Incineration Review

Options Appraisal

Report for: Scottish Government

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Appendices

Table 1: Glossary of terms

Term	Description
ACT	Advanced conversion technology
AD	Anaerobic digestion
APCr	Air pollution control residues (residues from flue gas treatment)
AQ	Air quality
ATT	Advanced thermal treatment
BMW	Biodegradable municipal waste
BREF	Best available techniques reference document
C&D	Construction & demolition
C&I	Commercial & industrial
CHP	Combined heat and power
CLO	Compost like output
Defra	Department for environment, food and rural affairs
EfW	Energy from waste
ELV	Emission limit value
EU	European union
PPC	Pollution prevention and control
RDF	Refuse derived fuel
HC&I	Household, commercial and industrial waste
HTL	Hydrothermal liquefaction

Term	Description
IBA	Incinerator bottom ash
IED	Industrial emissions directive
IVC	In-vessel composting
LVIA	Landscape visual impact assessment
MBI	Mass burn incineration
MBT	Mechanical biological treatment
MRF	Material recycling facility
MSW	Municipal solid waste
MWI	Municipal waste incinerator
NOx	Nitrous oxides
PHS	Public Health Scotland
RDF	Refuse derived fuel
SLCF	Scottish landfill communities fund
SEPA	Scottish environmental protection agency
SIMD	Scottish index of multiple deprivation
SRF	Solid recovered fuel
UKWIN	UK without incineration network
WML	Waste management licence
WtH	Waste to hydrogen

1. Introduction

1.1 Background

In May 2021 the Cabinet Secretary for Net Zero, Energy and Transport, set out a commitment to review the role of incineration in the waste hierarchy in Scotland (the incineration review).

A statement to Parliament by the Minister for Green Skills, Circular Economy and Biodiversity, in September 2021, set out the intention for this incineration review to:

- Be led by an independent chair.
- Prioritise consideration of national capacity requirements for incineration.
- Have scope to consider how emissions from existing incinerators can be reduced and residual heat may be reused; and consider the societal impacts of residual waste treatment, including health and community impacts.

In addition, the Minister set out the timeline for this review to be undertaken between December 2021 and March 2022.

In November 2021, the Minister appointed Dr Colin Church as the independent chair of the review. Dr Church indicated the intention for this incineration review to include opportunities for all stakeholders to provide their views and evidence. To achieve this, a call for evidence, including stakeholder consultation events, was launched in December 2021, and closed in February 2022. The consultation process set out to gather evidence on five broad topics, including several questions specifically relating to options for residual waste treatment and the consideration of their impacts.

1.2 Scope Of Work

The scope of work for this options appraisal comprised a rapid review of evidence, including a review of the call for evidence submissions, stakeholder consultation events and available literature.

The Scottish Government required this review of evidence to consider several aspects of different treatment options for household and commercial and industrial (HC&I) residual waste management, relevant to its possible future management in Scotland.

The aspects to be considered included the feasibility of implementation and the economic, environmental, societal and health impacts of the different treatment options (see section 2).

As outlined within the incineration review, the treatment options to be included within this review of evidence are:

- Incineration.
- Landfill.
- Export.
- Mechanical biological treatment (MBT).
- Biostabilisation.
- Emerging technologies.

Listed below are the matters excluded from the review of evidence:

- The incineration of biomass for energy.
- High-temperature incineration for the treatment of healthcare and hazardous wastes.
- Construction and Demolition (C&D) waste streams.
- An in-depth review of health impacts of residual waste treatment.
- Consideration of future policy and/or regulatory changes.

The scope of work for this review of evidence did not require Ricardo to form any conclusions on preferred treatment technologies, nor to make policy recommendations. The aim was to summarise available evidence in order to assist the independent chair.

2. Inclusion Criteria

The options appraisal gives precedence to Scottish-specific evidence, where it exists, and prioritises recent literature wherever possible.

2.1 Waste Treatment Technologies

2.1.1 Waste Feedstock

In addition to HC&I residual waste, this review of evidence has also considered such waste after it has been pre-treated to separate it into biodegradable municipal waste (BMW) and/or refuse derived fuel (RDF), or solid recovered fuel (SRF).

2.1.2 Incineration

Consideration of the incineration option has been split into conventional mass burn incineration (MBI) and advanced thermal treatment (ATT). The review of evidence associated with ATT has focussed on the processes of gasification and pyrolysis. Other variations of this treatment technology have also been considered within the emerging technologies section.

The review of evidence has also included the disposal and/or recovery of its residues such as incinerator bottom ash (IBA), fly ash, air pollution control residues (APCr) and metals.

2.1.3 Landfill

Consideration of the landfill option has centred on the disposal of stabilised BMW from in-vessel composting (IVC), as part of an MBT process, as well as the landfill of residual biodegradable non-municipal waste (BNMW, primarily consisting of C&I wastes) from any other treatment types (excluding hazardous and C&D wastes).

2.1.4 Export

Consideration of the option to export HC&I residual waste, in the form of RDF or SRF that has been pre-treated in Scotland, has included export to other destinations within the UK, as well as export outside of the UK. Ricardo understands that whilst this option is to be included within the review of evidence, it is to be considered in the context of a short-term or interim measure only.

2.1.5 MBT

Consideration of the MBT option has include MBT in any form, including biodrying, anaerobic digestion (AD) or IVC with RDF production for subsequent further treatment such as by incineration.

2.1.6 Biostabilisation

The treatment option of biostabilisation has include treatment of waste by IVC as part of the MBT process to biostabilise the waste, such that it can be subsequently landfilled in accordance with the Scottish landfill ban.

2.1.7 Emerging Technologies

The final treatment option has considered more emerging technologies that are not yet established.

2.2 Themes

Whilst the options appraisal has sought evidence to understand the environmental, social and health impacts of each of the identified treatment options, it should be noted that in order for a waste treatment facility, including any of the treatment options identified in section 1.2, to be operated in Scotland, it would first be required to obtain regulatory consent through the planning and pollution prevention and control (PPC) permitting or waste management licensing (WML) regimes (depending on the activity). Together, these would include site specific consideration of certain environmental, social and health impacts by regulators, such as the landscape visual impact, traffic, odour, air quality, noise, pests and other possible impacts associated with the location of a facility in relation to its sensitive receptors. Such consents are also granted subject to conditions, that implement relevant environmental quality standards and specific permitting requirements for environmental and human health protection.

2.2.1 Technical Feasibility

The options appraisal has sought evidence to understand the technical feasibility of each of the identified treatment options. Examples include consideration of how established each technology is for the relevant waste feedstock, its known track record and any evidence of any technical limitations and/or issues. The review of evidence included consideration of how quickly the technology can be implemented for the relevant feedstock and what the expected lifetime for each treatment option might be. Where evidence was available, this included consideration of expected downtime, and what might happen to feedstock during these periods. The review has also considered evidence regarding how feasible the technology it is to operate within the applicable regulatory framework in Scotland.

2.2.2 Economic Impacts

The options appraisal has sought evidence to understand the economic impacts of each of the identified treatment options. Consideration of these impacts has focused on the costs of waste management. Where evidence was available, information has been reviewed, considering, for example, factors such as gate fees and relevant taxes, cost of operation, cost of closure and aftercare (including whether this is likely to be covered by the public or by the operator) and the cost of any remediation activities, if required. The economic impacts considered have also included the creation of jobs for the local community, as well as the impact of public perception on prices of houses located, or products produced near, the treatment option. The options appraisal has not considered the possible impact of potential future policy or regulatory changes such as an incineration tax, for example, as this is outside the scope of work.

2.2.3 Environmental Impacts

The options appraisal has sought evidence to understand the full range of environmental impacts of each of the identified treatment options. This has included, where literature is available, impacts from construction to site closure (i.e., during the full lifecycle). Greenhouse gas emissions and carbon impacts have also been considered in addition to impacts such as leachate, emissions to air (including noise and emissions from transport), emissions to water, emissions to land and the impacts of the recycled materials from each treatment option (e.g., fuels, recycled metals) conserving the use of virgin materials.

2.2.4 Social Impacts

The options appraisal has sought evidence to understand the social impacts of each of the identified treatment options, including consideration of evidence regarding the number of complaints received. The review has considered this in the context of existing facilities and their geographical settings, however. For example, facilities located close to highly populates areas may receive more complaints, as opposed to facilities located within isolated rural areas. Anecdotal evidence has also been considered, as well as the impact on amenity, odour, noise, pests and traffic.

The social impacts considered have included factors such as house prices or desirability of living in the area, the public perception of living near the treatment option and the possible psychological impacts of worry where such evidence is available. Community impacts have also been considered, such as the use of heat networks and the impacts of community funds (e.g., Scottish landfill community fund) or provision of new community facilities as part of the process of developing a new treatment option.

2.2.5 Health Impacts

The final theme the options appraisal has sought evidence in relation to was health impacts. This included consideration of evidence regarding the long and short-term effects of each treatment option on human health and the impacts of any increased noise, air pollutants and the psychological effects of worry. Where possible, the disproportionate effects on certain socioeconomic groups have also been considered.

Ricardo understands that Public Health Scotland (PHS) is also currently undertaking a systematic review of health impacts of incineration and that this options appraisal will not duplicate this or look to draw any conclusions in this regard.

3. Incineration

3.1 Mass Burn Incineration

3.1.1 Overview

Mass burn incineration (MBI) refers to conventional incineration, namely moving or stepped grate, rotating kiln and fluidised bed technologies. To allow the combustion to take place, oxygen is required to fully oxidise the fuel (waste). MBI usually involves the combustion of unprepared residual MSW, although combustion of pre-treated MSW in the form of RDF or SRF is also common. Non-combustible materials such as metals and glass are recovered from the bottom ash and are usually sent for recycling.

3.1.2 Technical Feasibility

How established it is for HC&I waste?

As set out by Defra (2013a), incineration with energy recovery is generally considered a well-established technique for the treatment of MSW. The moving grate furnace system is the most commonly used combustion system for processing MSW in the UK (Defra, 2013a). In a moving grate process, the system will typically include a mechanism for distributing the incoming waste material across the grate and for transporting the combustible material forward, providing mixing as it traverses the length of the grate. The process enables complete combustion as the waste moves through the furnace.

The Best Available Techniques Reference Document (BREF) for Waste Incineration (WI BREF) (Neuwahl, et al., 2019) states that grate incinerators are widely applied for the incineration of mixed municipal wastes. In Europe, approximately 90% of installations treating MSW use moving grate-based technology. Other wastes commonly treated in grate incinerators, often as additions with MSW, include C&I non-hazardous wastes, sewage sludges and certain clinical wastes.

The use of fluidised bed technology for MSW incineration is limited in the UK, although it is widely applied to sewage sludge (Defra, 2013a). To combust MSW using a fluidised bed technique, pre-sorting of MSW material to remove heavy and inert objects is required. The waste is then mechanically processed to reduce the particle size. Overall, the waste requires more preparation than if a moving grate was used. Fluidised bed technology consists of a lined chamber with a granular bubbling bed of an inert material such as coarse sand/silica or similar bed medium (Defra, 2013a). The WI BREF (Neuwahl, et al., 2019) states that fluidised bed incinerators are widely applied to the incineration of finely divided wastes such as RDF and sewage sludge. It also states that fluidised beds have been used for decades for the combustion of homogeneous fuels such as coal, raw lignite, sewage sludge, and biomass.

An example of a fluidised bed process currently used in Scotland is the two-line MVV Baldovie EfW facility in Dundee. In January 2022, MVV started operating a third line, which uses moving grate technology (MVV, 2022a; MVV, 2022b). It was anticipated that the existing facility would be replaced by the new moving grate facility at the end of its operational life in April 2020 (MVV, 2020). However, MVV has since stated that the fluidised bed facility can continue to operate for longer than anticipated and has applied to operate the fluidised bed and moving grate facilities in parallel for a period of up to 10 years from April 2020.

Another UK example of a fluidised bed process is that used by FCC Environment at their EfW located at Allington. UK experience with fluidised bed facilities is reported as “problematic”, with both Dundee and Allington initially experiencing significant downtime, as reported by trade press and the operators annual report submitted to the Environment Agency (Kent Enviropower, 2009; LetsRecycle, 2008). Subsequent reports of operation at the Allington facility have indicated significant downtime in some years (e.g., annual availability 59% in 2010 and 72% in 2011) (Community Liaison Committee, 2012) and some further problems with the fluidisation technology. For example, in 2014 loss of fluidisation was the single largest cause of downtime, with total unavailability during 2014 (Kent Enviropower Ltd, 2015) of 19% and 16% in 2018 (Kent Enviropower Ltd, 2019). In 2019, FCC Environment launched a consultation on proposals to increase the capacity of the Allington facility to 850,000 tpa, but the new line would use moving grate technology (LetsRecycle, 2019).

In the UK there is currently one oscillating rotary kiln incinerator processing MSW, which is located in North East Lincolnshire (Defra, 2013a). As set out by Defra (2013a), rotary kilns have a wide application. The WI BREF (Neuwahl, et al., 2019) states that rotary kilns are very robust and almost any waste, regardless of type and composition, can be incinerated. Rotary kilns are very widely applied for the incineration of hazardous wastes and most hazardous clinical waste is incinerated in high-temperature rotary kiln incinerators (Neuwahl, et al., 2019). Incineration in a rotary kiln is normally a two-stage process consisting of a kiln and separate secondary combustion chamber (Defra, 2013a). The kiln is the primary combustion chamber and is inclined downwards from the feed entry point. The rotation moves the waste through the kiln with a tumbling action which exposes the waste to heat and oxygen.

Defra (2013a) states that an incinerator will typically have a higher net electrical and thermal efficiency than a comparable ATT process that also generates steam for power generation or direct heating. This is mainly due to the energy required to sustain the gasification or pyrolysis process.

Implementation and lifetime

The amount of time it takes to gain the necessary consents and permissions for an EfW facility can vary significantly, according to the scale and location of the facility, whether there were any appeals at the planning stage and which regulatory authority is determining the application. Due to a cyber-attack in 2020, some of SEPA’s services have been impacted, which may affect their timescales for determining permit applications.

As set out in the WI BREF (Neuwahl, et al., 2019), incineration facilities’ operation is usually long term (15 – 25 years). Generally, environmental permit and planning applications will assume a lifetime of approximately 25 years. Orkney Islands Council (2018) stated that the Shetland EfW facility “has an anticipated lifespan of 10 to 15 years under current maintenance programmes, with potentially later refurbishment work required to extend this further”.

Speed of Implementation

All proposed EfW facilities will need to go through the same processes before they are able to operate at the intended capacity. These include applying for the relevant permissions, procurement, constructing the facility and commissioning it. A developer cannot start building an EfW facility until planning permission has been granted and the facility cannot be operated until a PPC permit has been issued in accordance with the Pollution Prevention and Control (Scotland) Regulations 2012. As mentioned above, the time taken to apply for and be granted planning permission and a PPC permit can vary considerably, typically depending on the size and location of the facility and whether there is much opposition to the project. For this reason, there are not any clear timescales provided by regulators or local authorities, but it is generally considered that producing the applications and obtaining these permissions will take at least a few years. Constructing the facility is also expected to take approximately 2-4 years, but can take longer. Likewise, commissioning can be a lengthy process (Defra, 2014). A common approach is to obtain planning permission and procurements first, start construction and apply for a PPC permit during the construction process, in order to shorten the overall timeframe. However, regulators usually prefer the planning and permitting applications to be submitted in tandem (SEPA, n.d.)

Availability

Zero Waste Scotland (2021b) provides the installed capacity and actual amount of municipal waste incinerated at each of Scotland's EfW facilities operating in 2018, as set out in Table 2. It is worth noting that two of these began operating in 2018 and so the actual tonnage incinerated is likely to be an underestimate of the typical capacity. Fires at the Dundee facility in 2018 also meant that it was not operating for part of the year. Tonnages incinerated in the years since 2018 have not been published.

Table 2: Operational conventional EfW facilities in Scotland in 2018 which are permitted to take municipal waste. Adapted from Table 1: (Zero Waste Scotland, 2021b)

Facility name	Incinerator type	Incineration capacity (tpa)	Municipal waste incinerated in 2018 (tonnes)	Proportion of capacity used in 2018 (%)	Status in 2018 and energy generation type
Dunbar Energy Recovery Facility, Oxwellmains, East Lothians	Moving grate incinerator	300,000	41,284	14	Began operations in 2018, CHP potential, operating as electricity-only
MVV, Baldovie Industrial Estate, Dundee	Fluidised bed incinerator	110,000	94,624	86	Operational, CHP potential, operating as electricity-only

Facility name	Incinerator type	Incineration capacity (tpa)	Municipal waste incinerated in 2018 (tonnes)	Proportion of capacity used in 2018 (%)	Status in 2018 and energy generation type
Millerhill Energy Recovery Centre, Edinburgh	Moving grate incinerator	195,000	16,459	8	Began operations in 2018, CHP potential, operating as electricity-only
Lerwick Energy Recovery Facility, Lerwick, Shetland Islands	Moving grate incinerator	24,000	23,053	96	Operational, built and operating as heat-only

Tolvik (2021) concluded that, “across those EfWs which were operational for the whole of 2020, the average availability based on waste combustion was 89.2%”. This is in comparison to the pre-covid availability in 2019 of 89.5%. The availability based on turbine operations was lower at 85.9% but this was a material improvement on the 2019 figure of 81.9% (Tolvik, 2021).

As part of the PPC permit application process, operators are required to outline their plans for start-up and shutdown, including what will happen to the waste feedstock during downtime (whether planned or unplanned). If the shutdown has been planned, for example for maintenance purposes, the operator will try to use up the feedstock so there is little to no waste left on site during the shutdown period. If the shutdown is not planned, operators will typically try to divert feedstock to other nearby waste management facilities and will have fire prevention measures in place for any feedstock already on the site.

Performance

SEPA provides the compliance ratings for the four municipal waste-fired conventional incineration facility that were operational in Scotland in 2018 and 2019 (SEPA, 2022a). These are set out in **Error! Reference source not found.**. The Shetland facility was rated E xcellent in both years, while the MVV Dundee facility rose 3 categories from Poor to Good and the Dunbar and Millerhill facilities dropped from Excellent to Good. SEPA stated that in 2019, 78% of the assessed facilities were rated Excellent, 12% were Good, <1% were Broadly Compliant, 5% were Poor and <1% were Very Poor. Approximately 91% of the assessed licences were considered satisfactory (SEPA, 2020).

Table 3: Compliance ratings of energy from waste sites in Scotland in 2018 and 2019. Adapted from: (SEPA, 2022a) and (SEPA, 2020)

Site name	Operator	Type	Permit number	2018 compliance rating	2019 compliance rating
Lerwick Energy Recovery Facility (Shetland)	Shetland Council	Conventional incineration, heat-only	PPC/A/1003141	Excellent	Excellent
MEB (formerly Dundee Energy Recycling Ltd)	MVV Environmental Baldovie Ltd	Conventional fluidised bed incineration, electricity-only	PPC/A/1003157	Poor	Good
Dunbar Energy Recovery Facility	Viridor Waste Management Ltd	Conventional incineration, electricity-only	PPC/A/1032878	Excellent	Good
Millerhill Recycling and Energy Recovery Centre	FCC Waste Services (UK) Ltd	Conventional incineration, electricity-only	PPC/A/1136072	Excellent	Good

The February 2022 continuous emissions data for FCC Environment's Millerhill EfW facility are provided on their website and are shown in **Error! Reference source not found.** and REF _Ref98401432 \h * MERGEFORMAT **Error! Reference source not found.** as a percentage of the half hourly and daily emission limit values (ELVs). All emissions in that month were well below the permitted ELVs, however it is noted that the information is only provided on the website for one month at a time. The emissions information that was found for other EfW facilities in Scotland was not available in a format that was suitable for inclusion in this report.

Figure 1: Maximum emission as a percentage of 1/2 hourly ELV. Source: (FCC Environment, 2022)

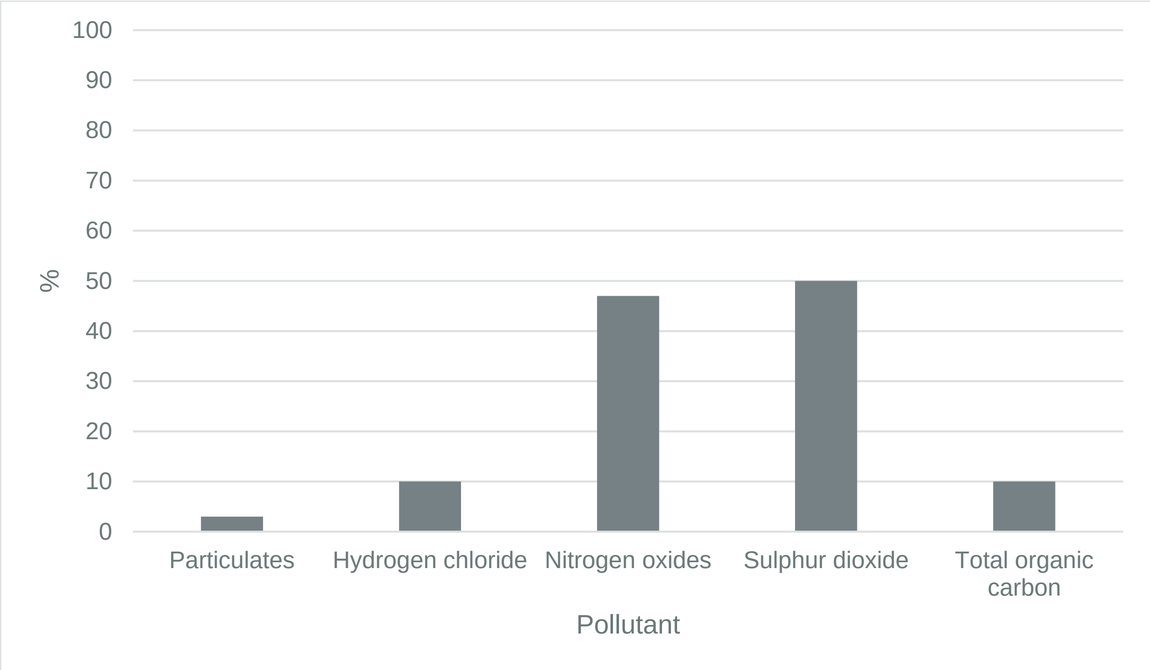
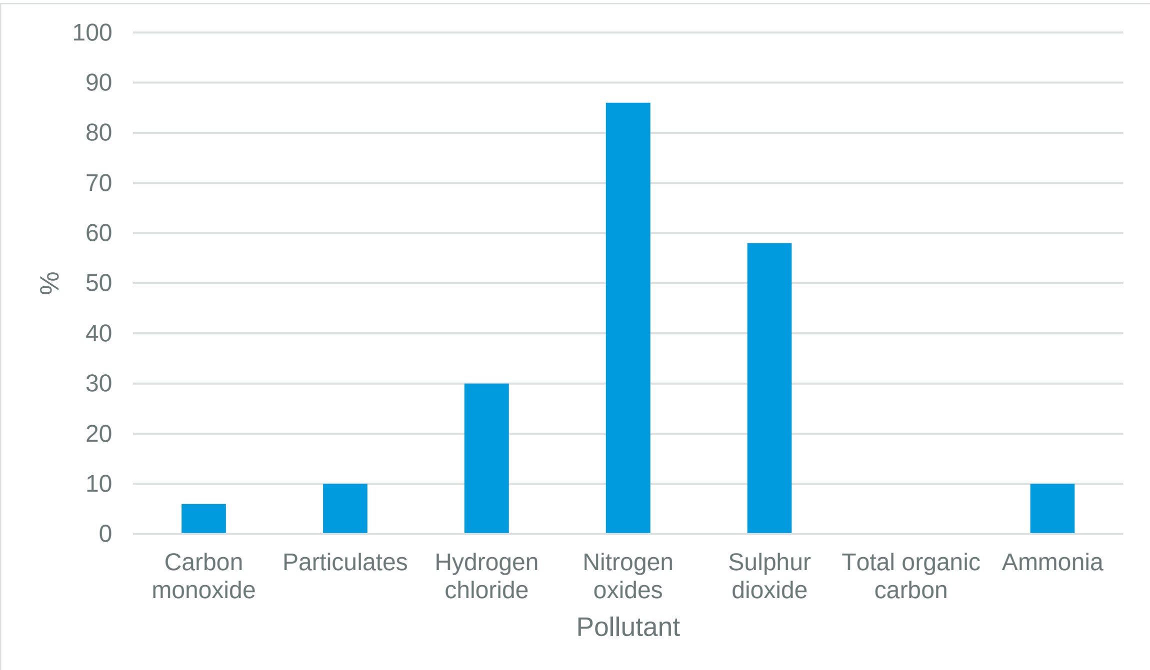


Figure 2: Maximum emission as a percentage of daily ELV. Source: (FCC Environment, 2022)



In the EfW sector, compliance is a combination of operator self-monitoring, reporting to and monitoring by the relevant regulator (Tolvik Consulting, 2021). EfWs in the UK are required to monitor their emissions to air, both continuously and periodically, depending on the pollutant being monitored. Emissions to water and composition of ash residues are also monitored at regular intervals. On average in 2020, continuously monitored emissions to air were 29.1% of the Emissions Limit Value (ELV) (2019: 28.8%). Meanwhile, for periodically monitored emissions, on average, emissions were 8.1% of ELV (2019: 8.5%) (Tolvik, 2021). Table 4 presents the annual percentages of each ELV from 2017 to 2020.

Table 4: Continuously monitored emissions to air. Source: Figure 30 (Tolvik, 2021)

	% of emissions limit value			
Parameter	**2017**	**2018**	**2019**	**2020**
Oxides of nitrogen	82.5	80.7	79.4	80.6
Hydrogen chloride	49.1	48.8	50.4	47.7
Sulphur dioxide	32.3	27.0	26.7	30.0
Ammonia	20.6	16.9	15.2	15.9
Carbon monoxide	16.3	13.5	13.7	13.8
Particulates	11.4	11.2	11.1	10.9
Total organic carbon	5	4.3	4.9	4.9
Simple average	31	28.9	28.8	29.1

Tolvik (2021) states that "operators advise that measurement uncertainty, limits of detection for small samples and impact of background pollutant levels can all affect the analysis, but that the protocols used by the sector should be such that reported results are effectively a worst case". Table 5 sets out the records of abnormal operations collated by Tolvik (2021). However, Tolvik (2021) did not provide definitions of "abnormal events" and "permit breaches" in their report. It is assumed that "abnormal events" are "technically unavoidable stoppages, disturbances, or failures of the purification devices or the measurement devices, during which the concentrations in the discharges into the air and the purified wastewater of the regulated substances may exceed the prescribed emission limit values", as set out in Article 13 of the Waste Incineration Directive. The "permit breaches" are assumed to include the abnormal events as well as any emissions above the permitted limits that occurred during normal operation.

Table 5: Abnormal Operations. Source: Figure 31 (Tolvik, 2021)

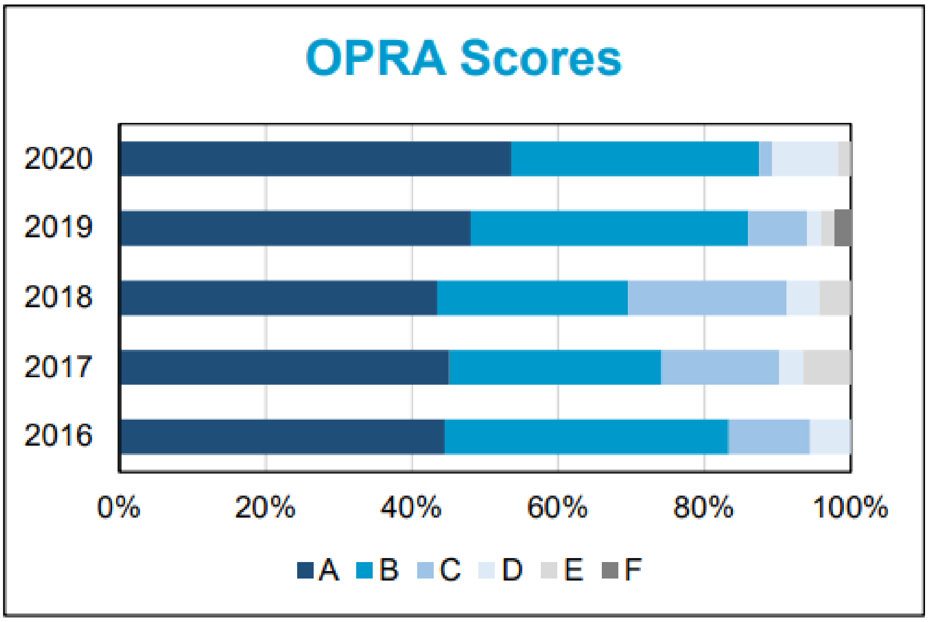
	Unit	Year	Total	Number of EfWs reporting	Per EfW
Abnormal hours	Hours	2018	130	38	3.4
		2019	96	42	2.3
		2020	168	48	3.5
Abnormal events	Instances	2019	87	44	2.0

	Unit	Year	Total	Number of EfWs reporting	Per EfW
		2020	72	48	1.5
Permit breaches	Instances	2019	127	39	3.3
		2020	148	47	3.1

It is noted by Tolvik (2021) that in 2020, one facility which was not previously operational, accounted for 76 hours of abnormal operations and "this was solely the cause of the increase in abnormal hours between 2019 and 2020". In 2020, five different EfWs reported more than 10 permit breaches and together accounted for 57% of all breaches (Tolvik, 2021). This is the same as in 2019.

Operational Risk Appraisal (OPRA) scores are a compliance rating given by the regulator as a result of an assessment of various operational risks, including location of sensitive receptors, emissions, permitted activities, environmental management procedures and previous operator performance. This score would then inform the annual subsistence costs for a permitted facility, as well as affecting permit variation or surrender fees. While Natural Resources Wales (NRW) still uses this system, the Environment Agency (EA) and SEPA switched to a different system in 2018/19. Figure 3 presents the EfW OPRA scores from 2016 to 2020 and the split from A (best) to F (worst), as reported by Tolvik (2021). This shows that the majority of OPRA scores (more than 80%) in 2020 were A to C, and a much smaller number of operators (approximately 10-15%) were scored D to F. It is unclear whether the Tolvik report includes the EA's and SEPA's equivalents to OPRA scores for the years after they switched schemes.

Figure 3. OPRA Scores by Year. Source: Figure 32 (Tolvik, 2021)



3.1.3 Economic impacts

The WI BREF (Neuwahl, et al., 2019) states that the economic aspects of incineration vary greatly between regions and countries, not only due to technical aspects but also depending on waste management policies. Capital and operational costs of an EfW facility vary significantly depending on the technology, scale, contract type, business model and feedstock (Recycling & Waste World, 2017). Some of the other factors that affect the overall cost of incineration include:

- Costs of land acquisition.
- Scale (there may often be significant disadvantages for small-scale operation).
- The flue-gas and effluent treatment requirements.
- The treatment and disposal/recovery of ash residues.
- The efficiency of energy recovery, and the revenue received for the energy delivered. The unit price of energy delivered and whether revenues are received for just heat or electricity or for both are both important determinants of net costs.
- The recovery of metals and the revenues received from this.
- Taxes or subsidies received for incineration and/or levied on emissions - direct and indirect subsidies can influence gate fees significantly i.e. in the range of 10–75 %.
- Planning and building cost/depreciation periods, taxes and subsidies, capital cost.
- Insurance costs.
- Administration, personnel, salary costs.

As well as the factors set out above, the operational costs of an EfW facility will include annual subsistence costs paid to the regulator. SEPA's annual subsistence fees for PPC A 5.1 (Chapter IV IED incinerators) with a municipal waste feedstock range from £16,369 to £21,723 in 2022-23 (SEPA, 2022c). Nixon et al. (2013) stated that operating costs for the flue gas cleaning systems are "the major expense for EfW facilities" and costs can range from 5 to 17 EUR (£4 to £14, using the average EUR to GBP exchange rate for 2013 of €0.85 to £1) per tonne of MSW incinerated.

An EfW facility may provide positive impacts in the form of employment and educational opportunities, and potentially as a low-cost source of domestic or industrial heating. A 50,000 tpa incineration facility would typically employ 2-6 workers per shift, utilising a three-shift system to allow for 24-hour operations (Defra, 2013a).

Development of incineration facility will involve capital expenditure of millions of pounds, potentially up to hundreds of millions of pounds. Nixon et al. (2013) stated that, of the facilities included in their study of UK incinerators, capital costs ranged from 3.5 to 4 million euros (£3 to £3.4 million) per MW. Defra's Incineration of Municipal Solid Waste (Defra, 2013a) sets out some potential funding sources for Local Authorities planning to develop EfW facilities:

- Capital Grants.
- Prudential Borrowing.
- Waste Infrastructure credits and Private Sector Financing.
- Other Private-Sector Financing.
- Existing sources of local authority funding.

Defra's Incineration of Municipal Solid Waste (Defra, 2013a) provides the Shetland EfW as an example. "The proposed facility was designed to provide heat which is supplied to both commercial and domestic customers. The thermal efficiency of the incinerator in terms of heat recovered is 80%. The capital cost for the incinerator was approximately £10m and the district heating network a further £11.5m. The heat supplied is provided at a competitive rate and has been well received by the end consumers. The cost of installing the heat exchangers per property to allow the heat to be used was between £2,000 and £5,000. The incinerator and heating network provide a significant financial benefit to the Shetland Isles." Some more recent examples are FCC Environment's Millerhill EfW facility and Viridor's Dunbar EfW facility, which reportedly cost £142 million (FCC Environment, 2019) and £177 million respectively (Stantec, 2022).

WRAP (2020) in their report on gate fees for 2019/20 reported that the median gate fee for EfW was £93/tonne compared to £89/tonne the previous year. For pre-2000 EfW facilities, the median gate fee was £62/tonne, compared to £65/tonne the previous year. For post-2000 facilities, the median gate fee was £95/tonne compared to £93/tonne the previous year. WRAP's report stated that the gate fees charged by facilities are related to the age of the facility, largely due to the build costs. For example, in 2019, any pre-2000 facilities would typically have offered a gate fee of £60/tonne or less, whereas more modern facilities would have charged between £80 and £90/tonne, dependent on the payment mechanisms in place. Quality of the material entering an EfW facility can also have a huge impact on performance and output of the facility (WRAP, 2020).

WRAP (2020) also concludes that, in the short term, the introduction of the Dutch and Swedish incineration taxes in 2020 have made exporting material for incineration from the UK to these countries significantly more expensive. This has in turn increased demand for EfW and driven up gate fees at EfW facilities in the UK. This has been more pronounced in regions producing greater quantities of RDF (i.e., less in the North and Scotland and greater in the south of England).

The Scottish Government (2019) concluded that, in the short term, the ban on landfilling BMW is likely to lead to a significant rise in residual waste treatment costs for organisations that have not already secured a long-term contract, as the price of local landfill will no longer restrict gate fees and there will be greater reliance on exports, whose price will be likely to be set by reference to the next cheapest option – typically, landfill in England. The study stated that the market is likely to stabilise at a price just above the current level. In the medium term, prices will be lower if additional incineration capacity is built in Scotland, but in the longer-term export may be more favourable. Costs will be lower if high levels of recycling are achieved. However, it is noted that this study focuses only on the impact of the BMW landfill ban on the cost and benefits of the disposal of residual waste. The likely economic and environmental benefits that might be expected from an increase in reuse and recycling was not considered and is not included within the results (Eunomia, 2019).

3.1.4 Environmental impacts

Emissions to air, land and water

Emissions to air are, and have long been, a major focus for waste incineration facilities. While significant advances in flue gas cleaning technologies have led to large reductions in emissions to air, the control of emissions to air remains an important issue for the sector (Neuwahl, et al., 2019). Assessments of the impacts of emissions to air from EfW facilities on the local air quality and sensitive receptors (including residents and designated ecological sites) are carried out at the planning and permitting stages of any development.

Legally binding emissions limits are set out within the issued permit and the relevant regulator will carry out compliance checks to ensure facilities are operating within their permitted limits. SEPA carries out compliance checks annually for most permitted activities, including EfW (SEPA, 2020).

Fluidised bed technology is capable of achieving lower NOx emissions in the raw gas than are typically achievable in moving grate systems (Neuwahl, et al., 2019). This is achieved through lower bed temperatures, which reduce thermal NOx formation but may produce higher CO emissions. However, additional abatement will still be required to guarantee compliance with the Industrial Emissions Directive (IED) and BAT Conclusions (BATC).

In most cases, where emissions to air from EfW facilities have been considered in literature, it is from a health perspective. This is discussed in section 3.1.5 below.

The WI BREF (Neuwahl, et al., 2019) states that noise from waste incineration is comparable with other industries and with power generation facilities. It is common practice for new EfW facilities to be installed in enclosed buildings. This normally includes carrying out operations such as waste tipping, mechanical pre-treatment, flue-gas treatment, and the treatment of residues inside a building. The impact of vibration on sensitive receptors is also usually screened out as insignificant during the EIA screening process. If it is not screened out at this point, a Noise and Vibration Assessment will be carried out to support the planning and permitting applications, which will include any mitigation proposed to ensure there would be no significant impact on sensitive receptors as a result of noise and vibration from the facility.

The wastewater produced at an EfW installation can also contain a wide range of potentially polluting substances depending upon the source and use of the water. The actual release will be highly dependent on the treatment and control systems applied (Neuwahl, et al., 2019). If the wastewater is proposed to be discharged to sewer, a trade effluent discharge consent (TEDC) must be applied for through the relevant sewerage undertaker. This will take into account the capacity and treatment capability of the destination wastewater treatment works in determining whether the discharge is accepted. If the proposed approach involves discharging to sewer, surface or groundwater, the impacts of this will be considered as part of the PPC permit application and, if issued, the permit will include the legal limits for key parameters such as flow rate, temperature, pH and relevant pollutant levels (UK Government, 2022). The environmental permit application will assess the potential environmental risks of emissions to air, land and water, which will be reviewed by the relevant regulator in the determination stage.

Climate impacts

Tolvik (2021) that there is a significant element of subjectivity in estimating carbon intensity of EfW, due to the absence of a standard methodology. This is further exacerbated by the wide variation in operational performance of individual EfWs and given that EfWs accept a range of wastes.

Zero Waste Scotland' (2021) calculated the carbon intensity and greenhouse gas (GHG) emissions of the six EfW facilities in Scotland that burned residual municipal waste in 2018. These facilities were:

- Three electricity-only conventional incineration facilities (Dunbar, Dundee/Baldovie and Edinburgh/Millerhill);

- Two gasifiers (Glasgow and West Lothian/Levenseat); and
- One heat-only facility (Shetland).

