon content, i.e. biogenic carbon which is converted to landfill gas)*	50%	Review of Landfill Methane Emissions Modelling (WR1908), Golder Associates (2014)
Carbon dioxide percentage of LFG	43%	
Methane percentage of LFG	57%	
LFG recovery efficiency	68%	
Oxidisation of landfill gas in cap	10%	
Fraction of recovered landfill gas used in engines	92%	
Methane slippage through landfill gas engine	1.5%	
Landfill gas engine efficiency	36%	
Molecular ratio of methane to carbon	1.33	Standard Values
Molecular ratio of carbon dioxide to methane	2.75	
Molecular ratio of carbon dioxide to carbon	3.67	
Global Warming Potential – methane to carbon dioxide	25	IPCC Fifth Assessment Report (AR5) 2014

Table 8: LFG emissions

Item	Unit	Landfill
Biogenic carbon	tonnes	111,012
Total DDOC content	tonnes p.a.	55,506
Methane in LFG, of which:	tonnes p.a.	42,184
-Methane captured	tonnes p.a.	28,685
-Methane oxidised in landfill cap	tonnes p.a.	1,350

Item	Unit	Landfill
-Methane released to atmosphere directly	tonnes p.a.	12,149
Methane leakage through gas engines	tonnes p.a.	391
Total methane released to atmosphere	tonnes p.a.	12,540
CO_2e released to atmosphere	tonnes CO2e p.a.	313,507

The value for biogenic carbon in Table 8 above is calculated by multiplying the annual tonnage of waste by the carbon content percentage of the waste, and then again by the percentage of that carbon which is derived from biogenic sources.

3.2.3 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	50 MJ/kg	BEIS "Greenhouse gas reporting: conversion factors 2021"

The power produced by the LFG engines 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 the carbon dioxide offset are shown in Table 10.

Table 10: LFG grid offset

Item	Unit	Landfill
Methane captured, of which:	tonnes p.a.	28,685
-Methane flared	*tonnes p.a.*	2,608
-Methane leakage through gas engines	*tonnes p.a.*	*391*
-Methane used in gas engines	*tonnes p.a.*	25,686
Fuel input to gas engines	GJ	1,284,324
Power generated	MWh	128,432
Total CO_2e offset through grid displacement	**t CO_2e p.a.**	**47,648**

3.3 Transport

There are carbon emissions associated with the transport of waste and reagents to the LSEP with the Proposal, 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
Payload – waste to landfill – Articulated lorries.	tonnes	22	Project specific assumptions. Assumed split of waste between RCVs and Articulated lorries of 11% and 89% respectively.
Payload – waste to landfill – RCVs.	tonnes	8	
Payload – waste to LSEP - Articulated lorries.	tonnes	22	
Payload – waste to LSEP - RCVs	tonnes	8	
Payload – IBA to disposal/recovery	tonnes	22	Project specific assumptions
Payload – APCr to disposal/recovery	tonnes	22	
Payload – Gasoil to site	tonnes	22	
Payload – Ammonia to site	tonnes	30	
Payload – Sodium bicarbonate to site	tonnes	28	
Payload – PAC to site	tonnes	20	
Articulated lorry CO_2 factor - 100% loaded	kg CO_2/km	0.92829	BEIS "Greenhouse gas reporting: conversion factors 2021" HGV (all diesel) Articulated (>3.5- 33t)
Articulated lorry CO_2 factor - 0% loaded	kg CO_2/km	0.62342	
Waste distance to landfill (one way)	km	35	Project specific assumptions
Waste distance to LSEP (one way)	km	240	Project specific assumptions – this is the maximum distance.
IBA distance to disposal/recovery	km	50	Project specific assumptions
APCR distance to disposal/recovery	km	115	Project specific assumptions – this is the maximum distance.
Reagent distance to LSEP	km	80	Project specific assumptions – this is the maximum distance.
Mass of waste	tonnes	728,000	Project-specific assumptions
Mass of IBA*	tonnes	167,440	
Mass of APCR	tonnes	18,928	
Mass of gasoil	tonnes	433	
Mass of ammonia	tonnes	3,640	
Mass of sodium bicarbonate	tonnes	11,648	

Parameter	Unit	Value	Source
Mass of PAC	tonnes	341	

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.

The carbon emissions associated with transport are presented within Table 12.

