POWERFUEL

Portland energy recovery facility

Environmental statement
Technical appendices

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Carbon assessment

FICHTNER

Consulting Engineers Limited

Portland ERF

Powerfuel Portland Ltd

Carbon Assessment

ENGINEERING + CONSULTING

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1 Introduction

1.1 Background

Powerfuel Portland Ltd is proposing to build an Energy Recovery Facility (ERF) facility (the ERF) at a site within Portland Port on the Isle of Portland in Dorset.

The ERF will be a single stream design and has been designed to treat 183,000 tonnes of refuse derived fuel (RDF) per year (the nominal design capacity), with a 10% design tolerance to treat up to 202,000 tonnes per annum (the maximum capacity). The ERF will generate 18.1 MWe at the nominal design capacity with approximately 15.2 MWe available for export.

1.2 Objective

The purpose of this Carbon Assessment is to determine the relative carbon impact of processing waste in the ERF, compared to disposal in a landfill. This has been assessed at the nominal and maximum capacities. The sensitivity of the results to changes in grid displacement factors and landfill gas recovery rates has also been assessed.

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 ERF capacity to treat all residual waste, so quite a lot of residual waste goes to landfill. If a new ERF is built in the UK, this means that less waste overall will be sent to landfill and therefore, at a national level, the correct comparator is landfill. This approach 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.

It is acknowledged that residual waste produced in Dorset does not all go to landfill at present and so the specific waste which would be processed at the Portland ERF might not currently go to landfill. Therefore, as requested by Dorset Council, the relative carbon benefits of the Portland ERF compared to alternative sites for an ERF in Dorset, elsewhere in the UK and Europe have also been considered, as well as the relative carbon benefits compared to current residual waste management routes in Dorset, which are a combination of landfill and ERFs outside Dorset. However, these comparisons do not take account of the second order effects, as any ERF which is currently processing residual waste from Dorset would need to secure waste from elsewhere and it is likely that the replacement waste will currently be going to landfill.

The carbon benefits of the project can be increased by exporting heat to a district heating scheme and power to ships moored in the port. These have also been considered.

2 Conclusions

1. The carbon emissions have been calculated for the ERF. This takes account of:
    a. carbon dioxide released from the combustion of fossil-fuel derived carbon in the ERF;
    b. releases of other greenhouse gases from the combustion of waste;
    c. combustion of gas oil in auxiliary burners; and
    d. carbon dioxide emissions from the transport of waste, reagents and residues.
2. The ERF has been given credit for exporting electricity, displacing carbon emissions from other power stations. The power displacement factor used in the main assessment was obtained from the UK fuel mix table and reflects the marginal source of displaced electricity, which is currently gas-fired power stations. It is considered that the construction of the ERF would have little effect on how other renewable energy plants operate and that a gas-fired power station is a reasonable comparator for the purposes of this assessment.
3. The net emissions for the ERF (items 1 and 2) have been compared with the net 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.
4. In the base case, the ERF is predicted to lead to a net reduction in greenhouse gas emissions of approximately 21,900 tonnes of CO_2-equivalent (CO_2e) per annum compared to the landfill counterfactual if operating at the nominal design capacity. At the maximum design capacity, this increases to 34,100 tCO_2e per annum.
5. There is the potential for the benefit of the ERF to be increased.
    a. If the ERF were to export power to ships moored in Portland Port, avoiding the operation of diesel engines, then the carbon benefit of the ERF over landfill would increase by around a further 4,500 to 5,500 tCO_2e per annum.
    b. If the ERF were to export heat as well as power, the carbon benefit of the ERF over landfill would increase by around a further 3,000 tCO_2e emissions per annum.

    Hence, the overall benefit of the ERF at the nominal design capacity, while exporting heat to a district heating scheme and power to ships moored in the port, is estimated to be about 30,000 tCO_2e per annum. This would be increased if operating at the maximum design capacity.
6. The sensitivity of this calculation to different grid displacement factors and different landfill gas recovery rates has also been considered. The lower figures used in the sensitivity analysis for grid displacement factor would only be relevant if the ERF were to displace other renewable sources of electricity. The results of the sensitivities for the base case provide a net reduction of greenhouse gas emissions within a range of -6,700 to +69,200 tonnes of CO_2e emissions per annum. There is only a predicted increase in greenhouse gas emissions if there is a high landfill gas capture rate, a low grid displacement factor, no heat export and no export of power to ships, which is a very unlikely combination of circumstances.
7. The benefit of the ERF over its lifetime will vary depending on how the electricity grid develops and when shore power and district heating are implemented. However, we have included an illustrative conservative calculation which shows that the ERF could reduce greenhouse gas emissions by around 62,000 tCO_2e over its lifetime.

3 Calculations

3.1 Energy Recovery Facility

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 the decomposition of waste within the waste bunker; however, decomposition will be actively avoided, and methane is not regarded to have relevant climate impacts in quantitative terms from the ERF. In addition, combustion air will be drawn from the bunker area. This means that any methane which does form from the decomposition of waste within the bunker will be drawn into the combustion chamber and burnt. As the methane would have arisen from biodegradable waste, any carbon dioxide produced by burning that methane will also be derived from biodegradable waste. Therefore, methane arising from the decomposition of waste within the bunker has been excluded from the assessment.

Exporting energy to the grid offsets greenhouse gas emissions from the generation of power in other ways. In the case of the ERF, the displaced electricity will be the marginal source which is currently gas-fired power stations. It is considered that the construction of the ERF will not significantly affect how nuclear, wind or solar plants operate. Therefore, the use of a gas-fired power station is considered a reasonable comparator when assessing the grid offset of the ERF. This is discussed in further detail in section 3.1.3.

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

3.1.1 Waste Throughput and Composition

The ERF will be designed to process waste with a range of NCV’s in accordance with the firing diagram for the ERF. Therefore, the hourly throughput will vary in accordance with the NCV of waste that is processed. A lower NCV of waste is typically associated with a lower fossil carbon content, therefore each tonne processed will have lower associated carbon emissions.

This assessment has been undertaken based on two waste compositions. The first is based on the nominal NCV and processing capacity of the ERF while the second is based on waste with a lower NCV and increased capacity up to the design threshold.