According to SEPA (2022a), there are currently eight EfW sites burning municipal waste in Scotland. This comprises the above six EfW facilities, as well as the South Clyde Energy Centre and Earls Gate Energy Centre.

Zero Waste Scotland (2021b) Life Cycle Analysis has been used to calculate the net GHG emissions per tonne of waste input for EfW against landfill as an alternative waste management option. The average carbon intensity calculated was 509 gCO_2/kWh. Electricity-only incinerators and gasifiers had an average carbon intensity of 524 gCO_2/kWh while the carbon intensity of the only heat-only incinerator operating in Scotland in 2018 was 325 gCO_2/kWh. This is in comparison to the carbon intensity of the marginal electricity grid in the UK in 2018, which was 270 gCO_2/kWh, and the carbon intensity for a central or small-scale natural gas facility for heat operating in the UK in 2018, which was 267 gCO_2/kWh. The average carbon intensity of the Scottish electricity grid in 2018 was 44 gCO_2e/kWh. The report stated that sending one tonne of residual municipal waste to EfW in Scotland in 2018 emitted 246 $kgCO_2e$, which was 27% less than if that waste was sent to landfill.

Zero Waste Scotland (2021b) also concluded that changes in the waste composition and technology can considerably alter the climate change impacts of residual municipal waste management. For EfW facilities, the fossil content of the waste has the most significant impact on GHG emissions per tonne of waste burnt. For landfill, the most significant factor is the biogenic content of waste entering landfill. Waste categories high in fossil carbon content include plastics and those high in biogenic carbon content include paper and food. When the amount of biogenic carbon in landfilled waste decreases, the GHG emissions from the landfill also decrease. It is assumed that all fossil carbon in the landfill is sequestered and so the reduction in biogenic carbon also reduces the amount of methane emitted from the landfill. The Zero Waste Scotland report stated that landfill and EfW impacts are equal when the proportion of food and paper waste in the residual municipal waste falls from the main model assumptions from 43.1% to 32.7%. In terms of technology type, Zero Waste Scotland (Zero Waste Scotland, 2021b) stated that the carbon intensity of electricity-only EfW facilities would be reduced by 30% if they were converted to Combined Heat and Power (CHP), but this would still be higher than the carbon intensity of alternative energy sources.

Zero Waste Scotland (2021b) also assessed the GHG emissions from meeting the BMW landfill ban in three different scenarios:

1. Incinerate all waste in facilities which operate at the 2018 levels;
2. Incinerate all waste in facilities which operate as CHPs; or
3. Upgrade all existing incinerators to CHPs and pre-treat waste sent to landfill using biostabilisation technology (the tonnage split between incineration and landfill remains at 2018 levels).

The 2018 baseline GHG emissions from managing residual municipal waste in Scotland were 422,892 tCO_2e. Scenario 1 would lower the emissions by 22% to 328,865 tCO_2e, Scenario 2 would reduce the emissions to 243,573 tCO_2e (42% below the 2018 baseline) and Scenario 3 could reduce the emissions by 72% to 116,926 tCO_2e. It is noted that he biostabilisation scenario is illustrative only and that more detailed research is required to understand the environmental impacts of this scenario in the Scottish context.

Zero Waste Scotland's 2017 & 2018 Carbon Metric summary Report (Zero Waste Scotland, 2020) found that carbon impacts from landfilling remained the second largest carbon contributor at 0.9 and 1 Mt CO_2e in 2017 and 2018 respectively, followed by incineration which remained at around 0.2 Mt CO_2e in both 2017 and 2018. Embodied carbon impacts from material production were the largest contributor to the whole-life carbon impacts of Scotland's waste.

Eunomia (2020) carried out an analysis comparing the emissions from landfill or incineration of one tonne of residual waste. Eunomia's GHG emissions analysis used a 'consumption' approach, meaning all emissions are included regardless of their location (Eunomia, 2020). The emissions benefits of recycling were included even though they are unlikely to occur in the UK.

The scenarios Eunomia looked at are as follows:

- Today: This scenario uses the current composition of household and commercial residual and recycling waste streams taken from WRAP's 2017 National Household Waste Composition and National Commercial Waste Composition reports.
- Expected-2035: This scenario models the changes in residual waste composition that would be expected if the UK implemented the aim of reaching a municipal recycling rate of 65% by 2035, as set out in the EU's Circular Economy Package. The Expected-2035 scenario models the effects of waste treatment over 100 years.
- Low heat decarbonisation: This scenario assumes that no progress is made in decarbonising heat provision.
- GWP20: Some may make the argument that, as climate change is such a pressing issue in the short term, carbon dioxide emissions are 'preferable' to methane emissions and the timeframe considered in analysis can hugely impact its conclusions. In this scenario, only methane emissions occurring in the first 20 years are considered, with the rest considered to be sequestered.

The results of Eunomia's analysis are provided in Table 6.

Table 6: Tonnes of carbon dioxide equivalent emitted (net) per tonne of waste treated via incineration or landfill. Adapted from Table 2-3: (Eunomia, 2020)

Scenario	Landfill (tCO_2e per t waste treated)		Incineration (tCO_2e per t waste treated)		
			Direct		Pre-treatment
	Direct	Biostabilisation	Electricity only	CHP	Electricity only
Today	0.32	-0.23	0.17	0.10	-0.29
Expected-2035*	0.30	-0.23	0.39	0.31	-0.18
Low heat decarbonisation	0.30	-0.23	0.39	0.26	-0.18

Scenario	**Landfill (tCO_2e per t waste treated)**		**Incineration (tCO_2e per t waste treated)**		
			Direct		Pre-treatment
	Direct	Biostabilisation	Electricity only	CHP	Electricity only
GWP20*	1.03	-0.17	0.39	0.31	-0.18

*Assumes the 65% recycling target is met and there is progress towards decarbonising energy systems

1. Biostabilisation includes a pre-treatment step to remove recyclables

In the present “today” scenario assessed in Eunomia’s report (Eunomia, 2020), incineration is shown to perform better than landfill. This is considered to be because of its electricity credit, i.e., the emissions reduction brought about by avoided electricity production elsewhere. EfW facilities with CHP perform better than electricity-only facilities. However, it should be noted that the assumed energy generation performance was in line with the best available technology operating in the UK and many older electricity-only facilities will perform worse than those modelled. For CHP, the analysis considered one of the best-performing CHP facilities in the UK at the time of writing (Sheffield).

In the scenario with pre-treatment of waste prior to either landfill or incineration, the result is a net emissions benefit today due to the additional credit arising from recycled materials. For the incineration with pre-treatment scenario, the result is slightly better than that of the bio-stabilisation with landfill scenario. This is because pre-treatment effectively removes a significant proportion of the remaining fossil carbon contained within materials such as plastics in the residual waste stream sent to the incineration facility.

The Expected-2035 scenario uses the expected residual waste composition and energy context in 2035. In this scenario, electricity-only incineration performs worse than landfill, while incineration operating in CHP mode and landfill are equivalent in terms of the tonnes of CO_2e emitted. It is noted that these results depend on the carbon intensity of the marginal sources of energy, i.e., if electricity and heat provision decarbonise less quickly than needed and anticipated, incineration may continue to perform better than landfill in this scenario.

In the scenario that assumes no progress is made in decarbonising heat provision, incineration facilities operating in CHP mode without pre-treatment would continue to be a net contributor to climate change. The report concludes that improvements in energy generation efficiency at incineration facility will be of diminishing value as the energy systems decarbonise. This trend is anticipated to continue beyond 2035, and the relative performance of incineration in comparison to landfill is expected to worsen up to 2050 (Eunomia, 2020).

The results of the analysis are also affected by the timeline used. For the GWP20 scenario, which only considers the emissions in the first 20 years, landfill appears significantly worse than incineration. The Eunomia report suggests that, when taking a short-term perspective with the view that climate action is extremely urgent, this means incineration might be preferable to landfill. However, this risks masking carbon dioxide’s long-term warming effect, for example the Paris Agreement target is set for 2100. The Eunomia report also notes that results generated by the lifecycle analysis methodology used do not properly consider the timeframe over which emissions from landfill are released. For incineration, the emissions occur immediately after treatment, whereas the emissions the first year after sending waste to landfill are a relatively small proportion of the total amount released over the 20-year period (Eunomia, 2020).

In Defra (2014) stated that by "using conventional analysis (disregarding biogenic carbon) the model indicates a good carbon case for continuing to include EfW as a key part of the hierarchy." The Defra study used a similar landfill model to that used in the Eunomia analysis, but it is noted in the Eunomia report that the sequestration of biogenic carbon is considered only as a sensitivity in the Defra report.

The aims of Defra's (2014) study were:

- To develop a simple model that allows variation of the critical factors and assumptions which impact the carbon-based environmental case for using EfW for treatment of residual waste, relative to landfill;
- To identify the balance point for this choice and understand how it is reliant on underlying assumptions; and
- To help determine what factors may need to be considered in order to ensure recovery of energy from residual waste remains environmentally superior to landfill (i.e. in line with the hierarchy) in the long term.

It is noted that other drivers, such as practicality, economics or fuel security, are important in determining the overall case for waste treatment choices and these were not considered in Defra's model.

The report concluded that, in order to move to a position where the carbon case for EfW is less equivocal and to minimise the risk of disbenefits:

- High efficiency solutions should be preferred, beyond that obtainable with mass burn incineration electricity only, for facilities commissioned beyond 2015.
- Use of heat provides the simplest route to ensuring continued primacy of EfW over landfill.
- The biogenic content of the waste should be maintained as high as possible through the removal of fossil plastics for recycling.
- The biogenic content of the waste needs to be understood and monitored in relation to the technology being used.
- Increasing the biogenic content of the waste fuel and the process efficiency of a facility during its lifetime will help ensure it continues to provide a carbon benefit.
- Mixed residual waste may need pre-processing to achieve the biogenic content required. The parasitic load required to do this should be included in efficiency calculations.
- It should not be assumed that extending the operational life of existing infrastructure is the best environmental option.

The approaches taken in each report differ in how they compare electricity-only incineration and landfill. Eunomia (2020) states that Defra's approach limits their analysis to simple incineration and landfill treatments; "no consideration is made of the effects of likely future waste compositions or the effects of pre-treatment. They thus ignore whether either of these approaches is suitable given that rapid decarbonisation is necessary." UKWIN (2021) states that GHG impacts can be highly sensitive to waste composition and that waste composition assumptions should therefore be justified, with sensitivity analysis included to show the impacts of future changes such as increased food and biowaste collection.

Tolvik (2021) stated that there is a general consensus that EfWs are not simply power stations and it is therefore incorrect to benchmark them solely against other sources of power generation. Thus, an estimate of carbon intensity needs to recognise the role of EfW facilities in diverting residual waste from landfill and, depending on their operational configuration, generating heat and contributing to recycling. The report estimated that in 2020, the average net carbon emissions across UK EfW facilities were 0.270 tCO_2e per tonne of waste, which is a slight increase from the recalculated 0.267 tCO_2e per tonne of waste seen in 2019. This increase excludes any benefits from avoiding landfill and reflects the ongoing decarbonisation of the grid, so reducing the benefits of power and heat exports from EfW. Tolvik (2021) stated that a recent report estimated the net impact of landfilling residual waste to be 0.320 tCO_2e per tonne, suggesting an average carbon benefit of EfW when compared with landfill of around 0.050 tCO2e per tonne of residual waste. It is noted that the range in EfW performance means that some EfW facilities will generate a bigger carbon benefit than average and the least efficient will show no benefit at all. Figure 27 of that report (Table 7 below) presents the estimated carbon emission data per tonne of waste input and the sources of those data.

Table 7. Estimated carbon emissions per tonne of waste input. Adapted from: Figure 27 (Tolvik, 2021)

	Per tonne of input waste	Unit	2017	2018	2019	2020
	Average CO_2 emitted	tCO_2	1.040	1.037	0.934	0.934
	% Fossil	%	47.9	47.9	47.9	47.9
Emissions	Fossil CO_2 emitted	tCO_2	0.498	0.497	0.448	0.448
	Other GHG emitted	tCO_2e	0.009	0.009	0.008	0.008
	Fuel/imported power	tCO_2e	0.005	0.004	0.004	0.004
	Total fossil emissions	**tCO_2e**	**0.511**	**0.510**	**0.459**	**0.459**
EfW Output	Power export	MWh	0.575	0.542	0.531	0.557
	Heat export	MWh	0.080	0.097	0.110	0.118
	Recycling benefit	t	0.019	0.019	0.019	0.019

	Per tonne of input waste	Unit	2017	2018	2019	2020
Substitution benefits	Power export	tCO_2e	(0.202)	(0.154)	(0.136)	(0.130)
	Heat export	tCO_2e	(0.016)	(0.018)	(0.019)	(0.020)
	Recycling benefit	tCO_2e	(0.023)	(0.039)	(0.038)	(0.039)
	Total benefits	**tCO_2e**	**(0.241)**	**(0.210)**	**(0.193)**	**(0.189)**
	Impact	**tCO_2e**	**0.270**	**0.299**	**0.267**	**0.270**
	Avoided landfill	tCO_2e	(0.320)			
	Net impact	**tCO_2e**	**(0.050)**	**(0.021)**	**(0.053)**	**(0.050)**

Policy Connect (2020) went a step further and stated in their report that the Government should support the development and integration of carbon capture and storage (CCS) technology into EfW facilities. However, the report does not consider the impacts of waste composition on GHG emissions and how pre-treatment can reduce the carbon impacts, which is likely to be a cheaper approach as CCS is considered an emerging technology in its use with EfW. UKWIN (2021) states that, "while heat export, carbon capture, and pre-treatment to remove plastics can potentially reduce overall GHG impacts of incineration, there are also uncertainties regarding deliverability and/or overall impacts".

Eunomia notes that Policy Connect's report "makes a favourable assumption about how much CO_2e is saved by diverting waste from landfill to incineration, without any discussion of the impact decarbonising the grid would have on this assumption" (Eunomia, 2020). Eunomia states that the modelling behind the report considers that 70% of UK incinerators will operate in CHP mode by 2030. This is compared to a figure of 20% that operated in CHP mode at the time of the Eunomia report.

Analysis conducted by UKWIN (2021) investigated current real world performance of the UK's Municipal Waste Incinerators (MWIs) based on information reported by operators and how this performance compared to historic GHG modelling carried out by the applicant for these facilities. UKWIN found that incinerators performed significantly worse than modelled for planning applications and environmental permits. The report stated that "incinerators often deliver lower levels of electricity generation and higher levels of fossil CO_2 emissions".

The key findings of the analysis were that, on average:

- The proportion of CO_2 that was fossil CO_2 was 13 percentage points higher than predicted at the planning or permitting stage.
- The fossil carbon intensity of electricity exported to the grid was around 49% higher than predicted by the applicant at the planning or permitting stage.
- Reported fossil CO_2 released per tonne of waste feedstock incinerated was around 20% higher than that predicted at the planning or permitting stage.

- Electricity generated by incinerators was 15% lower than implied by the claimed headline MW generation figure, i.e. an incinerator advertised as being capable of generating 10MW of electricity typically only generated 8.5MW.
- Electricity exported was around 28% lower headline MW generation figures.

Residues and recycling

The types and quantities of residue produced at an EfW vary according to the installation design, its operation and waste input (Neuwahl, et al., 2019). However, the following materials are commonly produced during the incineration process:

- bottom ash;
- boiler/fly ash (sometimes combined with bottom ash);
- other air pollution control residues (APCr) or flue gas cleaning (FGC) residues;
- sludge from waste water treatment.

APC residues are hazardous and fly ash can be hazardous, which can limit the available disposal and recovery options. Currently, the most common approach is to stabilise the residues before sending them to landfill. However, recovery opportunities are becoming more prevalent, such as carbonation and subsequent recycling of the residues (Zhang, et al., 2008).

Bottom ash (sometimes combined with boiler ash and fly ash, if non-hazardous) is usually left for a set period of time in order to stabilise leachates. After this stabilisation period, bottom ash is considered environmentally safe, although continual checks are required (Nixon, et al., 2013). Bottom ash can then be treated to recover the ferrous and non-ferrous metals, which are recycled, and the remaining bottom ash can be used in road, pavement and building construction or similar (Forteza, et al., 2004). It is noted that a report by Zero Waste Europe and ToxicoWatch (2019), concluded that, although the residues are often used in “green” solutions throughout the construction sector, “the content of hazardous compounds in those solutions exceed the safety limits recommended by scientific researches and the amended Basel Convention” (Zero Waste Europe, ToxicoWatch, 2019).

Defra (2013a) states that recyclables derived from front-end material separation or metals extracted from the bottom ash are typically of a lower quality than those derived from separate household recycling collection and therefore have a lower potential for high value markets. They can however be sold into the secondary metals markets for recycling and would still have a significant value. The metals in the bottom ash would not usually be recyclable at a typical MRF due to the level of contamination within the residual waste. This process therefore helps to increase recycling rates and replaces the use of virgin materials, the mining of which would have a high impact on natural resources (SL Recycling Ltd, 2022).

Friends of the Earth (2022) states that incineration contracts stop councils from recycling waste. However, the Waste (Scotland) Regulations 2012 introduced a ban on any metal, plastic, glass, paper, card and food collected separately for recycling to be sent to incineration or landfill from 1st January 2014, which would make it illegal for councils to send any of those materials put into household recycling to incineration, regardless of their contracts. The Waste (Scotland) Regulations 2012 also introduced the requirement that all new incinerators must ensure that metals and dense plastics have been removed from residual municipal waste prior to incineration (SEPA, 2022b).

3.1.5 Social impacts

New waste management facilities of any kind are likely to have both negative and positive impacts on local residents. The planning and PPC permit application will consider the potential impacts on local amenity (odour, noise, dust, traffic, landscape) in the context of the specific location and type and size of the facility.

One of the commonly stated social impacts of EfW facilities is that industrial sites are more likely to be located closer to less affluent population groups. A review of evidence conducted by Braubach and Fairburn (2010) found that across the reviewed studies, inequities were reported for risks related to residential location such as proximity to pollution sites, but increased exposure to environmental risks within more affluent population groups was rarely identified (Braubach & Fairburn, 2010).

The Scottish Index of Multiple Deprivation (SIMD) is a relative measure of deprivation which ranks 6,976 small areas (called data zones). Rank 1 represents the most deprived data zone in Scotland and 6,976 represents the least deprived data zone in Scotland. The rankings are split into deciles 1-10, which define the deprivation levels in 10% bands. Data zones in decile 1 are among the 10% most deprived areas in Scotland, and data zones in decile 10 are among the 10% least deprived. Fairburn et al. (2005) found that there was a strong relationship with socio-economic deprivation indicating increased exposure in more deprived data zones for industrial pollution, derelict land and low river water quality. More recently in 2021, in answer to a chamber and committees' question, the Scottish Parliament published the table presented in this report, showing the SIMD decile for incineration facilities operational in Scotland in 2019, accepting household or commercial waste (Scottish Parliament, 2021). On average, the EfW facilities (including the ATT facilities in Table 12) are not located disproportionately in the most deprived areas in Scotland. However, this is a very small sample size compared to the rest of the UK and one of the ATT facilities (Glasgow) is located in one of the most deprived parts of Scotland (decile 1).

Table 8. SIMD decile for incineration facilities operating in Scotland in 2019. Source: (Scottish Parliament, 2021)

Site name	Operator	Site activity	SIMD 2020 decile
Lerwick Energy Recovery Facility	Shetland Council	Incineration	3
MEB	MVV Environmental Baldovie Ltd.	Incineration	6
Dunbar ERF	Viridor Waste Management Ltd.	Incineration	7
Millerhill Recycling & Energy Recovery Centre	FCC Waste Services (UK) Ltd.	Incineration	6

Public opinion on waste management issues varies, although EfW facilitiess often receive staunch local opposition from individuals and both local and national organisations such as UKWIN, Friends of the Earth, Dovesdale Action Group and "SAY NO to Incineration at Barr/Killoch". Eshet et al. (2005) reviewed valuation estimates of externalities such as air pollutants, by-products, avoided burdens and energy recovery from incineration. The study concluded that there was inconsistency in part of the estimates across the reviewed studies, perhaps due to uncertainties around interactions with other factors that were not considered in the study. It was suggested that these values should be considered mostly as an indication for the order of magnitude of the externalities (Eshet et al., 2005).

Typically, the most positively viewed waste management options for MSW are recycling and composting. However, this is not necessarily reflected in local attitudes towards new waste and resource management facilities in their locality, including those for compositing and recycling. Defra (2013a) states that "public perception of waste incineration tends to be linked to issues associated with older facilities where the general site management requirements and pollution control measures were not as exacting as they are today". The IED sets stringent emissions controls for any type of thermal process regulated in the EU, and this was transposed into UK law following UK exit from the EU.

In response to the call for evidence, SEPA provided comments upon environmental impacts, as detailed below.

SEPA identified odour, noise, dust, litter and vermin as potential impacts from incineration on local communities. It stated that the main source of odour from incineration and co-incineration facilities is the handling and storage of delivered wastes and that odour is usually contained within the waste reception hall where air is extracted for use in the combustion process, thus destroying odorous compounds.

The environmental permitting regime also requires operators to produce an odour management plan and issued permits contain a standard condition – "All emissions to air from the Permitted Installation shall be free from offensive odour, as perceived by an Authorised Person, outside of the Site Boundary". This provides SEPA with a mechanism to assess whether there has been a breach of the permit. SEPA also noted that whilst odour complaints are received for incineration or co-incineration facilities these are low in number with few complaints being substantiated.

In terms of noise, SEPA stated that the main sources are from the operation of process equipment, steam venting and vehicle movements. SEPA state that measures to prevent or minimise noise from operational equipment are assessed during permit determination including the requirement for a noise assessment. The proposed noise attenuation (e.g. silencers and acoustic enclosures) must also be in accordance with BAT requirements. In addition, SEPA state that a general requirement is for operators to undertake a risk assessment to determine whether alternatives to standard tonal reversing alrms can be used to minimise any potential annoyance to nearby receptors from reversing HGVs. Permits also have a requirement for a noise survey to assess the impact at nearby noise sensitive receptors and for this to be repeated every two to four years depending on the proximity of the receptors.

SEPA stated that there should be minimal impacts of dust and litter from a well managed incineration facility due to their enclosed nature and use of covered vehicles and skips.

The number of complaints are usually very low or are unsubstantiated following investigation. Similarly, the enclosed nature of incineration facilities means birds are typically not a concern. Where baled waste is stored outside, this is restricted in quantity and storage duration to minimised the risk of vermin. SEPA also state that regular inspections are required to identify the presence of insects, birds or other vermin at an early stage. As a result, SEPA usually receive a low number, or no, complaints relating to vermin at incineration sites.

There are some concerns that being located near an EfW facility can have a negative impact on house prices in the local area (Liverpool Echo, 2015) and this was mentioned in some of the call to evidence responses, such as those by Dovesdale Action Group and UKWIN. There is limited published information available on this subject.

A study conducted by staff at Cranfield University (2013) looked at property prices surrounding three EfW facilitiess in the UK and compared the local price index before and after the facilities became operational. The study found no significant negative effect on property prices at any distance within 5 km of the facility, indicating that the perceived negative impact on property values is negligible (Phillips, et al., 2013).

A later study also carried out by Cranfield University (2017) used the Hedonic Pricing Method to quantify the impact of three EfW incinerators in England which were sited on previously industrialised land, at Newhaven, Marchwood and Allington. The study reported inconsistent impacts across the stage of development (planning, construction or operation) and distance from incinerator. The results showed some increases in property values within a specified distance, but the authors did not discuss this further as they could not explain why this might happen and stated that further research is needed in this area. Instead, they focused on the negative impacts found, which were impacts of 0.4% to 1.3% on the mean house prices once the EfW facilities were operational. It was hypothesised that the expected impacts relative to actual impacts could have a large influence on the results of a hedonic pricing study (Casado et al., 2017).

An american study from 1993 looked at how the effects of undesirable land use (incineration) evolve over the siting process and the life of the disamenity (Kiel and McClain, 1993). The study concluded that “the adjustment of house prices to the construction and operation of an undesirable facility is much more complex and prolonged than previously indicated”. The study indicated some price response to rumours of a facility and that the distance premium persists for 7 years after the facility began operating. It was stated that this is consistent with Galster’s hypothesis, that those who most strongly view the facility as a negative externality will relocate quickly, while others may withhold their decision until the facility is operating and they experience the effects (Kiel and McClain, 1993).

Another concern has been raised by dairy farmers located near the proposed Killoch EfW facility is that the presence of the incinerator will impact the quality of milk produced and therefore the price that can be charged for it (The Scottish Farmer, 2021). A similar example of this was also raised during the call for evidence and stated that perceived negative impacts from EfW facilities could result in loss of business.

Good practice in terms of regular consultation and engagement with members of the public is important in achieving planning consents and local acceptance of waste management infrastructure (Defra, 2013a). In its response to the call for evidence, Transition Black Isle requested that the public be kept informed throughout the process and that the review would have “the widest possible involvement of academics and companies with expertise in energy from landfill, experts in public engagement, experts in public health, experts in energy transfer, and experts in commercial scale composting”.

EfW facilities are also likely to provide vocational training for staff as well as a visitor centre to enable local groups to view the facility and learn more about how it operates (Defra, 2013a). For example, Millerhill EfW and Dunbar EfW have visitor and education centres which aim to provide local residents with information on the operation of the EfW facility and to educate school children on sustainable waste management.

3.1.6 Health impacts

Health impacts from municipal waste incinerators (MWIs) have long been a key topic of discussion around new EfW developments and are often raised as a concern by members of the public.

Some of the health-related issues raised by respondents to the call for evidence include:

- production of toxic particles and aerosols (Transition Black Isle);
- health implications for livestock, food production and the health and safety of the public as a consequence of proximity to incinerators (Dovesdale Action Group);
- concerns that adverse health impacts of incinerators are being underestimated because of the emphasis on the mass of particulate matter released as distinct from the number of particles released (UKWIN);
- increased roadside air pollution and impacts on quality of life as well as on existing health issues such as asthma and chronic respiratory diseases (SAY NO to Incinerator at Barr/Killoch).

Health Protection Scotland (now Public Health Scotland) issued a briefing note in 2009 regarding the incinceration of waste and reported human health effects (HPS, 2009). The briefing note concluded that the present regulatory regime governing waste incineration processes already incorporates a “precautionary” approach and sets emission standards explicitly designed to limit human exposure to potentially harmful contaminants. It was concluded that the evidence to date does not suggest that there is any need to adopt a more precautionary approach and that, providing that any existing or new incinerators operate in accordance with current regulations governing emissions, the scope for any adverse human health impacts associated with their emissions should remain minimal (HPS, 2009).

While some studies have reported associations between MWI exposures and adverse birth outcomes, there are few studies of modern MWIs operating to current European Union (EU) Industrial Emissions Directive standards (Ghosh, et al., 2019). Ghosh et al. (2019) looked at the associations between modelled ground-level particulate matter ≤10 μm in diameter (PM_{10}) from MWI emissions (as a proxy for MWI emissions) within 10 km of each MWI. Selected birth and infant mortality outcomes were then examined for all 22 MWIs operating in Great Britain from 2003–2010. The study also investigated associations with proximity of residence to a MWI. The analyses included 1,025,064 births and 18,694 infant deaths. The study found no evidence for increased risk of a range of birth outcomes, including birth weight, preterm delivery and infant mortality, in relation to either MWI emissions or living near an MWI operating to the current EU waste incinerator regulations in Great Britain. It is noted that one of the authors of the study, Anna Hansell, declared a Greenpeace membership and another, Brandon Parkes, declared a Friends of the Earth.

A study conducted by Enviros Consulting on behalf of Defra (Enviros Consulting Ltd, et al., 2004) examined epidemiological studies looking specifically at incinerators. Relatively few studies were found and those that were found focused on older facilities with higher emissions. A study by Cole-Hunter et al. (2020) found “a dearth of health studies related to the impacts of exposure to WtE emissions”. Cole-Hunter et al. (2020) concluded that “the limited evidence suggests that well-designed and operated WtE facilities using sorted feedstock (RDF) are critical to reduce potential adverse health (cancer and non-cancer) impacts, due to lower hazardous combustion-related emissions, compared to landfill or unsorted incineration”. The study also concluded that rigorous assessment of the technology and waste type is necessary to be carried out during the planning process in order to protect human health as “poorly fed WtE facilities may emit concentrated toxins with serious potential health risks, such as dioxins/furans and heavy metals”.

The Health Protection Agency, now part of Public Health England (PHE), undertook its own research of the available literature which focused primarily on the potential carcinogenic effects of pollution from incinerators including emissions of dioxins, with some consideration of the impact of particulate pollution. The impact of emissions of nitrogen oxides was not considered. The study concluded that “while it is not possible to rule out adverse health effects from modern, well regulated municipal waste incinerators with complete certainty, any potential damage to the health of those living close-by is likely to be very small, if detectable” (Health Protection Agency, 2010).

PHE published a position statement in 2019, based on research undertaken by Imperial College focusing on foetal abnormalities, which indicated that emissions from incineration were not considered to result in significant harm to health (PHE, 2019).

Air Quality Consultants (2020) carried out a study for the GLA which was one of the first to try quantifying the health impact of both particulate and nitrogen oxide pollution from incineration. The study concluded that 15 deaths of London residents per year were associated with emissions of nitrogen oxides and particulate matter from the five EfW facilities in London (Air Quality Consultants, 2020). Government datasets were used in the analysis to establish the anticipated health impacts of the pollution from these facilities. It is noted by Eunomia (2020) that existing evaluations of the health impacts of pollution are likely to be relatively conservative. Eunomia states that the current data used by the UK government to assess the health effects of pollution “does not include any consideration of the emerging evidence with regards to the health impacts, such as the links between NOx pollution and dementia and mental health issues” (Cerza, et al., 2019; King, 2019). The Particulate Research Group (2019) states that there is a lack of evidence regarding the threat to health posed by emissions of superfine particles emitted by facilities such as incinerators. It is noted that the Particulate Research Group (PRG), convened by Ron Bailey and chaired by Dr David Drew, comprises scientists Professors Mike Reeks and Vyvyan Howard, alongside Shlomo Dowen of the UKWIN (CIWM, 2019). It is also difficult to separate the impact of emissions from MWIs in comparison to other industrial activities as MWIs are not randomly located across the country and are often built in heavily industrialized areas with other sources of pollution (Font, et al., 2015).

In December 2021, The All Party Parliamentary Group on Air Pollution (TAPPGAP) published a grey paper titled ‘Pollution from Waste incineration: A Synopsis of Expert

Presentations on Health and Air Quality Impacts'. The paper summarised four presentations regarding the health and air quality impacts of waste incineration. One of these presentations was by Professor Vyvyan Howard, which stated that using weight or mass is not a useful metric for setting standards for PM. Instead, the number of particles should be used as "the majority of particles are ultrafine particles or nanoparticles", which can "spread throughout the human body – the brain, the heart, the kidneys" (TAPPGAP, 2021). Ruggero Ridolfi presented evidence of the biological impacts of air pollution from waste incineration. Ridolfi's study looked at "the prevelance of heavy metals in the toenails of children living near incinerators in Italy, including nickel, which is associated with acute childhood leukemia". The results of the study found that in the samples taken in the north-eastern areas, which contain the city's industrial zone and both waste incinerators, the concentration of metals in the toenails was 60% higher than in other areas of Forlì. Kirsten Bouman presented ToxicoWatch's findings concerning the accumulation of dioxins in chicken eggs up to 10 kilometres from incinerators. ToxicoWatch's biomonitoring research found that "the dioxin levels in eggs laid close to the incinerator in Harlingen exceeded the limits for safe consumption", while "eggs that were farther away from the incinerator (more than 10 km) were safe for consumption". Dominic Hogg's presentation was focused on air quality impacts, but also raised concerns that the list of pollutants regulated does not include all those that could be emitted by incinerators, such as brominated dioxins (TAPPGAP, 2021).

Jacob Hayler, executive director of the ESA, rebutted the findings of TAPPGAP's report, stating that it presents "a one-sided and selective view on the safety of essential energy recovery facilities in the UK" (MRW, 2021). Hayler referred to various studies that had concluded that "any safety risk associated with emissions from modern, well-run energy recovery facilities is very small, if indeed it exists at all". Hayler also stated that "under even the most ambitious recycling scenarios, the UK does not yet have sufficient energy recovery capacity to avoid sending residual waste to landfill, so it is essential that more capacity is developed to balance present and future needs" (MRW, 2021).

Douglas et al. (2017) used dispersion modelling to estimate spatial variability in PM_{10} concentrations arising from MWIs at postcodes within 10 km of MWIs in Great Britain in 2003−2010. Throughout the study, the authors refer to PM_{10} rather than total suspended particulates (total dust) as they state that size fraction studies have found all particulate incinerator emissions are <10 μm diameter (Buonanno, et al., 2009). Douglas et al (2017) found that the annual average modelled PM_{10} concentrations were 1.00×10^{-5} to 5.53×10^{-2} μg/m^3. This is a small contribution when compared to ambient background levels, which were typically 3−5 orders of magnitude higher (Douglas, et al., 2017).

The European Parliament's 'EU Air Quality Policy and WHO Guideline Values for Health' (2014) states that although WHO Air Quality Guidelines (AQGs) are based on health considerations, "exposure even below the guideline values may constitute health risks that cannot be excluded. This is especially true for pollutants such as PM for which it has been found that there is no threshold level below which adverse effects can be excluded. Also, mixtures of pollutants might have additive effects; highly sensitive groups might also be affected when exposed to levels at or below the WHO AQG" (European Parliament, 2014).

While Nixon et al. (2013) found that fluidized bed and rotary kiln technologies produced higher emissions of HCl and CO, Douglas et al. (2017) found no differences in PM_{10} emissions from Allington and Dundee compared to the other MWIs.

Douglas et al (2017) stated that, while ambient PM_{10} has been associated with adverse birth outcomes, ambient levels are much higher than those arising from MWI emissions. However, some epidemiological studies have found adverse birth outcomes associated with MWIs operating under the IED. Douglas et al. (2017) concludes that if these are causal associations, "it is likely to be due to agents other than PM_{10} that are also emitted from incinerators such as PCDD/Fs, PAHs, and heavy metals". However, Font et al. (2015) compared heavy metal emissions with measurements at nearby ambient metal monitoring sites around six MWIs in England and found limited evidence that emissions from MWIs reached ground level. Emissions data for the Dundee EfW facility from 2005 – 2010 are provided in Table 9, adapted from the Douglas et al. (2017) report.

Parkes et al (2020) investigated the risk of congenital anomalies in babies born to mothers living within 10 km of an MWI associated with: i) modelled concentrations of PM_{10} as a proxy for MWI emissions more generally and; ii) proximity of residential postcode to nearest MWI, in areas in England and Scotland that are covered by a congenital anomaly register. Their analysis included 219,486 births, stillbirths and terminations of pregnancy for foetal anomaly, 5,154 of these were cases of congenital anomalies. The study found no increased risk of congenital anomalies in relation to mean modelled PM_{10} concentrations from MWIs in England and Scotland as a proxy for MWI emissions more generally. Small increased risks (2–7%) were observed with proximity to the closest MWI for all congenital anomalies combined, congenital heart defects and genital anomalies. It was stated that these findings in proximity to MWI might reflect residual confounding, although it is not possible from these data to exclude a potential causal effect even in the absence of associations with modelled PM_{10} emissions. The study concluded that further monitoring of exposures and health outcomes near MWIs was needed (Parkes, et al., 2020).

Another, much less investigated, possible health impact of EfW facilities is the impact on mental health of living near a MWI. This might consist of worrying about the health impacts of pollution from the site. No specific studies have been found that investigated these effects. However, one study by Downey and van Willigen (2005) looked at the impact of industrial activity on individual well-being, including mental health, and found that industrial activity is associated with "perceptions of individual powerlessness and neighbourhood disorder, leading to higher levels of psychological distress". The study stated that further research is needed to investigate why industrial activity is associated with psychological distress and whether the link between industrial activity and depression is influenced by exposure to industrial pollutants (Downey & van Willigen, 2005). This may also have a social impact as individuals from less affluent areas experience greater mental health impacts than others from residential proximity to industrial activity and industrial activity is more likely to be located in or near less affluent population groups.

Table 9. Characteristics of the Dundee EfW. Adapted from Table 1: (Douglas, et al., 2017)

EfW facility	Facility type	Licensed throughput (tpa)	Years of data available	Population within 10km	Flues	No. of operational days	No. of days of missing data	No. of non-operational days	No. of days of emission above the EU-WID limit	Concentration of highest PM_{10} emission above EU-WID limit (mg/m^3)
Dundee	Fluidised bed	175200	2005 – 2010	172,002	1	1481	8	702	32	25
					2	1126	285	780	7	45

3.2 Advanced Thermal Treatment (Gasification And Pyrolysis)

3.2.1 Overview

Defra (2013b) set out how gasification involves the partial oxidation of a substance. This means that oxygen is added but the amounts are not sufficient to allow the fuel to be completely oxidised and full combustion to occur. The main product is a synthesis gas (syngas), which contains carbon monoxide, hydrogen and methane. The WI BREF (Neuwahl, et al., 2019) states that there are several different gasification processes available or being developed which are, in principle, suitable for the treatment of municipal wastes, certain hazardous wastes and dried sewage sludge.

Pyrolysis is the thermal degradation of a substance in the absence of oxygen. The products of pyrolysis are a solid residue and a syngas. The solid residue (char) is a combination of non-combustible materials and carbon.

Syngas from these ATT processes is a mixture of gases, including carbon monoxide, hydrogen, methane and a range of other volatile organic compounds (VOCs). A proportion of the syngas can be condensed to produce oils, waxes and tars. The condensable fraction can also be collected by cooling the syngas, which can then be used as a liquid fuel.

3.2.2 Technical Feasibility

How established it is for MSW

The WI BREF (Neuwahl, et al., 2019) states that alternative technologies for thermal waste treatment have been applied to selected waste streams and on a much smaller scale than conventional, combustion-based incineration.

Defra (2013b) states that raw municipal waste is usually not appropriate for pyrolysis or gasification and typically would require pre-treatment in the form of mechanical preparation and separation of glass, metals and inert materials. In general pyrolysis and gasification processes tend to prefer consistent feedstocks and there is a very limited track record of commercial scale pyrolysis facility accepting municipal derived wastes in the world.

There has been limited application of gasification and pyrolysis to MSW and RDF in the UK at commercial scale. This was the position as described by Defra (2013b) with only three operational facilities identified at the time. Since this date and also highlighted within the call for evidence, there has been a very mixed experience with ATT technologies within the UK.