Table 12: Transport emissions

Parameter	Unit	Waste to landfill	Waste to LSEP	IBA to disposal/ recovery	APCr to disposal/ recovery	Gasoil to LSEP	Ammonia to LSEP	Sodium bicarbonate to LSEP	PAC to LSEP
Tonnage	tonnes p.a.	728,000	728,000	167,440	18,928	433	3,640	11,648	341
Number of loads required	p.a.	36,364	36,364	7,611	861	20	122	416	18
One-way distance	km	35	240	50	115	80	80	80	80
One-way total vehicle distance per year	km	1,272,740	8,727,360	380,550	99,015	1,600	9,760	33,280	1,440
Total CO_2 emissions	**t CO_2**	**1,975**	**13,542**	**591**	**154**	**2**	**15**	**52**	**2**

4 Results

The results of the assessment are shown below. It can be seen that there is a net benefit of **159,989 tonnes** of carbon dioxide equivalent emissions per annum for the LSEP scheme with the Proposal when set against the base scenario of the waste going to landfill.

Table 13: Summary

Parameter	Units	LSEP with the Proposal
Releases from landfill gas	t CO_2e	313,507
Transport of waste and outputs to landfill	t CO_2e	1,975
Offset of grid electricity from landfill gas engines	t CO_2e	-47,648
Total landfill emissions	**t CO_2e**	**267,834**
Transport of waste to and outputs from LSEP with the Proposal	t CO_2e	14,358
Offset of grid electricity with LSEP with the Proposal generation	t CO_2e	-218,509
Emissions from the LSEP with the Proposal	t CO_2e	311,996
Total LSEP with the Proposal Emissions	**t CO_2e**	**107,845**
Net Benefit of LSEP with the Proposal	**t CO_2e**	**159,989**

Due to the relatively small value for construction phase emissions, this has not been considered any further for the purposes of this carbon assessment.

Another way of expressing the benefit of the LSEP with the Proposal is to consider the additional power generated by recovering energy rather than sending the waste to landfill and calculating the effective net carbon emissions per MWh of additional electricity exported.

1. Additional power exported = 588,972 – 128,432 = 460,540 MWh
2. Net carbon released = (311,996 + 14,358) – (313,507 + 1,975) = 10,872 tCO_2e
3. Effective carbon intensity = 10,872 ÷ 460,540 = 0.024 t CO_2e/MWh

4.1 Sensitivities

4.1.1 Refuse Derived Fuel

The exact composition of the waste to be used is not fully confirmed. There is the potential that there will be some refuse derived fuel (RDF) process at the LSEP. RDF as a fuel has a high NCV. Therefore, adding it to the waste composition will increase the overall NCV. To cover the potential scenario that some RDF is processed within the LSEP, a sensitivity analysis has been undertaken using a waste composition of 30% RDF (using waste composition data from Fichtner's previous projects) and 70% residual waste (using the same composition as the main assessment). Under this RDF scenario, the waste characteristics are now as shown in Table 14.

Table 14: Waste Characteristics – RDF scenario

Carbon content (% mass)	Biocarbon (% carbon)	NCV (MJ/kg)	Total waste throughput (tpa)
27.95	55.74	11.38	639,719

The higher NCV waste composition will result in a lower waste throughput, thereby reducing the quantity of raw materials consumed and residues generated at LSEP.

The RDF scenario uses two waste treatment alternatives; landfill, for the 70% residual waste; and export for the 30% RDF. Export assumes that RDF would otherwise be exported to a European EfW facility with CHP, which is a more accurate assumption for RDF waste. Therefore, the emissions of processing the equivalent waste in a European facility (assumed to be AEB Amsterdam), plus the additional transportation of waste via land to port, via ship to Europe and via land again to the European facility, are used as the alternative comparison for the 30% RDF waste. For the purpose of this assessment, the distances have assumed ship transport between Immingham port in the UK and Rotterdam port in the Netherlands, and road transport between Rotterdam and Amsterdam to represent an average distance between Rotterdam and EfW facilities across the Netherlands. The assumptions are presented within Table 15 below, with the transport results for the RDF in the RDF scenario presented within Table 16.