Waste composition data has been taken from different published sources to determine a composition which best reflects the design NCV of the ERF. The waste is a mixture of Commercial and Industrial (C&I) waste and municipal waste, so data has been taken from two sources to produce the assumed waste composition for the ERF.

- WRAP Cymru: “Commercial and Industrial Waste in Wales”, January 2020. This report gives an estimate for C&I waste for 2017. We are not aware of a more recent report for English waste.
- WRAP: "National Municipal Waste Composition, England 2017", January 2020. We have used the Residual Municipal Waste composition from Table 3, which is a mixture of household and commercial waste.

We have used about one third C&I waste and two-thirds municipal waste. In both cases, since the waste is will be processed into RDF before being delivered to site, we have removed 90% of glass and WEEE and 80% of bricks and rubble from these waste compositions. We have also removed 90% of plastic bags to reflect the significant change in this waste stream since the data was collected in 2017. This gives waste with a NCV of 11 MJ/kg, which is the design NCV at the nominal design point.

For the maximum capacity case, the waste composition has been adjusted by removing 23% of the dense plastics, given the government's focus on this waste stream.

Table 1 below shows the characteristics of the assumed waste compositions that are relevant to the Carbon Assessment. We have used about one third C&I waste and two-thirds municipal waste.

Table 1: Waste characteristics

Waste Scenario	Carbon content (% mass)	Biocarbon (% carbon)	NCV (MJ/kg)	Waste throughput (tpa)
Nominal capacity	28.42	55.93	11	182,640
Maximum capacity	26.07	59.97	9.95	201,912

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 this Carbon Assessment, only carbon dioxide emissions from fossil sources (e.g. plastics) needs to be considered, as carbon from biogenic sources (e.g. paper and wood) has a neutral carbon burden. The biogenic material in the residual waste which is being processed is considered to be 'waste' material. This means that there is no requirement to consider, for example, any land use implications in producing the biogenic material as, unlike energy crops which are grown for combustion, biogenic waste already exists.

The UK Government's document "Energy from Waste: A Guide to the Debate" states, in paragraph 40, *"Considering the energy from waste route, if our black bag of waste were to go to a typical combustion-based energy from waste plant, nearly all of the carbon in the waste would be converted to carbon dioxide and be released immediately into the atmosphere. Conventionally the biogenic carbon dioxide released is ignored in this type of carbon comparison as it is considered 'short cycle', i.e. it was only relatively recently absorbed by growing matter. In contrast, the carbon dioxide released by fossil-carbon containing waste was absorbed millions of years ago and would be newly released into the atmosphere if combusted in an energy from waste plant."* For landfill, paragraph 42 states *"Burning landfill gas produces biogenic carbon dioxide which, as for energy from waste, is considered short cycle."* Therefore, this carbon assessment is in line with government guidance for exactly this type of assessment.

It has been assumed that all of the carbon in the waste 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 waste by the ratio of the molecular weights of carbon dioxide (44) and carbon (12) respectively as shown in the equation below:

$$Mass\ of\ CO_2\ out = Mass\ of\ C\ in\ \times \frac{Mr\ CO_2}{Mr\ C}$$

Where Mr = molecular weight. The total fossil derived carbon emissions are presented in Table 2.

Table 2: Fossil CO_2 emissions

Item	Unit	ERF – Nominal	ERF - Maximum
Fossil carbon in waste	t C	22,873	21,071
Fossil derived carbon dioxide emissions	**t CO_2**	**83,869**	**77,259**

The process of recovering energy from waste releases a small amount of nitrous oxide and methane (from incomplete combustion), 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 are also influenced by flue gas treatment systems and the types of reagents used. These details are based on the final design of the ERF, which is not available at this stage. Therefore, 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/tonne waste	0.044	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 11 MJ/kg
CH_4 default emissions factor	kg CH_4/tonne waste	0.33	
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	ERF – Nominal	ERF - Maximum
N_2O emissions	t N_2O	8.04	8.88
Equivalent CO_2 emissions	**t CO_2e**	**2,491**	**2,754**
CH_4 emissions	t CH_4	60.27	66.63

Item	Unit	ERF – Nominal	ERF - Maximum
Equivalent CO_2 emissions	**t CO_2e**	**1,507**	**1,666**

The ERF would be equipped with auxiliary burners which would burn gasoil and would have a capacity of about 60% of the boiler capacity; assumed to be approximately 41.86 MWth. The auxiliary burners 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 18 hours total for start-up and shut down. Hence, the approximate total fuel consumption can be calculated as follows:

$$41.86 \times 10 \times 18 = 7{,}533.9\ MWh$$

Each MWh of gasoil releases 0.25[1] tonnes of carbon dioxide, so the emissions associated with auxiliary firing would be 7533.9 x 0.25 = 1,883 t CO_2e. This is the same for both cases.

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

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

Item	Unit	ERF – Nominal	ERF - Maximum
CO_2 emissions	t CO_2	83,869	77,259
N_2O emissions	t CO_2e	2,491	2,754
CH_4 emissions	t CO_2e	1,507	1,666
Burner emissions	t CO_2e	1,883	1,883
Total emissions	**t CO_2e**	**89,751**	**83,562**

3.1.3 Grid Offset

3.1.3.1 Displacement Factor

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 ERF, the displaced electricity would be the marginal source which is currently gas-fired power stations, for which the displacement factor is 0.349 t CO_2e/MWh[2]. Electricity generated by the ERF would be exported to the National Grid. 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 as a comparator.

It is considered that the construction of the ERF 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 nuclear plants and the generous subsidies often associated with the development and operation of wind and solar plants).

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[1] DEFRA – Greenhouse gas reporting: Conversion factors 2019

[2] DEFRA – Fuel Mix Disclosure Table – 01/04/2018 – 31/03/3019

Current UK energy projections[3] indicate that nuclear power stations will continue to be used over the coming decade, but it is generally expected that there will be a reduction in the number of nuclear plants up to 2050[4]. It is understood that nuclear power stations operate as baseload stations run with relatively constant output over a daily and annual basis[5], 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 CO_2 emissions. The Committee on Climate Change (COCC's) recent report on achieving net zero by 2050[6] includes nuclear power in all scenarios for future energy generation up to 2050.