Where it has been applied, the technology has experienced extensive ongoing operational difficulties that have led to this facility being closed for long periods, such as in the case of the development at Avonmouth by New Earth Solutions (since acquired by Beauparc) to treat RDF (Resource, 2017). Viridor's Glasgow facility has suffered ongoing construction delays due to its gasification technology Interserve provider leaving the market, whereas its sister facility at Dunbar based on conventional mass burn technology has reported a more straightforward construction (ENDS Waste & Bioenergy, n.d.). In 2019, it was reported that more household waste was being sent to the Allerton facility due to closure of a landfill (LetsRecycle, 2019). An RDF gasification facility called Eco Park Surrey started hot commissioning in late 2019 (LetsRecycle, 2020) and an update in 2021 stated that both the anaerobic digestion and gasification facilities have been performing well (Eco Park Surrey, 2022) though it is understood the gasification facility is still not fully operational. A fluidised bed gasification facility with RDF feedstock of smaller scale (100ktpa throughput), Levenseat Renewable Energy (LREL) in Scotland, was undergoing hot commissioning in early 2020 (Levenseat, 2020). “Levenseat EfW Phase 2” received planning consent in late 2020 to vary its consent and approach to a conventional combustion technology and to increase its capacity to 135 MW thermal (Levenseat, 2020).

There is limited experience of the application of pyrolysis technology for the treatment of MSW or RDF, its presence in the market is not well established and its commercial application is limited. A 2015 review of activity in the UK shows continued interest in research and pilot trials for some specific material streams, but no commercial scale or general MSW/RDF treatment facilities in the UK (Aston University European Bioenergy Research Institute, 2015).

Speed of Implementation

The speed of implementation for ATT processes will be similar to that of conventional incineration, as set out in section 3.1.2. However, recent experience points to delays within the construction and commissioning period.

Availability

Zero Waste Scotland (2021b) provides the installed capacity and actual amount of municipal waste incinerated at each of Scotland’s EfW facilities operating in 2018. It is worth noting that both of the ATT facilities began operating in 2018 and so the actual tonnage incinerated is likely to be an underestimate of the typical capacity. It is also unclear whether the capacity includes the tonnages accepted to the MRF and biological treatment elements of each facility. Tonnages actually incinerated in the years since 2018 have not been found.

Table 10. Operational ATT facilities in Scotland in 2018 which are permitted to take municipal waste. Adapted from Table 1: (Zero Waste Scotland, 2021b)

Facility name	Incinerator type	Incineration capacity (tpa)	Municipal waste incinerated in 2018 (tonnes)	Proportion of capacity used in 2018 (%)	Status in 2018 and energy generation type
Glasgow Recycling and Renewable Energy Centre (GRREC), Glasgow	Materials recovery facility (MRF), anaerobic digestion (AD) and gasifier	154,000	66,504	43	Began operations in 2018, producing SRF and electricity CHP potential, operating as electricity-only
Levenseat Thermal Waste	MRF, composting	200,000	63,355	32	Began operations in 2018, producing

Facility name	Incinerator type	Incineration capacity (tpa)	Municipal waste incinerated in 2018 (tonnes)	Proportion of capacity used in 2018 (%)	Status in 2018 and energy generation type
Treatment Facility, West Lothian	IVC and gasifier				SRF and electricity, CHP-ready

As with conventional incineration, the PPC process will require operators to outline their plans for start-up and shutdown, including what will happen to the waste feedstock during downtime (whether planned or unplanned).

Performance

Combustion of the fuels from the pyrolysis/gasification stage will be subject to the requirements of the IED and BATC. These emissions will require treatment and similar abatement to that applied to conventional incineration processes to ensure compliance with emission limits (CIWM, 2003).

Tarring can cause problems when using syngas in energy recovery at ATT facilities. The deposition of tars can cause blockages and other operational challenges and has been associated with facility failures and inefficiencies at a number of pilot and commercial scale facilities (Defra, 2013a). The application of a higher temperature secondary processing phase may be used to 'crack' the tars and clean up the syngas prior to its use in energy recovery. This process has the potential to provide higher efficiency energy recovery than is possible through other thermal treatment processes for waste. However, most commercial gasification facilities processing MSW-derived feedstocks utilise a secondary combustion chamber to burn the syngas and recover energy via a steam circuit. Whilst this is not incineration, the differences between the processes in practical and efficiency terms are less significant (Defra, 2013a).

Eco Park Surrey (2022) reported that the gasifier completed a continuous run of over two months at 95% availability, performing well and with all emissions within permitted levels. In October and November 2021 the gasifier and AD exported a combined total of over 1,700 MWh each month. The gasifier was shut down on 25 November 2021 ahead of scheduled inspections and routine annual maintenance and would be restarted in January 2022.

SEPA provides the compliance ratings for the two municipal waste-fired gasification facility that were operational in Scotland in 2018 and 2019 (SEPA, 2022a). These are set out in Table 11.

Table 11. Compliance ratings of gasification sites in Scotland in 2018 and 2019. Adapted from: (SEPA, 2022a)

Site name	Operator	Type	Permit number	2018 compliance rating	2019 compliance rating
Glasgow Recycling and Renewable Energy Centre	Viridor (Glasgow) Ltd	Gasification	PPC/A/1110002	Good	Broadly compliant
LREL	Levenseat Renewable Energy Ltd	Gasification	PPC/A/1150156	Good	Broadly compliant

3.2.3 Economic impacts

Reliable data concerning costs for each of the ATT options is difficult to obtain as there are very limited relevant examples in the UK that have achieved commercial operation. Although there are two gasification facilities in Scotland, these were developed as part of larger waste and resource management schemes, including material recovery and anaerobic digestion/composting, so cannot be used as an indicator of costs of a gasification facility alone. In many instances cost data is only based on estimates and has not been tested commercially, therefore possibly resulting in over optimistic estimates. Estimated costs for ATT are highly variable and range from lower than moving grate to significantly higher, but with a general consensus that the costs would be higher.

The capital costs for an ATT facility depend on the quality of waste to be processed, the technology used and the proposed location. Costs consist of those associated with the purchase of the ATT facility and land, preparation of the land prior to developing it, and indirect costs such as planning, permitting, contractual support and technical and financial services over the development cycle (Defra, 2013b).

Capital costs provided to Defra (2013b) by ATT technology suppliers and those reported in the trade press are wide ranging. A range of capital costs are shown below:

- £9m-£55m capital cost for facilities of 25ktpa – 100ktpa

The overall costs will be determined by gate fees for waste feedstock, the access to renewable energy incentives, sales of electricity / gas, operational costs associated with running the facility and the cost for disposal of facility residues (Defra, 2013b).

As with conventional incineration facilities, there are a number of funding sources for Local Authorities planning to develop ATT facilities (Defra, 2013b). In addition to the type of facility proposed, the supply contract type can also have cost implications. For example, a turnkey contract can often attract much higher contract costs compared to a supply and install only contract (Defra, 2013b).

Job creation is generally considered an economic and social benefit of new developments. Defra (2013b) states that typical employment for an ATT facility of 50,000tpa capacity would be in the order of 25 – 35 permanent staff. Information regarding the Levenseat EfW facility states that there would be 100 permanent jobs created in total from this development. This consists of 70 positions within the material recovery facility (MRF) and 30 within the EfW facility (Levenseat, n.d.).

3.2.4 Environmental impacts

There are limited studies on the environmental impacts of ATT technologies, and no studies were found which looked at ATT using municipal wastes. Generally, the emissions to air would be similar to those coming from conventional incineration and so many of the studies mentioned in section 3.1.4 are relevant to ATT processes. However, the overall efficiency of the gasification process is generally considered better than that of conventional incineration as the losses of elements such as moisture from the wet stream and biological elements are removed. Similarly, metals and inert materials are withdrawn from the system and the system operates at lower excess air so the calorific value of the waste, resulting in a higher waste to energy conversion with less CO_2 and NOx emitted.

Emissions to air, land and water

All facilities based on combustion, gasification or pyrolysis technologies where they burn waste materials and/or syngas will be required to comply with the BATC and, where these aren't applicable, IED. Most technology providers will only provide IED and/or BATC limit guarantees and will include similar abatement for all technology options to ensure that these levels are met. However, in practice, different unabated emissions performance is achieved by the various technologies (Neuwahl, et al., 2019). The flue gas cleaning processes required depends on the ATT process used. Fine particles in the syngas can be removed before or after combustion, depending on the treatment process and combustion technology employed (Defra, 2013b).

One of the main benefits claimed by manufacturers for ATT facilities is that pollutant emissions are lower than those from conventional incineration. The flue gases are maintained at high temperatures for a minimum time, as specified in the IED, after which the flue gases are cooled rapidly. These stages minimise the formation of potentially harmful substances and subsequent flue gas cleaning stages are installed to reduce the emissions to air of any remaining pollutants. The residual emissions to air from waste thermal treatment processes are discharged from a stack which is designed to provide sufficient dispersion of the low levels of remaining air pollutants (Defra, 2013b).

Any waste management operations can give rise to dust and odours. These can be mitigated through good building design, keeping operations within enclosed buildings, good working practices and dust suppression from vehicle movements (such as wheel washes). Potential odour emissions can typically be controlled through the building ventilation system and ATT processes are usually designed to operate under negative pressure within buildings in order to minimise dust and odour problems (Defra, 2013b). These issues are addressed in the planning and permitting stages of any ATT development.

As set out in section 3.1.4, noise and vibration is a potential issue for any waste treatment facility, included ATT. This is usually mitigated through noise level limits in planning conditions and a noise assessment carried out at the planning and permitting stages to set out what mitigation will be in place, if necessary.

As with conventional incineration, the enclosed nature of the operations significantly reduces the potential for impacts on the local water environment. Defra (2013b) states that the greatest potential for pollution to surface/ground water is linked to the arrangement for delivery of waste and the collection of processed materials. Uncontrolled emission to water are unlikely due to ATT facilities being under cover and the requirement to have a sealed drainage system on site. As stated in section 3.1.4 on conventional incineration, the operator will be required to apply for consent to discharge trade effluent from the process, via the regulator and/or local sewerage undertaker.

Climate impacts

The quantity of carbon dioxide released, either directly or indirectly, from the combustion of the waste will be fixed. The same requirement for carbon content in ash applies to gasification and pyrolysis processes subject to the IED and BATC. The products of gasification/pyrolysis processes (a combination of syngas, liquid fuel and solid residue) will contain the chemical energy associated with the same carbon input stream and will be converted by oxidation to carbon dioxide, assuming these are combusted.

The chemistry of the combustion process would be similar for each of the thermal treatment options considered, although the reactions might be optimised under differing conditions, typically giving rise to the same overall emission of carbon dioxide associated with a given waste feed composition (Defra, 2013b).

The climate studies mentioned in section 3.1.4 are also generally applicable to ATT technologies as they typically look at incineration as a whole, rather than splitting it into conventional and ATT.

Residues

The key outputs from ATT processes are typically: slag/char; ash (un-fused residue from gasification); APC residues; and syngas.

As with conventional incineration, recyclables may be recovered from front-end pre-treatment and/or from the ash. The materials recovered from ATT processes almost always include ferrous and non-ferrous metals, which are usually recovered from the front end of the process. Metal removal can help increase overall recycling levels and enable recovery of certain materials that would not normally be collected in household systems such as steel coat hangers (Defra, 2013b). Pyrolysis oil can be used in various chemical applications, subject to meeting quality requirements of the proposed end-use. Pyrolysis also results in a solid char that contains significant amounts of carbon. This would generally be disposed of to landfill or treated further to reduce the carbon content. Once the carbon content has been reduced, the ash residue could then be recycled as a secondary aggregate. Gasification tends to produce an ash which has a lower carbon content and has usually been melted or fused in the higher temperature processes, and this could be recycled as aggregate without further treatment. The ash produced can be recycled via the same routes as bottom ash from conventional incineration, as set out in section 3.1.4.

It is noted by Defra (2013b) that recyclate derived from an ATT plant processing household waste qualifies as being ‘recycled’ for any materials recovered (and reprocessed) from either end of the process. However, any slag, char or ash recycled (for example for use in construction aggregates) does not count towards recycling targets.

3.2.5 Social impacts

There are limited studies on the social impacts of ATT technologies, and no studies were found that looked at ATT using municipal wastes. As with conventional incineration, public opinion varies. New waste management facilities of any kind are likely to have both negative and positive impacts on local residents. Any new waste management developments are likely to provide vocational training for staff as well as a visitor centre to enable local groups to view the facility and learn more about how it operates (Defra, 2013b).

One of the commonly stated social impacts of EfW facilities in general is that industrial sites are more likely to be located closer to less affluent population groups. As stated in section 3.1.5, studies have found links between socio-economic deprivation and risks related to proximity to pollution sites (Braubach & Fairburn, 2010; Fairburn, et al., 2005). Table 12 shows the SIMD decile for ATT facilities operational in Scotland in 2019, accepting household or commercial waste (Scottish Parliament, 2021). The table shows quite a spread, from the Glasgow facility located among the 10% most deprived areas and the Dunbar and Levenseat facilities located in the 40% least deprived.

Table 12. SIMD decile for ATT facilities operating in Scotland in 2019. Source: (Scottish Parliament, 2021)

Site name	Operator	Site activity	SIMD 2020 decile
Glasgow Recycling & Renewable Energy Centre	Viridor (Glasgow) Ltd.	Incineration	1
LREL	Levenseat Renewable Energy Ltd.	Incineration	7

Eco Park Surrey (2022) reported that “during colder weather the steam exiting the stack is more visible and we have recently been receiving increased questions and complaints incorrectly referring to the steam plume and odour as smoke.” The planning and permitting application will consider the potential impacts on local amenity (odour, noise, dust, traffic, landscape) in the context of the specific location and type and size of the facility.

Defra (2013b) states that in public consultations ATT technologies score inconsistently when explained in detail as a residual waste treatment technology. There is a general distrust of advanced thermal treatment systems in the UK and national environment campaign organisation in the UK have a mixed position regarding ATT. Defra (2013b) suggests that this is partly due to uncertainty over technology and environmental performance and that this highlights the importance of proactive communication with the public throughout the development process.

As with conventional incineration, there are public concerns that the presence of EfW facilities of any kind, including ATT, have a negative impact on house prices. While there was very limited information found regarding this concern, a study by Cranfield University (2014) found no significant negative impact on property values within 5 km of the 3 EfW facilities assessed.

3.2.6 Health impacts

There are limited studies on the health impacts of ATT technologies, and no studies were found which looked at ATT using municipal wastes. Generally, the emissions to air would be similar to those coming from conventional incineration and so many of the studies mentioned in section 3.1.6 are relevant to ATT processes as these are applicable to incineration as a whole and do not separate conventional and advanced processes.

3.3 Summary

In summary, conventional incineration of MSW is considered technically feasible and can have both positive and negative economic, environmental and social impacts. Conventional incineration can provide electricity and heat, increase recycling rates and is generally considered to have less of an impact on the environment than landfill, although there are many factors which affect this. There is limited evidence of adverse impacts to health, but it is noted that further research is required in this area.

There is less evidence available looking at the effects of ATT of municipal wastes. Although there are two operational gasification facilities in Scotland, these are both part of wider resource and waste management facilities, which makes it difficult to discern the aspects solely relevant to the gasification facility.

Due to the similarities in processes, much of the literature that is available for conventional incineration of municipal waste is applicable to ATT as well.

4. Landfill

4.1 Overview

Landfill means a ‘waste disposal site for the deposit of the waste onto or into land (i.e., underground) (European Council, 1999)’. The Landfill Directive sets minimum standards for the location, design, construction and operation of landfills. Importantly, it defines the categories of waste that can be disposed of at landfill, including municipal waste, and the class of landfills which are divided into three classes: landfills for hazardous waste, landfills for non-hazardous waste and landfills for inert waste. Operators of landfills must apply for a PPC permit in Scotland and meet stringent conditions to minimise the environmental impact and risk to human health. The Directive also sets targets for the UK to reduce BMW disposed of to landfill. This included a 2020 target to reduce the biodegradable waste landfilled to 35% of that produced in 1995. According to the waste hierarchy it is the least preferable option (European Parliament, 2008; Scottish Government, 2017).

In Scotland, disposal of MSW to landfill is a mature management technique and is well established with a network of approximately 41 operational sites across the country (SEPA, 2021). The total waste disposed of to landfill was 2.6 million tonnes in 2020. Of this, household and similar wastes amounted to 736,000 tonnes (28.1% of total) and sorting residues amounted to 689,000 tonnes (26.4% of total). Since 2017, there has been a reduction of 487,000 tonnes of household and similar waste disposed to landfill – this has coincided with an increase of 256,000 tonnes of household and similar waste incinerated. These figures do not account for waste disposed of outside of Scotland. The Scottish Government intended to introduce a ban on BMW disposed of to landfill from 1 January 2021, however this was subsequently delayed and is discussed in more detail in the following section.

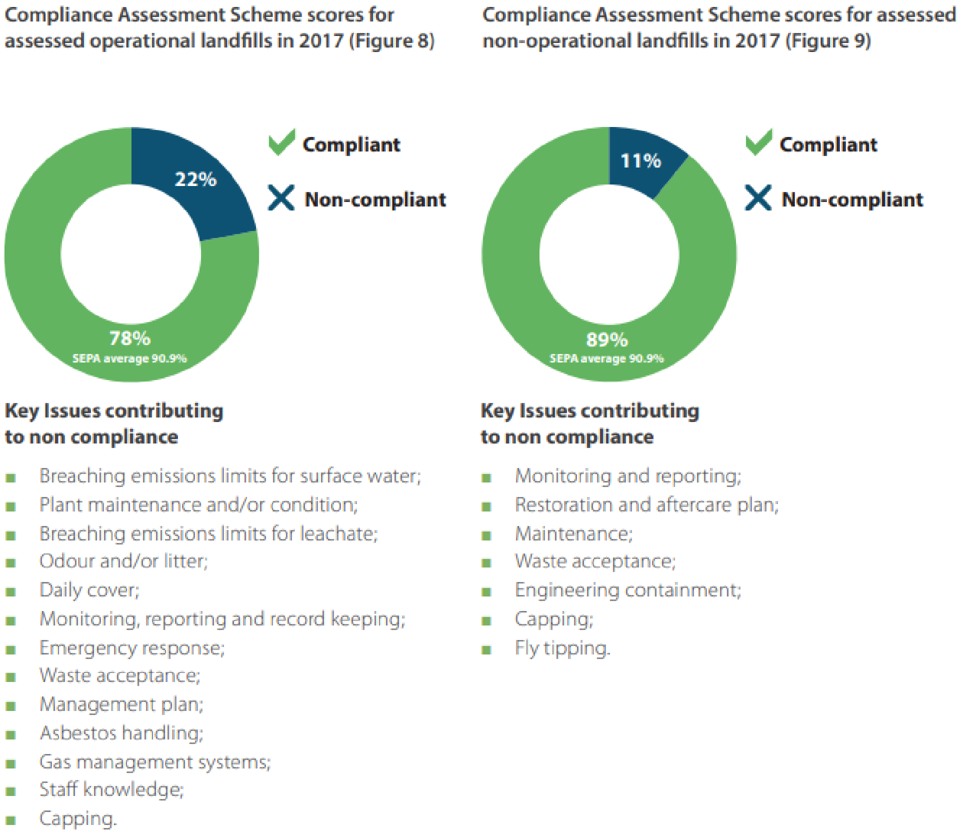
4.2 Technical Feasibility

Compliance with environmental law and applicable technical standards is important for landfills due to their potential environmental and human health impacts, as discussed in sections 4.4 and 4.6. The majority of environmental legislation in Scotland originates from the European Union including the Landfill Directive and Waste Framework Directive. The former sets minimum standards for the location, design, construction and operation of landfills. Landfill feasibility is largely dependent on finding a suitable location in terms of geology and nearby receptors as they are heavily linked to environmental and human health risk assessment. The operational lifetime of landfills depends upon their capacity and the quantity of waste received each year. However, there can be up to a 60-year (and in some instances, longer) closure and aftercare stage in which the landfill must continue to meet technical requirements and therefore landfills represent a significant investment in time and money.

Nationally, there is excess capacity in Scotland’s landfills to manage the forecast waste arisings over the next ten years (SEPA, 2020). However, this fails to consider the geographic distribution of landfill capacity – with certain regions, such as Tayside, having a capacity deficit. An option to increase capacity in these regions is to expand existing landfill sites. The feasibility of this is dependent upon planning and permitting considerations, whether it is consistent with local and national planning policy and site-specific conditions such as available space, topography, the proximity of environmental and human receptors to the site and the suitability of ground conditions. These factors mean it is difficult to estimate the feasibility and timescales, however it is likely that this would take from one to five years and require long term planning.

The Landfill Sector Plan (SEPA, 2020) sets out SEPA’s objectives for closed and operational landfills going forward, which impacts technical feasibility. This includes objectives to ensure operators are fully compliant with environmental protection laws and to help operators move beyond compliance to achieve best practice. The plan notes that current compliance levels are extremely low with only 78% of landfills compliant in 2017. Of the twelve non-compliant sites, ten have been non-compliant for two or more years which is considered as ‘chronic’ non-compliant by SEPA. Landfills receive the highest proportion of complaints of the sites regulated by SEPA with odour being the most common complaint. The compliance rates and key issues for operational and non-operational landfills are presented in **Error! Reference source not found.**. More recent c ompliance assessment data, for 2019, identified 19 operational and non-operational landfill sites where compliance was determined to be poor, very poor or at risk (SEPA, 2022). Enforcement action included five statutory notices, two final warning letters and nine monetary penalties.

Figure 4. Compliance assessment scheme scores for operational (left) and non-operational (right) landfills (SEPA, 2020)



There are various technical requirements that landfills disposing of MSW must adhere to. For example, a non-hazardous landfill must be lined on the base and sides prior to deposition of waste into separated cells and covered with an engineered cap, typically consisting of clay and other soils, following deposition. Decomposition of organic waste in landfills produces a gas consisting of methane, carbon dioxide and smaller amounts of other gases which are captured and burned off or used in an on-site energy generation facility. Moisture which enters landfills interacts with MSW to extract contaminants into the liquid phase – producing leachate. The leachate should be managed to protect soils, groundwater and surface water.

Following the ban on BMW disposed to landfill, operators will be required to demonstrate that treated BMW is no longer biodegradable and is therefore suitable for landfill. The Landfill (Scotland) Regulations 2003 (as amended) provide two ways to demonstrate that BMW is no longer biodegradable. This can be done through treatment by MBT or incineration.

Residues for disposal to landfill following MBT must achieve either:

- Respiratory Activity after 4 days below 10 mg O2/g dm; or
- Dynamic Respiration Index below 1,000 mg O2/kg VS/h.

Whereas the residues of BMW following incineration must achieve a Total Organic Carbon value of less than 5%.

This allows residues from treatment of BMW to continue to be disposed of to landfill where the treatment is shown to meet these tests.

Landfills are usually developed in several phases and once the permitted capacity has been reached, they are restored to allow use of the site for agriculture, amenities or nature conservation. However, before they are fully restored, they go through a period of closure, aftercare and restoration and permit holders are required to submit a detailed plan to SEPA setting out the specific activities they will undertake before proceeding to this stage. Aftercare can last for a period of up to 60 years and therefore permit holders must demonstrate to SEPA that they have financial provision to pay for the aftercare and restoration (UK Government, 2020).

Aftercare activities include installing capping and surface water drainage layers and assessing the effectiveness of the cap and any cap maintenance required. Other significant costs are associated with continued operation and maintenance of landfill gas and leachate management infrastructure. There is also a requirement for continued environmental monitoring of landfill gas and any other risks identified through a conceptual site model – these are likely to include surface water and groundwater monitoring. There are also costs associated with analysing samples and maintaining boreholes on site. The environmental impacts of landfill are discussed further in section 4.4. Surface water must continue to be managed including the costs of clearing and maintaining them. Where there continues to be a risk on the site, security may be required to limit public access to the site. Finally, any site-specific activities that are required must also be included in the financial provision along with the cost of producing the surrender report and performance reports or topographical surveys.

A report by Honace (2018) on behalf of Defra looked at landfill aftercare in the UK. The report included modelling of non-hazardous landfill aftercare costs to determine a low, medium, and high -cost scenarios for small and medium sized sites. A summary of the findings is presented in Table 13. This shows that for the central cost scenario, a modelled dilute and attenuate site costs between £0.39/m^3 and £1.52/m^3 and for a containment site it is between £0.93/m^3 and £6.26/m^3 for deposited wastes. This indicates that there are significantly greater costs per m^3 where leachate requires removal from site for treatment and for managing smaller sites in the order of 1 million m^3.

In Scotland, the total landfill capacity for operational non-hazardous landfill sites ranges from 27,000 tonnes to 35 million tonnes with a median of 1.7 million tonnes (SEPA, 2020). Assuming a conversion factor of 3 m^3/tonne for deposited waste, the median site is estimated to be in the order of 5 million m^3 which is near the size of a medium sized site in the report by Honace (2018).

Table 13: Estimated 60-year aftercare costs by £ per m^3 of deposited waste in UK (Honace, 2018)

Site type	Low cost scenario (£/m^3)	Central cost scenario (£/m^3)	High cost scenario (£/m^3)
Non-hazardous SMALL site (1Mm^3)			
Dilute and attenuate	0.54	1.52	4.04
Containment (leachate discharge to sewer)	0.74	2.66	8.48
Containment (leachate treatment plant)	1.71	4.64	13.27

Site type	Low cost scenario (£/m³)	Central cost scenario (£/m³)	High cost scenario (£/m³)
Containment (leachate tankering)	1.82	6.26	16.88
Non-hazardous MEDIUM site (6Mm³)			
Dilute and attenuate	0.15	0.39	1.22
Containment (leachate discharge to sewer)	0.27	0.93	3.30
Containment (leachate treatment plant)	0.71	1.80	5.42
Containment (leachate tankering)	0.99	2.73	7.50

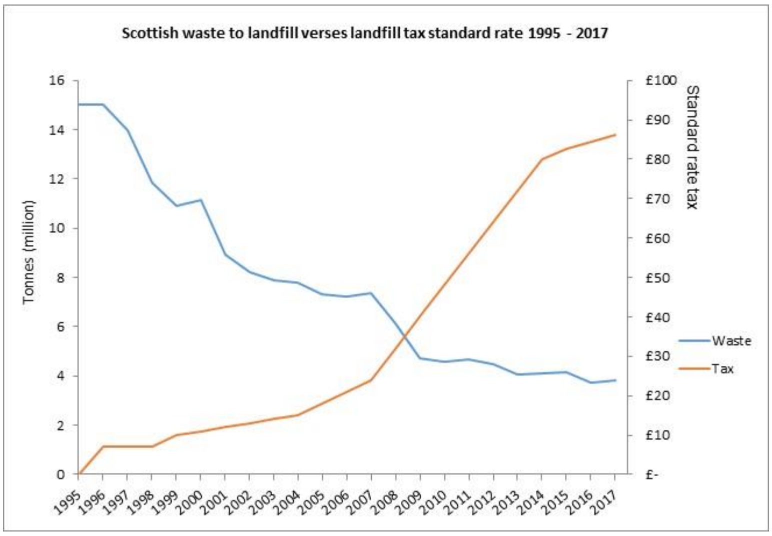
4.3 Economic Impacts

Landfill tax is paid by landfill operators on the disposal of waste at a landfill site. The tax was introduced in the Finance Act 1996 to incentivise the diversion of waste from landfill. In Scotland, provision is now made under the Scotland Act 2012 and subsequent Landfill Tax (Scotland) Act 2014. Since April 2015 it has been administered by Revenue Scotland and receipts/declarations are no longer included in HMRC figures. The tax has acted as a ceiling on the cost of waste management in the UK.

The tax is charged per tonne with two rates depending upon the type of waste. Non-hazardous and low-polluting waste, such as non-biodegradable wastes that have low organic content or do not break down under the anaerobic conditions that prevail in landfill sites to produce methane are charged with a lower rate, while all other taxable materials, including all disposals at an unauthorised site, are charged with the standard rate. From April 2022, the lower rate in Scotland is £3.15 per tonne and the standard rate is £98.60 per tonne (Scottish Government, 2021).

Landfill tax has been a key factor in the changing of attitudes and the diversion of waste from landfill. As seen in **Error! Reference source not found.**, the rate of landfill tax has b een increasing since it was introduced, whilst the quantity of waste sent to landfill has reduced. By diverting waste from landfill, the landfill tax has promoted other waste management routes.

Figure 5: The reduction of waste landfilled in Scotland against the rising landfill tax (Scottish Government, 2021)



The continued economic feasibility of landfills is dependent upon the availability of wastes that are suitable and permitted to be disposed of to landfill. The ban on BMW disposal to landfill in 2025 and an increase in the capacity of alternative residual waste treatment options in Scotland will reduce the feasibility of landfills and may lead to closures. This will subsequently reduce landfill tax revenues and therefore the tax received by Revenue Scotland. This will also reduce operators' contributions to community funds designed to benefit populations living near landfill sites – this is discussed further in Section 4.5. (Eunomia, 2019)

A report by Eunomia (2019) on behalf of the Scottish Government looked at the financial and economic implications for Scotland of the anticipated ban on BMW disposal to landfill in 2021. The alternative options were – (1) disposal in landfills in England or recovery in EfW facilities; or (2) export as RDF to continental or Irish EfW facilities. The report found that both alternatives resulted in an economic cost to Scotland. In option 1, an increase in Scottish incineration capacity mitigates some of this cost by reducing the quantity of waste that is exported and retaining the revenue in Scotland. However, this was based on a 2021 ban and given the market has more time to adjust this may reduce the economic costs. Another factor that the report considers is the extent to which waste minimisation and recycling targets are met. Should these continue to improve, it reduces economic costs of managing residual wastes outside of Scotland. Additionally, the report does not consider the wider economic costs of pursuing a more circular economy. A previous report by Zero Waste Scotland (2011) found that regulations for separate collection of recyclables and a ban on BMW disposed of to landfill could benefit Scotland's economy by £178 million by 2025. However, the assumptions made to estimate this figure are no longer valid as it was based on an earlier introduction of separate collections and landfill ban.

4.4 Environmental Impacts

The potential environmental impacts of disposing of residual waste to landfill and the resultant emissions include impacts to air, climate, land and water. These impacts are limited through legislative requirements and standards for the location, design, construction, operation and restoration of landfills. However, even with these controls there can be emissions in the form of air pollution typically released during operation (see section 4.6 for health impacts), greenhouse gas emissions from the decomposition of organic wastes and leachate produced through moisture entering the landfill and extracting contaminants into the liquid phase.

The GHG emissions from landfill and landfill with pre-treatment including bio-stabilisation were investigated by Eunomia (2020). The report considers the carbon dioxide, methane and nitorgen dioxide emitted in tonnes of carbon dioxide equivalent per tonne of waste. These were modelled in two primary scenarios – (1) based on the composition at the time and energy sources; and (2) a 2035 scenario where these have evolved through improved recycling rates and lower carbon intensity energy sources. A variation of the 2035 scenario was also modelled – (3) a scenario which uses the same waste composition and energy assumptions as the second scenario but emissions are only considered in the first 20 years and a higher global warming potential (GWP) is assigned to methane. The results, shown in Table 6, indicate that in both scenario 1 and 2 landfill has a significant GHG impact. When looking at scenario 3, the GHG emissions increases signficantly due to the short term impact of methane. However, the pre-treatment and bio-stabilisation of waste prior to disposal to landfill actually results in a net emissions benefit due to the recycled materials, assuming that the remaining organic waste in the residual stream is bio-stabilised prior to disposal. This contradicts with the Zero Waste Scotland (2022) report on alternative residual waste treatment which found that biostabilised waste does generate some landfill gas.

The Scottish Government (2019) undertook economic and environmental impact modelling of various market scenarios following the anticipated ban on BMW disposal to landfill on 1 January 2021. This modelling included the environmental impact of using different markets compared to a baseline, where waste continued to be managed as usual with no ban in place. Two options were modelled – (1) no new treatment capacity is developed in Scotland and (2) additional thermal treatment capacity is developed in Scotland. In both options there is an expected increase in haulage and waste exports to meet the gap between Scotland's residual waste capacity and the residual waste generated. Exports decrease over time in option 2 as thermal treatment capacity increases. As the ban has been delayed to 2025 this has given markets more time to prepare and therefore there should be a reduced reliance on exports. However, the use of alternatives to landfill is expected to increase emissions associated with transport when compared to landfill.

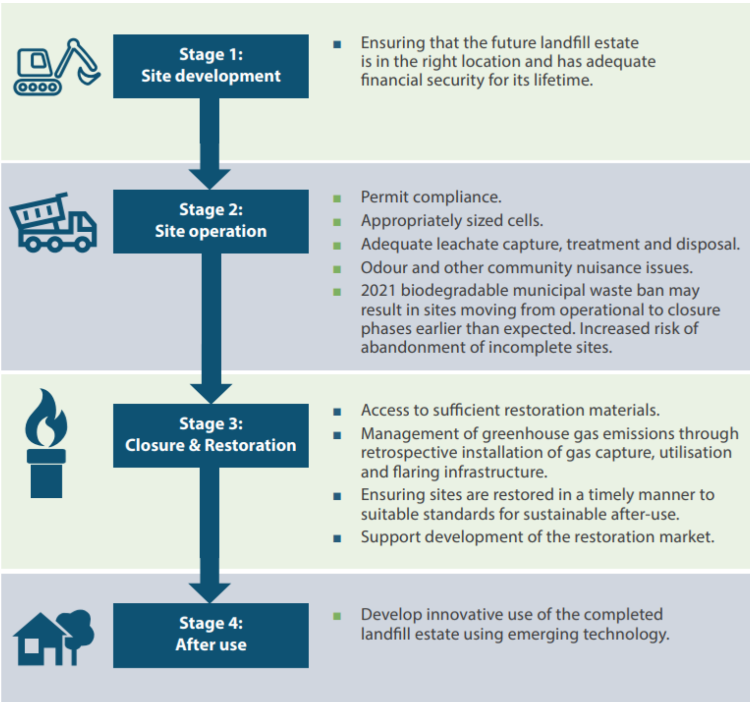
The environmental impact of a landfill is likely to vary from landfill to landfill based on a range of circumstances such as waste composition, environmental setting and operator compliance. A literature review of approaches to environmental risk assessments regarding landfill and the risk from landfill gas, leachate and degraded waste was completed by Butt, et al., (2008). This found that there was no coherent integrated risk assessment for landfill sites. A similar study undertook a comprehensive literature review to investigate how environmental impacts can be risk assessed on a logical and consistent basis to inform decision making with a particular focus on the risk from landfills and leachate (Butt, et al., 2014). The review concludes that there is not a consistent procedure for determining the holistic baseline for waste disposal sites, which risk assessors can use to analyse the risk of landfill leachate.

According to HPA, (2011), modern landfills in the UK are subject to risk assessments in accordance with their permit and therefore should be operated such that there is no significant impact on groundwater. The majority of leachate in a modern landfill is collected, treated on-site or at a sewage treatment works and safely discharged. The liners used should be effective in containing leachate with very limited quantities released to land or groundwater.

Koliopoulos & Koliopoulou (2006) established an experimental landfill in West Dunbartonshire to investigate whether waste pre-treatment and landfill management techniques can improve environmental protection. The results suggest that the co-disposal of non-hazardous wastes with inert waste and use of wet pulverisation can excelerate waste biodegradation through leachate recirculation. This can reduce the period of active landfill emissions and associated environmental risks. The stabilisation of the landfill in short timeframe prevent long-term landfill emissions.

SEPA issue permits to landfill operators that must be complied with and, ultimately, operators must comply with the Landfill Directive, Waste Framework Directive and waste hiearchy. The permitting process requires applicants to undertake a range of assessments which include habitats regulations assessments, landfill gas recovery, stability risk assessments and amenity risk. As previously mentioned, SEPA (2020) have developed a Landfill Sector Plan with an objective to improve landfill operators' compliance with environmental protection laws and where possible move beyond compliance. The key environmental challenges posed by the sector at each stage of the landfill lifecycle are presented in Figure 6.

Figure 6: Environmental challenges through the landfill lifecycle (SEPA, 2020)



At stage 1 environmental impacts and associated avoidance or mitigation measures are assessed through planning and permit applications for landfill sites. However, as most landfill sites in Scotland are in operation or closure stages, and with limited scope for future sites, the environmental impacts are largely regulated through compliance with existing permits. During operation operators must comply with their permits including requirements for cell engineering; leachate capture, treatment and disposal; and odour or nuisance. The landfill gas emissions must be managed at stage 2 and 3 through the installation of gas capture, utilisation and flaring infrastructure. Finally, landfills must be restored in accordance with planning and permitting requirements in a timely manner and to a suitable standard to enable sustainable after-use.

4.5 Social Impacts

The presence of landfills can have positive and negative social impacts on the local community. The need for waste disposal should be balanced with the impact on local communities and this is now considered as part of the planning application and subsequently through community funds which provide funding for community and environmental projects in recognition of the dis-amenity of landfill activity.

The Scottish Landfill Communities Fund (SLCF) was established in 2015 and it is funded by operators giving a percentage of their landfill tax liability to an 'approved body'. The SLCF is regulated by SEPA which oversees the distribution of the fund to community or environmental projects by approved bodies. A review of the performance of the fund was undertaken in 2020 (SEPA, 2020). The review found that 55% of landfill operators have contributed to the SLCF and it had funded over 1,400 projects with £32.7m of funding. The review provides a handful of case studies, but it does not attempt to assess the benefit of funded projects to the local community in any detail. The SLCF is expected to receive declining contributions in future years due to a reduction in reliance on landfills and because of the ban on disposal of BMW to landfill in 2025.

A study by Richardson, et al., (2010) explored the link between deprived communities and landfill sites in Scotland. The investigation looked at municipal landfill sites and local exposure to airborne emissions and found that socially deprived areas were disproportionally exposed to municipal landfill sites and their airborne emissions. The cause of this was investigated in more detail to determine whether deprivation preceded the landfill or was the result of landfill siting. The results imply that both disproportionate siting in deprived areas and post-siting housing market dynamics cause the link between deprived communities and municipal landfills. The study concludes that area deprivation may have preceded disproportionate siting to some extent, but landfill siting also preceded a relative increase in deprivation. A broader study looking at social inequality in environmental risks associated with housing and location in Europe had a similar conclusion – that social status and particularly low income are associated with increased exposure to environmental risks in private homes or in the residential area (Braubach & Fairburn, 2010).