For the 70% residual waste, landfill remains the alternative comparison. The remaining tonnage, incorporating the lower overall tonnage due to a higher overall NCV, and the removal on RDF tonnage, has been used to calculate the new number of loads for the residual waste. The payloads and distances of waste and reagents to and from the LSEP remain as detailed in Table 11. Additional assumptions (new tonnages for waste, residues and reagents) for the RDF scenario are presented within Table 15 below, with the transport results for the RDF scenario presented in Table 16.

Table 15: Assumptions - RDF scenario

Parameter	Unit	Value	Source
Residual waste tonnage	tpa	447,803	Project specific assumption.
RDF waste tonnage	tpa	191,916	
Payload – waste to export – Articulated lorries.	tonnes	22	
RDF distance to Immingham port	km	220	
Ship distance – Immingham to Rotterdam	km	522	
RDF distance from Rotterdam to Amsterdam	km	104	
CO2 factor – ship journey (export)	kgCO2e/ tonne.km	0.016142	BEIS GHG conversion factors 2021 (container ship average)
Mass of waste	tonnes	639,719	Project-specific assumptions
Mass of IBA	tonnes	147,135	
Mass of APCR	tonnes	16,633	
Mass of gasoil	tonnes	433	
Mass of ammonia	tonnes	3,199	
Mass of sodium bicarbonate	tonnes	10,236	
Mass of PAC	tonnes	300	

Table 16: Transport emissions - RDF scenario

Parameter	Unit	Waste to landfill	Waste to export (vehicle emissions)	Waste to export (ship emissions)	Waste to LSEP	IBA to disposal/ recovery	APCr to disposal/ recovery	Gasoil to LSEP	Ammonia to LSEP	Sodium bicarbonate to LSEP	PAC to LSEP
Tonnage	tonnes p.a.	447,803	191,916	191,916	639,719	147,135	16,633	433	3,199	10,236	300
Number of loads required	p.a.	22,368	8,724	-	31,954	6,688	757	20	107	366	15
One-way distance	km	35	324	522	240	50	115	80	80	80	80
One-way total vehicle distance per year	km	782,880	2,826,576	-	7,668,960	334,400	87,055	1,600	8,560	29,280	1,200
Total CO_2 emissions	**t CO_2**	**1,215**	**4,386**	**1,617**	**11,900**	**519**	**135**	**2**	**13**	**45**	**2**

The emissions from processing 191,916 tonnes RDF waste in a European EfW have been based on values provided by AEB, a large waste processing facility in Amsterdam which processes a significant amount of imported RDF.

A summary of results for the RDF scenario is provided in Table 17 When RDF is included within the waste composition, there is still a net carbon benefit of **132,261 tonnes of carbon dioxide equivalent emissions per annum.**

Table 17: RDF scenario summary

Parameter	Units	LSEP with the Proposal
Releases from landfill gas	t CO_2e	192,843
Transport of waste and outputs to landfill	t CO_2e	1,215
Offset of grid electricity from landfill gas engines	t CO_2e	-29,309
Total landfill emissions	**t CO_2e**	**164,748**
Export emissions	t CO_2e	57,310
Export transport emissions	t CO_2e	6,003
Total export emissions	t CO_2e	**63,313**
Transport of waste to and outputs from LSEP	t CO_2e	12,617
Offset of grid electricity with LSEP generation	t CO_2e	-218,509
Emissions from the LSEP with the Proposal	t CO_2e	311,996
Total Emissions – LSEP with the Proposal	**t CO_2e**	**106,037**
Net Benefit of LSEP with the Proposal	**t CO_2e**	**132,261**

4.1.2 LFG capture rate

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 literature that a conservative figure of 75% should be used. The sensitivity of the results to changes in LFG capture rate has been assessed in Table 18 below.

Table 18 below shows the estimated net benefit of the LSEP with the Proposal, in tonnes of carbon dioxide equivalent emissions per annum, for different landfill gas capture rates. It can be seen that there is a benefit for all LFG capture rates assessed.

Table 18: Landfill gas capture rate sensitivity analysis

LFG capture rate	Net benefit – LSEP with the Proposal (tCO_2e)
75%	89,650
68%	159,989
60%	240,376
52%	320,763

4.1.3 Grid displacement factor

The assessment has used the grid displacement factor applicable for a CCGT, as justified in Section 3.1.3. 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 Facility were to displace other renewable sources of electricity.