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 but increasing contribution to the grid. These are mainly used to provide balancing services by balancing intermittent supplies. As they are more carbon intensive than CCGTs, it is more conservative to ignore these.

In addition, recent bidding of energy-from-waste 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 government has recently set a target which will require the UK to bring all greenhouse gas emissions to net zero by 2050. Taking this into consideration, in the future, it is anticipated that the power which the ERF will generate will displace other forms of power generation, including renewable energy power stations. However, at this stage the mix of future generation capacity additions to the grid that might be displaced by the project is uncertain, and the emissions intensity of future displaced generation cannot be accurately quantified. Therefore, for the purposes of this assessment, it has been assumed that the ERF will displace a gas fired power station as this is considered a reasonable comparator.

In the recent decision letter on the Development Consent Order for the Riverside Energy Park, a large energy-from-waste plant (ref. EN010093, dated 9 April 2020), the secretary of state said in paragraph 4.12 that "CCGT is the appropriate counterfactual against which the Development should be assessed." This supports the approach taken in this carbon assessment.

The effect of changing the grid offset displacement factor has been considered as a sensitivity in Section 4.3.

3.1.3.2 Shore Power

It is intended that the plant will be able to export power to ships moored in Portland Port which currently run their own engines. This would cover vessels from the Royal Fleet Auxiliary (RFA) and cruise ships. The carbon intensity of ship-board power is relatively high, so displacing this type of electricity would have an increased carbon benefit compared to displacing grid power.

- Powerfuel Portland Ltd has estimated that the demand for shore power would be around 20,328 MWh in 2024, increasing to 24,423 MWh by 2045. This assumes that 60 - 65 cruise ships

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[3] https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2018

[4] National Grid's Future Energy Scenarios, 2019

[5] https://www.ofgem.gov.uk/data-portal/electricity-generation-mix-quarter-and-fuel-source-gb

[6] Committee on Climate Change, "Net Zero: the UK's contribution to stopping global warming), May 2019

visit Portland each year and the RFA ships spend 260 days in port a year, with a gradual increase in the fraction of ships which are capable to taking power from the shore.

- Ship engines have a specific diesel fuel consumption of 180 to 200 g/kWh. The carbon intensity of diesel fuel is 3,206.62 kgCO_2e/te[7]. Hence, the carbon intensity of shore power is 0.577 tCO_2e/MWh or more.

As this is not certain, we have assessed the carbon offset for the ERF with and without shore power.

3.1.3.3 Electricity only

The amount of carbon dioxide offset by the electricity generated by the ERF is calculated by multiplying the net electricity generated by the grid displacement factor. The ERF will be designed to generate 18.1 MWe and export 15.2 MWe.

The carbon dioxide offset by electricity generation is counted as a carbon benefit and is shown in Table 6 below.

Table 6: ERF electricity offset

Item	Unit	ERF - Both cases	
Net electricity export	MW	15.2	
Net electricity exported	MWh	121,600	
Total CO_2 offset through export of electricity to grid only	**tCO_2e p.a.**	**42,438**	
With Shore Power		**2024**	**2045**
Shore power output	MWh	20,328	24,423
CO_2 offset through shore power	tCO_2e p.a.	11,733	14,097
Electricity output to grid	MWh	101,272	97,177
CO_2 offset through export to grid	tCO_2e p.a.	35,344	33,915
Total CO_2 offset through exported electricity	**tCO_2e p.a.**	**47,077**	**48,012**

3.1.3.4 Heat Export

This assessment assumes that any heat output from the ERF will offset emissions from natural gas boilers. Table 7 details the assumptions for heat export. The average heat output from the ERF is assumed to be 2.29 MW, which is based on a heat network being constructed to supply the Osprey Leisure Centre, HMP The Verne, HMP YOI Portland and the Comer Homes development.

A boiler efficiency of 90% has been assumed, to determine the quantity of natural gas combusted that the exported heat would offset. This is then converted to a carbon dioxide offset by multiplying the amount of natural gas displaced by the grid displacement factor for natural gas.

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[7] DEFRA – Greenhouse gas reporting: Conversion factors 2019

The export of heat will reduce the electrical output of the Facility. The reduction in electrical output is determined using the Z ratio, which has been estimated based on guidance from the combined heat and power quality assurance (CHPQA) scheme. Assuming an average heat export of 2.29 MWth, the electrical output would be **14.85 MWe.**

Table 7: ERF heat export assumptions

Item	Value	Source
Boiler efficiency	90%	Typical boiler efficiency
Natural gas offset factor	0.20374 kg CO_2/kWh	BEIS "Greenhouse gas reporting: conversion factors 2020
Z ratio	6.6	CHPQA Guidance note 28

Table 8 details the carbon dioxide offset through natural gas offset and the reduced carbon dioxide electricity offset as a result of the lower electricity export.

Table 8: ERF heat and electricity export offset

Item	Unit	ERF – Both cases	
Heat output	MWth	2.29	
Total heat output	MWh	18,307	
Natural gas offset	MWh	20,341	
CO_2 offset through natural gas offset	**t CO_2e p.a.**	**4,144**	
Net electrical output (with heat output)	MWe	14.85	
Total electricity generated (with heat output)	MWh	118,826	
CO_2 offset through generated electricity to grid only	**t CO_2e p.a.**	**41,470**	
With Shore Power		**2024**	**2045**
Shore power output	MWh	20,328	24,423
CO_2 offset through shore power	tCO_2e p.a.	11,733	14,097
Electricity output to grid	MWh	98,498	94,403
CO_2 offset through export to grid	tCO_2e p.a.	34,376	32,947
Total CO_2 offset through exported electricity	**tCO_2e p.a.**	**46,109**	**47,043**

3.2 Landfill

When waste 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 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 degradable 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' (2014).
    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.
3. LFG is made up of 57% methane and 43% carbon dioxide, based on a detailed report carried out by Golder Associates for DEFRA[8].
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, 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.

Table 9 outlines the LFG assumptions and Table 10 shows the equivalent carbon emissions associated with landfill.