In response to the call for evidence, SEPA noted that the number of complaints received are likely to be significantly lower for waste incineration or co-incineration than for landfill. It highlighted that landfills can result in impacts on the local community throughout their lifecycle. During operation, deposition of waste to land can result in issues associated with odour, dust, noise and vermin. Of these, odour from landfills was identified as a significant cause of public complaints made to SEPA. Three sites are classified by SEPA as sites of ongoing community impact and in 2021 these sites accounted for 987 substantiated complaints to SEPA. SEPA state that odour has potential impacts on quality of life and wellbeing – noting that odour can cause stress and anxiety even when the substances causing the odour are not harmful to health at the levels detected at waste.

4.6 Health Impacts

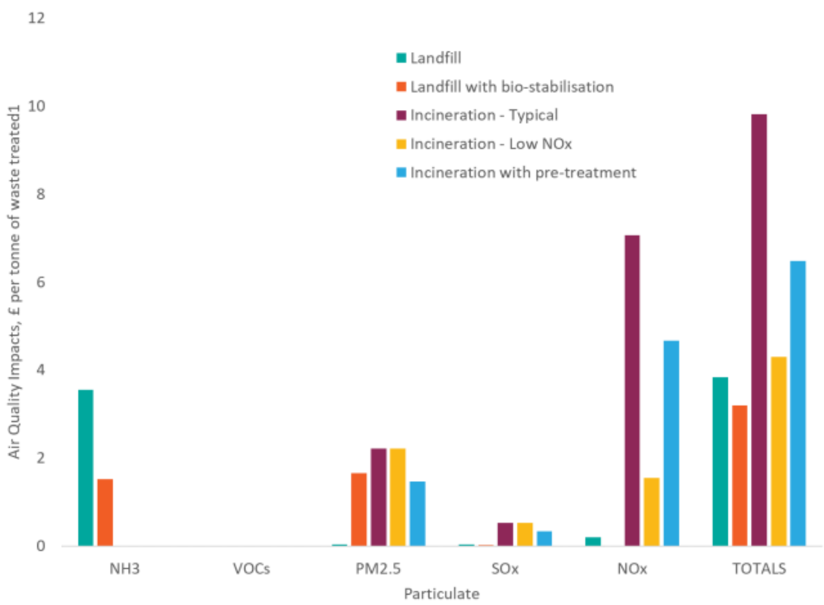
The disposal of waste to landfill and subsequent emissions can present a pollution risk and potential health hazard. Pollutants can migrate through exposure pathways to nearby human receptors. These emissions comprise airborne pollutants (gases, dust, micro-organisms and odours) and leachate. The impacts of these pollutants are minimised through stringent requirements for the location, design, construction and operation of landfills which act to limit generation of pollutants or the available exposure pathways. The health impact of landfills is difficult to quantify as it varies from landfill to landfill depending upon specifics such as location, design and waste composition present. However, there have been a range of studies investigating the available data on populations living near landfills and modelling the air quality impacts.

A study by Jarup, et al., 2002 looked at the cancer risk in populations living near landfills in Great Britain following concerns of possible excess risks of bladder, brain and hepatobiliary cancers and leukaemia. The base population included those living within 2 km of 9,565 landfill sites that were operational at some point between 1982 and 1997. The findings showed that there were no excess risks of cancer for this population compared to those living more than 2 km from a landfill site. These findings were upheld when the base population was limited to those living near hazardous landfill sites.

Other studies have looked at the risk of adverse birth outcomes in populations living near landfill sites. An initial study of landfills in Great Britain found a small excess of congenital anomalies and low and very low birth weight in populations living near landfill sites but noted that there was no apparent causal mechanism and that this result may be due to issues with the data or analytical technique (Elliott, et al., 2001). A follow-up study of the risk of adverse birth outcomes in populations living within 2 km of special (hazardous) waste landfill sites in Scotland was investigated by Morris, et al., 2003. The study found that there were no statistically significant excess risks of congenital anomalies or low birth weight in populations living near special waste landfill sites.

A more recent study by Eunomia (2020) on behalf of ClientEarth, investigated the air quality impacts of landfill in comparison to incineration through a literature review and modelling. For the purpose of the report, two types of landfill were considered – landfill without pre-treatment and landfill with bio-stabilisation. The modelling results presented in Figure 7 show that of the health impacts considered from landfill, ammonia has the greatest impact on human health. Bio-stabilisation reduced this impact slightly but also increased particulate emissions modelled as PM2.5. The report estimated that a landfill facility treating 400,000 tonnes of waste each year would have a human health impact in the order of £1.5m. Overall, the report concluded that landfill had a smaller impact on local air quality than incineration.

Figure 7: Air quality impacts of waste treatment systems (assuming typical performance of incineration facilities) (Eunomia, 2020)



4.7 Summary

It is technically feasible to continue operating landfills receiving BMW following the 2025 ban where it is first treated through either MBT or incineration and given that the residue meets the requirements under the Landfill (Scotland) Regulations 2003 (as amended). Increases in waste minimisation and recycling and the impact of the 2025 ban will reduce the economic feasibility of landfill and is anticipated to result in the closure of landfills and reduced landfill tax revenue which will also impact community funds and the benefits to the local communities. Landfill where the relevant regulations are followed, the resulting environmental impacts can be largely mitigated, although these are less controllable than other technologies that take place within buildings and over shorter timescales. GHG emissions from landfills can also be higher than alternative residual waste treatments. In terms of health impacts, there is not any substantial evidence that populations living near landfills in the UK have higher occurrences of cancer or adverse birth outcomes. However, landfill does impact local air quality with ammonia being a common issue, but the air quality impact is not as great as that from incineration.

5. Export

5.1 Overview

An alternative to landfill is the export of waste as refuse derived fuel (RDF) or solid recovered fuel (SRF), depending upon the required technical specification. This involves separation of combustible materials such as plastic, paper, cardboard, composites, textiles and organic materials. The treatment can include screening to remove recyclable material and high-moisture content bio-degradable waste and then shredding to produce the required calorific value, composition, moisture content and particle size. Producing SRF requires more advanced processing, and the output must meet the requirements of

European Standard EN 15359, whereas there is no specific standard for RDF. The RDF or SRF is typically bulked in one tonne bales which are suitable for export by cargo vessel. Exports from the UK to the rest of Europe are utilised for recovery of energy in an EfW facility or other facility suitable such as multi-fuel CHP facility and cement kilns.

5.2 Technical Feasibility

The production of RDF and SRF in Europe has largely been driven by landfill diversion targets originating from the Landfill Directive, targets for recycling of MSW in the Waste Framework Directive and more recently by targets set by the Circular Economy Package. The production and export of RDF and SRF has been increasingly used in the UK to manage residual waste with exports increasing from 250,000 tonnes in 2011 to 3.4 million tonnes in 2015 (Eunomia, 2016). However, the Covid-19 pandemic and the introduction of taxes on RDF and SRF imports in the Netherlands and Sweden were identified as causes for a reduction of exports in 2020 (LetsRecycle, 2021).

The technologies used for production and recovery of RDF and SRF are advanced and are well established in Scotland. A report by Eunomia (2016) estimated that the infrastructure available for production and recovery of RDF and SRF in northern Europe consists of 383 dedicated EfW facilities, 13 advanced conversion technology (ACT) facilities, 103 pre-treatment facilities (MBT or autoclave technologies), 73 IED compliant biomass plants and 102 cement kilns capable of processing SRF. A breakdown by country and facility is provided in Table 14. The report includes modelling of Europe's residual waste treatment capacity and indicates that there may be an overcapacity by 2026. According to SEPA, there were eight sites capable of accepting RDF for incineration in 2018 (SEPA, 2020).

Table 14: Residual waste treatment facilities in northern Europe in 2015 (Eunomia, 2016)

Country	Number of facilities in 2015				
	Incineration	ACT	MBT (and other pre-treatment)	IED compliant biomass	Cement kilns
Belgium	16	0	0	0	4
Czech Republic	5	0	0	0	6
Denmark	35	0	0	1	1
France	97	1	4	0	33
Germany	105	0	63	40	31
Ireland	3	0	0	0	3
Netherlands	13	0	0	1	1
Norway	22	2	0	3	2
Poland	5	0	0	0	10
Sweden	35	0	0	9	3

Country	Number of facilities in 2015				
	Incineration	ACT	MBT (and other pre-treatment)	IED compliant biomass	Cement kilns
United Kingdom	47	10	36	19	8
Total	383	13	103	73	102

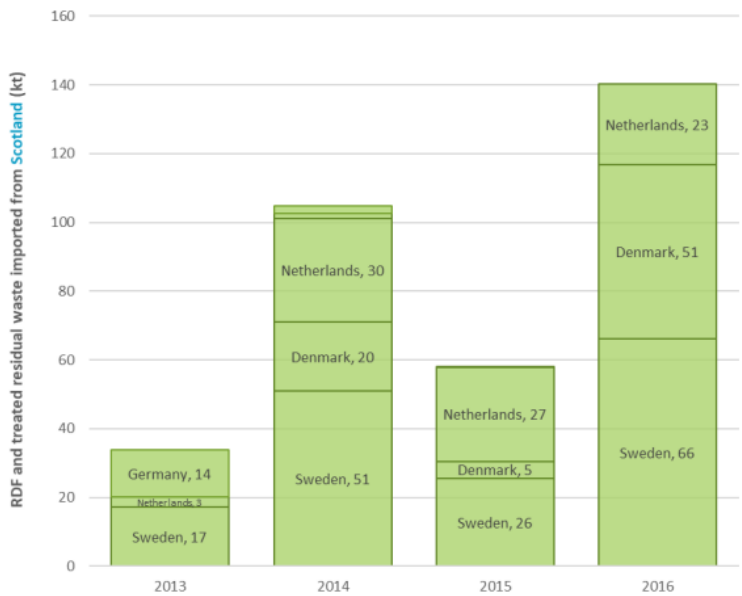
On this basis, it is anticipated that there should be sufficient capacity within the rest of the UK or Europe to manage increased exports of RDF or SRF from Scotland. Scotland's existing MBT and other pre-treatment facilities, along with any additional capacity required, can be utilised to produce RDF or SRF prior to export.

5.3 Economic Impacts

A report by Tolvik Consulting (2016) looked at the UK export market for RDF and found that the majority of RDF had been exported to the Netherlands, Germany, Sweden or Denmark. These countries have had a demand for RDF due to an overcapacity of EfW in previous years. This combined with higher landfill tax and limited EfW capacity in the UK meant that post-2010 it became economically viable to export RDF over increasing distances. This was confirmed in a report by the Environment Agency that looked at the cause of the trend in RDF exports from England (Environment Agency, 2015).

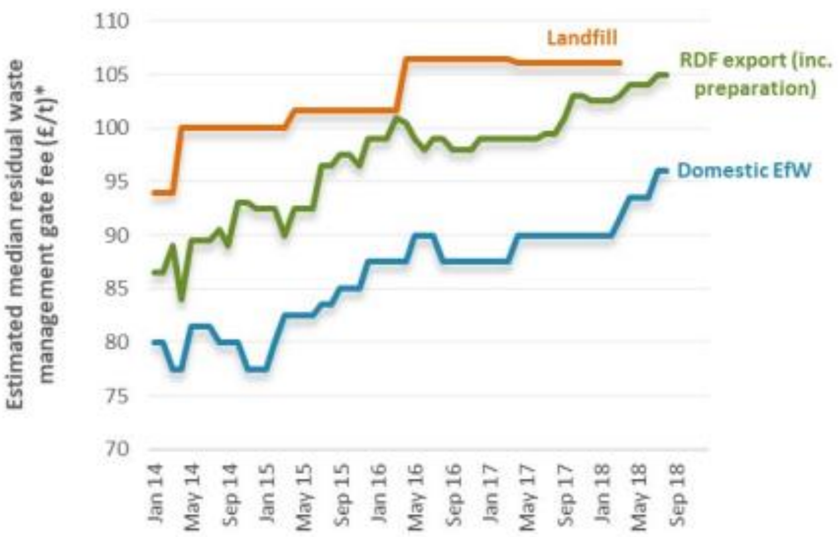
A breakdown of RDF exported from Scotland by destination between 2013 and 2016 is provided in Figure 9. This shows the increasing trend in the export of RDF to the Netherlands, Denmark and Sweden. In its response to the call for evidence, SEPA estimated that 96,781 tonnes of waste was exported from Scotland for incineration in 2020 – based on WasteDataFlow data.

Figure 8. RDF imports from Scotland by country (CIWM, 2018)



The estimated median gate fee for RDF exports in comparison to landfill and domestic EfW is shown in **Error! Reference source not found.**. The gate fee for RDF exports i ncluding preparation has exceeded £100/tonne, however the increasing cost of landfill has been an important factor in ensuring RDF export is a competitive market outlet (CIWM, 2018). Domestic EfW has consistently been cheaper than exporting RDF historically, but demand has exceeded the available EfW capacity in the UK.

Figure 9. Estimated median residual waste management gate fee (£/tonne) in the UK (CIWM, 2018)



However, the Covid-19 pandemic and the introduction of import taxes on RDF in certain European countries has seen the quantity of RDF exported from the UK plateau and decrease in recent years. According to letsrecycle.com (2020), the Netherlands introduced a €31/tonne import tax on waste for incineration on 1 January 2020 and this was followed by a steep decline in exports from the UK. A similar tax was introduced in Sweden at approximately £6/tonne on 1 April 2020. The lower rate in Sweden and good relations between exporters and importers has meant that Sweden continues to be a strong market for UK RDF exports.

The ban on disposal of BMW to landfill in Scotland is likely to mean that there continues to be a market for the export of RDF. The cost of treating BMW prior to disposal of compliant residual waste in Scotland and the cost of disposing of BMW at landfills in England may provide a cap on the cost exporters are prepared to pay to export RDF for recovery.

5.4 Environmental

The environmental impacts of preparing RDF for export occur in Scotland whilst the impact of EfW incineration will occur outside of Scotland. The treatment of residual waste to produce RDF typically involves the use of MBT, and the environmental impacts of this are discussed in section 6.4. The environmental impacts of incineration are discussed in section 3.1.4.

An additional environmental impact associated with exporting RDF is the GHG emissions from transport by road and cargo vessel. In a report produced for the RDF Export Group

(Eunomia, 2015), the carbon dioxide emissions from transport of RDF are estimated to be relatively insignificant in comparison to those from wider waste processing activities.

5.5 Social Impacts

The social impacts of RDF exports are associated with the treatment of residual waste in Scotland to produce RDF. This is typically through the use of MBT and the impacts of this are discussed in section 6.5. Additional social impacts will occur outside of Scotland associated with the incineration of waste and these are discussed in section 3.1.5.

5.6 Health Impacts

The health impacts of RDF exports are associated with the treatment of residual waste in Scotland to produce RDF. This is typically through the use of MBT and the impacts of this are discussed in section 6.6. Additional health impacts will occur outside of Scotland associated with the incineration of waste and these are discussed in section 3.1.6.

5.7 Summary

The treatment of residual waste to produce RDF in Scotland followed by the export of RDF via cargo vessel to countries with excess EfW capacity, such as Sweden, is currently a technically feasible option as it uses established technologies such as MBT and EfW. The economic feasibility is currently dependent upon the gate fees for disposal of residual waste to landfill in Scotland. As this has increased, it has become increasingly competitive to export RDF to EfW facilities in northern Europe. However, the introduction of import taxes on waste for incineration in countries such as the Netherlands and Sweden has reduced exports of RDF, increasing demand for a UK based solution, and in the meantime may have increased disposal to landfill. The ban on the disposal of BMW to landfill in Scotland is likely to mean the cost of exporting RDF will be competitive. The environmental and social impacts of incineration and MBT are discussed in sections 3 and 6, respectively.

6. Mechanical Biological Treatment (Mbt)

6.1 Overview

Defra (2013d) outlines how MBT is a residual waste treatment process that involves both mechanical and biological treatment methods. Whilst treatment of source segregated food waste at an AD or IVC facility involves both mechanical and biological processing, such a facility is not referred to as an 'MBT' facility. Instead, MBT processes typically refer to the treatment of whole 'black bag' or residual waste typically from HC&I waste sources. MBT is not considered as a final treatment destination, as outputs from the process such as RDF still require further treatment and management.

The mechanical processing that takes place at an MBT facility involves size reduction and sorting of the residual waste into different components. Typically, materials are separated into recyclable fractions, RDF, contaminants and an organic rich fraction. The organic rich fraction is then processed utilising an aerobic composting or an AD process, both of which are biological processes. The output of the biological process is often a compost like output (CLO) or RDF or, for AD processes, digestate and biogas.

The first MBT facilities were developed with the aim of reducing the environmental impact of landfilling residual waste, with a key advantage of MBT being that it can be configured to achieve different aims (Defra, 2013d). Examples of such MBT facilities, provided by Defra (2013d), were configured to provide:

- Pre-treatment of waste going to landfill.
- Diversion of MSW going to landfill, through mechanical sorting into materials for recycling and/or energy recovery from RDF.
- Diversion of biodegradable MSW going to landfill by:
    - Reducing the dry mass of BMW prior to landfill.
    - Reducing the biodegradability of BMW prior to landfill.
- Stabilisation into compost like output (CLO) for use to land.
- Conversion into a combustible biogas for energy recovery.
- Drying materials to produce a high calorific organic rich fraction for use as RDF.

For this options appraisal review, the treatment option of MBT will include MBT in any form such as biodrying, AD or IVC with RDF production for subsequent incineration. The biostabilisation of waste via MBT will be covered separately in Section 7.

6.2 Technical Feasibility

Through information obtained and reviewed through the call for evidence, Scottish Government (2019) and Zero Waste Scotland (2022), it is understood that Scotland has two operational MBT facilities:

- Glasgow Renewable Energy Centre (GRREC).
- Lochar Moss in Dumfries and Galloway.

At the GRREC facility, mechanical processing is followed by wet AD and a gasification process integrated with the residual waste MBT process. Therefore, the MBT facility is focussed on generating RDF for the gasification process, with wet AD at the same site.

The Lochar Moss facility is understood to consist of biodrying and RDF production.

There are three further facilities in Argyll and Bute, which some sources describe as MBT. These facilities are referred to as Dalinlongart, Lingerton and Moleigh. However, it appears that these facilities comprise of other site activities such as landfill, HWRC, composting (non-residual) and transfer station i.e., not residual waste MBT (Zero Waste Scotland, 2022). Waste return data (SEPA, 2019) also supports that position. Further investigation into these facilities is recommended to confirm the exact nature of operations.

MBT technology is therefore currently established within Scotland, but at only two facilities. It is more prevalent in England, where there are approximately 20 MBT facilities, split between the following organic processing type:

- 6 Biodrying (all produce RDF/SRF)
- 8 Wet AD (all produce RDF/SRF in pre-treatment mechanical processing)
- 1 Dry AD with IVC (produces RDF)
- 5 IVC (four out of the five produced RDF in 2019)

The only English MBT facility that does not produce RDF is the Waterbeach MBT-IVC facility in Cambridgeshire, which is operated by AmeyCespa (East) Limited (Amey) and discussed further in Section 7 Zero Waste Scotland (2022).

Within the call for evidence responses, it is notable that responses from industry and professional bodies highlight that the UK is reducing its reliance upon MBT, with sites continuing to close. This was also referred to by Tolvik (2017a).

There have also been reports in trade press of issues at some UK MBT facilities, including issues with technology design, under-performance against contract targets, poor financial performance, contractual disputes, contract termination and some facility closures. This was also mentioned within responses to the call for evidence, notably highlighting the recent contract dispute and subsequent closure of the Tovi Eco Park in Basildon, Essex (LetsRecycle, 2020). Such issues have also occurred with other residual MSW technologies and contracts, but it is nonetheless useful to be aware of the issues encountered with MBT implementation in Britain to date.

The experience in the UK, and in many instances in the EU, is that MBT facilities are typically constructed with a lifespan of around 30 years, and contracts with local authorities are typically for 20 to 25 years. On that basis, MBT may not always be feasible as a short to medium term waste management solution.

In terms of MBT performance, Defra (2013) specifically noted:

"Recyclables derived from the various MBT processes are typically of a lower quality than those derived from a separate household recyclate collection system and therefore have a lower potential for high value markets. The types of materials recovered from MBT processes almost always include metals (ferrous and non-ferrous) and for many systems this is the only recyclate extracted."

Tolvik (2017a), when assessing recycling performance of MBTs in the UK, noted that the definition of the "contracted" recycling performance (i.e., as required under contract with the local authority) may differ from the recycling performance used in official returns. The example given was that the classification of organic "fines" used in land remediation/improvement projects which are not eligible for inclusion in official recycling statistics, but which have been contractually accepted as "recycling".

After giving this consideration, Tolvik (2017a) reported the "contracted" recycling performance expected outcome from local authority clients with an MBT facility. The highest (self-) reported recycling performance for an MBT in the UK identified was 18%, as shown in Table 14. Tolvik (2017a) also stated that where publicly reported, for the majority of MBTs reviewed, the recycling performance has consistently fallen below contractual targets. Tolvik (2017a) suggest that this is largely due to difficulties in finding suitable markets for the "recyclates" which was also mentioned within responses to the call for evidence.

However, Tolvik (2017a) did not state the number of MBTs contacted and, therefore, included within its analysis (analysis summarised in Table 14).

Table 15: Recycling Rates at UK MBT Facilities (Tolvik, 2017a)

Recycled Material	Range Reported	Observations
Metals (Ferrous and Non-Ferrous)	1 – 3%	All MBT facilities recover metals – may include metal recovery from IBA from resultant thermal treatment of outputs
Heavies (Glass and Stone)	0 – 8%	Generally need to pay (reduced) disposal cost
Plastics	0 – 6%	With low oil prices, poor quality and reduced demand from China, very limited available markets
Organic Fines	0 – 9%	Used to produce CLO for land remediation
Total	1-18%	

Based upon a wide range of data sources of varying accuracy, Tolvik (2017b) provided an analysis of the average annual moisture loss at operational MBT facilities in the UK. This suggests that performance ranges from between 1 – 34%, with an input weighted average loss of 20.2%. Across all current UK MBTs at the time of the report, this equated to a total mass reduction of 0.42Mt (Tolvik, 2017b).

One of the perceived advantages of MBT (Defra, 2008) was the possibility of employing various technology configurations. One option is to generate renewable energy through processing the mechanically separated organic fraction of the residual waste stream in an AD process to generate biogas. Defra (2013) suggest that biogas electricity production per tonne of waste can range from 75 up to 225 kWh, varying according to the feedstock composition, biogas production rates and electrical generation equipment. Tolvik (2017a) at the time of writing its report, stated that eight MBT facilities in the UK have an installed electrical generation capacity of greater than 1 MW. The average reported load factor (power generation divided by installed capacity) is stated as 21%, which is distorted by one facility with an average load factor in excess of 60%. By way of reference, Tolvik (2017a) mentions that a typical AD facility with food waste as a feedstock would have an average load factor of at least 70%.

Tolvik (2017a) outlines further that whilst a low load factor is not explicitly a metric of technical underperformance, it would seem unlikely to be cost efficient for an MBT facility to be designed with a generation capacity so far in excess of the expected output (i.e., with such a low load factor). Tolvik (2017a) indicates that there could be several potential causes of this apparent underutilisation and state that it is most reported as a change in waste composition, with low food waste quantities as a result of separately collected food waste. Zero Waste Scotland (2022) also report issues at British and mainland Europe MBT facilities associated with a change in waste composition, especially a reduction in the amount of food waste content in residual waste. Scotland has already implemented a separate food waste collection system and the Climate Change Plan outlines the commitment to reduce Scotland's food waste by 33% by 2025 (Scottish Government, 2018).

6.3 Economic Impacts

Tolvik (2017a) considered the cost of waste management across 29 British waste disposal authorities. The findings indicate that the five most expensive, per tonne of residual waste treated, primarily relied upon MBT, whereas only seven of the 29 primarily rely upon MBT. The authors noted that the analysis was 'not necessarily the most robust' but that their findings were 'unlikely to be a co-incidence'.

Due to the low number of MBT facilities in Scotland, the following commentary considers Britain as a whole, although the predominant focus is England.

Due to the different configurations available, MBT processes vary significantly in terms of technology, complexity, scale and cost (Defra, 2013). Defra (2013) indicated that MBT development costs are relatively high, with example estimates for the actual cost of construction provided within the range of £50 - £125m for MBT facilities with a capacity range of 80 - 225ktpa.

Local authority contracts are generally in place for several years, and many MBT facilities in the UK have been developed under PPP/PFI agreements, with complex contractual terms, that include wider waste management services. Determining an exact cost for MBT, and then making comparisons with other technology options is therefore problematic at a national scale.

Economies of scale can be expected with waste facilities, which was also mentioned within responses to the call for evidence, where smaller facilities are less likely to be competitive on price.

WRAP (2011) explained the difficulties in researching and reporting MBT gate fees:

- 'The wide range of facility types and the variety of treatment processes to which the label of MBT is attached makes it difficult to provide an analysis of gate fees.
- The quality of the MBT output has a significant impact on the gate fee, as low-quality process residues may attract a higher rate of landfill tax. Other major influencing factors on MBT gate fees are the SRF market, recovered materials prices, the feed in tariff and the allocation of contractual risk.
- Factors expected to influence the market for MBT in future were increases in the landfill tax and developments in market prices for MBT outputs (metals, plastics, SRF). Feedback from WMCs [waste management companies] indicated that the latter may lead to lower gate fees or an increase in the use of reward share mechanisms in future contracts.

WRAP (2015) notes that it was not always possible to determine MBT gate fees from data submitted by local authorities, as the cost was included within a broader PPP or PFI contract. The data presented is reliant upon those local authorities that supply data and, of those, the authorities that supply data that can allow determination of the MBT gate fee.

The WRAP gate fee reports stopped reporting MBT gate fees altogether from 2018 onwards, and whilst the exact reason is not provided in the reports, the report authors state it was removed at the request of WRAP.

The WRAP gate fee report information should be reviewed with consideration to the above points, and wider caveats provided within the reports. A summary of the gate fee information, for WRAP reports published between 2011 and 2020, is provided in Table 16. The reports contain data that predominantly applies to the previous year.

Table 16: Summary of WRAP Gate Fee Report gate fees (local authority reported) (Source: WRAP, 2011 to 2020)

Report Year	MBT (£/tonne)	EfW (pre 2000 facilities, £/tonne)	EfW (post 2000 facilities, £/tonne)	EfW (pre and post 2000 facilities, £/tonne)
2011	£84 (median)	£54 (median)	£73 (Median)	Not stated
	£57 - £100 (range)	£35 - £79 (range)	£54 - £97 (range)	Not stated
2013	£76 (median)	£58 (median)	£90 (median)	Not stated
	£66 - £82 (range)	£32 - £76 (range)	£62 - £126 (range)	Not stated
2014	£84 (median)	£58 (median)	£94 (median)	Not stated
	£25 - £104 (range)	£35 - £100 (range)	£62 - £112 (range)	Not stated
2015	£88 (median)	£73 (median)	£65 (median)	Not stated
	£68 - £107 (range)	£36 - £110 (range)	£65 - £132 (range)	Not stated
2016	£85 (median)	£58 (median)	£95 (median)	£86 (median)
	£67 - £111 (range)	£22 - £90 (range)	£65 - £131 (range)	£22 - £131 (range)
2017	£88 (median)	£56 (median)	£91 (median)	£83 (median)
	£66 - £170 (range)	£26 - £90 (range)	£50 - £144 (range)	£26 - £144 (range)
2018	Not included	£57 (median)	£89 (median)	£86 (median)
		£44 - £94 (range)	£33 - £117 (range)	£33 - £117 (range)
2019	Not included	£65 (median)	£93 (median)	£89 (median)
		£44 - £89 (range)	£50 - £121 (range)	£44 - £125 (range)
		£62 (median)	£95 (median)	£93 (median)

Report Year	MBT (£/tonne)	EfW (pre 2000 facilities, £/tonne)	EfW (post 2000 facilities, £/tonne)	EfW (pre and post 2000 facilities, £/tonne)
2020	Not included	£49 - £104 (range)	£48 - £150 (range)	£48 - £150 (range)

The information presented in Table 15 does not show a significant difference between the reported gate fees for MBT compared to EfW facilities. However, the data for MBT is only presented up until the 2017 report, containing data for the calendar year 2016. For reasons explained, it is difficult to pinpoint a typical gate fee for MBT facilities. However, there is no evidence to suggest that it is a cheaper option than EfW and, in some instances, it may prove to be the more expensive option per tonne of waste treated.

6.4 Environmental Impacts

Defra (2013) highlight the key issues when considering the planning implications of an MBT facility, stating that they are common considerations to most waste management facilities:

- location
- traffic
- air emissions / health effects
- dust / odour
- bio-aerosols
- flies, vermin and birds
- noise
- litter
- water resources
- design principles and visual intrusion
- size and land-take
- public concern

The environmental impacts listed would be considered through the planning and permitting process in order to obtain the relevant consent for a facility, addressing local sensitive receptors with the location of any such facility. When applying for a PPC permit, an MBT facility would have to meet the standards outlined within the Best Available Techniques (BAT) Reference Document for Waste Treatment. This will include ELVs for factors such as emissions to air and water.

6.4.1 Location

Defra (2013) refer to Planning Policy Statement (PPS) 10 for the Planning of Sustainable Waste Management which contains general guidance on the selection of sites suitable for waste facilities. This guidance does not differentiate between facility types, but Defra do provide guidance on potential location impacts of MBT facilities:

- Facilities are likely to require good transport infrastructure. Such sites should be located close to a primary road network or alternatively have the potential to be access by rail or barge.
- The location of such facilities together with other waste operations with the examples of MRF and ATT facilities given, can be advantageous. The potential co-location of such facilities on resource parks or similar was also highlighted in the PPS 10 and Companion Guide.
- General concerns around bio-aerosols from biological processing may require an MBT facility to be located away from sensitive receptors.

6.4.2 Traffic

Defra (2013) state that MBT facilities may be served by large numbers of heavy goods vehicles (HGV) depending upon the scale of the facility. This may impact upon local roads and amenity of local residents depending upon the site's location. It is stated that for a 50,000tpa capacity facility, approximately 20-30 refuse collection vehicles (RCV) per day would be anticipated. This would be reduced if bulk transport systems are used. Ricardo is uncertain whether this figure provided accounts for any removal of material from the facility (noting that traffic movements could be reduced if return vehicle loads were utilised).

6.4.3 Air emissions / health effects

Defra (2013) primarily refer to air emissions in the form of bio-aerosols which are covered in Section 6.4.5. The health effects from MBTs are also covered separately in Section 6.6.

The impact of air emissions and health effects on the combustion of RDF, whilst potentially being at a co-located facility are addressed within the incineration review of this options appraisal.

6.4.4 Dust / odour

Any waste management operation involving biodegradadable waste can give rise to dust and odours, for which the control from MBT facilities also needs consideration. As MBT facilities are within enclosed buildings, potential odour emissions can be controlled through the buildings ventilation system.

6.4.5 Bio-aerosols

Defra (2013) states that bio-aerosols may comprise of complex mixtures of micro-organisms which are transported in the air. Some bio-aerosols can cause health problems, notably Aspergillus Fumigatus, but also some other fungal spores and bacteria. Raised levels of community exposure to bio-aerosol may arise within 250m downwind of a composting facility and under rare circumstances at distances of up to 0.5 km (Defra, 2008). The health effects from MBTs are also covered separately in Section 6.6.

6.4.6 Flies, vermin and birds

The enclosed nature of MBT operations will limit the potential to attract vermin and birds. However, during hot weather it is possible that flies could accumulate.

The impact of flies at MBT facilities has been a reported environmental issue and the source of a high number of complaints, reported in trade press (LetsRecycle, 2011 and 2013).

6.4.7 Noise

The main contributors to noise associated with MBT outlined by Defra (2013) are likely to consist of:

- Vehicle movements (internal and external).
- Mechanical processing (e.g., shredding, trommels etc.).
- Air extraction systems.

6.4.8 Litter

Litter problems can be reduced if good site working practices are adhered to and maintained. This will be controlled through the PPC process and can involve processes such as regular site inspections, cleaning and maintenance.

6.4.9 Water resources

The level of water usage would be specific to the exact technology employed at any facility and whether water harvesting, and reuse would be integrated into the process. The enclosed nature of MBT operations reduces the likelihood of potential impacts on the water environment providing there is adequate drainage infrastructure to manage leachate/effluent and the separation of rainwater (Defra, 2013).

6.4.10 Design principles and visual intrusion

Defra (2013) states that current planning guidance emphasises the importance of good design in new waste facilities. Good design principles should also be extended to other aspects of the facility in regard to issues such as access and site layout, energy and water efficiency. Visual intrusion impacts would be delt with on a site-specific basis.

6.4.11 Size and land-take

Defra (2013) outlines a number of consented facilities and outlines their capacity and total land-take, noting that this is likely to vary depending upon the specific technology used. An average MBT facility was stated as having a height of 10-20m though some facilities may have a stack is using particular air clean-up systems which may increase the overall height.

6.4.12 Public concern

In general Defra (2013) state that public concern relates primarily to amenity issues (such as odour, dust, noise, traffic, litter etc.). With facilities that form part of a larger development such as the inclusion of thermal treatment of RDF, health concerns can also be a perceived issue. This is covered in more detail within Section 6.5.

6.4.13 Carbon

Please refer to Section 7.4 which looks at the carbon impacts for the different configurations of MBT.

6.4.14 CLO

The processed organic material from an MBT can be managed in several ways. The output from IVC processes is known as compost like output (CLO) and the output from AD processes is known as digestate. CLO is also sometimes known as stabilised organic material (SOM) and 'stabilite' is a term commonly used in continental Europe (Zero Waste Scotland, 2022).

As it is not from a segregated source, CLO or digestate cannot comply with the requirements of PAS100 (publically available specification for composted materials) or PAS110 (publically available specification for whole digestate, separated liquor and separated fibre derived from anaerobic digestion), nor the Quality Protocols employed in England, Wales and Northern Ireland or the Additional Scheme Rules for Scotland. As such, it remains a waste following treatment and subject to continued regulation as a waste. Due to the quality of CLO and its regulation as waste, there is effectively no possibility for it to be utilised in agriculture where food production is involved.

For CLO or digestate to be applied to other (non-food production) land, where it is used in place of non-waste material to perform a particular function i.e., for land restoration purposes, regulator approval is required in each case to ensure that the waste recovery test is met for each particular scheme. This poses a problem for operators because MBT facilities are typically constructed with a 25 year life, and each land restoration project will have limited demand for the CLO or digestate. The experience of UK MBT operators has been one of difficulty finding such outlets for digestate and CLO, and sometimes difficulty in securing regulator approval.

The Environment Agency (2009) in a revision to a previous technical report assessed the potential human health and environmental risks from chemicals following the use of MBT outputs (CLO) on land for which the following conclusions are made:

- Undiluted CLO present potential environmental and human health risks from metals and priority organic micropollutants.
- If CLO were applied to agricultural land at rates limited by nitrogen, environmental risks could arise for Cd, Cr and Zn, accounting for the existing concentrations of these metals in the receiving soil.
- The 90th percentile levels of plastics were relatively high
- Significant uncertainty remains when assessing potential human health risks. There are very few established soil guideline values (SGVs) and their use in the context of land application is also questionable. This report relies heavily on limits from other jurisdictions. There is a need for a policy decision from the Environment Agency on the preferred choice of provisional human health limit values when UK values are not available.

6.5 Social Impacts

Defra (2013d) discusses the social and perception considerations for MBT facilities. In regard to social considerations, it is stated that the impact of MBT facilities is likely to have both positive and negative impacts.

Positive social impacts were stated in the form of employment and educational opportunities. Employment figures for MBT facilities would be dependent on the size of the facility as this will impact on the number of shift patterns during operations for example. Defra states that provision for both unskilled and semi-skilled workers as well as professionals will be required for the running of MBT facilities. The guidance document provides an employment guide based on current and proposed facilities (at the time of the report) up to 8 people would be needed for a MBT facility of 50,000tpa capacity, 40 for 265,000tpa plant and 85 for a 417,000tpa facility. It was also noted that many of the newer MBT facilities being built at the time were including visitors' centre to enable local groups to view the facility and learn more about how it operates.

Negative social impacts on social amenity (e.g., odour, noise, dust, landscape) were stated as important considerations when siting any waste management facility. Transport impacts associated with the delivery of waste and onward transport of process outputs may lead to impacts on the local road network.

Defra (2013d) stipulates that as a result of greater publicity, education and more comprehensive waste services, people are participating, to a greater extent, in waste reduction and recycling activities. This leads to greater levels of engagement in waste management activity. Defra (2013d) also state however, that there is still a significant challenge in accepting waste management infrastructure. New waste facilities of whatever type are rarely welcomed by residents close to where the facility is to be located.

Public opinion on waste management issues is wide ranging and can often be at extreme ends of the scale. Defra provided an example of a public consultation highlighting the diversity of opinion with regard to MBT facilities, shown in Figure 10.

Figure 10: Public consultation on MBT (Defra, 2013d)

"A public consultation covering part of the Midlands region demonstrated a mixed response from stakeholders and councillors concerning MBT as a preferable waste management solution. Respondents to this consultation felt that an incineration based EfW plant was the most desirable method of treating the area's residual waste.

In a public consultation for a County Council in the South of England, MBT was indicated to be preferable to EfW technologies. Reasons for this result were given as public perception concerns over the emissions from an incinerator, and a wide held belief that MBT was a greener technology with better recycling potential. The consultation indicated that the majority of respondents were prepared to incur an additional £30 council tax cost if it meant procurement of an MBT facility over an EfW."

6.6 Health Impacts

Defra (2013) stipulates that no studies have specifically looked at the health effects of MBT facilities at the time of their guidance document being produced. Within their document, Defra state that the health effects are expected to be comparable to those from IVC facilities, primarily related to bio-aerosol emissions. Although studies on composting facilities have found no increase in cancer or asthma in populations nearby, there have been public concerns that open composting operations could in theory affect the health of those living in close proximity. Research undertaken by Defra (2008) suggests that communities located more than 250m away from composting facilities are unlikely to be exposed to harmful levels of bio-aerosols. However, they may experience odours associated with the process as these can travel much further.

6.7 Summary

In terms of technical feasibility there are established MBT facilities within Scotland and the wider UK. The technology has had mixed experiences, with cited reports of issues with technology design and contractual performance.

The literature results in difficulty in obtaining the exact costs of MBT and there is little evidence to suggest it is a cheaper option than EfW. In some instances, literature suggests it could be a more expensive option per tonne of waste treated.

The environmental impacts specific to MBT are considered to be centred around odour and bio-aerosols. These are also the main amenity concerns, when social impacts are considered. The literature suggests that public opinion to MBT can be mixed and perhaps reflects a lack of true understanding of the treatment technology.