Table 18 below shows the estimated net benefit of the LSEP with the Proposal, in tonnes of carbon dioxide equivalent emissions per annum, for different grid displacement factors. It can be seen that there is a benefit for all grid displacement factors assessed.

Table 19: Landfill gas capture rate sensitivity analysis

Grid displacement factor (t CO_2e/MWh)	Net benefit – LSEP with the Proposal (tCO_2e)
0.371	**159,989**
0.349	**149,857**
0.320	**136,501**
0.280	**118,079**

4.1.4 Waste composition sensitivity

Government strategy emphasises the aim to reduce the amount of both plastics and food waste in residual waste. The reduction in either of these would have opposing impacts on the waste composition: a decrease in plastic waste would create a higher biogenic waste composition and so decrease the carbon emissions and increase the net carbon benefit, whereas a decrease in food waste would create a lower biogenic waste composition and so increase the carbon emissions and decrease the net carbon benefit.

If we are to assume a similar reduction in both, the impacts of each would to some extent cancel the other out. It is difficult to predict or quantify the amount of plastics and biodegradable waste removal expected over time, without further information on waste patterns or the effectiveness of local and national waste reduction strategies. However, a quantitative waste composition sensitivity analysis has been undertaken to assess the effect of removing various fractions of plastic and food waste on the results. For the purpose of the sensitivity test, we have assessed the scenario in accordance with the design thermal capacity and electrical generation of LSEP with the Proposal. This has resulted in slight differences to the tonnages and NCV of the waste processed for the different scenarios.

Table 20: Waste composition sensitivity analysis

Parameter	Units	Original	25% less plastic	25% less food	25% less plastic and food
Waste composition					
Total landfill emissions	**t CO_2e**	267,834	284,770	258,494	261,122
Total Emissions – LSEP with	**t CO_2e**	107,845	89,414	114,872	96,466

Parameter	Units	Original	25% less plastic	25% less food	25% less plastic and food
the Proposal					
Net Benefit of LSEP with the Proposal	**t CO_2e**	159,989	195,356	143,622	164,656
Effective carbon intensity	**t CO_2e/MWh**	0.02361	-0.06083	0.06214	0.01597

It is acknowledged that retaining a relatively high biogenic carbon content in the waste fuel to be processed at the LSEP will be key in sustaining the carbon benefits of the LSEP. The DEFRA report '*Energy recovery for residual waste: A carbon based modelling approach*' states that the biogenic content of the waste should be maintained as high as possible through the removal of fossil plastics for recycling, and that increasing the biogenic content of the waste fuel and the process efficiency of a plant during its lifetime will help ensure it continues to provide a carbon benefit compared to landfill. The report does not include within the scope whether anaerobic digestion (AD) or composting of source segregated food waste is superior in environmental performance to EfW. However, in line with the hierarchy, high biogenic content in residual waste fuels needs to be driven by greater removal of fossil plastics rather than additional biogenic material, which is acknowledged and accepted.

Further analysis of projected changes in waste composition over the lifetime of the LSEP with the Proposal is presented within section 4.3.

4.2 Comparison with s36 consent

A comparison between the design of LSEP under the s36 consent and LSEP with the Proposal has been undertaken. The following design parameters have been assumed in the comparison:

- LSEP under the s36 consent: 600,000 tpa, 67.3MW gross / 58.5MW net electrical generation.
- LSEP with the Proposal: 728,000tpa, 76.9MW gross / 69.9MW net electrical generation.

Furthermore, values for reagents consumption and residue production have been scaled appropriately for the assessment of transport emissions under the s36 consent.

The results of the comparison are presented within Table 21.

Table 21: Comparison with s36 consent

Parameter	Units	LSEP with the Proposal	LSEP under S36 consent
Releases from landfill gas	t CO_2e	313,507	258,385
Transport of waste and outputs to landfill	t CO_2e	1,975	1,628
Offset of grid electricity from landfill gas engines	t CO_2e	-47,648	-39,271
Total landfill emissions	**t CO_2e**	**267,834**	**220,742**
Transport of waste to and outputs from LSEP with the Proposal	t CO_2e	14,358	11,835

Parameter	Units	LSEP with the Proposal	LSEP under S36 consent
Offset of grid electricity with LSEP with the Proposal generation	t CO_2e	-218,509	-174,559
Emissions from the LSEP with the Proposal	t CO_2e	311,996	257,440
Total LSEP with the Proposal Emissions	**t CO_2e**	**107,845**	**94,717**
Net Benefit of LSEP with the Proposal	**t CO_2e**	**159,989**	**126,025**

As can be seen from Table 21, the carbon benefits associated with LSEP with the Proposal are greater than the carbon benefits associated with LSEP under the s36 consent. This is because although the direct emissions of LSEP with the Proposal are greater due to the increased throughput, LSEP with the proposal has a greater carbon benefit associated with electricity offset (due to increased generation) and greater avoided emissions from landfill disposal of the waste.