Table 9: LFG assumptions

Item	Value	Source
DDOC 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 Values
Molecular ratio of CO_2 to CH_4	2.75	
Molecular ratio of CO_2 to C	3.67	

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

Item	Value	Source
Global Warming Potential – CH_4 to CO_2	25	United Nations Framework for Climate Change Global Warming Potentials

Table 10: LFG emissions

Item	Unit	ERF – Nominal	ERF – Maximum
Biogenic carbon	tonnes	29,033	31,571
Total DDOC content (biogenic carbon not sequestered – degradable)	tonnes p.a.	14,517	15,785
Methane in LFG[9], of which:	tonnes p.a.	11,033	11,997
- Methane captured	tonnes p.a.	7,502	8,158
- Methane oxidised in landfill cap (capping material)	tonnes p.a.	353	384
- Methane released to atmosphere directly	tonnes p.a.	3,177	3,455
Methane leakage through LFG engines	tonnes p.a.	102	111
Total methane released to atmosphere	tonnes p.a.	3,280	3,566
CO_2e released to atmosphere	**tCO_2e p.a.**	**81,992**	**89,158**

The value for biogenic carbon in Table 10 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 the carbon which is derived from biogenic sources.

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 11.

Table 11: 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 LFG Engines	90.9%	
Methane leakage through LFG engines	1.5%	
LFG engine efficiency	36%	

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[9] Calculated as (Total DDOC content) x (% of landfill gas that is methane) x (molecular ratio of methane to carbon)

Item	Value	Source
Methane net calorific value	47 MJ/kg	Standard value

The power produced by the LFG engine is based on the amount of methane, the heat content of methane and the engine efficiency, as per the assumptions in Table 11. The power generated by the LFG engines and the carbon dioxide offset are shown in Table 12.

Table 12: LFG grid offset

Item	Unit	ERF – Nominal	ERF - Maximum
Methane captured, of which:	tonnes p.a.	7,502	8,158
- Methane flared	tonnes p.a.	682	742
- Methane leakage through LFG engines	tonnes p.a.	102	111
- Methane used in LFG engines	tonnes p.a.	6,718	7,305
Fuel input to LFG engines	GJ	113,665	343,334
Power generated	MWh	31,574	34,333
Total CO_2e offset through grid displacement	**t CO_2e p.a.**	**11,019**	**11,982**

3.3 Transport

There would be carbon emissions associated with the transport of waste and reagents to the ERF, and the transport of residues (i.e. Incinerator Bottom Ash (IBA) and Air Pollution Control Residues (APCr)) from the process to their respective waste treatment/disposal facilities. The assumptions for determining these emissions are presented in Table 13. These all assume that all transport is by road.

If waste and/or residues are transported by ship, then the emissions would be reduced. This is because there would be no net carbon emissions associated with sea transport because it is envisaged that this would divert RDF to Portland Port from existing shipments that currently pass through the English Channel. Therefore, this has not been considered further and the assessment of transport impacts is considered to be conservative and worst case as a proportion of the waste is expected to be delivered by ship.

Table 13: Transport assumptions

Parameter	Unit	Value	Source
Articulated lorry load size – waste to landfill	tonnes	24	Project-specific assumption. (65% by bulker, 35% by RCV)
Articulated lorry load size – waste to the ERF	tonnes	24	100% by bulker
Articulated lorry load size – Export of APCr	tonnes	27.1	Project-specific assumption
Articulated lorry load size – Export of IBA	tonnes	12	

Parameter	Unit	Value	Source
Articulated lorry load size – Import of lime	tonnes	27.5	
Articulated lorry load size – Import of activated carbon	tonnes	21	
Articulated lorry load size – Import of ammonia	tonnes	10	
Articulated lorry load size – Import of fuel oil	tonnes	32	
Articulated lorry load size – Export of ferrous metals from the ERF	tonnes	17	
Articulated lorry CO_2 factor - 100% loaded	kg CO_2/km	0.96235	BEIS "Greenhouse gas reporting: conversion factors 2020" HGV (all diesel) Articulated (>3.5- 33t)
Articulated lorry CO_2 factor - 0% loaded	kg CO_2/km	0.64607	
Waste distance to landfill (one way)	km	80	
Waste distance to the ERF (one way)	km	160	Max transport distance. See section 4.4 for sensitivity assessment on this figure.
IBA distance to recovery	km	160	Transport to Avonmouth
APCr distance to recovery	km	160	Transport to Avonmouth
Ferrous metals distance to recovery	km	5	Local outlet
Lime distance to the ERF	km	350	Transport from Buxton
Activated carbon distance to the ERF	km	300	Assumption
Ammonia distance to the ERF	km	300	Assumption
Fuel oil distance to the ERF	km	50	Assumption
		Nominal	**Maximum**
Mass of waste	tonnes	182,640	201,912
Mass of IBA (15% of waste)	tonnes	27,396	30,287
Mass of APCr (3.4% of waste)	tonnes	6,210	6,865
Mass of recovered ferrous metals (10% of ash)	tonnes	2,740	3,029
Mass of lime (estimated)	tonnes	3,700	3,700
Mass of activated carbon (estimated)	tonnes	53	53
Mass of ammonia (estimated)	tonnes	900	900
Mass of fuel oil (from earlier)	tonnes	595	595

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.