7. Biostabilisation

7.1 Overview

As discussed in Section 6.1, MBT facilities can be configured to achieve different objectives. Within this section, the options appraisal review considers the MBT-IVC process to biostabilise waste. If MBT-AD is utilised, then it must be followed by IVC in order to achieve the level of biostabilisation necessary for it to be landfilled in Scotland. This is more problematic for digestate from a wet AD process, as opposed to a dry AD process (Zero Waste Scotland, 2022).

7.2 Technical Feasibility

There are currently no MBT facilities within Scotland that are configured for biostabilisation and this is mentioned within responses to the call for evidence. Some responses also state that there is a lack of evidence as to whether the stabilised output will meet the requirements of the SEPA guidance and Landfill (Scotland) Regulations 2003.

The only English MBT facility that does not produce RDF is the Waterbeach MBT-IVC facility in Cambridgeshire, which is operated by AmeyCespa (East) Limited (Amey) (Zero Waste Scotland, 2022). It is unclear to what extent biostabilisation is being achieved at the Waterbeach facility, and this will be influenced by factors such as the waste input, facility design and manner of operation. Zero Waste Scotland (2022) suggest that evidence points to the stabilised output being sent to landfill, with additional plans for an EfW facility to be built nearby. IVC technology can however, subject to design and operation, achieve a level of biostabilisation that could meet the criteria associated with the forthcoming landfill ban in Scotland, but this criteria does not exist in England and no facility has achieved this to date.

As stated within the MBT section above, and in responses submitted during the call for evidence, technical issues have been encountered with MBT in the UK and the direction of travel for UK waste management is away from MBT facilities. There was a need for caution, in using biostabilisation, mentioned in some responses from waste management companies and professional body trade organisations to the call for evidence. However, some responses from environmental groups, community groups and individual members of the public highlighted the potential benefits of MBT.

7.3 Economic Impacts

There is limited information available regarding the economic costs of biostabilisation for landfill, as biostabilisation is often part of a larger MBT process. Therefore, the literature reviewed within Section 6.3 is most relevant, where applicable.

A response received within the call for evidence states that biostabilised residual waste would still be subject to the upper standard rate of landfill tax. Without any change to the tax rate, it would be unlikely for investment in this approach to be brought forward by the market. This was indeed also highlighted by Eunomia (2008).

7.4 Environmental Impacts

The core environmental impacts are widely considered to be similar to those reported in Section 6.4.

Eunomia (2020) carried out analysis that compared the emissions of incineration and landfill for one tonne of residual waste, shown in Table 16. Eunomia's GHG emissions analysis used a 'consumption' approach, meaning all emissions are included regardless of their location.

Table 17. Tonnes of carbon dioxide equivalent emitted (net) per tonne of waste treated via incineration or landfill. Adapted from Table 2-3: (Eunomia, 2020)

Scenario	Landfill		Incineration		
			Straight		Pre-treatment
	Straight	Biostabilisation[1]	Electricity only	CHP	Electricity only
Today	0.32	-0.23	0.17	0.10	-0.29
Expected-2035[2]	0.30	-0.23	0.39	0.31	-0.18
Low heat decarbonisation	0.30	-0.23	0.39	0.26	-0.18
GWP20[2]	1.03	-0.17	0.39	0.31	-0.18

1. Biostabilisation includes a pre-treatment step to remove recyclables
2. Assumes the 65% recycling target is met and there is progress towards decarbonising energy systems

With any modelling exercise, it is always worth considering the various assumptions made within the report such as emission factors and waste compositions used to name but a few. Therefore, comparison between studies can often be difficult and close attention should be made to any assumptions and the impact these may have on any outputs.

Within Table 16, Eunomia (2020) indicates their 'Today' scenario would result in landfill with biostabilisation having slightly lower emissions when compared to incineration with pre-treatment. Eunomia indicates that this is largely due to the pre-treatment element resulting in emission benefits due to the additional credit arising from recycled materials. The pre-treatment element also effectively removes a large proportion of fossil carbon within the residual waste sent to incineration.

In general, landfill with biostabilisation, under the different scenarios, indicates a saving in terms of emissions.

Zero Waste Scotland (2022) undertook a carbon life cycle assessment for the biostabilisation of treating residual waste in Scotland. The report concludes that a number of assumptions had to be made in order to arrive at the complete model of the fate of residual waste through an MBT process and the associated carbon impacts. Two scenarios were modelled for the biological treatment process: 1) dry-AD plus IVC and 2) IVC alone. The results indicate that:

- Treatment of residual waste through an MBT facility employing Dry-AD and IVC technologies, followed by landfill, yields a carbon saving of 195kg CO2e per tonne.
- Treatment of residual waste through an MBT facility employing IVC technology alone, followed by landfill, yields a carbon saving of 131kg CO2e per tonne.

Based on these results, Zero Waste Scotland (2022) make the following conclusions:

- The overall positive results are primarily driven by the benefits of recycling the materials delivered during the pre-sorting. Of these materials, the biggest contribution comes from recycling non-ferrous metal. This is because the production of virgin aluminium involves very significant amounts of electricity, which are offset if the aluminium can be sourced from scrap. In total, the pre-sort materials deliver a total carbon saving of 211kg CO_2e per tonne of waste.
- Although much smaller, the next most significant contribution arises from the methane emitted by the biostabilised waste after it is landfilled. The model anticipates that the two technologies produce different weights of biostabilised waste, with the Dry-AD+IVC yielding methane emissions of 72kg CO_2e/t, and the IVC-alone 65kg CO_2e/t. These are of course impacts, not benefits.
- The third largest contribution arises from the energy consumption and production at the MBT facilities. Whilst the emissions impact from the IVC-alone facility is relatively small, at 11kg CO_2e/t, the Dry-AD+IVC facility both uses and creates electricity, the net effect being a carbon saving of 66kg CO_2e/t.
- In contrast, waste transport (an impact of 5kg CO_2e/t) and the materials used at the Dry-AD+IVC facility (an impact of 6kg CO_2e/t) make relatively negligible contributions to the overall results.

7.5 Social Impacts

As with any new waste activity, aspects such as traffic, pests, odour, noise, visual impact and health are often of concern to locals. The social impacts of biostabilisation are likely to be similar to those of most waste activities and MBT in particular. Therefore, the information provided in section 6.5 is also relevant to this section.

7.6 Health Impacts

The possible health impacts from biostabilisation will be similar to those for MBT as MBT includes biological treatment processes. Therefore, the information in section 6.6 is relevant to biostabilisation as well.

7.7 Summary

In terms of technical feasibility, biostabilisation is less established within Scotland and the UK. Literature around the economic, environmental, social and health impacts are very similar to MBT without biostabilisation.

8. Emerging Technologies

8.1 Overview

This section outlines some of the emerging technologies that may be used to treat HC&I waste in the future. As these are emerging technologies, there is very limited, if any, evidence of their use with HC&I waste at a commercial scale.

8.2 Waste To Fuel

8.2.1 Pyrolysis/gasification

Evidence of the use of ATT technologies such as pyrolysis and gasification, which can be used to produce a fuel in the form of syngas or pyrolysis oil, has been provided in section 3.2.1.

8.2.2 Enzymatic hydrolysis/fermentation

Hydrolysis and fermentation are processes that can be applied to sorted residual MSW, following the removal of the inorganic fractions. Enzymatic hydrolysis is applied to generate a sugar-rich intermediate product that is then anaerobically fermented to generate butanol, hydrogen as well as acetone and ethanol. Butanol has gained interest as a versatile chemical that can be used as an additive or complete biofuel. Pilot and demonstration plants for this technology have been developed across the UK, Europe and the US, gaining interest from key players in the chemical and fuel industry such as BP and Dupont (BP United States, 2017). The main environmental benefits associated to this technology are related to the carbon savings of replacing fossil fuels with waste generated biofuels. Disadvantages of the process include low efficiencies and high costs (Meng, et al., 2019; de Vrije & Claassen, 2018).

8.2.3 Waste to hydrogen

Waste-to-Hydrogen (WtH) is a branch of EfW technology with an emphasis on producing hydrogen from the waste materials to use as a fuel. Hydrogen is considered a “clean” fuel as the product of its combustion is just water. Currently, most hydrogen is produced from fossil fuels and if this can be changed it has the potential to make a significant contribution towards the decarbonisation of the energy sector (Lui, et al., 2020)Lui et al. (2020) critically assessed the potential of waste as a source of hydrogen production via both thermochemical (pyrolysis and gasification) and biochemical (fermentation and photolysis) processes. The report identified current bottlenecks, which included expensive production and operation processes, heterogeneous feedstock, low process efficiencies, inadequate management and logistics, and lack of policy support. The report concluded that the costs are currently too high to allow waste to be viewed as a serious competitor for hydrogen production. The economic feasibility would be affected by feedstock processing and advanced energy efficiency processes such as torrefaction, which can improve hydrogen yields and production rates.

8.3 Hydrothermal Liquefaction

Hydrothermal Liquefaction (HTL) is depolymerisation process involving high pressures, high temperatures and catalysts that has successfully been used to convert wet biomass into bio-crude oil. The process has been used for a variety of organic feedstocks such as sewage sludge, manure, algae, agricultural waste, wood waste and food waste), and there is potential for it to be used for mixed municipal waste. The technology is primarily in the pilot or demonstration phase. Advantages of HTL include its suitability for a variety of feedstocks including wet organic waste, the high energy content of the fuel produced and the minimal environmental impacts. Disadvantages of HTL include the immaturity of the technology, high processing costs and the lack of evidence of success with mixed municipal solid waste (Akhtar & Saidina Amin, 2011; Subramanya & Savage, n.d.; Watson, et al., 2020; HyFlexFuel, 2021).

8.4 Treatment Of Incineration Bottom Ashes

IBA is a by-product of MSW incineration, appearing as a grey heterogeneous material from rich in ferrous and non-ferrous metals, glass and minerals. IBA sizes can range from few micrometres to several centimetres, affecting the possible treatment that can be applied to the material. The main applied processes for IBA recovery in the UK consist in the production of an aggregate that can be reused in construction and roads applications. However, in order to reach high recycling rates, new processes are being explored for the enhanced recovery of ferrous and non-ferrous metals from IBA. These processes generally involve magnetic and eddy current separation, as well as inductive sorting. In particular, the recovery of heavy non-ferrous metals might make the process economically viable (Syc, et al., 2020; Mehr, et al., 2021; Syc, et al., 2018).

8.5 Integrated Resource And Waste Management

While integrated resource and waste management schemes are not technically considered “emerging technology”, this is a minority approach to management of HC&I wastes and there are not many examples of this in commercial operation. There are two such facilities in place in Scotland: Levenseat and Glasgow Recycling & Renewable Energy Centre (GRREC). The Levenseat site includes: mixed waste recycling via a MRF; food and garden waste recycling via in-vessel composting (IVC); EfW using gasification; aggregate recovery via a screening and wash plant; and pre-treatment of waste for AD via Anaergia’s OREX press (Levenseat, n.d.). The Glasgow RREC consists of: a Smart-MRF for separating waste for recycling; AD for treatment of the food and organic waste; and an EfW facility using gasification (Viridor, n.d.). There was no evidence found concerning the overall feasibility or impacts of these facilities as a whole. The feasibility and impacts of the EfW components, where these were found, have been set out in section 3.2.1.

The benefits of this approach are keeping the wastes in one place for the separation and treatment processes, which minimises the chance of mistakes created from passing the waste through various facilities/waste handlers and also reduces transport of the waste. The disadvantages of this approach are that costs will be higher to implement and operate multiple processes instead of just one, and a larger area of land would be required to fit the various processes into it.

9. Summary Of Key Findings

Table 18: High-level summary of treatment technologies against the inclusion criteria

Treatment Technology	Technical Feasibility	Economic Impacts	Environmental Impacts	Social Impacts	Health Impacts
Mass Burn Incineration	Generally considered as a well-established technology which has already seen deployment within Scotland. Electricity and heat can be captured and utilised. The UK average availability is typically approximately 89% for waste combustion. Specific data for Scotland is impacted by facilities only recently becoming operational. Compliance ratings for the operational	The cost of MBI development is largely dependent upon the size and technology to be used. The median gate fee for EfW facilities in the UK was reported as £93 per tonne in 2019/20. This was an increase from £89 the previous year. Construction and operation of MBI facilities will create employment and potential educational (e.g., through visitor centres) opportunities.	The main environmental impacts are considered as emissions to air, land and water. Carbon emissions are a current hot topic and there is an element of subjectivity in defining this impact partly due to assumptions that are made. Generally acknowledged that MBI will result in a carbon benefit when compared to sending	Common referred to social impacts are that EfW facilities are more likely to be located in industrial settings closer to less affluent population groups. However, there is varying evidence to validate this point. Public opinion to waste management in general varies.	This is one of the key discussion points with various studies having been undertaken. The general consensus is that any health impact is likely to be small but cannot be ruled out entirely. It is understood that PHS is undertaking their own review on health impacts as part of the incineration review. One less researched health impact is the potential mental health of living near to a MBI.

Treatment Technology	Technical Feasibility	Economic Impacts	Environmental Impacts	Social Impacts	Health Impacts
	MBI in 2019 for Scotland were either rated 'excellent' or 'good' by SEPA.		residual waste to landfill. The fossil content of residual waste is one of the main impacts on carbon emissions. By-products of the incineration process (e.g., metals, IBA and APCr) are typically recovered.		
Advanced Thermal Treatment	There has been limited application of ATT (gasification and pyrolysis) facility development within the UK. Scotland currently has two operational gasification facilities, but these have both had to overcome delays in making it through to commercial operations.	The capital costs to develop ATT facilities will depend upon the exact size of the facility and technology to be used. Construction and operation of ATT facilities will create employment and potential educational (e.g., through visitor centres) opportunities.	There is limited literature on specific environmental impacts from ATT facilities. This is due to the impacts being similar to those of MBI facilities. As ATT facilities often require pre-treatment this can provide an opportunity to capture some recyclable materials	The social impacts of ATT are considered to be similar to those of MBI facilities. There is limited literature available specific to the impacts of ATT facilities.	The health impacts of ATT are considered to be similar to those of MBI facilities. There is limited literature available specific to the impacts of ATT facilities.

Treatment Technology	Technical Feasibility	Economic Impacts	Environmental Impacts	Social Impacts	Health Impacts
	ATT facilities need pre-processing of the feedstock to refine the fuel mix going into the ATT process. There is limited information of the current availability and performance of Scotland and UK based ATT facilities.		through the use of other technologies such as MBT or residual waste MRF.		
Landfill	Modern landfills are well established with modern engineering (e.g., cell and underly development with the capture of leachate and methane). Feasibility to an extent for additional landfill development is dependent on whether suitable locations can be	Landfill tax is charged per tonne at two rates depending upon the type of waste. The lower rate in Scotland is £3.15 per tonne and higher rate is £98.60 per tonne. There is a clear correlation in waste to landfill reducing as landfill tax rates increase.	The key environmental impacts are emissions to air such as methane from the decomposition of waste and risk to groundwater through leachate.	Landfills can be considered to have both positive and negative impacts. The Scottish Landfill Communities Fund (SLCF) is funded by landfill operators in Scotland and distributes funds to the local community. A review found that the SLCF had funded over 1,400	there is not any substantial evidence that populations living near landfills in the UK have higher occurrences of cancer or adverse birth outcomes. However, landfill does impact local air quality with ammonia being a common issue.

Treatment Technology	Technical Feasibility	Economic Impacts	Environmental Impacts	Social Impacts	Health Impacts
	found with the correct geology and nearby sensitive receptors. The use of landfill is changing from 2025 with the implementation of the BMW landfill ban and potential extension to include BNMW. Regulatory compliance is said to be low with 78% of landfills compliant in 2017.			projects with £32.7m of funding. This fund is expected to drop as reliance on landfill decreases.	
Export	The export of RDF and SRF is well established within the Scotland and the UK.	The gate fee for RDF exports including its preparation has exceed £100 per tonne. The initial growth in RDF exports has declined since the peak in 2017. This is	The main additional environmental impact of RDF/SRF export when considering post generation and prior to its energy recovery is the associated transport	The social impacts of exports are considered to be within the generation of RDF/SRF and an applicable facility.	The health impacts of exports are considered to be within the generation of RDF/SRF and an applicable facility.

Treatment Technology	Technical Feasibility	Economic Impacts	Environmental Impacts	Social Impacts	Health Impacts
		largely considered due to the increase in UK EfW capacity and the implementation of import taxes in destinations such as the Netherlands.	emissions. This will vary by its destination and mode of transport.		
Mechanical Biological Treatment	MBT has had a mixed history within the UK with reports of issues centred around technology design, performance and contractual disputes. MBT technology can be configured to different purposes. The majority of MBT facilities within the UK, including the two within Scotland, primarily produce RDF.	There is limited data on gate fees available for MBT facilities. However, some reported date indicates that there is not much difference between EfW gate fees, though this is only available up to 2017. When a study considered the cost of waste management across British waste disposal authorities. The findings indicate	Environmental impacts are similar to those of other waste management operations. Specific impacts from MBT are considered to be centred on bio-aerosols, dust and odour. There are also concerns around the suitability of end markets for CLO that has not been stabilised.	MBT facilities are stated as likely to have positive and negative social impacts. Positive impacts are centred around job creation and the potential to create educational facilities. Negative social impacts are centred around amenity such as through potential issues with odour, noise and dust.	There is limited literature on the specific health impacts of MBT facilities. It is considered that the main risk is centred on bio-aerosols with impacts reviewed for similar composting facilities. The literature suggests that communities located more than 250m away from composting facilities are unlikely to be

Treatment Technology	Technical Feasibility	Economic Impacts	Environmental Impacts	Social Impacts	Health Impacts
	The recyclable material extracted from the residual waste is reported as being lower than expected with a low value.	that the five most expensive, per tonne of residual waste treated, primarily relied upon MBT, whereas only seven of the remaining primarily rely upon MBT. The authors noted that the analysis was 'not necessarily the most robust' but that their findings were 'unlikely to be a co-incidence'.			exposed to harmful levels of bio-aerosols. However, odours associated with the process are likely to occur as these can travel further.
Biostabilisation	Biostabilisation technology is not well established within Scotland and the wider UK.	There is limited information available on the cost of development or gate fee prices. Without any change in tax rate, biosabilised residual waste would still be	The environmental impacts are similar to those for MBT. In terms of carbon, studies indicate that this is a potential low carbon option. Though there is an element of subjectivity in	The social impacts are not considered to any different to that of MBT.	The health impacts are not considered to any different to that of MBT.

Treatment Technology	Technical Feasibility	Economic Impacts	Environmental Impacts	Social Impacts	Health Impacts
		subject to the higher rate of landfill tax.	defining this impact partly due to assumptions that are made.		
Emerging Technologies	Due to the emerging nature of these technologies the specific impacts are not in all cases as advanced to allow for comparison purposes.				

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Appendices

Appendix 1 – Call for Evidence Summary

Appendix 1 Call for Evidence: Summary of Responses

10.1 Overview

The following tables outline a summary of the call for evidence responses received and reviewed as part of this options appraisal. This is not the full range of evidence submitted and reviewed as part of this options appraisal, as not all responses were formatted in a way to be replicated into this report.

Within the below tables, Ricardo have not validated any of the information and have simply reported upon what has been submitted through the call for evidence.

10.2 Call For Evidence: Question 10 Summary

Category	Q10: What treatment options for residual waste should Scotland consider?
Local Government	Proven technologies which will be capable of delivering a reliable service in the long-term.
Local Government	At present, it would seem that the only legally compliant, technically proven and scalable option is likely to be to direct residual biodegradable municipal waste to energy-from-waste facilities. If other legally permissible, and technologically and environmentally acceptable, options can feasibly be made available then the possibilities may broaden.
Local Government	No response.
Local Government	To meet the obligations of the landfill directive, coupled with our ambitions to be ever less reliant of fossil fuels, Scotland requires a solution that has a proven track record. EfW provides a reduction in carbon emissions (compared to landfill), as well as heat and power. There is a recognition that EfW still contributes to carbon emissions, and further work needs to be done on carbon capture, with the aim of making this treatment a zero-carbon contributor - not carbon offsetting (though this should be considered on the run up to the realisation of zero-carbon). To help maximise diversion, all facilities should front end their treatment with MBT (dirty MRF).

	Given the existing recycling targets and financial drivers, the waste hierarchy remains with a preference for reduce reuse recycle over treatment/incineration. Therefore, these options should therefore complement each other.
Local Government	The authority provides every household and business with a Food and Garden Waste kerbside collection service. This waste is treated using a dry AD process which has achieved PAS110. Options are being consider to treat the residual waste from other island groups using a form of in-vessel composting that would reduce the level of biodegradability. However, it is extremely difficult in practical terms to reduce biodegradability close to zero without using an energy from waste process.
Local Government	SEPA's thermal treatment derogation scheme should remain, and upon implementation of DRS this could be applied to all local authority collections as recovery of metals and plastics should have been maximised at that stage. Consideration also has to be given to the treatment of bulky waste collected at Household Waste and Recycling Centres and at the kerbside. Will this material meet the testing requirements to be considered as biodegradable waste, or could it continue to be sent to landfill? If not mechanical pre-treatment of this waste stream prior to incineration should be considered. By incorporating pre-treatment waste could be processed through a variety of mechanical / electrical processes to remove recyclable material at the front end of the EfW plant rather than trying to salvage recycled scrap material from bottom ash.
Local Government	Scotland should look at tried and tested, efficient, bankable systems for waste disposal that produce a minimum of residues to be disposed of. These technologies should also include plans to decarbonise the process. Mass burn is tried, tested and bankable and for all intents and purposes the discharges are continuously monitored to ensure they meet the stringent guidelines for emissions. Although I have no direct experience of some of the other technologies the information from other Councils has led me to believe that they threw up ongoing challenges with residues and effective markets for outputs such as CLO.
Local Government	Moving grate incineration remains the proven and cost-effective technology for treating municipal waste from approx. 50,000/tonnes per annum upwards. The technology requires low energy input as no pre-processing of waste is required, produces heat and power and there are proven commercial means to recycle all solid residues from the process. Gasification for smaller scale operations has yet to demonstrate a reliable track record and

	requires significant pre-treatment. Bio-stabilisation may produce small amounts of heat and power (if AD is part of the process) otherwise is an energy consuming option and unproven in relation to its ability to meet standards for landfilling, which in themselves are not clearly established.
Local Government	It should be considered that the circumstances and drivers within some of these smaller rural, and particularly the island, communities, is very different and a flexible approach should be taken without falling into the trap of mandating a "one size fits all" approach. It may even be the case that in certain circumstances landfill may indeed by a good option?
Local Government	There are several residual waste treatment solutions is use within the sector each with their own benefits and challenges. There is no single solution for Scotland however when selecting a technology and facility design the following must be considered: location and capacity to support local need, transport impact for feedstock and output, material composition and impact on future change and the environmental & Social impact.
Professional body, trade organisation or governing body	Before moving into the treatment options for residual waste, the body believes the point needs to be made about reducing waste at source, repairing and reusing and then recycling. Residual waste should be just that. Continuing to focus on the treatment of residual waste seems to come at the expense of focusing on interventions that would reduce volumes at source. The treatment of residual waste also plays a key public health role and therefore needs to be robust, deliverable and sustainable. There are six possible options for the treatment of Scotland’s residual waste. 1. Landfill Historically landfill was the main disposal methodology for waste, but government policy since the 1990’s has focused on diverting as much waste as possible from landfill, in order to promote recycling and recovery. This was initially achieved by the landfill tax when it was introduced in 1996 and then by progressive Bio-degradable Municipal Waste (BMW) diversion targets from the 1999 European Landfill Directive. This has helped to increase recycling and fostered the development of alternative treatment methods. The implementation of a Scottish biodegradable waste ban in December 2025 will place further limitations on residual wastes that are suitable for landfill, and therefore its primary role for the management of residual waste will diminish further. Whilst landfill is at the bottom of the waste hierarchy and considered the option of last resort for residual wastes, it will continue to play a small but important part in the disposal of waste that cannot be recycled or treated currently, but this role will be significantly less than is currently the case.

CIWM notes suggestions in the review narrative (and elsewhere) on the potential role for landfill for the disposal of fossil-carbon material (sequestration). CIWM is concerned that this would represent a regression of 20+ years of waste policy in Scotland.

Scotland's post-2025 landfill policy landscape would nonetheless benefit from urgent review and clarification. In the context of anticipated landfill closures in advance of the landfill ban, it is important that some landfill resource is protected and, when exhausted, replaced. Landfill should therefore be considered a specialist treatment option (dealing with wastes that are difficult to recycle or not appropriate for EfW) and supporting the waste hierarchy, by providing a disposal outlet for materials and residues produced by activities taking place further up the waste hierarchy.

2. Energy from Waste (EfW)

Conventional moving grate EfW plant provides a robust, well-tried and tested technology with high availability and the ability to treat a heterogeneous waste stream and are one of the few 'bankable' technologies for the treatment of residual waste.

EfW is above landfill in the waste hierarchy and is also a less carbon intensive option for the management of residual waste, saving around 200kg CO2e for every tonne of waste diverted from landfill. The exact saving will of course vary, because this is influenced by several factors, including the efficiency of the EfW facility and the composition of the residual waste. Life cycle assessments carried out to date all arrive at the same conclusion as Zero Waste Scotland's (ZWS) EfW report, which is that EfW results in fewer emissions than landfilling the same waste.

More than 50% of the residual waste stream is biogenic and therefore EfW is a low carbon option for producing heat and power to local homes and businesses. However, it is inappropriate to compare the carbon intensity of EfW with other (renewable energy) power generation sources, without considering the avoided emissions from landfill.

EfW also serves a dual purpose; firstly as a primarily a public health and sanitation function, and secondly the utilisation of heat and power of the waste treatment process.

3. Advance Thermal Treatments (ATT)

The term ATT covers many different forms of alternative thermal treatment technologies, but the main ones are Gasification and Pyrolysis, these are good with single waste streams (e.g. wood, plastic, tyres etc…), but less accepting of mixed and heterogenous waste such as residual waste.

CIWM is aware of reports that suggest that gasification and pyrolysis constitute some of the riskiest and most unreliable technologies in the waste industry. There are a litany of failures in the UK leading to bankruptcies and abandonment, such as those in the Isle of Wight, Dargavel, Avonmouth and Tees Valley.

A report entitled ‘Patented blunderings’, efficiency awareness, and self-sustainability claims in the pyrolysis energy from waste sector (by Andrew Neil Rollinson and Jumoke Mojisola Oladejob - circa 2018) said that ‘a pyrolysis plant for self-sustaining Energy from Waste is thermodynamically unproven, practically implausible, and environmentally unsound’, it also highlighted widespread commercial failures and a lack of focus on thermodynamic fundamentals.

4. MBT

The original concept of MBT was to increase recycling, reduce the tonnage of waste to landfill, prepare a ‘compost like output’ (CLO) suitable for land remediation, generate biogas and/ or to prepare a Refuse Derived Fuel (RDF) to a specification. MBT was seen by many as an alternative to EfW.

The Tolvic report details recycling rates for MBT facilities currently range between 1% and 18% of all inputs, but in many cases the recycling performance at MBT facilities has consistently fallen below contractual targets. As well as quantities being down the quality of recovered materials is significantly poorer that source segregated materials. Also, with tightening environmental legislation reducing potential land applications, opportunities for long term, sustainable markets for CLO have been found to be very limited, resulting in MBT being effectively a pre-treatment for RDF production. Tolvic reported that MBT led residual waste solutions have proved to be more expensive than EfW based alternatives and yields no commercial benefit.

CIWM notes with some concern that disposal of bio-stabilised outputs from MBT to landfill is, inexplicably, gathering favour within ZWS and who are continuing to promote this as a viable residual waste treatment option. It is therefore disappointing that the much-anticipated ZWS report (on the feasibility of bio-stabilised outputs to landfill) has not yet been published or is available for consideration as part of this review.

It is worth noting that the UK is reducing its reliance on MBT with sites continuing to close. MBTs have also proven to be difficult to operate because of compositional issues. The most recent plant failure that CIWM is aware of in England was the Tovi Eco Park – Urbaser Balfour Beatty MBT in Basildon, Essex. This operation went into administration in August 2020 after a protracted Court5 case between the operator (UBB) and Essex CC, which essentially was dispute over composition verses whether the plant had been designed properly.

Crucially, industry experience strongly suggests that MBT outputs would not meet the stringent respiration thresholds of Scotland's landfill ban and the body is unaware of any research of UK-based MBTs that has reached a different conclusion in this regard.

CIWM reiterates our concerns that this is not a viable option for the management of Scotland's residual waste, and based on practical, previous experience, appetite within the industry to further invest in this technology is low. This technology would also necessitate a continuation of landfill capacity for the disposal of MBT outputs, with the resource and land use impacts inherently associated with landfill; including landfill gas generation, amenity issues and potential impacts on the ground and surface water. The costs would also be significantly higher given that landfill tax (the materials will also be subject to standard rate landfill tax) would still need to be levied on the residual waste.

5. RDF Export

The Climate Change Committee in its Sixth Carbon Budget recommended that to meet Net Zero, the UK should Phase out exports of waste by 2030. Therefore the body does not see the export of RDF as a viable long-term option for the management of residual waste, and that all efforts to manage Scotland's waste onshore should be consider instead. Exporting of waste is also seen unfavourably by policy makers, and the general consensus is that Scotland should build capacity to manage a municipality's waste within the municipality (i.e. the proximity principle).

6. SRF Production

Landfill tax has successfully made other waste treatment solutions more affordable by comparison to it, but value for money/ financial cost is still the biggest driver for a waste disposal contract. Intermediate treatment options and those involving the double handling/ transportation of waste add cost and are viewed less favourably to a single stop solution.

The exception to this is where Solid Recovered Fuel (SRF) is prepared, which can then be considered as a fuel replacement that incurs less cost. There are currently no examples in Scotland of SRF producers being co-located with SRF users, which are mainly cement kilns, where transport costs can be negated to keep this option viable. This form of treatment was used by Dumfries and Galloway for a while for part of the output from their Ecodeco facility, but it was a short-term contract. Cement Kilns are mainly located in areas of high construction/ development (e.g. on the outskirts of Cities). This route has successfully been adopted in Eastern Europe partly for this reason, although SRF production is more common from single stream waste such as tyres than from

	mixed residual wastes. It should be noted that household waste to SRF requires significant processing and there is only a limited fraction (plastic/ paper etc) suitable for SRF fuel.
Professional body, trade organisation or governing body	There are three possible options for the treatment of Scotland's residual waste 1. EfW 2. Landfill 3. MBT/RDF export <u>EfW</u> EfW is above landfill in the waste hierarchy and is also a less carbon intensive option for the management of residual waste, saving around 200kg CO2e for every tonne of waste diverted from landfill (6). The exact saving will of course vary as it is influenced by several factors including the efficiency of the EfW facility and the composition of the residual waste. However, life cycle assessments carried out to date arrive at the same conclusion as ZWS's EfW report (7): EfW results in fewer emissions than landfilling the same waste. More than 50% of the residual waste stream is biogenic and therefore EfW is a low carbon option for producing heat and power to local homes and businesses. However, it is inappropriate to compare the carbon intensity of EfW with other (renewable energy) power generation sources, without considering the avoided emissions from landfill. EfW has a dual purpose: primarily a public health, sanitation function with the generation of heat and power a useful by-product of the waste treatment process. <u>Landfill</u> Two decades of Scottish Government waste policy have been focused on diverting waste from landfill, helping boost household recycling to nearly 45% (and 60% for 'all waste') and reducing landfill of waste by 63% since 2005. Landfill is also at the bottom of the waste hierarchy and should therefore be considered as home of last resort for Scotland's non-recyclable, non-combustible residual waste. However, this is not to suggest that there is no role for landfill post 2025 and there are residual wastes not suited to recycling (or produced from the recycling process itself) or unable to meet the tight input specification of EfW for which landfill will likely remain the home of last resort. We therefore suggest that the review also considers Scotland's post-2025 policy landscape for landfill, including resilience planning.

We note suggestions in the review narrative (and elsewhere) on the potential role for landfill for the disposal of either fossil-carbon material (sequestration) or MBT outputs. We consider neither option desirable and are concerned that this would represent a regression of 20+ years of waste policy in Scotland.

Simplistically and within its own system boundary, our sector could minimise its direct and indirect emissions by incinerating all biogenic waste and landfilling all other types of waste – this would reduce emissions from sorting, digesting, composting and recycling operations which are energy and therefore carbon intensive operations. However, this would have significant health and environmental impacts and would increase emissions in other parts of the economy thereby driving Scotland further away from a net zero circular economy.

Scotland's post-2025 landfill policy landscape would nonetheless benefit from urgent review and clarification. We see a continued (albeit reduced) role for landfill in a supporting capacity for the waste hierarchy for the disposal of non-combustible, non-recyclable waste. In the context of anticipated landfill closures in advance of the landfill ban, it is important that some landfill resource is protected and, when exhausted, replaced. Landfill should therefore be considered a specialist treatment option (dealing with wastes that are difficult to recycle or not appropriate for EfW) and supporting the waste hierarchy (by providing a disposal outlet for materials and residues produced by activities taking place further up the waste hierarchy). Landfill could also be considered as a bridging capacity, as an outlet for residual waste during times of (un)planned EfW downtime and maintenance. Until such time as Scotland's EfW market matures, there simply will not be the additional headroom capacity within the existing EfW system to accommodate this waste from other plants.

<u>MBT/RDF export</u>

Please note comments above on the pressures on the RDF export market.

We note with some concern that disposal of bio-stabilised outputs from MBT to landfill is, inexplicably, gathering favour within ZWS and which is continuing to tout this as a viable residual waste treatment option. It is therefore disappointing that the much anticipated ZWS report (on the feasibility of bio-stabilised outputs to landfill) has not yet been published, or is available for consideration as part of this review.

It is worth noting that the UK as a whole is reducing its reliance on MBT with sites continuing to close (8). Crucially, industry experience strongly suggests that MBT outputs would not meet the stringent respiration thresholds of Scotland's landfill ban. We are unaware of any research of UK-based MBTs that has reached a different conclusion in this regard. This is not to suggest that there is no future role for MBT in Scotland's residual waste treatment landscape. Such will likely remain in the mix of treatment solutions in one guise or another as a pre-treatment process for ATT. Furthermore, development of technologies such a chemical recycling could

	provide an outlet for the plastic component of MBT feedstock, where such had not been captured by upstream recycling collection systems. We reiterate our concerns that this is not a viable option for the management of Scotland's residual waste and, based on practical, previous experience, appetite within the industry to further invest in this technology is low. It would also necessitate a continuation of landfill capacity for the disposal of MBT outputs, with the resource use and land-use impacts inherently associated with landfill. References (6) https://www.greeninvestmentgroup.com/assets/gig/news/gib-residual-waste-report-july-2014-final.pdf (7) https://www.zerowastescotland.org.uk/content/climate-change-impact-burning-municipal-waste-scotland (8) https://www.tolvik.com/wp-content/uploads/2017/09/Tolvik-2017-Briefing-Report-Mechanical-Biological-Treatment.pdf
Professional body, trade organisation or governing body	We do not address landfill in this response given it is subject to a ban from 2025 and the carbon performance of incineration over landfill on similar wastes is well understood and widely reported. Only incineration and MBT are therefore considered below. We also reference other emergent systems that are yet to prove market viability. Our following comments are in context to the current system of mandated recycling for kerbside recyclates, food waste and extensive green waste collections, where the residual waste systems needed address the remaining wastes. Energy from Waste: EfW offers a reliable, resilient alternative to landfill for the management of residual waste. This reliability and resilience is essential to ensure waste is prevented from becoming a public health issue. Our current failures in delivering EFW solutions relate to an absence of any national strategic planning capability and failures in procurement to deliver proximate regional solutions in appropriate locations at optimised scales. However, the body believes that we have a pressing responsibility to address the carbon emissions from energy form waste facilities more effectively.

Whilst more than half of the residual waste stream is biogenic, levels of non-biogenic wastes are a significant source of carbon emissions.

To mitigate the major carbon impacts of incineration the body consider the following measures to be necessary.

1. Implementation of measures to encourage the separate collection of waste plastics from municipal, commercial, and industrial producers.

2. Support for demonstration projects to optimise these measures. Body members can offer integrated solutions to support this approach.

3. Supportive measures could include:

a. Specific planning guidance relating to facility location and energy efficiency.

b. More specific and challenging permit conditions to drive energy use efficiency.

c. Public procurement addressing the carbon emission issue as a condition of contract awards

d. Economic and financial instruments. There are several potential options to stimulate innovation and investment in reducing the non-biogenic carbon intensity of residual waste and high levels of energy use efficiency (heat and power) here including, adding EfW to the UK ETS scheme, or a Carbon Tax specific to incineration. Neither of these options are without their challenges including the nature of change of law clauses in public sector PFI projects or commercial feedstock agreements.

4. A nuanced and detailed strategy to reduce residual waste. Again, body members have a detailed understanding of the many issues contributing to residual waste production and the key components of a mitigation strategy.

MBT:

The body share the sector wide concern on the promotion of MBT as an alternative treatment option for residual wastes. We can see no evidenced, experiential, or technical reasons for this support. This is a matter where the professional perspectives of operators must be considered. Whilst there is a long history of MBT failures in the UK, many working on ideal residual streams, the composition of residual waste in the context of the current Scottish waste management system is significantly sub-optimal, making MBT even less viable as an option given the challenging respiration thresholds in the landfill ban.