4.3 Lifetime carbon benefit and grid displacement sensitivity analysis

The benefits discussed above within the assessment mostly relate to a single year. Within the analysis below, it is assumed that the LSEP will commence operation in 2023 and have a lifetime of at least 25 years. Therefore, the carbon benefits will accumulate over time; however, the annual benefits will also vary over time as a number of key assumptions will vary.

In this section, we have considered the lifetime benefits of the LSEP with the Proposal and compare to the LSEP under the s36 consent on an illustrative basis. We have varied a number of assumptions over time, described as follows:

1. The government's policy is to decarbonise grid electricity. The government has recently set a target to bring all greenhouse gas emissions to net zero by 2050. This means that the benefit of displacing electricity will reduce. As explained in section 3.1.3, whilst it is considered that the correct comparator at present is CCGTs and that this will remain the case for some time, for illustrative purposes we have used the long run marginal generation-based emission factors[5]. These are only relevant if the LSEP were to displace other renewable sources of electricity, and are considerably more conservative than the DEFRA grid displacement factor used in the main assessment. The long-run generation based factors start at 0.233 kg CO2e/kWh in 2023 and dropping to 0.0276 kg CO2e/kWh by 2047.
2. Waste composition will vary over time in line with government strategy, which aims to reduce the amount of both plastics and food waste in residual waste. Within the scenario below, a removal rate of approximately 2% per year for plastics (up to a maximum of 30%) and 3% per year for food waste (up to a maximum of 50%) is assumed.

The net benefit of the LSEP with the Proposal each year compared to landfill, and the cumulative benefit of the LSEP with the Proposal and LSEP under the s36 consent over time, are illustrated in Figure 1 below.

Applying these assumptions, the cumulative benefit of the LSEP scheme with the Proposal over 25 years operation is estimated to be approximately **277,383 tCO_2e**.

The cumulative benefit of LSEP scheme under the existing s36 consent over 25 years operation is estimated to be approximately **190,912 tCO2e**.

[5] Green Book supplementary guidance: valuation of energy use and greenhouse gas emissions for appraisal, BEIS, 2020

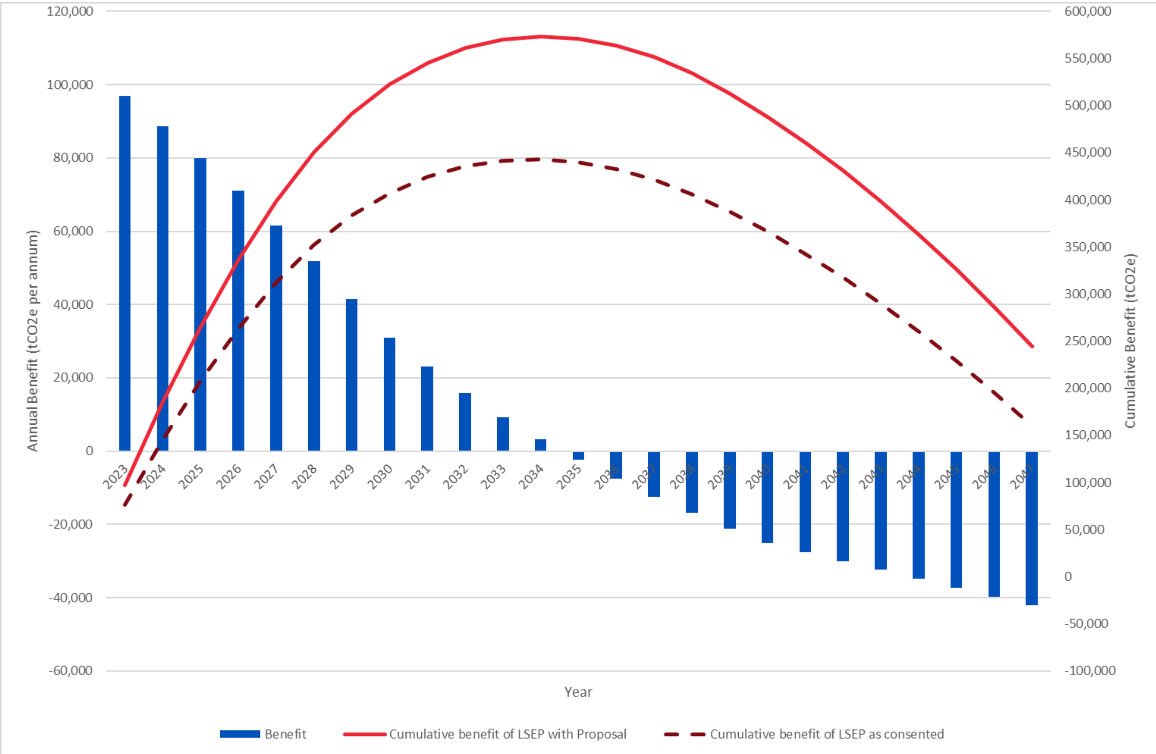
Accordingly, **the cumulative benefit of the LSEP scheme with the Proposal will be significantly greater than the LSEP scheme under the existing s36 consent.**