Table 14: Transport calculations

Parameter	Unit	Waste to landfill	Waste to the ERF	IBA to recovery	APCr to recovery	Lime to the ERF	Carbon to the ERF	Ammonia to the ERF	Fuel oil to the ERF	Total for ERF
ERF - Nominal										
Tonnage	tonnes p.a.	182,640	182,640	27,396	6,210	3,700	53	900	595	
Number of loads required	p.a.	7,610	7,610	2,283	230	135	3	90	19	
One-way distance	km	80	160	160	160	350	300	300	50	
One-way total vehicle distance per year	km	608,800	1,217,600	365,280	36,800	47,250	900	27,000	950	
Total CO_2 emissions	**t CO_2e p.a.**	**979.21**	**1,958.41**	**587.52**	**59.19**	**76.00**	**1.45**	**43.43**	**1.53**	**2,728**
ERF - Maximum										
Tonnage	tonnes p.a.	201,912	201,912	30,287	6,865	3,700	53	900	595	
Number of loads required	p.a.	8,414	8,414	2,524	254	135	3	90	19	
One-way distance	km	80	160	160	160	350	300	300	50	
One-way total vehicle distance per year	km	673,120	1,346,240	403,840	40,640	47,250	900	27,000	950	
Total CO_2 emissions	**t CO_2e p.a.**	**1,082.66**	**2,165.32**	**649.54**	**65.37**	**76.00**	**1.45**	**43.43**	**1.53**	**3,003**

4 Results

4.1 Energy Recovery Facility – power only

The results of the assessment are shown below. It can be seen that there is a net carbon benefit of about **21,900 tonnes of carbon dioxide equivalent emissions per annum** for the ERF compared to sending the same waste to landfill, increasing to **34,100 tonnes of carbon dioxide equivalent emissions per annum** in the maximum capacity case. These figures increase further if power is exported to ships in port.

Table 15: Summary

Parameter	Units	Nominal	Maximum
Releases from LFG	t CO_2e	81,992	89,158
Transport of waste and outputs to landfill	t CO_2e	979	1,083
Offset of grid electricity from LFG engines	t CO_2e	-11,019	-11,982
Total landfill emissions	**t CO_2e**	**71,952**	**78,259**
Transport of waste to and outputs from the ERF	t CO_2e	2,728	3,003
Offset of grid electricity with ERF generation	t CO_2e	-42,438	-42,438
Emissions from the ERF	t CO_2e	89,751	83,562
Total ERF Emissions	**t CO_2e**	**50,040**	**44,126**
Net Benefit of the ERF	**t CO_2e**	**21,912**	**34,132**
Net Benefit with shore power, 2024	t CO_2e	26,550	38,771
Net Benefit with shore power, 2045	t CO_2e	27,485	39,705

Another way of expressing the benefit of the ERF 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.

The effective net carbon emissions per MWh of additional electricity exported for the ERF is calculated as follows in the nominal case:

1. Additional power exported = 121,600 – 31,574 = 90,026 MWh
2. Net Carbon released = (89,751 + 2,728) – (81,992 + 979) = 9,507 tCO_2e
3. Effective carbon intensity = 9,507 ÷ 90,026 = 0.106 t CO_2e/MWh

A similar calculation for the maximum case gives an effective carbon intensity of -0.042 t CO_2e/MWh.

4.2 Energy Recovery Facility – CHP mode only

The results of the assessment are shown below for the plant operating in CHP mode. It can be seen that there is a net carbon benefit of about **25,100 tonnes of carbon dioxide equivalent emissions per annum** for the ERF compared to sending the same waste to landfill, which is an improvement of over **3,000 tonnes** over the power-only case. In the maximum capacity case, this increases to **37,300 tonnes of carbon dioxide equivalent emissions per annum** and further increases if power is exported to ships in port.

Table 16: Summary

Parameter	Units	Nominal	Maximum
Releases from LFG	t CO_2e	81,992	89,158
Transport of waste and outputs to landfill	t CO_2e	979	1,083
Offset of grid electricity from LFG engines	t CO_2e	-11,019	-11,982
Total landfill emissions	**t CO_2e**	**71,952**	**78,259**
Transport of waste to and outputs from the ERF	t CO_2e	2,728	3,003
Offset of boiler natural gas use	t CO_2e	-4,144	-4,144
Offset of grid electricity with ERF generation	t CO_2e	-41,470	-41,470
Emissions from the ERF	t CO_2e	89,751	83,562
Total ERF Emissions	**t CO_2e**	**46,864**	**40,950**
Net Benefit of the ERF	**t CO_2e**	**25,088**	**37,308**
Net Benefit with shore power, 2024	t CO_2e	29,271	41,444
Net Benefit with shore power, 2045	t CO_2e	30,206	42,378

Again, the effective net carbon emissions can be calculated, allowing for the benefit of displacing heat. The effective net carbon emissions per MWh of additional electricity exported for the ERF is calculated as follows:

1. Additional power exported = 118,826 – 31,574 = 87,252 MWh
2. Net Carbon released = (89,751 + 2,728 – 4,144) – (81,992 + 979) = 5,363 tCO_2e
3. Effective carbon intensity = 5,363 ÷ 87,252 = 0.061 t CO_2e/MWh

A similar calculation for the maximum case gives an effective carbon intensity of -0.093 t CO_2e/MWh.

4.3 Sensitivities

The two key assumptions in this 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 ERF 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 17 shows the estimated net benefit of the ERF (in power-only mode), in tonnes of carbon dioxide equivalent emissions per annum, for different combinations of grid displacement factor and landfill gas capture rate. Table 18 shows the same for the ERF in CHP mode. Both tables are based on the nominal design case. In both cases, the results have been shown with and without shore power.

It can be seen that there is a benefit for all LFG capture rate and grid displacement factor combinations, except for a very high LFG capture rate and a low grid displacement factor with no shore power and no heat export.

Table 17: Sensitivity analysis – power only

Grid Displacement Factor (t CO_2e/MWh)	**LFG Capture Rate**			
	75%	**68%**	**60%**	**52%**
No Shore Power				
0.349	3,664	**21,912**	42,766	63,620
0.30	-588	17,501	38,173	58,845
0.23	-6,662	11,199	31,611	52,023
Shore Power (2024)				
0.349	8,303	**26,550**	47,405	68,259
0.30	5,047	23,135	43,807	64,479
0.23	396	18,256	38,668	59,080
Shore Power (2045)				
0.349	9,238	**27,485**	48,339	69,193
0.30	6,182	24,270	44,942	65,614
0.23	1,818	19,678	40,090	60,502

Table 18: Sensitivity analysis – CHP Mode

Grid Displacement Factor (t CO_2e/MWh)	**LFG Capture Rate**			
	75%	**68%**	**60%**	**52%**
No Shore Power				
0.349	6,841	**25,088**	45,942	66,796
0.30	2,725	20,813	41,485	62,157
0.23	-3,156	14,705	35,117	55,529
Shore Power (2024)				
0.349	11,479	**29,727**	50,581	71,435
0.30	8,359	26,447	47,119	67,792
0.23	3,902	21,763	42,175	62,587
Shore Power (2045)				
0.349	12,414	**30,661**	51,515	72,369
0.30	9,494	27,582	48,255	68,927
0.23	5,324	23,184	43,596	64,009

4.4 Alternatives

Dorset Council has asked for the carbon emissions from the proposed ERF to be compared with four alternatives:

- The carbon emissions of sending the RDF to other Energy Recovery Facilities in the UK;
- The carbon emissions if sending the RDF to other Energy Recovery Facilities overseas;

- The carbon emissions of managing the RDF in Energy Recovery Facilities within Dorset on allocated sites (Insets 7-10 of the new Waste Plan); and
- The current combination of waste management approaches in Dorset.