In terms of the final disposal of MBT residues, these would most likely have to be incinerated. Much of the research being promoted by organisations such as ZWS Europe (an organisation that the body broadly supports) is theoretical or at best preliminary and fails to consider the wider Scottish resource management system. We are

	trying to fix the wrong problem here. The previously referenced Tolvik report provides a coherent perspective of experience with MBT to date. We see nothing on the MBT technology horizon, which would fit our current circumstances, to lead us to disagree with the views presented in that report. It may offer niche solutions (see Question 11) but fails significantly to offer the reliability and resilience necessary for the safe and cost-effective management of residual waste. Emergent but as yet undemonstrated at full scale viable operation for residual waste: • Hydrothermal Carbonisation (high temperature, high pressure water system capable of breaking down organic matter and waste plastics to create bio-coal for example. However, this is just another route to combustion. It is showing promise in the de-polymerisation of waste plastics. • Mixed waste hot enzyme wash out of organics - Liquids to AD: 3D fraction for metals and plastics recovery. (FCC / DONG) • True Gasification to flexible syngas back-end value platforms (e.g., high efficiency gas engine to power or hydrogen production). Yet unproven and failing after years of attempts to produce clean syngas outputs, but efforts continue!
Professional body, trade organisation or governing body	Scotland should also ensure it considers the need for gasification and pyrolysis in the development of renewable transport fuels, green chemicals and hydrogen. Current developments of such projects across the UK do consider the use of RDF. Examples of such developments can be seen within the UK's Renewable Transport Fuel Obligation scheme. These projects could see the delivery of solutions for hard to treat sectors. The commercial use of carbon capture and storage should also be considered, especially in relation to the existing waste recovery infrastructure, where it is likely it will need to be retrofitted in order to maintain the use of the existing infrastructure and avoid the development of a future capacity gap.
Professional body, trade organisation or governing body	As noted in response to previous questions submitted, the body believes that there should be full consideration of the role of cement manufacturing in Scotland as a means to add significant value or new life to end of life materials in Scotland. There is one cement manufacturing plant in Scotland, at Dunbar, which is regulated by SEPA, covered by the UK ETS.
Professional body, trade organisation or governing body	We consider that there are three realistic options for the treatment of Scotland’s residual waste: EfW, landfill or MBT/refuse derived fuel (RDF) export. We suggest that there are technical reasons for all of those to be part of the mix for the treatment or disposal of residual waste. Fundamentally, there will be some types of waste that still require to be landfilled even after the landfill ban is put in place.

Business that operates one of more incineration facilities in Scotland	EfW EfW saves around 200kg of CO_2e for every tonne of waste diverted from landfill.5 The exact saving will be determined by factors including the efficiency of the EfW facility and the composition of the residual waste. However, life cycle assessments carried out to date arrive at the same conclusion as ZWA's EfW report: EfW results in fewer emissions than landfilling the like for like waste.6 EfW can also present a low carbon option for supplying heat and power to local homes and businesses. However, it is inappropriate to compare the carbon intensity of EfW with other (renewable energy) power generation sources, without considering the avoided emissions from landfill. The primary purpose of EfW is a public health, sanitation function, with the generation of heat and power a useful by-product of the waste treatment process. Landfill Two decades of Scottish Government waste policy have been focused on diverting waste from landfill helping boost household recycling to nearly 45% (and 60% for 'all waste') and reducing landfill of waste by 63% since 2005. Landfill is also at the bottom of the waste hierarchy and should therefore be considered as home of last resort for Scotland's non-recyclable, non-combustible residual waste. Nevertheless, beyond 2025 there will continue to be residual wastes which cannot yet be recycled (or arise as a product from the recycling process itself), or materials which hare unable to meet the input specification of EfW. Landfill will likely remain the last resort for such materials. We note suggestions in the review narrative (and elsewhere) on the potential role for landfill for the disposal of either fossil-carbon material (sequestration). We consider neither option desirable and are concerned that this would represent a regression of 20+ years of waste policy in Scotland. Scotland's post-2025 landfill policy landscape would nonetheless benefit from urgent review and clarification. In the context of anticipated landfill closures in advance of the landfill ban, it is important that some landfill resource is protected and, when exhausted, replaced. Landfill should be considered a specialist treatment option to deal with wastes that are difficult to recycle or not appropriate for EfW, that supports the waste hierarchy by providing a disposal outlet for materials and residues. produced by activities taking place further up the waste hierarchy. Landfill could also be considered as a bridging capacity, as an outlet for residual waste during times of (un)planned EfW downtime and maintenance. Until such a time in Scotland's EfW market matures, there simply will not be the headroom capacity within the existing EfW system to accommodate this waste from other plants. [5]GIB_WASTE_MARKETREP_02.indd (greeninvestmentgroup.com) [6]The climate change impact of burning municipal waste in Scotland | Zero Waste Scotland

	<u>MBT/RDF Export</u> As outlined above, we are supportive of the trends towards re-shoring of RDF for domestic use. The UK as a whole is reducing its reliance on MBT with sites continuing to close. This reflects that this is not a viable option for the management of Scotland's residual waste and, based on practical, previous experience, appetite within the industry to further invest in this technology is low. It would also necessitate a continuation of landfill capacity for the disposal of MBT outputs, with the resource use and land use impacts inherently associated with landfill.
Business that operates one of more incineration facilities in Scotland	There is only one technology that has consistently over many years and in many countries proved itself to be capable of safely treating large volumes of residual waste in a reliable and energy efficient manner, with a very high tolerance for different types of waste feedstock, and that is grate-based combustion with energy recovery. There are several hundred examples of the technology which was developed in the 1970's; many of the early facilities are still operating today. The core combustion process is not particularly complex but highly controllable and maintainable. There are significant economies of scale available from this technology, both in terms of cost but also from enhanced energy efficiency. Despite the demonstrated advantages of grate-based combustion, there have been many attempts to modify the process in an attempt to increase energy efficiency through the use of fluidised bed technology, however the marginal improvements to combustion efficiency have consistently been cancelled out by higher maintenance costs, less reliable and delayed facilities and challenging feedstock specifications resulting in high preparation costs and the disposal of rejected material. In recent years, there have been attempts to basically de-construct the thermal energy recovery process by use of staged combustion technologies, generically known as gasification. The development of "gasification" technologies has been artificially driven by favourable electricity tariffs and an as yet unrealised ambition to use them to produce clean syngas for use in the transport sector. However, in practice, these "gasification" technologies have proved to be complex, difficult to commission, not suited to scale up and in consequence there have been very few successful examples in the UK while elsewhere in the world where subsidies have not been available, the technology has barely been used. The non-thermal alternative solution that has been tried for residual waste is Mechanical Biological Treatment. This has proved to be highly challenging in terms of commercial viability (lack of markets for materials extracted,

	inability to produce a compost like material that can be used in agriculture, odours, mechanical failures) and has generally been abandoned as a solution in the UK.
Business that operates one of more incineration facilities in Scotland	EfW is clear opportunity - for localised heat recovery (more energy in waste than needed to destroy it) = heat export. EFW at local level - proximate, localised plants (avoiding transport) will need flexibility in waste acceptance criteria (SEPA are keen to "limit" waste types) - it would be more helpful to this agenda if the wastes were categorised as residual v recyclable - increasing the opportunity for waste currently prohibited, to be able to avoid landfill (e.g., textiles). Anaerobic Digestion - currently largely the preserve for food waste disposal in Scotland - though globally (esp EU) is utilised for numerous waste streams (including textiles-a major residual waste landfill problem). Can the scope for waste acceptance be relaxed to allow BNMW to be accepted at AD?
Business that operates one of more incineration facilities in Scotland	In the businesses view only combustion with front end recycling/separation, circulating fluid bed combustion technology with electrostatic precipitation of particulates in the flue gas and followed by flue gas condensation. This mix of technologies is the cleanest and most efficient available. Additional comment: None of the technologies mentioned in page 25 (last paragraph before Q10 in the document) reduce the carbon impacts of 'incineration'. First one must be clear about what is understood by the terms 'mass-burn' and 'incineration' and have a deep understanding of the various technologies and their thermo-chemical efficiencies. 'Mass burn' and 'incinerator' are non-scientific non-engineering terms that don't help to allow the layman to understand the state of the industry today. The term incinerator should only be used to describe a facility that is designed to simply burn waste without any ancillary benefit other than its destruction. Modern 'energy recovery' plants are mandated by legislation to produce a minimum amount of useful energy in the form of electricity and/or heat. Within the industry today there are a range of technologies which are proven and fund-able and some that are not. There are many misconceptions around what is generally known as 'advanced thermal conversion' particularly where it is employed using mixed residual waste as fuel. Syngas consisting of mostly hydrogen and carbon monoxide where waste is the raw fuel is inconsistent, subject to drop-out as condensate, and practically useless as a building block from which to generate fuels or even use in an internal combustion engine.
Business that operates other	The business is of the opinion that once suitable capacity is available and planned for processing of recyclate and food waste, then any remaining residual waste should be sent to the current fleet of incinerators in operation and

(non-incineration) residual waste treatment facilities outside of Scotland	construction, the mechanical biological plants that also exist and Scotland should also consider the use of Solid Recovered Fuel (SRF) in cement kilns. This would increase the use of alternative fuels at cement kilns, in Scotland, other part of the UK, Ireland and elsewhere in Europe. The businesses latest major investment is a new dedicated SRF plant, producing high calorific SRF for industrial users. The latest technology has been utilised in this new production line and is capable of maintaining the most exacting SRF material specifications. By investing in the latest technology we are able to efficiently produce a high quality grade of fuel which is submitted to strict testing, ensuring that the material we produce complies with both the regulatory standards and the fuel user's own specifications. Our production operates in compliance with CEN/TS 15359.
Business that does not operate a residual waste treatment site but produce waste that ultimately is treated at one	No comment.
Not for profit environmental organisation	The organisation has ongoing research to understand the viability of biostabilisation. The use of biostabilisation is dependent on the process meeting the requirements of the SEPA guidance and the Landfill (Scotland) Regulations 2003. It should be noted that we are not aware of any plants that meet the required standards. We do not have any evidence to provide about other forms of alternative residual waste treatment. Please refer to our response to question 8 and 14 for evidence regarding the impacts of incineration and landfill.
Environmental Group	Please look first at the composition of the "residual waste" to see how much is actually made up of recyclable materials. By comparing recycling rates from the best performing local authorities with the rest, especially those with incinerators close at hand, it is clear that much more "waste" could be separated out before it goes anywhere near an incinerator or a landfill site. How does East Renfrewshire achieve a recycling figure of 67.8% (2019), when the Scottish average is only 44.9%. Yes, there are cultural and behavioural issues involved, and differences

	between urban and rural, but why has the recycling figure in the City of Edinburgh gone into reverse, between 2015 and 2019? Maybe it's because incineration has become an easier option. So, the first treatment option for residual waste should be better segregation of recyclable, repairable and reusable materials at source, thereby reducing the volume of residual waste significantly. The question is seeking an end-of-pipe solution, whereas the first priority should be reducing the flow of residual waste.
Environmental Group	As UKWIN points out in their report, the 27% figure does not hold up to scrutiny especially when a higher proportion of it is plastic which produces 2 tonnes per tonne of waste when burned whereas in landfill it is largely inert but would obviously be much better recycled. Biostabilisation avoids methane in landfill and anaerobic digestion as mentioned in the response to question 9 would enable energy to be produced.
Environmental Group	A ban on burning plastic would dramatically reduce greenhouse gas emissions from incinerators. Burning plastics releases fossil carbon into the atmosphere directly contributing to climate change. There are two immediate technical consequences of a ban: firstly, plastic would need to be separated from the remaining residual waste streams; and secondly, an alternative disposal mechanism is required in the short term. Existing mechanical pre-treatment processes can separate plastic from other wastes but are not 100% effective, for example composite materials pose a problem. Therefore, a staged introduction of the plastic ban may be necessary, based on the technical limitations of today’s sorting technologies and waste composition. A total ban should be implemented as soon as possible, which would incentivise alternatives to ‘hard to sort’ and ‘hard to recycle’ plastic products. Plastic that is unsuitable for recycling, can be landfilled, essentially storing the plastic, lowering greenhouse gas emissions. As well as banning plastic, additional sorting should be compulsory. A compositional analysis of Scottish household waste found 59% is typically recyclable. This component should be removed at a final sorting stage. The full potential of the role of biostabilisation in Scotland needs to be further explored.
Environmental Group	The reports of Zero Waste Scotland and DEFRA illustrate that incineration is avoidable for most wastes. The alternatives to incineration, such as reuse, recycling and composting, are preferable economically, environmentally and socially. One of the aims of the ban on landfilling Biodegradable Municipal Waste (BMW) is to reduce greenhouse gas emissions. The Guidance from SEPA states, “If municipal waste that is also biodegradable waste has undergone a treatment process to the extent that it is no longer biodegradable, it will not be categorised as BMW and will not be subject to the landfill ban.”

	Mechanical Biological Treatment (MBT) is one process by which biodegradable waste could be biostabilised before being landfilled and there is evidence that it is a proven technology with plants operating across Europe. Zero Waste Scotland's Technical Report 'The climate change impacts of burning municipal waste in Scotland' considers biostabilisation and concludes, "The large potential savings from biostabilisation indicate this option warrants further consideration to explore the practical, legal and financial barriers to be overcome." Zero Waste Europe's Policy Briefing highlights the importance of adopting Material Recovery and Biological Treatment as a strategy for the management of residual waste in the circular economy. According to the Briefing, "Treatment options for residual waste based on the MRBT concept show various advantages compared to incineration and co-incineration: ● MRBT-types of treatments are remarkably more scalable (i.e. able to be adopted at different sizes of operational capacities) than incineration. MRBT is based on biological stabilisation and mechanical sorting systems, which are inherently modular. While Best Available Technology (BAT) incinerators incur significant diseconomies of scale, as well as being less effective, at less than 100.000-150,000 t/year, MRBT may work at much less than 100.000 t/year (many biological treatment sites operate at less than 50.000 t/year). Therefore, MRBT could better address the proximity principle, and make various districts totally autonomous for residual waste management. ● Sites designed to operate through biological stabilisation and material recovery, are markedly cost competitive with incineration. Capital expenditure (capex) at a BAT level may be in the range of EUR 200-400 per t/year of installed capacity, while BAT incinerators typically are around EUR 1000 per t/year and more. This implies a lower use of financial resources for residual waste management, and a larger part of the budget may be dedicated to separate collection, reuse and recycling. ● MRBT types of installations are typically faster to implement than incinerators. Planning, procurement, permitting, construction and approval may typically take two years, which is much less than the time taken to have an incinerator up and running."
Environmental Group	Additional incineration capacity should not be considered as a valid option for Scotland to consider. Allowing more incineration (and the lock-in and other issues it generates) is incompatible with Scotland's recycling, waste prevention, circular economy and climate change ambitions. If there is a need for short-term 'transitional' capacity on the road to a circular economy, then this should be through biostabilisation of waste to reduce the methane impacts, whether as a standalone option or as part of a

wider Material Recovery and Biological Treatment system. Evidence that supports biostabilisation as a viable waste management option which is preferable to incineration includes:

• Building a bridge for residual waste: Material Recovery and Biological Treatment to manage residual waste within a circular economy (Zero Waste Europe, January 2021)

• Greenhouse Gas and Air Quality Impacts of Incineration and Landfill (ClientEarth, December 2020)

• Report for the EC Directorate-General for Environment entitled 'Development of a Modelling Tool on Waste Generation and Management - Appendix 6: Environmental Modelling' which was used in the Impact Assessment of the European Circular Economy package (Eunomia and the Copenhagen Resource Institute, 2014)

• Good Practice Guidance for Assessing the GHG Impacts of Waste Incineration (UKWIN, July 2021)

• The climate change impact of burning municipal waste in Scotland (Zero Waste Scotland, July 2021)

• Holistic Resource systems white paper (TOMRA, June 2021)

• The Ultimate Guide to Mixed Waste Sorting (TOMRA, October 2021)

• What is the best disposal option for the “Leftovers” on the way to Zero Waste? (Dr. Jeffrey Morris, Dr. Enzo Favoino, Eric Lombardi and Kate Bailey, May 2013)

• Landfill Bans: Feasibility Research (WRAP, November 2012)

• The Economics of Waste and Waste Policy (Defra, June 2011)

While removing food waste from the waste stream will reduce the proportion of biowaste that would degrade if sent directly to landfill, there is still a need to consider how these emissions could be minimised if biowaste is sent to landfill (e.g. as part of a 'transitional' strategy to treat residual waste as recycling rates improve while avoiding the 'lock-in' of waste incineration).

Even if there are potential challenges associated with the immediate use of biostabilisation, the potential savings from such approaches are very relevant when considering lower-cost medium-term residual waste treatment options that could allow for further increases in recycling and composting. This is especially relevant when considering whether or not to allow more waste incineration capacity which could lock in the use of that capacity for decades to come as the expense of the top tiers of the Waste Hierarchy.

The potential emissions savings from bio-stabilisation prior to landfill was considered in the July 2021 report from Zero Waste Scotland. Figure 16 of this report shows a comparison to the potential savings from reducing biodegradable material to landfill. This could be achieved using biostabilisation. If levels of biogenic carbon can be reduced from 15% to 5% of residual municipal waste, landfill impacts would fall from 337 kgCO2e/t to 59 kgCO2e/t.

Providing further detail, the report also notes: "The estimated greenhouse gas emissions from biostabilisation in this study are in line with estimates from such plants operating in Europe. The biostabilisation scenario in this study is illustrative only and further, more detailed research is required to understand the environmental impacts of this scenario in a Scottish context more fully."

"Biostabilisation as described in a referenced report, refers to a specific type of technology where waste is pre-treated before landfill to reduces its biodegradable content, in accordance with the respiratory test criteria described in the section 4.2.b.i of the Waste (Scotland) Regulations 2012. Biostabilisation is a proven technology with plants operating across Europe, although there are no such plants in Scotland or the rest of the UK."

Footnote 3 states: "For example, J. de Araújo Morais et al. (2008) Mass balance to assess the efficiency of a mechanical–biological treatment, Waste Management, Volume 28, Issue 10 found that biochemical methane potential of residual municipal waste was reduced by over 80% after treatment."

According to the conclusions of the report: "The large potential savings from biostabilisation indicate this option warrants further consideration."

It is explained within the 'frequently asked questions' section of the report's webpage that: "…for residual waste which cannot be recycled, Biostabilisation technologies could offer a low carbon solution to landfill…"

'Mechanical and Biological Treatment' (MBT) and 'Material Recovery and Biological Treatment' (MRBT) processes can extract recyclates for recycling and then biostabilise any residues prior to landfill.

Assessments have found that MBT-Landfill/MRBT approaches can result in significantly lower CO2e emissions than sending the same waste to incineration, especially when the benefits of the biogenic carbon sink in landfill and the impact of the decarbonisation of the electricity supply are taken into account.

MBT/MRBT systems are much cheaper to establish than incineration, thus MBT/MRBT systems provide greater flexibility than incinerators, as they are more able to accommodate future improvements in waste prevention and recycling.

This means MBT/MRBT avoids the environmentally harmful impacts of feedstock 'lock-in' associated with residual waste treatment facilities such as incinerators which cost hundreds of millions of pounds to build.

Defra noted the potential benefits of MBT-landfill back in 2011, stating: "MBT (mechanical biological treatment)-landfill provides the best emissions performance in terms of the treatment/disposal of residual waste. It essentially involves landfilling somewhat stabilised wastes with some material recovery. The magnitude of the environmental impact depends on the extent to which the waste is stabilised".

This issue was considered further by Eunomia and the Copenhagen Resource Institute (CRI) in 2014 in a report for Directorate-General for Environment at the European Commission entitled 'Development of a Modelling Tool on Waste Generation and Management - Appendix 6: Environmental Modelling' which was used in the Impact Assessment of the European Circular Economy package.

According to the European Waste Model document: "The central aim of aerobic stabilisation processes is to produce an output which has a reduced biodegradability, thereby decreasing the environmental impacts associated with landfilling this material, although in some Member States such as France the stabilised output is applied to land. The pre-treatment process also typically removes metals and plastics for recycling".

"The approach for modelling the impacts of stabilisation processes draws upon work by Eunomia on behalf of WRAP, which was based upon a raft of published research. The body of research included work by Baky and Eriksson, Sonneson, and Komilis and Ham, all of whom investigated the link between the biochemical composition of the waste and the release of CO2 within composting processes. This research, together with data sourced from technology suppliers, was used to model the degradation of carbon fractions within our model and the subsequent release of biogenic CO2 from the process."

Zero Waste Europe published a briefing note in January 2021 which includes information about the recyclate recovery performance of existing MRBT plants. The report explores MRBT's potential use as part of a 'bridge strategy' for managing residual waste within the context of the transition to a more circular economy.

The report found that MRBT was the lowest-carbon option considered, with lower emissions even than incineration with plastics removed (referred to as 'MWS plus incineration' with MWS meaning 'municipal waste sorting').

According to the Zero Waste Europe report: "…a MRBT system that combines biological treatment and sorting equipment allows us to 'stabilise' the organics that are included in residual waste, so as to minimise their impact once buried in a landfill, while also helping to recover materials such as metals, plastics, paper that are still included in residual waste after separate collection…with ongoing decarbonisation of energy, and factoring the GHG savings from aerobic degradation, prior to landfilling, of biodegradable materials included in waste, MRBT becomes the most climate-friendly option, both whether biogenic CO2 is considered or not."

	"…replacing the RDF-production units in MBT plants with equipment to sort residual waste and recover the materials which are worth recovering…[This] could help ensure the: 1. Reduction of the negative impacts at landfills, due to the biological treatment of the dirty organics; 2. Sufficient diversion of materials from landfills, due to process losses from biological stabilisation and the recovery of some of the other materials; 3. Flexibility of the operational lay-out, given that the sorting systems may similarly be used with materials from kerbside programmes for further separation of different metals, different polymers and different paper grades after separate collection, to help enhance the effectiveness of collection and subsequent recycling systems. The combination of these operational goals can be described as…MRBT. This is key as it distinguishes [MRBT] from old-fashioned MBT to emphasise the intended goal of merging…recovery of some waste materials and biological stabilisation of fermentable materials before landfilling". More recently, the potential for increased aerobic biological stabilisation prior to landfill as part of a system that includes increased sorting prior to landfill was explored in the ClientEarth report 'Greenhouse Gas and Air Quality Impacts of Incineration and Landfill'. According to the ClientEarth report: "The bio-stabilisation process allows the aerobic degradation of organic material in the residual stream to take place under controlled conditions, releasing biogenic carbon dioxide. This reduces the biogenic carbon content of the stream sent to landfill, thereby reducing methane emissions from the waste once in landfill." The report found that landfill with pre-sorting and bio-stabilisation was roughly on par with incineration with plastics removed and recycled (what it calls 'incineration - pre-treatment') but significantly better than incineration of a mixed waste feedstock that includes plastic (what it calls 'incineration straight') even with combined heat and power (CHP).
Other	A network of EfW plants across the central belt with the heat and power generated to drive adjacent plastic reprocessing plants.
Other	The main alternatives to incineration for residual waste are; • Mechanical Biological Treatment (MBT) - followed by incineration, landfill or a combination of both • Refuse Derived Fuel (RDF) & Solid Recovered Fuel (SRF) production and export to England and the EU for incineration

• Direct landfilling in Scotland until 31 December 2025 and England thereafter

The practical reality is that Scotland needs safe, sanitary, cost effective and low carbon management routes for our residual waste. Our capacity gap analysis highlights an ongoing need for residual waste treatment infrastructure to meet the 2025 landfill ban

Mechanical Biological Treatment

MBT is not a final recovery or disposal route like incineration and landfill but a form of pre-treatment. MBT plants can be configured to produce material for incineration or landfill but still relies on one or both options. A review undertaken by Tolvik covering 15 years of MBT operation in the UK highlighted that not only did recycling performance at MBT facilities consistently fall below contractual targets, MBT-led residual waste solutions for local authorities have proved to be more expensive than EfW alternatives.

We remain sceptical about the ability of MBT (and residual waste treatment in general), to deliver high quality recyclate that the market will accept. There is increasing pressure on recyclate quality and our experience from our inspections is that materials extracted from residual waste are almost always more contaminated than source-segregated materials. Further, efforts to improve source segregation such as the Deposit Return Scheme, will make investment in mixed waste sorting even less attractive over the medium term – large capital investment for a diminishing opportunity.

We remain strongly against the use of MBT to produce so-called ‘compost-like-output’ (CLO). CLO made from residual waste is entirely unsuitable for use in horticulture, agriculture, or forestry and may only be suitable for landfill disposal. As the recent experience has shown, long-term waste strategy should not rely on restoring closed landfills or other former industrial land with CLO.

MBT designed and operated to landfill the CLO after bio-stabilisation is of less concern to us and ZWS suggest that this may be the lowest carbon form of residual waste treatment (although the analysis did not include incineration with Carbon Capture and Storage). However, MBT configured in this way is unlikely to be economically viable at the current landfill tax rate. Bio-stabilised residual waste is still subject to the upper standard rate of landfill tax. Without a change to the tax rate, it is unlikely that any investment in this approach would be brought forward by the market. This was highlighted by Eunomia in 2008.

Where MBT is taken forward, it must be with ‘eyes open’. The purpose is not to produce recyclate – mixed waste produces poor quality recyclate and focus must be upstream at the source segregation stage. Further, CLO is

	also not a desirable material for use as a soil substitute. Where used, MBT must be costed, configured and operated to stabilise residual waste prior to landfill as its primary focus. RDF Export Over the years, Scotland has exported RDF to Norway, Sweden, the Netherlands and Denmark for incineration. In 2020, 36,117 tonnes of RDF were exported from Scottish ports. There are seven Scottish operators exporting waste from English ports under English notifications although we do not hold data on the total tonnages. RDF exports from the UK have been in decline since its peak in around 2017. The development of domestic incineration capacity, currency exchanges, RDF import taxes have worked to reduce this market although it remains competitive. Local Authorities report waste incinerated outside of Scotland in Waste Data Flow (WDF). In 2020, the total reported was 96,7871 tonnes. This will be a mix of export from Scottish ports, export from English ports (such as Immingham) and incineration in English facilities. We know there are seven Scottish operators exporting under English notifications. The information in WDF does not allow for a complete breakdown. Direct Landfill Landfill is a significant but declining option for BMW management in Scotland with just over 1m tonnes landfilled in 2020. As described in other sections, landfill has the highest carbon impact, is the least well controlled in terms of pollution prevention and has the highest impact on community well-being. Other Other, less common, options for residual municipal waste exist but we has no experience of assessing applications for these technologies. • Mechanical Heat Treatment • Pyrolysis with a view to making liquid fuels • Plasma gasification
Other	Incineration by way of Energy from Waste is a proven, safe and reliable method of Residual Waste treatment, as has been operating at commercial scale for many years now in the UK and across similar economies in Northern Europe. High levels of EfW capacity (proportionate to Residual Waste tonnages) are evident where landfill bans are in place.

	Figure 7 within the response shows the projected balance of Residual Waste, EfW and landfill capacity across a sample of European countries. The Netherlands, Germany, Denmark and Sweden have very limited landfill activity for Residual Waste (most have some form of landfill bans in place). These countries have high recycling rates and high levels of EfW capacity in relation to Residual Waste. Where landfill is still permitted (UK, FR, ES, IT) there are projected to be lower proportions of EfW capacity. In Italy and Spain there is a high reliance on the use of Mechanical Biological Treatment ("MBT") to pre-treat Residual Waste ahead of final disposal to landfill. Recycling rates (under CE protocols) are lower in these countries. Processing of Residual Waste by way of MBT is in decline in the UK due to the high operating costs of the facilities and their limited impact on Residual Waste tonnages. The CfE document makes reference to the 2017 Tolvik Briefing Report on MBT performance. Appendix 1 of that reports lists 4.0Mt of operational MBT facilities and 1Mt of facilities that have ceased operation. Appendix 1 of this response document updates that same list of MBT sites for the current operational status of the facilities in 2021. This demonstrates that the headline operational capacity has now reduced to 2.6Mt and the facilities that have ceased operation have increased to 2.2Mt. 9 MBT facilities have closed since the 2017 Tolvik report was published. In 2019 the Residual Waste inputs into the 19 facilities that were operational in that year was 2.7Mt, Residual Waste outputs were 2.2Mt, which indicates that at best the impact on reducing Residual Waste tonnages was 0.49Mt, 18% of inputs. Whilst the role of mechanical/biological pre-treatment of Residual Waste may have a role to play in the mix of treatment solutions in Scotland, evidence from elsewhere in Europe is that any significant role of MBT is inconsistent with the deployment of a landfill ban. MBT/MT is likely at best to be able to provide some form of feedstock composition adjustment for Residual Waste. This is currently deployed at various EfWs/ATTs in Scotland and some of the related Local Authority input contracts.
Individual	Taking plastics out of the waste stream. Then recycle that material source.
Individual	There are numerous approaches to residual waste treatment, and they should all be considered. Landfill should not be excluded. Properly constructed landfill with energy recovery where possible must be a continuing option. Incineration (energy recovery) also has a part to play.

Individual	As long as the existing and planned facilities function as intended, then the scope for new capacity (and new options) seems limited. If there was any additional investment, it should come in the form of additional investment to improve climate change performance and contributions to recycling, or abatement of key air pollutants such as NOx. These could be driven by swift implementation of a tax on NOx and fossil-derived CO2 from incineration, and a lower rate of landfill tax to be applied to stabilised biowaste. There is no reason, on grounds of climate change, for a preference for incineration over a solution based on sorting, followed by stabilisation of waste prior to its landfilling. The argument for or against one or the other ought to be based on other features / criteria.

10.3 Call For Evidence: Question 11 Summary

Category	Q11: What emerging technologies are there for small scale residual waste treatment to support remote and island communities?
Local Government	None.
Local Government	A mobile recycling solution to serve remote communities.
Local Government	No response.
Local Government	An option may be to bale residual waste in rural and island communities, for onward transport for treatment/incineration.
Local Government	In addition to the potential use of in-vessel composting processes, the authority is also considering the viability of small-scale waste to hydrogen technology as an alternative. However, they state that this technology has not been proven to work for municipal wastes and a pilot scheme will be needed to provide proof of concept.
Local Government	Currently unaware of emerging small-scale technologies. Small communities would need to use the waste hierarchy in a much more robust manner due to the limited geographical spread of EfW plants in Scotland.

Local Government	No response.
Local Government	The authority is not aware of emerging technologies that cost-effectively deal with municipal waste completely. The alternative to standalone small-scale technology is to transport residual waste to a larger facility. There are cost issues associated with this but providing the destination utilises proven technology, this is a low-risk option and one that in time can benefit from the development of carbon neutral transport solutions.
Local Government	The authority is not aware of any emerging technologies that cost-effectively deal with municipal waste completely.
Local Government	The authority is not aware of any proven technologies for remote communities.
Professional body, trade organisation or governing body	The body is not aware of viable small-scale technologies coming to market to support remote and island communities. Options generally remain as set out in Question 10, and whilst these could be delivered at a smaller scale the relationship of cost vs capacity is not linier. Therefore, smaller plants in most cases have higher capital and operational costs per tonne processed, than a medium or large facility. Given limited waste quantities the need for fuel preparation or use of supporting fuel to ensure the requirements of the Industrial Emissions Directive (i.e., BATAELs) are met, can be a significant issue. Another key issue is how 'bankable' small-scale innovative technologies can be and generally speaking these are not externally fundable, because they are seen by most investors to be very high-risk.
Professional body, trade organisation or governing body	We are not aware of any additional residual waste treatment options beyond those listed in our response above. While these could conceivably be delivered at small scale in remote areas, there remains a trade-off between (operational) costs and economies of scale.
Professional body, trade organisation or governing body	Low cost MBT with residuals sent to EfW on the mainland reducing volumes and treatment and transport costs. MBT in this instance would be more viable in the absence of AD for food waste on many islands. Small scale CHP district heating displacing imported oil fuels and supporting co-located food production systems reducing food imports. Island specific solutions essential.

Professional body, trade organisation or governing body	A whole-system approach should be considered for remote and Island communities. Identifying how waste can be best used in line with the waste hierarchy and local needs. Recycling should be prioritised, especially if biogenic material that can be composted to produce useful resources for local agricultural areas, common in such communities. Gasification and Pyrolysis plants also tend to be modular in nature, meaning they can be relatively small and make good use of available waste streams where economically recyclable material has already been removed. Such systems could be used to produce both heat, power and transport fuels, where appropriate.
Professional body, trade organisation or governing body	No comment.
Professional body, trade organisation or governing body	No comment.
Business that operates one of more incineration facilities in Scotland	Not aware of any bar for those listed in response to question 10. While these could conceivably be delivered at small scale in remote areas, there remains a trade-off between costs and economies of scale.
Business that operates one of more incineration facilities in Scotland	No response.

Business that operates one of more incineration facilities in Scotland	The business operates a Thermal Energy Plant for conversion of residual waste to energy (decarbonised production and waste avoidance stated thus far by 90% from benchmark). This plant is licensed to receive 30,000 T waste/annum and occupies just c1,000 sqm footprint (33mx30m building). They state that the facility operates at a cost per tonne similar to current landfill disposal rates. The business states that the facility is applicable on small scale, has proven its technique in accordance with Scottish law over a decade of operation- with a broad waste input availability. Emissions are said to be typically an order of magnitude below the EU WID. The business states that the technology was described in EU BREF (BAT) as an emerging technique (BREF publication 2013) but is now fully implemented and commercialised. The business states that this type of plant is perfectly suited to remote, small scale communities, for conversion of locally collected BNMW or BMW and for conversion into locally useable heat. The business states that their own plant is close to waste producer and heat users, converts c 100T waste/day into c 5MWh thermal energy (per hour) and even "exports" surplus energy.
Business that operates one of more incineration facilities in Scotland	There are small scale technologies available but they are expensive, tend to be only biomass proven but not using mixed waste as fuel. Many people talk about technology when in fact what is key is the holistic design approach involving a number of technologies that must be integrated and it is the lack of attention to this need for correct integration that often leads to failure.
Business that operates other (non-incineration) residual waste treatment facilities outside of Scotland	No specific comment.
Business that does not operate a	No comment on emerging technologies for residual waste treatment in rural and island communities. The business would note that existing regulations and policies do not support multi-waste feedstock treatment centres. In rural and island communities, where waste quantities are limited, this could affect the viability of a

residual waste treatment site but produce waste that ultimately is treated at one	waste treatment facility. For example, if sewage sludge was imported to a PAS110 compliant AD plant, it would lose its certification and the operators would not be able to report data as being 'recycled'. Similarly, sewage sludge imports to AD facilities with dedicated feedstocks (e.g. distillery residues, farm wastes) would affect how the resultant digestate could be used. Given that all these materials are currently recycled to land, a holistic approach to the associated regulations and policies could be beneficial to the approaches taken to manage waste in rural and island communities.
Not for profit environmental organisation	No response.
Environmental Group	Once again, encouragement of repair, upcycling and exchange shops/cafes would help to reduce the volume of residual waste.
Environmental Group	The Western Isles have an anaerobic digester, which has been in use for many years. They also have a local plastics manufacturer, Stornaway Plastics which was producing pegs and fishing gear from recycled plastic such as plastic bottles and bottle tops, but are currently not using recycled feedstock. If more small communities had their own companies able to recycle waste into useful products, a local circular economy would be possible and the carbon emissions associated with transporting waste reduced. If 3D printers could be used with recycled plastic feedstock this would be ideal for small communities. The small community of Fort William used to have its own paper mill which used local wood. That closed a number of years ago, along with many other paper mills in Scotland. The group have not been able to find out which ones recycle paper, but if each council could identify their nearest and send their paper and card direct to them and perhaps negotiate a deal for using the resulting product, then a circular economy with small circles could be created. Recycled is obviously best, but is often more expensive. If it was made cheaper and locally and recycled options promoted it would be the obvious choice and this would bring costs down further. Paper can and should be recycled at least 10 times. Community Composting has been tried in a number of places. A particularly good scheme operates in the Cotswolds. An area of land near some tennis courts has been made available. Residents bring their garden waste to the site, leave it in a pile at one end and volunteers stack it into the relevant compost heap. When it is ready the bin is labelled and residents can help themselves. One problem is the paperwork required and it not being eligible

	for funding. The current Keep Scotland Beautiful project which involves 8 community groups in the Highland will include community composting and food waste reduction. Aluminium should not be part of residual waste, but a small community in Fort William hosts the last remaining smelter in the UK. It uses hydro energy and has plans for expanding to recycling but only to make rods for construction. If it could make a wider range of products Scotland would not need to import these, so moving to more of a circular economy.
Environmental Group	An example of an emerging technology is the rNature Automatic composting machine. The supplier's website states that the technology uses a natural aerobic process, using oxygen for the decomposition of the waste and so it does not add to emissions of greenhouse gases. The technology does require electricity to operate and so may not be suitable for remote or island communities where there is no means of accessing electrical power. The BBC showed this technology in action at a café and farm in South Devon. In many cases in rural and island regions communities are coming together to find solutions. We draw attention to this project on the Outer Hebrides which uses Anaerobic Digestion to treat organic wastes and produce biogas. Though AD is not an emerging technology, the project demonstrates how different renewable energy technologies can be integrated in order to achieve a circular economy. Another such community venture is The Highland Community Waste Partnership (HCWP), which is being coordinated by Keep Scotland Beautiful. Comprising eight groups from across the Highlands, the partnership aims to build a movement for more sustainable consumption and to support communities to reduce their carbon footprints. The programme will include reducing food waste, tackling single use items, and increasing the use of pre-loved, repaired and shared goods. The feasibility of community-scale composting is one of the projects.
Environmental Group	No direct response, covered in question 10.
Other	Highlighted the Shetland Isles plant and used it as a model of excellence.
Other	We have not been approached with any new treatment technologies for remote island communities.
Other	Other than Gremista, there are no other relevant examples that Tolvik is aware of in the UK that are operating at commercial scale. A small-scale facility in the Isle of Wight has been in construction for many years and therefore it is not possible to assess its reliability.

Individual	Reference is made to the Beacon Project at Glenfarg, Perthshire where sorting plastic waste into type ready for recycling is a very interesting scheme, which could be rolled out to different areas including smaller / island regions. The individual states that they are not an expert but have a particular interest in the plastic pollution problem. They refer to the Ellen McArthur Foundation and to We Don't Have Time webinar on plastics recycling.
Individual	Examples from other countries of small-scale energy recovery projects are numerous. Where communities are isolated, these may provide the best carbon limiting option
Individual	It depends, arguably, on what currently happens to the waste, and how any products for consumption are delivered to the island. For such communities, it is likely to make far more sense to move more strongly towards a circular economy, including (for islands) restricting what comes on to the island to items which can be readily collected for recycling, with the aim being to completely eliminate the need for any residual waste treatment. Reuse / refill might play a strong role in such communities as means for delivering what is consumed. In rural areas, creative combinations of bring (back) and door-to-door collections can support cost effective achievement of very high recycling rates. Focusing on residual waste treatment in such areas is simply looking at the problem in the wrong way.

10.4 Call For Evidence: Question 12 Summary

Category	Q12: What data can you share with the Review on the costs of operating any options for managing residual waste in Scotland, especially costs based on real experience?
Local Government	The local authority operates a waste treatment facility for which they would be happy to share information on the costs of operating such a facility by separate cover if required. The local authority stated that the cost of residual waste processing is increased by long travel distances required to find appropriate off-takers for residual waste processing.
Local Government	The 2020/21 cost for landfilling residual waste was nearly £11m; £6.259m on contracts to receive, transfer, transport, treat and/or dispose of the residual element of municipal waste (including £3.8m in landfill tax) and £4.56m for using the landfill sites (including £3.7m on landfill tax).