Although both the LSEP scheme with the Proposal and LSEP scheme under the existing s36 consent show that net disbenefits in CO2 emissions would eventually occur (over the counterfactual landfill equivalent), the cumulative carbon benefit of the LSEP for both schemes remains positive (with the LSEP with the Proposal offering a greater carbon benefit overall).

Furthermore, and in addition to the uncertainty surrounding the predictions in future waste composition, the analysis is based on the very conservative assumption that:

a) the LSEP displaces power at the long run marginal rate (which we consider to be incorrect); and
b) the LSEP does not export heat throughout its lifespan.

Figure 1: Cumulative benefit of the LSEP scheme with the Proposal and comparison with the LSEP scheme as currently consented



5 Further discussion

5.1 Potential for further carbon benefits

The export of heat from the LSEP is, at present, an economically unviable option. This has been confirmed through a recent study undertaken in July 2021. This 'Heat Demand Investigation' can be viewed in full at the appendices to the Supporting Statement of the s.36 variation application. Accordingly, heat export considerations have not been included within the main body of this assessment. However, the LSEP has been designed to be a Combined Heat and Power (CHP) ready plant, and it will therefore be possible to export heat from the LSEP if options to do so become viable in the future. If heat were to be exported, the net benefit of the LSEP will increase.

The design of the LSEP does not allow for on-site metals recovery. However, the IBA, in which there will be some metal content, will be sent offsite where it will be processed and metals removed. The recycling of these metals brings further carbon benefits compared to if the same tonnage of metals were otherwise sent to landfill.

The fuel procurement strategy and fuel contracts are not yet finalised, and there is still potential for the availability of rail borne waste to be implemented within the lifetime of LSEP. However, the option for rail as a transport mode has recently been assessed within an 'Alternative Transport Modes' report (June 2021). The report can be viewed in full at the appendices to the Supporting Statement of the s.36 variation application. The report concluded that delivery of waste to the LSEP by rail is an unviable option at present, and as such, it has not been quantitatively assessed within this assessment. However, if a proportion of waste were to be brought to LSEP site by rail, this would provide a more efficient transport route and the overall transport emissions associated with the LSEP would be reduced, hence overall carbon benefits of the scheme would increase.

5.2 Carbon and climate change policy and CCUS

As stated within Section 4.3, the UK government has recently set a target to achieve net zero emissions by 2050. Cheshire West and Cheshire Council declared a climate emergency in 2019 and have two plans to set out the associated challenges and action. They have committed to borough wide carbon neutrality by 2045.

The Committee on Climate Change (COCC) recently published a technical report[6] which sets out recommendations to the UK government on how to achieve the target of net zero carbon emissions by 2050. The CCC Report sets out how key biodegradable waste streams should be diverted from landfill within the UK alongside an increase in recycling. To achieve this and deliver substantial emissions reductions in the waste sector, the report advises that key investment is required in alternative waste treatment facilities (such as anaerobic digestion, mechanical-biological treatment and EfW). The report envisages a future generation mix where renewables dominate, which includes generation from both hydro and energy from waste plants. The continued development and investment in low carbon technologies will be key in achieving a net-zero future. The intermittency of renewables is recognised and there is support for base-load low-carbon generating plants. Consequently, EfW plants (which provide and reliable source of partially renewable energy) would play a key role in UK renewable power generation and contribute to achieving a net zero future.