Each of these alternatives has been considered below in semi-quantitative terms.

4.4.1 Other ERFs in the UK

The direct carbon emissions from combusting waste are the same whether it is combusted at Portland or elsewhere. This means that, from a carbon perspective, the only differences between ERFs at different locations are the transport impacts for transporting waste and any differences in the carbon displaced by generating power or heat.

We consider that the primary focus here is on RDF produced at the Canford Magna MBT plant which is 60 km away from the proposed development and produces around 60,000 tonnes of RDF p.a. The remaining waste for the proposed development could come from a wider catchment area, which could be closer to or further away from the alternative ERF. We have therefore compared two possible ERFs with the proposed development.

1. Marchwood ERF, which is 47 km away from Canford Magna and is the closest alternative and is currently used by Dorset Council; and
2. Lakeside EfW near Slough, which is 145 km away and which is currently used by Bournemouth, Christchurch and Poole (BCP) Council for waste from Poole.

Portland vs Marchwood

The difference in transport impacts from Canford Magna is marginal. Transporting 60,000 tonnes of waste an additional 13 km to Portland ERF would increase carbon impacts by around 52 tCO_2e per annum.

The change in transport impacts for the remaining waste is unclear as that waste could arise closer to or further away from Marchwood. If the remaining 122,000 tonnes of waste were transported an additional 30 km to Portland on average, this would increase carbon impacts by around 120 tCO_2e/annum.

According to its 2019 annual report to the Environment Agency, the Marchwood ERF exported 582 kWh/te of waste processed. It is unclear what the NCV of this waste was but given that Marchwood ERF treats residual household waste, it is likely to be around 10 MJ/kg, which is consistent with the NCV for the Portland ERF in the maximum capacity case. For this case, the Portland ERF is expected to export 602 kWh/te. Therefore, the Portland ERF would export an additional 20 kWh/te, or 4,040 MWh per annum. If this displaces CCGTs, as in the base case, the additional benefit would be 4,040 MWh x 0.349 $teCO_2e$/MWh = 1,410 $teCO_2e$.

Combining these differences, the Portland ERF would reduce greenhouse gas emissions by around an additional 1,240 te CO_2e per annum compared to the Marchwood ERF. This ignores the potential benefits of 4,500 to 5,500 te CO_2e per annum from exporting power to ships, which is not available at Marchwood.

Portland vs Lakeside

The difference in transport impacts from Canford Magna to Lakeside is less marginal. Transporting 60,000 tonnes of waste an additional 85 km to Lakeside would increase carbon impacts by around 340 tCO_2e per annum.

The remaining waste is likely to arise closer to Portland ERF. If the remaining 122,000 tonnes of waste were transported an additional 70 km to Lakeside on average, this would increase carbon impacts by around 610 tCO_2e/annum.

Lakeside ERF did not report its power generation to the Environment Agency in 2019. However, according to its application for R1 status in 2014, it has a net electrical efficiency of 23.5%, which means that it would be expected to export 16.4 MWe when processing the same waste as the Portland ERF. Therefore, the Lakeside ERF would export an additional 1.2 MWe, or 9,600 MWh per annum. If this displaces CCGTs, as in the base case, the additional benefit would be 9,600 MWh x 0.349 $teCO_2e$/MWh = 3,350 $teCO_2e$.

Combining these differences, the Portland ERF would reduce greenhouse gas emissions by around 2,400 te CO2e per annum less than the Lakeside ERF. This ignores the potential benefits of exporting power to ships, which is not available at Lakeside and would improve the benefit by around 4,500 – 5,500 $teCO_2e$ per annum, and the potential benefit of district heating, which is a further 3,000 $teCO_2e$ per annum.

Conclusion

From this simple calculation, it can be seen that sending waste to the Portland ERF would have a slight benefit over sending the same waste to Marchwood ERF but a slight disbenefit compared to the Lakeside ERF. However, this disbenefit is more than outweighed by the potential advantages of exporting power to ships.

4.4.2 Other ERFs in Europe

Comparing the carbon emissions for waste exported to ERFs in Europe is complex, because there are a number of significant uncertainties. While the direct emissions from combusting the waste are the same, the transport emissions are very different, the type of electricity which is displaced may be different and the potential for exporting heat will be different.

1. Transport
    a. RDF is transported to Europe by ship from a number of ports. In some cases, the RDF is transported by road to the east of England before being shipped, but we have assumed that waste from Dorset would go to a local port (Southampton). The waste would be transported from the port to the EfW plant by road as well and this distance could be similar to the distance to Portland ERF. Hence, we can assume that the road emissions are the same in both cases.
    b. According to data in WRATE, the Environment Agency's modelling tool, carbon emissions from ship transport of waste are 0.00849 $kgCO_2e$ per tonne of waste per km.
    c. Hence, if 183,000 tonnes of waste is shipped from Southampton to Rotterdam (about 290 nautical miles or 537 km), the emissions would be 0.00849 x 183,000 x 537 ÷ 1000 = 834 tCO_2e. If the same waste is shipped to Gothenbury (about 830 nautical miles, or 1,537 km), the emissions would be 2,387 tCO_2e.
2. Electricity displacement
    a. The type of electricity displaced depends on the country which the waste is sent to. The five primary destinations for RDF from England are The Netherlands, Sweden, Germany, Norway and Denmark.
        i. Sweden and Norway generate most electricity from renewables and export electricity to other European countries. This means that generation of electricity from waste is likely to lead to a reduction in fossil fuel generation elsewhere in Europe.