Local Government	Unable to share this information as it is subject to commercial and operational sensitivity or to legal restrictions.
Local Government	N/A.
Local Government	Our costs for landfill disposal are currently £60.50 plus landfill tax. To accommodate the increased costs of building a new compliant cell, this is expected to rise to £67.00 from April 2022. As the authority owns and operates the landfill site, in addition to the capital cost of land remediation, there will be on-going revenue costs associated with the management of the closure plan, when operations finally cease. Unless a local, scalable EfW solution can be achieved, the cost of managing an EfW option would need to include the gate fee from the EfW plant, the cost of baling, wrapping and storing baled waste and the costs of transportation by lorry and ferry to a mainland EfW plant. The use of a bulker trailer is likely to reduce gate fees but would result in lower payloads and higher transport costs. At present, this is not a real opportunity regardless of costs due to the capacity shortfall of the ferry network. Currently, all ferry routes to the mainland from the Western Isles are over subscribed for an increasing part of the year. Although there is a dedicated freight run, this is carried out using the main passenger/vehicle ferry operating a 24-hour service. This service is not sufficient for the current level of demand and would not have spare capacity to accommodate a significant increase in traffic caused by having to transport residual waste, a need for ferry capacity for 500 additional 28 tonne trailers for baled waste per annum.
Local Government	The authority is undergoing a procurement and thus there are no real cost data currently.
Local Government	Redacted due to commercially sensitive information.
Local Government	The authority is not able to provide any details of its contractual arrangements for reasons of commercial confidentiality. They state that it should be noted that the call for evidence relating solely to Scottish costs presents the risk of securing limited and unrepresentative data. Consideration should be given to utilising data from operations in similar jurisdictions, for example England and Wales, to ensure that reliable conclusions can be drawn.

Local Government	The authority is unable to provide any details of its contractual arrangements for reasons of commercial confidentiality.
Local Government	Not able to provide this information due to commercial sensitivity.
Professional body, trade organisation or governing body	Data publicly available from sources such as Letsrecycle.com and WRAP are considered broadly representative of operating costs of residual waste treatment options in Scotland. Sharing of actual data is difficult given confidentiality requirements of most contracts. Care is required when assessing gate fees as some Local Authority contracts have bespoke requirements, which are reflected in the gate fees so they cannot be compared as like for like. For example, Authorities may have contributed to the capital cost of the scheme, which would reduce the overall gate fee. For example, Dundee & Angus Council's contract includes the pretreatment of waste where this is necessary, while Aberdeen's contract does not include the capital cost of the plant, since this was paid for separately by the Councils involved. The body would see the upper ranges of EfW costs quoted by LetsRecycle.com and WRAP as being the most representative figures for new plants, given recent inflationary pressures on EPC contractors costs and control measures for stricter emissions limits being required. RDF costs have also increased in recent years, particularly in countries where an import and incineration/ RDF taxes have recently been applied. Again, care is required when assessing gate fees as some quoted costs may not include the cost of baling and wrapping, which adds to overall costs. Comparable data for MBT is less readily available. Tolvik found that a sample of UK waste disposal authorities, which utilised MBT as a residual waste treatment option, had higher than average waste disposal costs. Generally, when comparing like for like, EfW is the most cost-effective option, followed by RDF Export, Landfill and MBT.
Professional body, trade organisation or governing body	Data publicly available from sources such as letsrecycle.com (9) and WRAP are considered broadly representative of operating costs of residual waste treatment options in Scotland (with the upper ranges of quoted costs as being the more representative figures for new plants in Scotland given recent inflationary pressures on EPC contractors costs and control measures for stricter emissions limits). EfW is generally considered the most competitive of the available residual waste treatment options (at around £80-£105/tonne) compared to landfill (£110-£125/tonne (including landfill tax)). Comparable data for MBT is less

	readily available (due to fewer operational sites) but a Tolvik report (10) found that a sample of UK waste disposal authorities which utilised MBT as a residual waste treatment option had higher than average waste disposal costs. As noted above in our response to question 9, it is worth noting that costs of RDF export have increased in the years since Tolvik published its analysis. That said, there are of course some caveats when assessing (and comparing) publicly available data on gate fees. Some local authority contracts have bespoke requirements which are reflected in the gate fees so they cannot always be compared like for like (e.g., a local authority may have contributed to the capital cost of the EfW scheme which would reduce the overall gate fee). References (9) https://www.letsrecycle.com/prices/efw-landfill-rdf/ (10) https://www.tolvik.com/wp-content/uploads/2017/09/Tolvik-2017-Briefing-Report-Mechanical-Biological-Treatment.pdf
Professional body, trade organisation or governing body	UK price ranges for landfill (including tax) and incineration are widely published including WRAP price reports. Members of the RMAS, have experience of RDF export and SRF production and export. In terms of RDF and SRF exports their view is that disposal savings were marginal, access to EU markets is tightening and domestic solutions would always provide lower cost solutions. There is limited recent data on MBT prices in the UK market due to the historically poor performance of MBT and the relative lack of reference sites. The following Tolvik report summarises and updates an earlier review of MBT performance and costs. There are various sites including the Binn Eco Park and Levenseat that can demonstrate ABPO compliant in vessel composting (one application of MBT) that highlights the challenges of plastic waste contamination, rendering many of the outputs unsuitable for use on land. This experience would be typical of MBT residuals, necessitating thermal recovery of the output materials under current landfill ban rules.
Professional body, trade	No response.

organisation or governing body	
Professional body, trade organisation or governing body	No comment.
Professional body, trade organisation or governing body	No comment.
Business that operates one of more incineration facilities in Scotland	Data publicly available from sources such as letsrecycle and WRAP are considered broadly representative of operating costs of residual waste treatment options in Scotland. EfW gate fees are typically around £80-£105/tonne, with Scottish EfW gate fees towards the upper end of the range. Landfill costs are £110-£125/tonne including landfill tax. Comparable data for MBT is less readily available (due to fewer operational sites but a Tolvik report found that a sample of UK waste disposal authorities which utilised MBT as a residual waste treatment option had a higher than average waste disposal costs. As noted above in our response to question 9, it is worth noting that costs of RDF export have increased in recent years
Business that operates one of more incineration facilities in Scotland	The median UK landfill gate fee for 2020 was £116 per tonne (inclusive of Landfill Tax). Accessing landfill capacity outside of Scotland as a solution to the ban will incur this level of cost plus the cost of transportation, plus the annual increases added as a result of the escalator that UK Landfill Tax is subject to. This, coupled with the potential political ramifications created by revenue from Council Tax collected in Scotland being used to meet the costs of UK Landfill Tax outside of Scotland, renders landfill disposal elsewhere in the UK a non-viable option. Likewise, refuse-derived fuel export is also becoming economically unfavourable due to import taxes being levied by receiving countries. The two primary options for indigenous residual waste treatment in Scotland are mechanical & biological treatment (MBT) and thermal treatment/incineration. In terms of MBT, median gate fees for a biological treatment process such as in-vessel composting coupled with mechanical processing results in a combined cost of £80 per tonne. However, issues with compost-like output

	(CLO) generated by MBT facilities achieving end-of-waste status in the UK mean that the majority of CLO would have to be landfilled as biostabilised waste. This would add an additional landfill cost of around £93 per tonne (assuming 80% of MBT input tonnages would be landfilled as CLO). This gives a combined potential cost of MBT of £173 per tonne. Added to this, the residence time required to achieve the biodegradability criteria to comply with the BMW ban could result in a process that can take weeks to complete. This would require very large individual facilities to maintain the throughput necessary to deal with the residual wastes generated. Incineration has a 2020 median gate fee of £93 per tonne, making it a significantly more attractive option for the treatment of non-recyclable waste, as well as having the benefit of re-usable heat and power generated from a residence time of the order of minutes rather than weeks.
Business that operates one of more incineration facilities in Scotland	The landfill disposal rate is typically £150/T upwards. Internalisation of waste via EfW is broadly equivalent (plant amortisation period crucial to this assessment).
Business that operates one of more incineration facilities in Scotland	Costs are very variable but for economically viable energy recovery facilities in the current legislative and economic climate O&M costs are around £60/tonne of raw waste delivered processed and combusted per annum.
Business that operates other (non-incineration) residual waste treatment	No specific comment.

facilities outside of Scotland	
Business that does not operate a residual waste treatment site but produce waste that ultimately is treated at one	No comment.
Not for profit environmental organisation	Our ongoing research into biostabilisation has included analysis of the WRAP Gate Fee Reports for 2011-2020. Although the output of the research is not yet available, this work has determined that establishing gate fees for mechanical biological stabilisation can be challenging due to the variety of technologies and contract arrangements. However, the evidence indicates that the gate fees may be similar cost to, or more expensive than, energy from waste. It should be noted that the WRAP gate fee data did not include mechanical biological stabilisation after the 2017 report (2016 data).
Environmental Group	None.
Environmental Group	The more waste is reduced, the less you have to pay for disposing of it. Community larders and sharing sheds have been set up across the Highlands in response to the pandemic. They are an ideal local response which addresses waste and food poverty. Set up costs are minimal. A shed costs around £2-500 depending on size. Some have fridges. A secondhand fridge was donated to the North Kessock one, so was free and avoided the cost of disposal of the fridge. Electricity costs about £50 per year and is donated by the church next door. Local food which would have ended up in landfill, such as surplus festive food or short date items are made use of. A post is placed on facebook if a large amount comes in. A number of larders reuse additional items such as school

	uniform, books, CDs and games. Most are run by volunteers, so running costs are minimal and avoid costs for support services which are able to make use of the larders to provide relief directly to communities. Community tool libraries are another way of avoiding unnecessary purchase of items which will only be used occasionally and making use of items which may become available during house clearance. Culbokie Community Trust is setting one up.
Environmental Group	No response.
Environmental Group	The Highland Council is proposing to build a waste incinerator in Inverness to treat approximately 80,000 tonnes per annum of residual waste that is currently sent to landfill. The Medium-Term Financial Plan update to the Council reports that, “Based on one of the studies commissioned initial estimates of the cost of an energy from waste combined heat and power plant at this site ranged from £95m to £185m, but this excluded costs associated with the district heating network, grid connections, hydrogen production and new depot with EV charging.” The Report ‘Approach to appraising the options for the long-term management of residual waste’ presented to the Communities and Place Committee of the Highland Council on 12 May 2021, point 3.1.1, states “In 2020/21 the Council sent approximately 74,500 tonnes of residual waste to landfill. Expenditure on landfilled waste totalled: • £6.259m on 4 contracts, including £3.8m on associated landfill tax. • Disposal costs at our internal landfill sites at Seater (Caithness) and Granish (Aviemore) was £4.56m, including £3.7m on landfill tax.”
Environmental Group	When taking costs into account, it is important to consider not just the financial costs to the operator, waste authority, or waste producer, but to also consider the wider costs to the environment and to society. When local authorities pay the landfill tax this is a type of ‘transfer payment’ rather than a cost as such, because the money remains within the public purse. When businesses pay the landfill tax it increases the money in the public purse. To quote the Inspector in the Battlefield incinerator decision: “Landfill tax savings were claimed as a benefit of the appeal scheme in the appellant’s presentation to EH [English Heritage]. In financial analysis terms such tax payments would be a cost. However, in an economic analysis it seems to me that it would be more of a transfer

payment, and so not a cost to society as a whole. Landfill tax is a device to divert waste away from landfill with consequential climate change benefits. To factor in an additional benefit of landfill tax savings would, to my mind, introduce an element of double counting”.

This stands in stark contrast to any public funding that would be diverted to pay for carbon capture facilities at incinerators or to help fund combined heat and power schemes, which would reduce the money in the public purse.

At present the landfill tax system does not adequately distinguish between sending waste untreated to landfill and sending biostabilised waste to landfill. Furthermore, the CO2 released from incineration is not currently taxed, and nor is the harm caused by incinerator lock-in reflected in the costs.

These deficiencies and market failures can, and we argue should, be rectified. These adjustments would allow for the cost of treatment to more closely match the environmental impacts of those options, with benefits suitably rewarded and disbenefits appropriately penalised.

However, in the meantime, it is important to consider that the overall costs of sending biostabilised waste to landfill is far less than the costs of building new incineration capacity, and it is the wider society who would be picking up the tab if the latter were allowed to proliferate at the expense of the transition to a more circular economy.

With regard to direct financial costs associated with residual waste treatment options, the group notes the following, taken from page 19 of ‘Building a bridge: Strategy for residual waste’ : “Sites designed to operate through biological stabilisation and material recovery, are markedly cost competitive with incineration. Capital expenditure (capex) at a BAT level may be in the range of EUR 200-400 per t/year of installed capacity, while BAT incinerators typically are around EUR 1000 per t/year and more. This implies a lower use of financial resources for residual waste management, and a larger part of the budget may be dedicated to separate collection, reuse and recycling”. [emphasis in original]

A focus on just biostabilisation (e.g. through aerobic digestion) could significantly decrease biological stabilisation costs. Furthermore, for some materials the cost of extracting them could be significantly less than the revenue generated from their sale.

Turning to evidence that is UK-based, the group notes the May 2020 ‘Energy from Waste Plants with Carbon Capture’ report from Energy Systems Catapult Limited which provides an illustrative example of the capex associated with a 350,000 tpa incinerator with and without carbon capture as follows: £220m without carbon capture (£629 per tonne), and £320m with carbon capture (£914 per tonne). These cost estimates were based on historic data (from business cases, etc. published between 2014 – 2017), meaning the costs can be expected to have risen since then due to inflation and other economic factors (e.g. Brexit).

For data associated with Scotland we turn to the November 2015 'Addendum to Energy from Waste Business Case' produced by Amec Foster Wheeler Environment & Infrastructure UK Limited for Aberdeen City Council. This provides a Total EfW EPC Cost Estimate (capex) of £870 per tonne/year capacity which is stated to be valid for projects between 50 and 120ktpa, and a Total Final Capex Estimate of £902 per tonne/year capacity for projects exceeding 120ktpa. It is stated that these figures have an accuracy of +/- 50% and do not include contingency margins.

As above, economic circumstances have changed since 2015 which could be expected to have increased the Capex (capital expenditure) costs of incineration in Scotland.

A report entitled 'Approach to appraising the options for the long-term management of residual waste' presented to the Highland Council's 12th May 2021 Communities and Place Committee considered the costs of a range of residual waste treatment options, including cost estimates for the construction of an 88ktpa incinerator in Inverness.

The Committee Report states: "The [2020 SLR] report identified that the capex for developing a technically feasible EfW facility at the Longman site, capable of processing 88,000 tonnes of residual waste per annum, is likely to be a base cost of £95m, excluding any internal Council costs, uplifts for risk, optimism bias and funding. When incorporating adjustments for risk, optimism bias, cost escalation allowance for inflation post 2019/20 and interest during construction, the report forecasts the total Option 2 funding requirement at £185m".

Thus, whereas Capex figures from 2015 ranged between £870 - £902 per tonne/year capacity, figures from 2020 ranged between £892 - £1,264 per tonne/year capacity (including some M&E costs but excluding contingency, risk, off-balance sheet items, and funding costs, as well as excluding all operational expenditure).

Eunomia's January 2008 'Biostabilisation of Wastes: Making the Case for a Differential Rate of Landfill Tax' report proves further evidence that biostabilisation is significantly less expensive per tonne than incineration, once the taxation issue has been resolved. Figure 3 from that report, estimates that the per-tonne treatment cost of biostabilisation is around half the per-tonne cost of incineration.

According to a 2009 report by Arcadis and Eunomia for the European Commission: "Stabilisation technologies are low capital cost treatments for residual waste. We have used a figure of €230 per tonne [of capacity], and an operating cost of €19 per tonne before disposal costs. A French study into the cost of MBT found that a 30,000 tpa stabilisation system with residues to landfill will cost €4.5 million in 2005 prices. This suggests a cost of €150

	per tonne [of capacity]. This is considered to be quite a low cost. In the UK an examination of various MBT configurations from 2005 has suggested that for a stabilisation facility of this nature would incur a capital cost of €201 per tonne [of capacity]. These costs are similar to those for in-vessel composting, reflecting similarities in technology, though scale will usually be larger, and there are costs of residue disposal to be considered…”
Other	Nothing up to date.
Other	No response.
Other	Figure 8 with the response provides an evolution of median gate fees across the UK as a whole for Residual Waste sent to EfW, RDF Export and landfill which Tolvik consider is broadly representative. Figure 9 provides specific gate fees for 14 specific long and medium term contractual arrangements for Residual Waste treatment at EfW in Scotland that Tolvik is aware of under various confidentiality arrangements. The simple average of these gate fees is £97/tonne, and weighted average £99/tonne, all based to April 2021 prices. **MBT Cost build up** The CfE document makes reference to the 2017 Tolvik Briefing Report on MBT which provided modelled gate fees in the range of £125 - £135/tonne. This analysis assumed the cost of treatment of the RDF outputs (by way of export) were in the range of £65-£75/tonne respectively. In 2021 the cost for RDF Exports (as reported by Letsrecycle) was considerably higher in the range of £91-£99/tonne, not dissimilar to UK and Scottish EfW gate fees as shown above. Due to taxes in importing countries rates are expected to remain at these higher levels as a minimum. The resulting required gate fee for a new MBT facility, based upon the same modelling assumptions in the 2017 MBT report would indicate MBT gate fees in the range of £143-£149/tonne. This is without assuming any indexation of the other cost lines in the simplified model. **Residual Waste Treatment Cost comparison** Figure 11 with the response shows the cost of Residual Waste Treatment for 13 Waste Disposal Authorities in the UK (of the 17 in Appendix 1) that use some form of MBT processes, and compares this cost to the landfill gate fees of £10-£30/t plus landfill tax (per the CfE document), and current EfW gate fees in Scotland shown in Figure 9.

	The cost to the Waste Disposal Authorities has been taken as the Net Expenditure from the 2020-21 Revenue Expenditure outturn figures published by Government, and therefore include some ancillary costs and income possibly not directly related to MBT treatment. However, based on Tolvik's market knowledge, these are likely to have a limited impact. Figure 11 would suggest that the economic cost of Residual Waste treatment is likely to be lower by way of EfW and/or landfill as compared to treatment using MBT processes. **Summary** From the evidence above it is clear that the most economically sustainable method of treatment of Residual Waste in terms of the £/tonne cost to waste producers, from both Local Authority and C&I sources, is by way of incineration at EfW plants. In recent years between 87% to 91% of Residual Waste inputs to EfWs in Scotland has been from public sector sources, which have been at the average gate fees as described above (£97-£99/t). These are lower than equivalent gate fees to the alternative of landfill, MBT and RDF Export and therefore a lower overall cost to public sector finances.
Individual	The individual states that they do not have this background, so unable to give specific information.
Individual	The individual states that their local experience is of a waste management company that 'fiddled' its figures to SEPA to avoid tax payments and, in their own words to a Revenue Tribunal, 'sought to gain competitive advantage' for waste management tenders. The tenders were of course attractive to the local authority anxious to save costs. The upshot has been extra expense to the local authority (prices increased to compensate for losses) unable to renegotiate and held ransom by contracts signed that have to be honoured.
Individual	The UK has little history of MBT facilities based on stabilising waste prior to landfill. There are two main (related) reasons for this: a) the extent to which 'stabilisation' contributed to the 'loss in biodegradability' of municipal waste was deliberated on at length before a measure was introduced with which few had any familiarity. This was important from the mid-2000s until the point where landfill tax was obviously going to increase to levels which made stabilisation expensive as a result of the treatment of stabilised outputs for the purpose of landfill tax (see next point); b) the tax on landfill of stabilised biowaste is the same as it is for untreated waste (i.e., the standard rate). This is despite the fact that it significantly reduces the principle quantifiable externalities associated with landfilling,

	namely, the propensity to generate methane (and the size of these externalities is a matter of ongoing discussion in the context of climate change). These matters are now, arguably, both in the hands of the Scottish Government to determine. The Government could decide: a) to set a threshold level of stability, which all wastes would need to be below prior to being landfilled; b) require landfills receiving such wastes to operate with active cover layers, designed to oxidise any residual flux of methane through the cap; and b) set a lower rate of tax commensurate with the reduced externalities that the threshold was designed to deliver. This would radically alter the economics of the treatment. Note that there remains no incineration tax (despite the externalities linked to air pollution and climate change), and that bottom ash from incineration remains taxed at the lower rate. The individual is not familiar with any credible study which exists which indicates a level of benefit from incinerating waste which is sufficient to justify the additional costs relative to landfill.

10.5 Call For Evidence: Question 13 Summary

Category	Q13: What data can you share with the Review on the wider costs associated with options for managing residual waste in Scotland, especially where those costs have materialised?
Local Government	None.
Local Government	The authority will spend upwards of £3m to 2024/25 for landfill restoration.
Local Government	Unable to share this information as it is subject to commercial and operational sensitivity or to legal restrictions.
Local Government	N/A.

Local Government	Restoration costs for closed cells depend on ground conditions and the level of work required. Historical information can be made available if required.
Local Government	The authority provided information on the financial provisions for landfill and indicated the potential lifespans for a range of landfill operations (inert, hazardous, non-hazardous etc.). Examples of aftercare costs were also provided.
Local Government	No evidence.
Local Government	No response.
Local Government	Unable to provide any information.
Local Government	No response.
Professional body, trade organisation or governing body	The wider costs of residual waste management can include matters such as haulage costs (road, rail ferries etc), transfer stations costs and/ or pre-treatment costs (i.e. baling and wrapping for RDF). It is difficult to give accurate costs for these options as arrangements are generally bespoke and a function of the tonnage being transferred/ treated/ transported (i.e. collection transfer and treatment in the highlands or isles will not be comparable with say the central belt). It is noted that ferry costs from the Islands, will play a large part in the overall cost and reliability of their service.
Professional body, trade organisation or governing body	Nothing further to add beyond the response to question 12.
Professional body, trade organisation or governing body	We are not aware of any specific studies on these wider costs. However, in terms of wider costs these include: • The long-term site monitoring and restoration costs of landfill. Landfill operators could easily identify these costs. • The secondary costs of MBT residue disposal. These would be market prices for incineration and are widely published.

Professional body, trade organisation or governing body	No response.
Professional body, trade organisation or governing body	No comment.
Professional body, trade organisation or governing body	No comment.
Business that operates one of more incineration facilities in Scotland	Nothing to add further to the response to question 12.
Business that operates one of more incineration facilities in Scotland	Article 16 of the EU Waste Framework Directive describes the "proximity principle" of treating and disposing of waste in facilities located as close as possible to the source of the waste "in order to ensure a high level of protection for the environment and public health". This principle also minimises costs associated with the transportation of waste, hence why it is a fundamental requirement to give serious consideration to the development of residual waste treatment infrastructure at a regional level. As the majority of operational or pipeline incineration capacity is located across the Central Belt, this will be preferentially advantageous to those local authorities located within the Central Belt and will create a disparity in transportation costs between those councils and councils located in more peripheral areas of Scotland.

Business that operates one of more incineration facilities in Scotland	N/A
Business that operates one of more incineration facilities in Scotland	Cannot provide anything beyond opinion on this question.
Business that operates other (non-incineration) residual waste treatment facilities outside of Scotland	No specific comment.
Business that does not operate a residual waste treatment site but produce waste that ultimately is treated at one	No comment.

Not for profit environmental organisation	No response.
Environmental Group	None.
Environmental Group	Much more use could be made of collecting landfill gas to use for energy production which would offset costs of maintenance of closed landfill sites. If waste was seen as a resource, then it would be seen as an asset rather than a cost but much more benefit is realised higher up the waste hierarchy. The costs of incineration are considerable, particularly the climate cost. The Stern Review detailed the costs of early action were very small compared with the huge costs of climate change. Lord Stern later admitted that he had been wrong. The consequences of not acting were far far worse. The climate cost for the whole UK of CO2 from incineration is about £25 million per year. In 2017 Highland Council along with many other Councils in Scotland decided to charge for garden waste collection. This will soon be £45 per annum. This charge has resulted in a reduction of garden waste collection from about 31,000 households to 27,000 today. Whilst costs of running the scheme are calculated and it is said to make a profit for the Council, the costs of the extra waste sent to landfill (as people increasingly put garden waste in free general waste bins) are not. No attempt has been made to make a grade of compost which can be sold, or at least used on Council sites to avoid the purchase of peat and other compost. Other authorities such as Merton have been selling compost to residents using the recycling centre for many years. Landfill costs are rising and total landfill cost was over £10m. It may well be that the cost of these for extra garden waste going to landfill are more than the supposed profits and certainly it is moving things in the wrong direction. If householders had access to the compost produced they could avoid purchase of environmentally damaging peat. Free uplift of as much waste which can be recycled and composted as possible and considering charging for and reducing frequency of general waste collections would be much more likely to drive reductions in residual waste.
Environmental Group	No response.
Environmental Group	Some of the key findings of ‘Evaluation of the climate change impacts of waste incineration in the United Kingdom Report’ (UKWIN, October 2018) are:

	• "Waste incinerators currently release an average of around 1 tonne of CO_2 for every tonne of waste incinerated. • The release of CO_2 from incinerators makes climate change worse and comes with a cost to society that is not paid by those incinerating waste. • In 2017 the UK's 42 incinerators released a combined total of nearly 11 million tonnes of CO_2, around 5 million tonnes of which were from fossil sources such as plastic. • The 5 million tonnes of fossil CO_2 released by UK incinerators in 2017 resulted in an unpaid cost to society of around £325 million. • Over the next 30 years the total cost to society of fossil CO_2 released by UK's current incinerators would equate to more than £25 billion pounds of harm arising from the release of around 205 million tonnes of fossil CO_2." We call upon the Scottish Government to follow the polluter pays principle and to impose a tax on incineration.
Environmental Group	In terms of wider financial costs, it is important to consider environmental externalities. In 2011 Defra identified three key market failures, none of which have been satisfactorily addressed in Scotland (or indeed in England): • "On the whole, those treatment options which reduce embedded emissions by reducing energy associated with extraction, primary production etc., such as reuse and recycling, do not have their full external benefits reflected in the price of disposal." • "The emissions from waste combustion of non-biogenic material (via any technology including mass-burn incineration) are also not comprehensively reflected in the price of disposal. Unless the installation in question is in the ETS (municipal solid waste incinerators are excluded) a negative externality persists – such installations are creating GHG emissions without paying the relevant price." • "Subject to proving its environmental performance, MBT-landfill does not have its environmental benefits reflected in the price of disposal." Incinerators emit around a tonne of CO_2 per tonne of waste incinerated, with around half of this being fossil CO_2. However, at present nothing is paid for the cost to society of this CO_2. BEIS's central carbon values in £2020 prices per tonne of CO_2 rise from £241/tonne for 2020 to £280/tonne in 2030 and £378/tonne in 2050. However, this is not reflected in the price of incineration, nor is the impact of the material being lost to society which results in virgin materials from being used at significant carbon cost.

	On the other hand, the cost of landfilling waste is around £100/tonne, with no discount for the impacts being reduced due to lower levels of food waste or waste being mostly biostabilised prior to landfill. As such, there are currently perverse financial incentives to incinerate waste which would have lower impacts if they were biostabilised and sent to landfill, and recycling is having to compete with what is in effect a subsidised incineration market. As noted in the Environment, Climate Change and Land Reform Committee's November 2020 report on the Green Recovery Inquiry, “a robust carbon pricing regime” is needed in Scotland. Addressing these market failures should result in lower overall emissions, especially if money raised from an incineration tax is invested in waste prevention efforts. The introduction of an incineration tax would be consistent with the Zero Carbon Commission's September 2020 report on 'Helping Britain Achieve Net Zero by 2050' which advocated for "a new carbon tax on incineration and other energy from waste schemes (i.e. Advanced Conversion Technologies)". According to the Commission: "There is a good case for carbon taxation on incineration, which produces substantial emissions...a tax on incineration would increase incentives to recycle and/or generate less waste…".
Other	Nothing up to date.
Other	The WRAP gate fees study is a UK summary report which includes results from Scottish Local Authorities and waste operators. It shows median gate fees in 2020 for recycling (MRF recycling, composting and AD) remain significantly lower than for residual waste treatment (incineration and landfill) and the median gate fee for incineration (£93 per tonne) is lower than landfill (£113 per tonne - i.e., £24 + landfill tax). The median gate fees for residual waste show that landfill tax ‘prices in’ incineration in line with the existing waste hierarchy. The gate fee study does not include prices for MBT. The Tolvik report referenced in Q4 suggests a gate fee “floor” for MBT of £125 per tonne in 2017. This is based on 60% of inputs being sent for incineration as RDF, 20% moisture loss, 9% recycling and 11% landfill. MBT focussed on bio-stabilisation to landfill would be expected to be more expensive.
Other	Please see response to question 12.
Individual	From a biodiversity point of view, believe that stemming the production and use of single plastics is an important factor.

Individual	Where referred to in a previous question around disputed costs, these had been negotiated and agreed with the local authority who was then faced with additional costs relating to remodelling of the Landfill and lack of alternative waste disposal options.
Individual	See response to Q12.

10.6 Call For Evidence: Question 14 Summary

Category	Q14: Do you have any evidence that the Review should consider in comparing the carbon impacts of options for residual waste treatment?
Local Government	No detailed evidence is held. However, would be willing to offer access to their treatment facility for testing to help build on the available data.
Local Government	Within an EfW feasibility study commissioned by the local authority a carbon impact comparison was made utilising the Waste and Resource Assessment Tool for the Environment (WRATE). The consultants cautioned against identifying a preferred option based on carbon assessment modelling alone given the range of assumptions used in modelling. In general terms, however, and in order of least environmental impact to highest environmental impact the results were: *Local medium-scale EfW CHP facility *Road transport of residual waste to Central Belt EfW CHP facility *Local medium-scale EfW electricity output only facility *Road transport of residual waste to Central Belt EfW electricity output only facility *Landfill
Local Government	The local authority has a WRATE model for the contract and a requirement for carbon reporting and improvement. However, this was unable to be shared as the information is subject to commercial and operational sensitivity or to legal restrictions.

	The local authority also includes frontend processing of the residual waste to target plastics and metals extraction. The frontend process is a modern material recovery facility that could be configured in the future to target other material extraction to ensure that the solution is as flexible as possible for the duration of the contract.
Local Government	N/A.
Local Government	Compositional analysis is required to be able to set a baseline for the effectiveness of current systems. The original Defra estimate of the biodegradable content of residual waste collections was 68% for UK collections. The report from Zero Waste Scotland on the composition of household waste at the kerbside, published in 2017, suggested that paper and card made up 20%, food waste 23% and garden wastes 17% of waste arisings. For the island areas, where very few householders outside of a town use their residual bins for garden wastes, this baseline total is likely to be considerably lower. When kerbside recycling collection services are added, including food and garden waste collection, the percentage remaining will be quite low.
Local Government	The Zero Waste Scotland report on the Climate Change Impacts of Burning Municipal Waste in Scotland highlighted the complexity of comparing the carbon impacts of Residual Waste Treatment. The report was subject to considerable challenge which resulted in changes to the report. The engagement and construct of any such report would have to be carefully thought through, particularly when attempting to compare the carbon impact of differing residual waste treatment options.
Local Government	Stated that waste analysis of waste streams will be provided when available.
Local Government	No waste composition analysis has been undertaken since 2017 and are not considered to be representative of current waste arisings.
Local Government	Caution should be taken when drawing assumptions from existing data as, our opinion is that waste analysis in Scotland has been sparse and not carried out in any kind of consistent, robust and representative manner. The authority recommends that a full programme of analysis is undertaken to create a full and representative data set.
Local Government	No response.

Professional body, trade organisation or governing body	EfW is the least carbon intensive option for the management of residual waste, saving around 200kg CO2e for every tonne of waste diverted from landfill. The results of ZWS's amended EfW report was broadly consistent with industry experience and results from elsewhere, which found that EfW results in around 30% less emissions than landfilling the same waste. The ZWS report did not fully investigate the potential carbon savings of removing plastics from the residual waste stream, the impact of district heating and Carbon Capture and Storage. A more in-depth assessment of these issues carried out in conjunction with EfW operators is likely to demonstrate additional reductions in CO2 emissions.
Professional body, trade organisation or governing body	As noted in our response to question 10 above, EfW is the less carbon intensive option for the management of residual waste, saving around 200kg CO2e for every tonne of waste diverted from landfill. The results of ZWS's amended (ie second) EfW report was broadly consistent with industry experience and results from elsewhere which find that EfW results in around 30% less emissions than landfilling the same waste (11). That said, the ZWS EfW report did not fully assess the carbon impact of removing plastics from the residual waste stream; or the benefits of combined heat and power (CHP) and Carbon Capture Utilisation and Storage (CCUS), all of which are expected to demonstrate further reductions in CO2 emissions. References (11) https://www.esauk.org/application/files/5216/1901/7260/Fichtner_ESA_ZWS_response_final.pdf
Professional body, trade organisation or governing body	This is a complex issue with many variables including: • The management systems in place prior to residual wate production (e.g., dry mixed recycling systems, food waste digestion, deposit refund schemes and green waste composting). • The resulting composition of the residual waste, including importantly it's plastics content. • The biodegradability of residuals in MBT systems. • The fate of MBT residues. • The mix of energy displaced by energy from waste facilities. • The level of energy use efficiency from incineration facilities.

• The level of integration of power from incineration facilities with renewable energy sources in private grid systems offering additional grid system reliability from the production of baseload power.

• The displacement of carbon from downstream heats uses (e.g., the displacement of gas central heating in CHP schemes) or at a more fundamental system level from the displacement of fossil fuels for protected heated horticulture and the opportunity to develop low food mile food production systems with concomitant carbon emission reductions.

• The fate of aggregates from incineration and the aggregates displaced.

• The relative resilience of each system in providing other societal services such as ensuring waste does not accumulate and pose a wider health risk.

This suggests the assessment of the relative merits of different approaches to residual waste management are highly system specific. The body would also suggest that we are missing detailed information on residual waste composition (all sources) and the detailed carbon flow data at a whole system level to fully inform this review. The following study describes these complexities.

Evidence: https://ec.europa.eu/environment/pdf/waste/studies/climate_change_xsum.pdf

In a maturing waste management system with kerbside and deposit systems for recycling dry recyclates, food waste and green waste and with a landfill ban in place and noting the system costs inherent in having to pay for the disposal of MBT residues. The body takes the view that MBT offers limited advantages, even if there was a demonstrated history of reliable MBT systems. From where we are in Scotland the optimum solutions would to be to seek to reduce waste arisings through reduced consumption, improved product design, increased recycling participation rates through improved and more consistent messaging and with incineration for residuals with incentivised carbon emission mitigation including high energy use efficiency (heat and power) and reduced incineration of non-biogenic wastes (plastics).

In a straight comparison of incineration and landfill the corrected ZWS report (October 2021), widely reported, supports wider comparative findings that emissions from incineration are on average 25-30% lower than landfill. The two reports noted below offer further commentary on this issue.

Evidence: Boundaries matter: Greenhouse gas emission reductions from alternative waste treatment strategies for California's municipal solid waste Resource Conservation and Recycling: Volume 57, December 2011, Pp 87-89.

Evidence: Greenhouse Gas and Air Quality Impacts of Incineration and Landfill

	Anne Bulinger, Lauren Duffield, Dr Chris Sherrington. Eunomia, March 2021.
Professional body, trade organisation or governing body	We are aware of the recent report on the problems of reporting of Greenhouse gas emissions from 'waste' indicators and inventories. This report details how the current indicators do not always reflect the true impact of waste treatment options.
Professional body, trade organisation or governing body	The body is currently commissioning a brief study that will examine the carbon impacts of different waste treatment options compared to the use of waste in incineration and in anaerobic digestion. This work is expected to be completed by the end of March and the body will share the work, in confidence, with the review upon request.
Professional body, trade organisation or governing body	No comment.
Business that operates one of more incineration facilities in Scotland	In relation to decarbonisation and net zero, EfWs provide the lowest carbon, technically viable option to deal with waste that cannot be recycled. As we noted in our response to question 10, EfW saves around 200kg CO2e for every tonne of waste diverted from landfill. The results from ZWS's amended (i.e. second) EfW report was broadly consistent with industry experience and results from elsewhere which find that EfW results in around 30% less emissions than landfilling the same waste. We are currently exploring two methods of decarbonsing our EfW facilities, through front end decarbonisation of the waste and the caputure and usage/storage of CO2. Removing plastic from the residual waste stream prior to combustion is a promising route towards reducing EfW emisisons and increasing the material available for recycling. We have run trials at two facilities in Scotland that have indicated an ability to remove 16% of waste (70% in the form of plastics), thereby reducing the fossil emissions of a tonne of black bag waste by up to 281 kgCO2e i.e. it reduces the fossil emisisons by more than half. However the separated material is highly contaminated with other materials, including food waste, and recycling these plastics to a good standard through mechanical processes is often not feasible. In response to this challenge, a rapidly growing filed of exploration is chemical recycling. This converts plastics into their constituent molecules and should enable potentially infinite recycling of plastics.