[6] Net Zero Technical Report (Committee on Climate Change, 2019)

The CCC have recently (June 2021) published their most recent recommendations to the UK government on how to achieve the target of net zero carbon emissions by 2050[7].The report notes the rising contribution to overall UK emissions from EfWs and recommends the fitting of carbon capture utilisation and storage (CCUS) or carbon capture and storage (CCS).

This report recognises the benefits of CCS to the carbon emissions, but notes that CCS technologies are still being developed and are currently not economically or technically feasible for application in large-scale EfW projects. However, EfW plants may have the potential to incorporate these systems in the future.

The recently published UK Government report '*Ten Point Plan for a Green Revolution*' outlines the governments ambitions to capture 10 Mt of carbon dioxide a year by 2030. The government aims to incorporate CCS in up to four industrial clusters in areas such as the North East, the Humber, the North West, Scotland and Wales (due to their proximity to the North Sea), with CCS developed primarily alongside hydrogen plants.

Although the Ten Point Plan does not make specific reference to the incorporation of CCS with EfW, the 2020 Policy Connect report ('*No Time to Waste*'), states the following with regards EfW with CCS:

> *"Carbon Capture and Storage (CCS) technology is increasingly being trialled for different industries across the world. Recently a number of EfW plants across Europe have incorporated CCS both during the design and retrospectively"*.

Taking this into consideration, the Applicant will continue to review the feasibility of retrospectively installing a CCS system as these technologies develop, subject to commercial and economic feasibility and government schemes.

The COCC technical report from 2021[8], was only released in June 2021, and so the government has not yet published a formal response. However, the response [9] to the COCC progress report of 2020[10], identified that *"energy from waste, has a key role to play in achieving net zero"*. The response also enforced the aim to reduce volumes of biodegradable waste sent to landfill or residual treatment, with "*remaining waste will increasingly be treated by alternatives to landfill, such as energy from waste plants*". The government is also taking further steps to work towards waste prevention including developing a new tax on plastic packaging that has less than 30% recycled content and introducing a ban on the supply of plastic straws, stirrers and cotton buds. As identified in section 4.1.3, it is estimated that the LSEP will continue to provide a carbon benefit compared to landfill when taking into consideration the removal of plastics and food wastes, and section 4.3 shows that the LSEP will continue to have a positive cumulative carbon benefit over its operational lifetime

In the context of the waste hierarchy, recovery is the only other alternative destination for residual waste aside from landfill and should be favoured over disposal. There will always be residual waste remaining once materials that can be recycled or reused has been extracted. As some of the waste processed in EfW plants is biogenic/biodegradable (referred to as 'short cycle' carbon), the technology is partially renewable and considered to be a 'low-carbon' form of energy generation. As stated in section 4, the effective net carbon intensity of the LSEP with the Proposal is estimated

[7] Reducing UK emissions: 2021 Progress Report to Parliament (Committee on Climate Change, June 2021)

[8] Reducing UK emissions: 2021 Progress Report to Parliament (Committee on Climate Change, June 2021)

[9] The Government Response to the Committee on Climate Change's 2020 Progress Report to Parliament, Reducing UK emissions. Presented to Parliament pursuant to section 37 of the Climate Change act 2008 (HM Government, October 2020).

[10] Reducing UK emissions: 2020 Progress Report to Parliament (Committee on Climate Change, June 2020)

to be 0.024 t CO_2e/MWh.). The carbon intensity of a gas-fired power station, which would be displaced by the LSEP, is 0.371 t CO_2e/MWh. This demonstrates that the carbon intensity of the LSEP with the Proposal is inherently lower than fossil fuel generation when the avoidance of landfill is taken into account.

ENGINEERING CONSULTING

FICHTNER

Consulting Engineers Limited

Kingsgate (Floor 3), Wellington Road North,
Stockport, Cheshire, SK4 1LW,
United Kingdom

t: +44 (0)161 476 0032
f: +44 (0)161 474 0618

www.fichtner.co.uk