        ii. The Netherlands, Denmark and Germany also use a reasonable quantity of renewables but not as much as Sweden and Norway, so it is likely that generation of electricity from waste is likely to lead to a reduction in fossil fuel generation. The Netherlands and Germany, in particular, still generate more electricity from coal than in the UK but also generate power from natural gas.
    b. The UK also imports electricity from Europe, particularly France and The Netherlands, and the electricity grid on mainland Europe is generally more integrated between different countries. This means that electricity generated from energy-from-waste plants in The Netherlands, for example, could displace UK electricity, in much the same way that electricity generated from UK energy from waste plants does.
    c. Hence, it is likely that the carbon benefits of power displacement will be similar for European plants.
3. Heat displacement
    a. More European plants are connected to district heating systems than UK plants. Many are connected to extensive systems with multiple heat sources and users. Therefore, there is more potential for heat displacement for plants in Europe.
    b. As demonstrated in the main assessment, displacing heat has a carbon benefit. If the European plant exports three times as much heat as assumed for the Portland ERF, then the additional benefit would be around 9,000 tCO_2e per annum
4. Waste displacement
    a. A final complicating factor is that European EfW plants, particularly those linked to district heating schemes, are probably still running at capacity and significant quantities of waste is being sent to landfill. This means that burning UK waste in these plants means that some other European waste is not being burned and is probably being landfilled.

Overall, exporting waste to European EfW plants may have a carbon benefit over sending waste to a UK plant, but it would not contribute to diverting waste, overall, from landfill.

4.4.3 Other ERFs in Dorset Waste Plan

We have assumed that an ERF constructed at one of the sites in the Dorset Waste Plan would be identical to the proposed development, with a nominal design capacity if 183,000 tpa. This means that the only differences, in carbon terms, would be the distance travelled to deliver waste, the potential for exporting heat and the potential for exporting power directly to users. The direct emissions to atmosphere and the benefits of displacing other forms of electricity by exporting to the grid would be identical for all cases.

The four sites are discussed in detail in the Comparative Assessment against Waste Local Plan Allocated Sites. The points which are relevant for the carbon assessment are covered below. In particular, we have not considered whether an ERF of this size is deliverable at these sites and note that the site at Mannings Heath Industrial Estate, Poole, is too small for an EfW plant of the same capacity as the proposed development at Portland.

1. Eco Sustainable Solutions, Parley
    a. The site has some potential for district heating but no specific heat users have been identified.
    b. The site is 10-15 km from Poole and Bournemouth, 50 km from Dorchester and 16 km from Canford Magna MBT plant. This suggests that Dorset waste would travel around 15 km on average, releasing 184 tCO_2e per annum.
2. Canford Magna, Poole

   a. The site has potential for district heating for Magna Business Park, but no specific heat users have been identified.
   b. The site already includes an MBT plant and produces 60,000 tonnes per annum of RDF for export to Europe. This RDF could be processed in an ERF with no transport.
   c. The site is 10-15 km from Poole and Bournemouth and 40 km from Dorchester. Allowing for zero transport for the RDF already present, this suggests that Dorset waste would travel around 10 km on average, releasing 122 tCO_2e per annum.
3. Mannings Heath Industrial Estate, Poole
   a. The site may have potential for district heating as it is in an industrial estate but no specific heat users have been identified.
   b. The site is 10 km from the centres of Poole and Bournemouth, 40 km from Dorchester and 6 km from Canford Magna MBT plant. This suggests that Dorset waste would travel around 10 km on average, releasing 122 tCO_2e per annum.
4. Binnegar Environmental Park, East Stoke
   a. There is no potential for district heating.
   b. The site is 20-30 km from Dorchester, Poole and Bournemouth, and 24 km from Canford Magna MBT plant. This suggests that Dorset waste would travel around 25 km on average, releasing 306 tCO_2e per annum.

For comparison purposes, the proposed development is 60 km from Canford Magna and a similar distance away from Poole and Bournemouth, but only 20 km from Dorchester. This suggests that Dorset waste would travel around 55 km on average, releasing 673 tCO_2e per annum. Therefore, carbon emissions associated with transporting waste by road to Portland ERF would be around 370 to 550 tCO_2e higher. However, the Portland ERF has three potential advantages which more than outweigh this disadvantage:

1. Potential for district heating with several potential customers identified (as set out in section 3.1.3.4), which would displace around 3,000 tCO_2e per annum.
2. Potential for exporting power to ships, which would displace around 4,500 to 5,500 tCO_2e per annum.
3. Potential for waste to be delivered by ship from longer distances away, with an associated reduction in road traffic emissions.

4.4.4 Existing Management of Dorset Waste

Dorset Council has asked that the carbon benefits of the ERF be compared with the current management of Dorset's waste from council collections.

1. **Household waste**

   At present, we understand that residual waste generated in Dorset is exported from the county to energy from waste plants elsewhere in the UK or to landfill sites elsewhere in the UK (specifically Hampshire and Somerset), and some is converted to RDF and exported to Europe. According to the DEFRA Dataset ENV18-LACW 2018/19, 51,344 tonnes was sent to landfill and 109,984 tonnes was sent to ERF from the whole of Dorset (including Bournemouth and Poole). Some of the waste sent to ERFs was sent to Veolia's plants in Hampshire and to the Lakeside EfW in Slough, while some is treated at the Canford Magna MBT to produce RDF which was exported to Europe via Southampton.

2. **Commercial waste**

   It is unclear where the commercial waste generated in Dorset is treated. A baseline report prepared by consultants on behalf of the Bournemouth, Dorset and Poole waste authorities in October 2017, provided estimates of C&I waste arisings in the waste plan area and indicated that 92,558 tonnes of waste was sent to landfill.

We have assessed the case where all of the council-collected residual waste is sent to the new ERF, along with enough commercial waste (currently going to landfill) to fill the plant. Considering the nominal design case, this means that waste is diverted from three routes.

1. **ERF in the UK – 40,000 tonnes.**

   This is considered in section 4.4.1 and it was shown that the carbon emissions from sending waste from Dorset to the Marchwood EfW plant, which is the closest, would be similar to sending waste to the Portland ERF.

2. **ERF in Europe – 60,000 tonnes.**

   This is considered in section 4.4.2 and it was concluded that there might be a benefit if the European plant exports heat. For a plant in the Netherlands, the estimated benefit would be around 8,000 tCO_2e for 183,000 tonnes of waste, so would be 2,600 tCO_2e for 60,000 tonnes of waste.

3. **Landfill in the UK – 82,000 tonnes**

   This is considered in the main assessment. In the nominal design case, the benefit of the Portland ERF over landfill was 21,912 tCO_2e for 183,000 tonnes of waste, so would be 9,820 tCO_2e for 82,000 tonnes of waste.

Therefore, the benefit of the Portland ERF over current residual waste management approaches for Dorset Waste is estimated to be 7,200 tCO_2e per annum. This does not take account of the additional benefits associated with the provision of shore power from the proposed Portland ERF, which would otherwise not be available and which would improve the benefit by around 4,500 – 5,500 $teCO_2e$ per annum, or the potential benefit of district heating, which is a further 3,000 $teCO_2e$ per annum.

4.5 Lifetime Benefit

The benefits discussed above all relate to a single year. The ERF is expected to start operating in late 2023 and to have a life of at least 25 years, so the carbon benefits will accumulate over time. However, the benefits will vary over time as a number of the key assumptions will vary.

In this section, we have considered the lifetime benefits of the ERF on an illustrative basis. We have varied a number of assumptions with time.

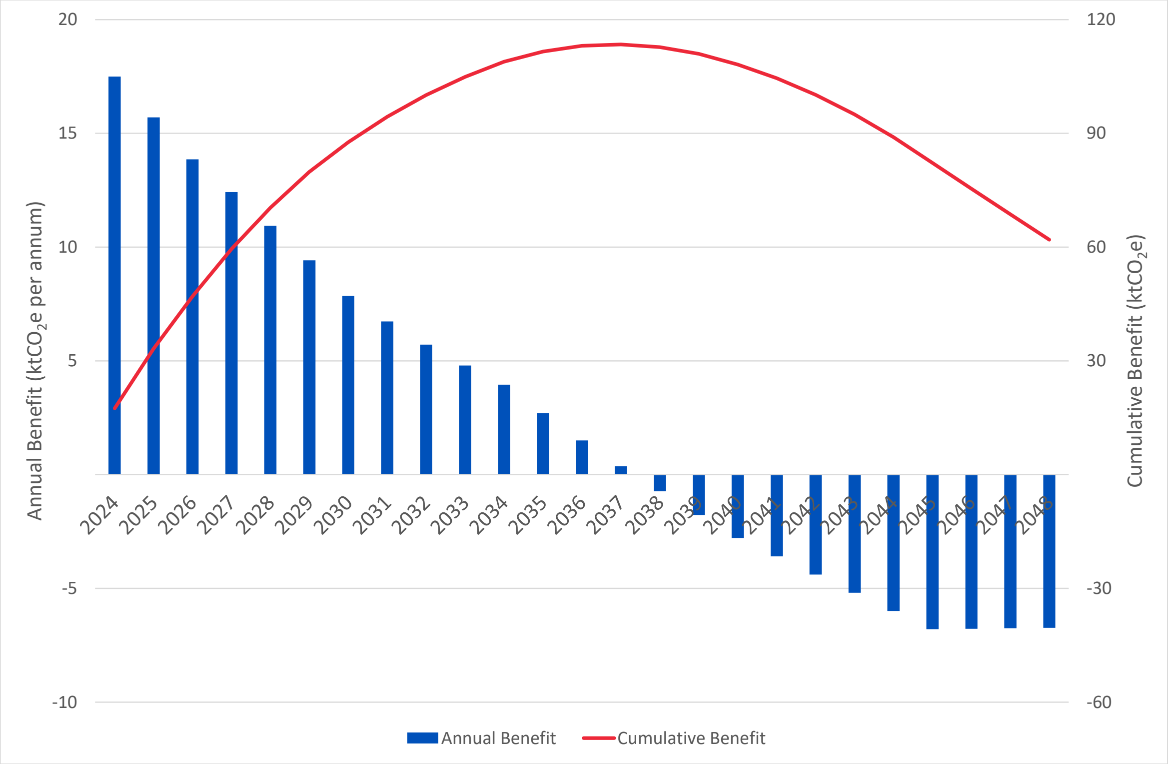
1. The government's policy is to decarbonise grid electricity, which means that the benefit of displacing electricity will reduce. While we consider, as explained in section 3.1.3, that the correct comparator at present is power from CCGTs and that this will remain the case for some time, for illustrative purposes we have used the long run marginal generation-based emission factor taken from the "Green Book supplementary guidance: valuation of energy use and greenhouse gas emissions for appraisal", published by BEIS. This is considerably more conservative, starting at 0.2191 kg CO_2e/kWh in 2024 and dropping to 0.0276 kg CO_2e/kWh by 2048.
2. Shore power is assumed to ramp up linearly from 20,328 MWh in 2024 to 24,423 MWh in 2048.

3. District heating is assumed to take longer to be developed. First users are assumed to be connected in 2027, with a linear ramp up to the full heat export of 18,307 MWh by 2034, 10 years after the plant opens. (This is expected to be conservative as key potential heat users (including the 2 prisons) are interested in a heat supply much sooner, whereas new housing that may connect to the heat network is likely to be delivered in stages).
4. Landfill gas capture rates are assumed to increase gradually from 68% in 2024 to 75% in 2045, as it is likely that landfill performance will improve.

It is likely that waste composition will vary, but we consider that it is not possible to predict waste composition over 25 years and so we have not allowed for this. Variations in waste composition could make the performance of the ERF compared to landfill better or worse. We understand that Powerfuel will take account of the changing composition of the waste when calculating their net carbon position over time for the purposes of their net-zero carbon commitment (discussed in the report "Achieving Carbon Neutrality".)

With these assumptions, the net benefit of the Portland ERF over 25 years is estimated to be 61,926 tCO_2e. The net benefit per year and the cumulative benefit over time are illustrated below.

Figure 1: Lifetime Carbon Benefit



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