	CCUS is currently the only viable technology that can capture the CO2 emissions from EfW to rerach net zero. The majority of EfWs are of very similar design therefore making CCUS replicable across the UK. This presents the opportunity to deploy at pace.
Business that operates one of more incineration facilities in Scotland	The carbon emissions of the proposed Killoch ERP have been calculated, and compared to the alternative carbon emissions to landfill, within Chapter 13 of the EIAR submitted with the planning application. Chapter 13 of the EIAR states that the Killoch ERP will result in a 12% carbon saving, compared to the equivalent amount of waste being sent to landfill. In addition, a net zero plan has been developed which will reduce this further. An updated EIAR chapter is being prepared.
Business that operates one of more incineration facilities in Scotland	The business states that the C footprint of their operations has reduced c90% following implementation of EFW v Landfill and fossil fuel metrics as published (DEFRA). EfW can count on both waste input as a C input and heat export as C output. The business says that with BNMW waste having a heat value (LHV) c 15MJ/kg and generating a surplus equivalent to 1kWh heat export /input kg received, the potential for BNMW to be a major source of Scotland’s renewable Heat map is an extraordinary opportunity. The business states that their personal view is that theoretically, with EfW consuming BNMW post 2025 (and at 1kWh per kg) we wouldn't need to use fossil fuels to heat our homes, at least on paper and significantly reduce the national footprint accordingly.
Business that does not operate a residual waste treatment site but produce waste that ultimately is treated at one	No comment.
Business that operates one of	The business would be happy to share, on a confidential basis their internal study on carbon emissions.

more incineration facilities in Scotland	
Business that operates other (non-incineration) residual waste treatment facilities outside of Scotland	<u>SRF compositional analysis</u> SRF cement Wood 2.17% Plastic film 69.60% Fabric 13.55% Paper & cardboard 14.68% <u>RDF compositional analysis</u> Glass 6.40% Paper and cardboard 16.30% FE Metal 1.70% Non FE 2.00% Mixed scrap metal 1.80% Dense plastic 9.80% Plastic film 10.20% Garden waste 1.20% Food waste 24.80% Weee 0.90% Misc. Combustible 2.90% Textiles and footwear 6.00% Misc. non combustibles 3.80% Haz waste 0.70%

	Healthcare waste 9.80% Fines <10mm 1.70% No further comment, other than to say in all circumstances the carbon impact of recycling should be considered alongside to impact for Residual Waste treatment such that observers are continually informed as to the benefits of recycling over and above residual waste treatment.
Environmental Group	No - but obviously if reusable and repairable items, along with recyclable plastics, paper and card, are removed from "residual waste" before incineration, then the carbon impacts will be reduced along with the calorific value. I am sure that the incinerator operators carry out compositional analysis of the "residual waste" as well as the local authorities, and there should be regulations applied to both parties requiring that this is done on a consistent, comparable and audited basis, with the data supplied to a Government agency (SEPA or ZWS).
Environmental Group	The 42 incinerators in the UK produce 5 million tonnes of fossil CO2 per year, contributing considerably to climate change costs to the tune of about £325million a year. Building more incinerators would lock this in. Moving to a circular economy including MRBT would avoid much of this.
Environmental Group	Studies have clearly shown that the most effective waste measures in terms of carbon come from preventing its existence in the first place. An in-depth and peer reviewed study by Zero Waste Scotland estimated the carbon impact of sending one tonne of municipal waste to incineration in Scotland in 2018 to be 246 kgCO2e/t, which is 27% lower than the impact of sending the waste to landfill. However, this study assumed that all biogenic carbon in landfill biodegrades, whereas about half is stored as biogenic carbon. This approach conformed to international reporting guidelines, but is inappropriate for comparisons between technologies, used to aid policy decisions. When biogenic carbon is included the emissions from incineration are comparable, or greater than landfill.
Environmental Group	We draw attention to 'The Good Practice Guidance for Assessing the GHG Impacts of Waste'. One of the Key Findings of this research is that incinerators often perform significantly worse than modelled for planning applications and environmental permits. Incinerators often deliver lower levels of electricity generation and higher levels of fossil CO2 emissions, resulting in a higher carbon intensity than claimed by those promoting such schemes. A second report from UKWIN, 'Evaluation of the climate change impacts of waste incineration in the United Kingdom' uses the default values adopted by Defra for carbon-based modelling in order to compare the climate

	change impacts of incineration with sending the same waste directly to landfill. The results of the comprehensive analyses are set out in easily understood table form.
Environmental Group	This Call for Evidence question invites consultees to provide evidence such as compositional analysis. The groups website includes links to eight examples of compositional analysis (alongside references to WRAP data on recycling opportunities, etc.) covering a range of waste streams (e.g., Commercial and Industrial (C&I), household residual, municipal, landfilled C&I, etc.) undertaken at regional and national levels. These studies demonstrate that much of what is incinerated is not genuinely residual waste, but rather valuable material that could and should have been recycled or composted. Compositional analysis studies show that there are many instances where the majority (i.e., over 50%) of 'waste' collected at the kerbside could have been recycled or composted had it been put into the correct bin. And not all these studies take account of the opportunities for Councils to extend the range of materials they accept for recycling at the kerbside. The vast majority of incinerators in the UK have no facility to remove recyclable material prior to incineration, and so all of the recyclable and compostable material delivered to these facilities ends up in the incinerator. Difficult-to-recycle materials are increasingly being redesigned or phased out, meaning incinerators are becoming increasingly reliant upon burning recyclable and compostable material. The more that citizens and businesses are confident that material collected for recycling or composting is in fact recycled or composted the more likely it will be that these materials end up in the recycling stream rather than the residual waste stream. The easier it is for consumers to recycle, e.g. through extending the range of plastics collected for recycling and allowing all dry materials to be collected for potential recycling, the greater the reduction in the quantity of material the makes up the residual waste stream. Much of what is left in the residual waste stream, e.g. ceramics and cat litter, are not combustible. Responding to the Call for Evidence's invitation to provide case studies and carbon reports, UKWIN draws attention to both our 'Good Practice Guidance for Assessing the GHG Impacts of Waste Incineration' and our 'Evaluation of the climate change impacts of waste incineration in the United Kingdom', as well as to Zero Waste Scotland's 'The climate change impact of burning municipal waste in Scotland' and Eunomia's report for ClientEarth entitled 'Greenhouse Gas and Air Quality Impacts of Incineration and Landfill'. As set out below, the group has also carried out bespoke analysis for the Scottish Incineration Review's Call for Evidence regarding the real world carbon performance of incinerators in England and Scotland, and the unpaid CO2 cost of Scottish incineration capacity.

Good Practice Guidance for Assessing the GHG Impacts of Waste Incineration (UKWIN, July 2021)

When considering the impacts of incineration, it is necessary to take into account the recommendations made by UKWIN within our July 2021 Good Practice Guidance for Assessing the GHG Impacts of Waste Incineration and the associated evidence base. The report's recommendations are outlined below.

TRANSPARENCY AND OPENNESS TO SCRUTINY

1. Methodology and modelling assumptions, including underlying data and how it was derived, should be transparent and verifiable. Scrutiny of environmental claims made to support waste incineration should be facilitated rather than frustrated.

IMPACT OF WASTE COMPOSITION AND TECHNOLOGY ON ENERGY AND GHG OUTPUTS

2. Key outputs such as power export and greenhouse gas (GHG) emissions are dependent on waste composition and the processes used. When modelling future emissions it is necessary to ensure that outputs are internally consistent with inputs.

3. GHG impacts can be highly sensitive to waste composition. Waste composition assumptions should be justified and sensitivity analysis should be used to show the impacts of future changes such as increased food and biowaste collection.

4. While heat export, carbon capture, and pre-treatment to remove plastics can potentially reduce overall GHG impacts of incineration, there are also uncertainties regarding deliverability and/or overall impacts. Sensitivity and lifecycle analysis can be used to explore a range of possibilities and to reflect relevant uncertainties.

THE ROLE OF LANDFILL AS A BIOGENIC CARBON SINK

5. To produce a valid comparison when comparing waste treatment options such as landfill and incineration that release different quantities of biogenic CO_2 it is necessary to account for these differences, especially the impact of the biogenic carbon sink in landfill.

DISCREPANCIES BETWEEN THEORETICAL AND REAL WORLD PERFORMANCE

6. The carbon performance of modern waste incinerators is often significantly worse than was predicted through modelling at the planning and permitting stages. This discrepancy between predicted and actual carbon performance needs to be taken into account when modelling, and robust sensitivity analysis is needed to ensure that CO_2e emissions from incineration are not significantly underestimated.

7. Power export underperformance, e.g. due to turbine or generator failure or during commissioning, is a realistic prospect for modern waste incinerators that needs to be taken into account when modelling anticipated power output and associated climate impacts.

DISPLACEMENT OF OTHER SOURCES OF ELECTRICITY AND/OR HEAT

8. When considering the carbon intensity of displaced energy, it is necessary to take account of the progressive decarbonisation of the energy supply rather than simply assuming that a new energy source would displace fossil fuels. The carbon intensity of electricity displaced by a new incinerator can be estimated using the average BEIS Long-Run Marginal Emissions Factor (MEF) over the lifetime of the plant.

WASTE TREATMENT COMPARATORS/COUNTERFACTUALS

9. When considering how waste would be treated if it were not sent to an incinerator, account should be taken of the prospect that it might otherwise have been reduced, reused, recycled or composted. Account should also be made of how landfilled waste could be bio-stabilised to reduce methane emissions.

LOW CARBON CLAIMS

10. Energy from mixed waste incineration should not be described as ‘low carbon’. Incineration involves the direct release of significant quantities of CO2.

The analysis that informed Recommendations #6 and #7 found that, for the incinerators studied, on average:

a. The proportion of CO2 that was fossil CO2 was 13 percentage points higher than predicted at the planning or permitting stage.

b. The fossil carbon intensity of electricity exported to the grid was around 49% higher than predicted by the applicant at the planning or permitting stage

c. Reported fossil CO2 released per tonne of waste feedstock incinerated was around 20% higher than that predicted at the planning or permitting stage.

d. Electricity generated by incinerators was 15% lower than implied by the claimed headline megawatt (MW) generation figure, i.e. an incinerator advertised as being capable of generating 10MW of electricity typically only generated 8.5MW.

e. Electricity exported was around 28% lower headline MW generation figures.

Further evidence on real world carbon performance for UK incinerators UKWIN’s Good Practice Guidance for Assessing the GHG Impacts of Waste Incineration compared figures advanced by Viridor at the planning application and environmental permit application stages with the real world performance reported to England's incineration industry regulator, the Environment Agency, by Viridor.

This showed that real world performance was significantly worse than anticipated performance.

Beyond the values in the report's main findings, the report itself includes the data used to calculate the results.

These calculations relied on knowing the fossil/biogenic fraction of the waste.

Subsequent to the release of the Good Practice Guidance UKWIN managed to obtain Viridor's Beddington incinerator figures for 2020 from the Environment Agency.

The Beddington incinerator's fossil carbon performance for 2020 was slightly worse than that for 2019. This difference (i.e. the increase) can be attributed to the biogenic fraction of the waste falling from 50.6% in 2019 to 44.1% in 2020 (meaning that 55.9% of the carbon in the waste feedstock was fossil carbon).

With this information, it is now possible to produce updated figures for the carbon impacts of incineration facilities in England for 2019 and 2020 which includes the newly obtained 2020 Beddington figures (outlined within the response).

This analysis of English carbon performance, as reported by Viridor to the Environment Agency, indicates that around 50% of the feedstock is considered biogenic, which means around 50% of the CO2 is considered fossil CO2. It also confirms that around 1 tonne of CO2e is released per tonne of waste incinerated, and that energy exported by incinerators has a high carbon intensity.

Evidence on real world carbon performance of Scottish incinerators

By comparing CO2 information provided by operators to SEPA's Scottish Pollutant Release Inventory for 2019 with information on the quantity of waste incinerated at those plants in 2019 stated in the operators' Annual Performance Reports, it can be estimated that incinerators in Scotland also release around 1 tonne of CO2 per tonne of waste incinerated.

We know from the operator's annual report for Baldovie that the 102,042 tonnes of CO2 released in 2019 was based on CEMS measurements of CO2 emissions. We do not have any evidence that any of the other Scottish emissions figures reported were based on CEMS monitoring, and so they are potentially less accurate than the figures for Baldovie.

The Annual Environmental Reports provided to SEPA by plant operators provide information on electricity generation and hours of operation which can be used to compare the theoretical maximum MWe capacity of incinerators in Scotland against real world performance.

This indicates that on average these incinerators – during their operational hours - operated at 78% of their electrical generation capacity, with real world export performance only 63% of the theoretical generation capacity. This is a measure of performance when the plants are operating, not of the 'availability' of the plants.

Operator reports for Millerhill and Baldovie include information on electricity exported in 2019. This can be combined with information on CO2 released in 2019 to estimate the carbon intensity of exported electricity from those incinerators (outlined in the full response).

These figures indicate that the carbon intensity of these two Scottish incinerators was higher than the carbon intensity of all the incinerators studied in England. As there is a similar level of CO2 released per tonne processed this difference can largely be attributed to less electricity being exported per tonne processed for the facilities that reported CO2 emissions.

To illustrate the performance of incineration plants relative to other forms of electricity generation, the figure from the UKWIN Good Practice Guide has been updated with Scottish incinerators shown in the full response.

The performance for Baldovie and Millherhill is compared directly to the performance assumed for 2018 by Zero Waste Scotland in Table 3 of their technical report, where the plants appear to be referred to as EOP2 and EOP3 respectively.

For the facilities where carbon intensities can be calculated, the ZWS assumption as to the carbon intensity of the electricity is between 47% and 87% of the real world figure (i.e. an average of 65% of the real world value).

This provides evidence that real world performance of Scottish incinerators is significantly worse than the performance assumed by Zero Waste Scotland (ZWS) in 'The climate change impact of burning municipal waste in Scotland' (July 2021) which used operator-provided data on projected performance to estimate a far more optimistic (but still high carbon) performance. These discrepancies cannot be explained away by minor differences in calculation methodology.

Part of the reason for these discrepancies could be explained by the use of overly optimistic assumptions by ZWS regarding the efficiency of these incineration facilities based on theoretical generation capacities claimed by plant operators and applicants.

For example, the ZWS report assumed "Plant efficiency averaged 25% for the electricity-only plants" but in 2020 the Glasgow gasification plant reported a total electrical generation figure of just 17%.

This evidence provides an additional indication that the current real world performance of incinerators in Scotland could be far worse than predicted by Zero Waste Scotland's modelling, thus calling into question the robustness of the ZWS report's conclusions regarding the current impacts of incineration compared to landfill.

Estimate of future unpaid CO2 cost of Scottish incinerators

Based on the above information it is possible to provide an estimate that around 0.5 tonnes of fossil CO2 would be released per tonne incinerated at Scottish incinerators. This can be combined with incineration capacity and BEIS' price estimates for carbon to provide an estimate of the future unpaid fossil CO2 cost of Scotland's incinerators.

BEIS provides a 2027 central fossil CO2 value of £268/tonne.95 At 0.5 tonne of fossil CO2 per tonne incinerated, the unpaid cost would be around £134 per tonne. Scotland currently has around 1.56mtpa of municipal waste incineration capacity, with a further 1.58mtpa under construction, and outstanding planning applications or announcements for around 1mtpa of additional capacity. This means that by 2027 incineration capacity in Scotland could be around 4.2mtpa even if no new projects are announced. 4.2m × £134 = £562.8m, i.e. more than £560m if all the incineration capacity announced for Scotland were also built. The operational and consented capacity is already set out above. The figures for capacity announced or in planning is as follows:

Scottish municipal waste incineration capacity which is in the planning system or has been announced as being under development or consideration:

Plant Capacity Status was stated as 1,076,000+ Excludes substantial phase 2 expansion of Levenseat EfW because announcement reported by ENDS post-dated UKWIN's analysis.

The climate change impact of burning municipal waste in Scotland (Zero Waste Scotland, July 2021)

While the call for evidence document states "In July 2021, Zero Waste Scotland published a report, the Climate Change Impacts of Burning Municipal Waste in Scotland. This suggested that incinerating municipal waste in Scotland resulted in 27% fewer emission than landfilling the same waste" this is not an accurate representation of the report's findings.

In relation to the 27% figure, we note that:

• The 27% figure related to 2018 and not to present or anticipated future adverse climate impacts of incineration, and we further note that decarbonisation of the grid and removal of food waste would reduce the benefits of incineration.

• The 27% figure related to sending waste directly to landfill, and not to the biostabilisation scenario which indicated that landfill could have significantly lower impacts than incineration.

• Chapter 5 of the report acknowledges a number of data gaps, including with respect to the composition of residual municipal waste and the energy outputs of EfW incineration plants, and thus energy displacement.

• The impact of displaced electricity is assessed based on the UK grid, not the more-decarbonised Scottish grid.

• No account is made in the calculations for the fact that landfill releases less biogenic CO2 than incineration, i.e. that landfill acts as a partial carbon sink for biogenic carbon.

• The report figures are based on incinerator applicants' energy output estimates which, as per UKWIN's analysis above, is often unrealistically optimistic, e.g. due to the failure to take into account anticipated turbine non-availability.

To quote from the Zero Waste Scotland (ZWS) report (with emphasis added):

• "Sending one tonne of waste to EfW emitted 246 kgCO2e/t on average, which is 27% lower than the emissions from sending the same waste to landfill in Scotland in 2018. The emissions from both EfW and landfill are highly dependent on the composition of waste, which is variable and changing over time. If the fossil carbon in waste increases, EfW emissions rise. If the biogenic carbon in waste increases, landfill impacts rise."

• "The significance and variability of key parameters such as the composition of waste and the decarbonisation of the grid, illustrate the importance of regularly updating the evidence base for this subject area."

• "When biogenic carbon decreases (e.g. if the proportion of food and paper waste in municipal residual waste falls), landfill greenhouse gas emissions fall…Landfill and EfW impacts are equal when the proportion of food and paper waste in residual municipal waste falls from the main model assumptions by 10.4% from 43.1% to 32.7%."

As such, the report itself acknowledges that looking back at assessments based on historic carbon intensities and waste composition (which is what the 27% figure does) results in an inaccurate assessment of the current and future impacts of incineration.

A number of limitations/deficiencies in the report raise doubts that the 27% was even accurate in 2018. These indicate that the report underestimated the carbon impacts of incineration and overestimated the impacts of landfill.

The ZWS report states that: "The EfW plants in this study are assumed to displace UK marginal electricity grid". Figure 1 of the report seems to indicate that the carbon intensity of the Scottish incineration grid is significantly lower than the UK average.

The ZWS report states that: "Data on the energy outputs of EfW plants, and thus energy displacement, are based on PPC permits, rather than annualised energy data or NCV".

As noted above, the evidence and analysis behind Recommendation #6 and #7 of UKWIN's Good Practice Guidance indicates that the use of permit application data will tend to overestimate energy outputs, and this is supported by the above evidence from Scotland that both gasification and conventional incineration plants generate and export significantly less than the theoretical generation capacity, with observed efficiency being lower than predicted in the ZWS report.

The ZWS report states that "biogenic and fossil carbon are counted differently" in the assessment, but this improperly skews the analysis in favour of incineration. Ignoring biogenic CO2 means that the comparison fails to take into account the fact the ~50% of biogenic carbon which is sequestered in landfill means it is acting as a 'carbon sink' for CO2 which would be released if the waste were to be incinerated.

The modelling fails to account for this difference in biogenic CO2 emissions despite significant evidence and logic that failing to do so results in invalid comparisons.

For example, a European Commission report has noted that: "…in comparative assessments between processes, it cannot be valid to ignore biogenic CO2 if the different processes deal with biogenic CO2 in different ways…".

For more details see Recommendation #5 of UKWIN's Good Practice Guidance for Assessing the GHG Impacts of Waste Incineration.

Based on the above, it would be reasonable to conclude that if the Zero Waste Scotland report were to be updated to address all of the issues raised then it would find that not only is incineration currently worse than landfill in Scotland but that as the grid decarbonises and the amount of food waste in the feedstock decreases incineration is set to get progressively worse over the coming years.

However, it should be noted that these observations strengthen rather than weaken the important conclusion of the ZWS report that "EfW can no longer be considered a source of low carbon energy within a UK and Scottish context".

Evaluation of the climate change impacts of waste incineration in the United Kingdom (UKWIN, October 2018)

This report found that:

• Waste incinerators currently release an average of around 1 tonne of CO2 for every tonne of waste incinerated.

• The release of CO2 from incinerators makes climate change worse and comes with a cost to society that is not paid by those incinerating waste.

• In 2017 the UK's 42 incinerators released a combined total of nearly 11 million tonnes of CO_2, around 5m tonnes of which were from fossil sources such as plastic.

• Electricity generated by waste incineration has significantly higher adverse climate change impacts than electricity generated through the conventional use of fossil fuels such as gas.

• The 'carbon intensity' of energy produced through waste incineration is more than 23 times greater than that for low carbon sources such as wind and solar; as such, incineration is clearly not a low carbon technology.

• When waste is landfilled a large proportion of the carbon is stored underground, whereas when waste is burned at an incinerator the carbon is converted into CO_2 and immediately released into the atmosphere.

• Over its lifetime, a typical waste incinerator built in 2020 would release the equivalent of around 1.6 million tonnes of CO_2 more than sending the same waste to landfill. Even when electricity generation is taken into account, each tonne of plastic burned at that incinerator would result in the release of around 1.43 tonnes of fossil CO_2.

• Due to the progressive decarbonisation of the electricity supply, incinerators built after 2020 would have a relatively greater adverse climate change impact.

• Composition analysis indicates that much of what is currently used as incinerator feedstock could be recycled or composted, and this would result in carbon savings and other environmental benefits. Thus, incinerating waste comes with a significant 'opportunity cost'.

As noted in the previous section of the response, this report was written by Eunomia for ClientEarth. The report highlights how biostabilising waste prior to landfill can result in significantly lower impacts than sending waste directly to incineration. It also shows that sending waste straight to landfill results in lower emissions than sending waste to incineration in the ‘expected-2035’ scenario.

While the report includes reference to the potential for reductions in fossil CO_2 emissions from diverting all plastics to recycling (when it calls incineration with "pretreatment"), this scenario might be overestimating the potential for low-grade plastic to be recycled and the extent to which the benefits of this compensate for the biogenic CO_2 emissions from incineration.

Unfortunately, the underlying information regarding these assumptions is not available, and so it is difficult to fully assess these claims. What we would not want to see is material being diverted for ‘plastic recycling’ only to then be converted into a fossil fuel for combustion or subjected to environmentally harmful pyrolysis treatment.

Other	The Review should consider the realities of the situation: EfW provides an excellent opportunity to capture far more of the recyclable material (albeit in the form of calorific value) that any other waste treatment would significantly reduce our landfill tonnages and allow compliance with the intended ban on landfilling untreated municipal waste.
Other	No response.
Other	A number of opponents of EfW have pointed to the poor carbon performance of EfW against other forms of power generation. To put this into context, in 2020, excluding heat and steam export, it is estimated that the average carbon intensity of direct stack emissions of an EfW in the UK was 1000 gCO_2eq/kWh and that of a CCGT fired power station is generally assumed to be 373 gCO_2eq/kWh. However by making this comparison, the questioner is looking to answer an entirely different question – "What is the best way of generating 1MWh of power?" As a result most informed observers recognise that EfW cannot be compared in this way directly to a power generation facility. Consider an alternative question and the need to identify the best available option for a tonne of Residual Waste. Whilst there is no definitive methodology to assess the carbon impact of EfW, in general there is a recognition that the assessment needs to consider, on a per tonne of waste input basis: **The level of greenhouse gas emissions** – primarily from "fossil" CO_2. Greenhouse gas emissions are largely a function of the composition of Residual Waste, and in particular the portion from fossil-based waste streams. Given the "sanitary" requirement of EfW for public health/pollution control purposes, there are limitations EfW operators' ability to select Residual Waste fuel with the lowest fossil fuel component. **The value of the direct benefits of EfW** Maximising the efficiency of an EfW in terms of power and heat export and, where applicable, metals recycling serves, from a carbon perspective, as a mitigant to the emissions generated. Here once again there are limitations when compared with a power plant – waste as a fuel is heterogenous, there is a much greater obligation on operators to manage emissions to ensure compliance with environmental

	legislation, and facilities are, in a power sector sense, relatively small in scale. These all contribute to an EfW typically having a much lower thermal efficiency than a dedicated power station. **The impact of avoided landfill** Landfilling Residual Waste results in carbon emissions – primarily the release of methane - which can be measured in part, but also needs discounting for future years which is a very complex assessment. Please find link below to Tolvik's assessment of the carbon impact of EfW in the UK, as an average of all plants operating in the years assessed. See pages 11 and 12 of https://www.tolvik.com/publishedreports/view/uk-energy-from-waste-statistics-2020/ . The outcome of any assessment of the carbon impact of specific EfWs, including the relatively small cohort in the case of Scotland, is highly dependent upon a number of factors. This includes the performance and efficiency of each EfW, power, heat and metal recycling undertaken, the composition of the feedstock in terms of proportions of fossil/non-fossil and the baseline assumptions of carbon intensity of outputs and conversion factors used. Therefore any evaluations made by the CfE review on EfWs should be based upon specific data from Scottish EfWs and not industry averages. Tolvik has not undertaken any specific analysis on the carbon impact of landfill, nor processing for Residual Waste by way of MBT, but a number of other organisations have done so which the CfE team may wish to consider.
Individual	No.
Individual	No response.
Individual	See studies submitted alongside.

10.7 Call For Evidence: Question 15 Summary

Category	Q15: What other aspects should the Review consider when assessing the environmental impacts of residual waste treatment options?
Local Government	The location of residual waste treatment facilities – most facilities which are accessible are in Northern England or in the Scottish central belt. All options require significant travel distances for which it is assumed that there are many other Scottish local authorities in a similar position. If Scotland moves forward with the existing capacity in its current locations, then hauling residual waste becomes the only option for rural councils to access this treatment capacity.
Local Government	No information to add.
Local Government	Stated that their contract is in compliance with its PPC permit and as such is meeting the legislative requirements.
Local Government	Carbon impact - preferentially, treatments should have minimum carbon impact.
Local Government	All comparisons made between technologies should take account of all of the real-world conditions rather than generalised presumptions. This should include all waste transport emissions, control measures at the landfill site (e.g., landfill gas capture and treatment/use) and the waste composition.
Local Government	EfW needs to be considered in the context of a whole systems approach to resource use. The priority is on reduction of waste, its reuse and high-quality recycling. However, we are still left with a residue that requires to be treated. At the moment, from a carbon impact perspective EfW provides a medium-term solution, with limited or no other viable options, particularly with the upcoming bio ban in 2025.
Local Government	No evidence.
Local Government	Transport impacts can be an important consideration however, these should perhaps take account of Scottish Government policies and intentions to decarbonise transport in the medium-term. It is likely that decarbonising transport will also address other air pollution concerns such as nitrogen oxides impacts on health outcomes. Consideration should be given to the overall energy balance of treatment options; for example, are options that

	require lower energy inputs or generate heat and power for export more environmentally advantageous than those that do not?
Local Government	The authority has heavily invested in alternative fuels for its fleet, including the recent delivery of hydrogen powered refuse collection vehicle. Perhaps the production of hydrogen from the energy produced by EfW facilities to fuel waste transport could be looked into further and be considered a circular activity for waste treatment?
Local Government	The review should consider the impact of transport on the full “cradle to grave” journey of waste and effective capture and usage of heat and energy from the process.

Professional body, trade organisation or governing body	When considering options, carbon impact is one of several considerations albeit an important one. The environmental impacts of residual waste treatment options could look at matters such as:
	• The impact on groundwater from waste facilities
	• Amenity matters such as:
	  ○ odour
	  ○ dust
	  ○ noise
	  ○ vermin (birds, rats etc)
	• Air Quality from:
	  ○ diffuse emissions
	  ○ point sources
	• Visual impact
	• Light pollution
	• Vibration
	The above list is not exhaustive list and consideration should also be made of the technical feasibility and reliability of the technology. It should be noted that residual treatment facilities are required to meet the technical standards outlined in Best Available Techniques (BAT): Reference Documents (BREFs) and are caried out in enclosed buildings to minimise fugitive emissions restrictions imposed by BAT: Associated Emission Levels (BATAELs).

Professional body, trade organisation or governing body	No further comment beyond the response to question 10.
Professional body, trade organisation or governing body	The RMAS suggests considering the following: 1. The non-biogenic resource conservation efficiencies of competing options (all virgin raw material extractions have impacts in one form or another). 2. Bio-aerosol impacts of MBT systems. 3. The secondary treatment impacts of MBT outputs. 4. Comparative system resilience against an agreed set of resilience criteria (e.g., avoided environmental impacts from system failures, air quality impacts). 5. Options to improve dioxin and furan monitoring.
Professional body, trade organisation or governing body	No response.
Professional body, trade organisation or governing body	Key points to be considered, not in a priority order, are: • Does the residual waste treatment option move the waste up the waste hierarchy? • Is the treatment option, the option with the lowest carbon impacts, including when waste transport is taken into account? • Are there wider impacts (e.g., air or water quality) that should be considered? • What residues are produced from the waste treatment option and how are these managed? • Does the treatment option displace existing use for that waste or require new assets? The body is keen that the role of cement production at Dunbar in Scotland is recognised within the review to ensure that perverse environmental, economic and societal outcomes are avoided. However, we equally recognise, as clearly stated in the call for evidence, that the unique nature of Scotland, such as its remote communities, means that a one-size fits all approach residual waste management is not achievable or desirable.

Professional body, trade organisation or governing body	There are a number of links between the management and treatment of waste and the wider environmental and energy policy position and related targets. Those targets need to be considered when the impacts of waste treatment are being reviewed and decided upon.
Business that operates one of more incineration facilities in Scotland	No further comment to the response in question 10.
Business that operates one of more incineration facilities in Scotland	In addition to the carbon impacts, it is important for the Review to consider the other environmental aspects of incineration when compared to other waste treatment. The examples below are specific examples of the other environmental influences which the proposed Killoch ERP will provide. Energy recovery; The Review should consider the environmental impacts of using the residual waste to produce electricity. Incineration with energy recovery achieves two goals; the removal and treatment of residual waste, and the use of this waste which would otherwise be consigned to landfill to produce energy. The Killoch ERP is designed to generate approximately 137,600 MWh of electricity per annum, of which approximately 124,000 MWh per year will be exported back to the local electricity distribution network. This gives a net electricity generation of 0.82 MWh per tonne of waste processed. Whilst electricity can be generated from residual waste sent to landfill through the combustion of methane which is emitted during the decomposition of residual waste, the proportion of electricity generated is significantly less than for an equivalent EfW. For the Killoch ERP, the electricity production potential for an equivalent landfill has been calculated as 0.17 MWh per tonne of waste. It is expected that the Killoch ERP will generate enough electricity to power 45,000 homes. Alternatively, sending the same amount of waste to an equivalent landfill is expected to generate enough electricity to power 9,300 homes. Furthermore, Killoch ERP will utilise the heat created by the process to heat Barr's onsite offices, and is exploring opportunities to develop a district heating network to provide other local residences and business with heat produced by the process. Metals recycling; The Review should consider the additional recycling of metals which is provided by EfW facilities. The incineration process cleans and separates metals from mixed waste, which otherwise could not be recycled. This makes further recycling possible: a wide range of metals are extracted from the incinerator bottom

	ash produced as a by-product of the incineration process. These metals are reused for new products such as aluminium castings for the automotive industry, with a considerably lower carbon footprint than the alternative of mining transporting and processing metal ores. However, if the same waste was processed in a landfill facility, the additional recovery of metals would not be achieved. Aggregate production; The Review should consider the environmental benefit of the re-use of byproducts produced by the incineration process. Following the removal of metals, the remaining portion of the bottom ash can be used as an aggregate in the construction industry in place of virgin materials. The Killoch ERP is predicted to produce up to 34,000 tonnes of bottom ash for use in the construction industry. If this same waste was instead sent to a landfill facility, there would be no further material produced which could be re-used, and there would be 34,000 tonnes of additional virgin materials consumed by the construction industry. Additionally, the Air Pollution Control Residues (fly ash) produced at EfW Facilities can also be utilised as an aggregate, following treatment. Therefore, the Killoch ERP has the potential to produce a further 6,500 of aggregate material per annum. Land use; The Review should also consider the environmental impact of land use between different treatment options. This should include a comparison between the footprints of EfW facilities and other residual waste treatment options. The incineration process is a consistent and reliable process with the capacity to treat large volumes of waste over many years at the same single facility. This is compared to landfill, which, to treat the same volume of waste that the Killoch ERP would expect to process within a 25 - year lifetime, would require vast volumes of ground space over perhaps multiple landfill sites. Additionally, options for the remediation of sites used for incineration and landfill facilities following their closure should be assessed.
Business that operates one of more incineration facilities in Scotland	The business states that their own plant, as evidenced over a decade of independent testing, third party tests, regulatory real time reporting etc is rated excellent and that there has never been a stack emissions failure. The detail in licences varies per operator, as do other "conditions" unrelated to emissions. Therefore, care needs to be taken on generalisations. The CAS system is also no longer in use by SEPA. Compliance thresholds apply to all licence holders.
Business that operates one of more incineration	Perhaps how future proof the plant is with regard to the Dec 2020 EU WI-BREF which will find its way into the PPC Regulations eventually in our view, and particularly regarding emissions of sub-2.5 micron particulates for

facilities in Scotland	which technology exists to mitigate these in the form of flue gas condensation (FGC). Reference to the Eunomia report on page 23 with regard to the damage impact of 2.5 micron particulates refers.
Business that operates other (non-incineration) residual waste treatment facilities outside of Scotland	No comment.
Business that does not operate a residual waste treatment site but produce waste that ultimately is treated at one	No comment.
Not for profit environmental organisation	Although estimating the carbon impacts of waste has helped Scotland to better understand the impact of waste on warming our planet, it provides limited insights into the true environmental cost of waste. Focusing solely on the carbon impacts of waste might lead to the development of policies that shift the problem from climate change to other issues, such as biodiversity, which could inadvertently increase the overall burden on the planet. Zero Waste Scotland is currently working on the development of the Scottish Waste Environmental Footprint Tool (SWEFT), a world-leading science-based tool to evaluate the environmental impacts of waste generated and managed in Scotland and support our transition to a circular economy. Built following latest advancements in ecological economics, SWEFT quantifies the environmental impacts across 33 material categories and 16 environmental indicators, including climate change, land use, material use, water scarcity, and air quality.

Environmental Group	No evidence to offer.
Environmental Group	No response.
Environmental Group	Incineration contributes directly to climate change by releasing carbon into the atmosphere from burnt material. The emissions from incineration are included in the energy sector, rather than the waste sector in Scotland's emissions reporting. This gives policy makers the false impression that waste sector emissions are declining26, when they are, in fact, being diverted to another sector. This carbon accounting loop-hole has allowed the emissions from incineration to increase unnoticed – their emissions masked by the relatively larger impacts of the rest of the energy sector. The Scottish Government's climate change advisory body, the Climate Change Committee estimates that incinerators now emit more carbon than coal burning in the UK. Scotland must make the reporting of incineration emissions more transparent and start attributing incineration emissions to the waste sector in its Climate Change Plan.
Environmental Group	Many of the environmental impacts of incineration that concern us are possibly out with the remit of the review as they are usually dealt with at the planning stage, e.g., locating an incinerator on greenbelt land, the visual impacts of incinerators, etc. The site for the proposed incinerator in Inverness is adjacent to the shoreline of the Moray Firth which is a Ramsar site, an SPA and an SAC. To us it just does not make sense to build an incinerator that could be emitting many toxins and pollutants, including dioxins and heavy metals, onto and into an area of the highest environmental protection.
Environmental Group	With respect to lock-in, the high Capex associated with building new incinerators, and the current level of existing incineration capacity in Scotland, mean that allowing new incinerators to be built would considerably increase the risk of lock-in. Furthermore, as recyclable and compostable material is progressively diverted from existing incinerators an increasing quantity of existing capacity is freed up. As has already been mentioned, incineration destroys materials, meaning that nutrients and materials are lost to the circular economy. Even when incineration produces material outputs such as incinerator bottom ash aggregate a significant proportion of the value in the material has been lost, and it means that the original

	product/material would need to be replaced. If properly designed, landfill can allow for future mining of materials such as hard-to-recycle plastics once recycling technologies have improved or circumstances have changed. This means that, from a circular economy perspective, landfill can be better than incineration both in terms of preserving materials for future use and in terms of avoiding lock-in that harms the transition to a more circular economy. With respect to air quality, it must be said that the experience of Covid reinforces the urgency and importance of the need to improve air quality. Whilst the degree of harm caused to air quality by incinerators is a matter of debate, it is widely accepted that incinerators degrade air quality to some extent, moving in the wrong direction with respect to public health in this regard. Furthermore, there are concerns that adverse health impacts of incinerators are being underestimated because of the emphasis on the mass of particulate matter released as distinct from the number of particles released.
Other	EfW plants have been working very successfully on the continent for decades, complying with EEC/EU legislation. The 'environmental risks' are simply red herrings.
Other	<u>Life Cycle Analysis</u> The recent focus on carbon in reports referenced does not provide the whole picture of environmental impacts – well-being, water pollution, air pollution etc. A full lifecycle assessment would provide a more complete view of the options and the trade-offs. There are a range of other (non-carbon) impacts associated with residual waste treatment technology. These include; <u>Environmental Issues – Waste Incineration</u> One of SEPA's objectives for incineration or co-incineration plants is to ensure a high level of environmental protection through the application of Best Available Techniques (BAT). BAT is defined for the waste incineration activity by EU Waste Incineration (WI) BAT Conclusions (BATC) as derived from the WI BRef Guidance25 which is produced by a collaborative process run by the EU to comply with the Industrial Emissions Directive 2010/75/EU and implemented in Scottish law by the Pollution Prevention and Control (Scotland) Regulations 2012 (PPC). <u>Air Emissions</u>

SEPA assesses applications for waste incineration and co-incineration installations against current legislation and technical guidance, consults on proposals with interested parties and issues permits placing controls on operational conditions, monitoring and emission limit values (ELVs) for releases to air.

During the planning and permitting process the applicant must carry out detailed air quality dispersion modelling to determine potential impacts on local air quality (both directly from the installation itself and indirectly e.g. increases in local traffic).

There are currently two leading models used for regulatory purposes – the Air Dispersion Modelling System (ADMS), developed by Cambridge Environmental Research Consultants (CERC), and AERMOD, developed by the US Environmental Protection Agency (USEPA).

These models predict ground-level concentrations for each pollutant and consider measured background air quality and other facilities with consent to understand cumulative impacts.

Modelling studies must assume the following worst case operational scenarios.

• Pollutants continually discharged at the upper end of the BAT-AEL26 range (daily average emissions or over sampling period for parameters which are not continuously monitored) or the Annex VI ELV (half-hourly), as appropriate)

• No allowance is made for downtime or maintenance – the plant is assumed to operate 100% of the time.

• Volatile Organic Compounds (VOCs) are discharged at the emission limit assuming 100% of the emission was either benzene or 1,3-butadiene.

• Pollutants where no emission limit is specified are modelled at typical / maximum concentrations for operating incineration facilities.

• Concentrations are converted to grams per second by multiplying the concentrations by the stack flow rate.

The predicted ground-level concentrations of pollutants, known as the process contribution (PC) from modelling, is risk assessed according to the methodology in IPPC H1 Guidance to understand the scale and extent of any impact. This includes comparison with the relevant Air Quality Standards and Objectives (AQS and AQO) and Environmental Assessment Levels (EALs) set for the protection of human health.

The impact of emissions from a proposed installation must also be assessed for local sites which have a conservation designation (such as Site of Special Scientific Interest – SSSI). A stack height screening assessment must be undertaken to determine an appropriate stack height for the proposed incineration or co-incineration installation. This is carried out as part of the modelling exercise with a sensitivity analysis undertaken for a range of stack heights. The stack height is a crucial variable in making sure emissions disperse effectively and do not exceed local air quality objectives.

Examples of these assessments can be found in the decision documents for incineration facilities which are publicly available. The most recent include;

• Westfield - 1181922 | Scottish Environment Protection Agency (SEPA)

• Earls Gate - 1157446 | Scottish Environment Protection Agency (SEPA)

• FCC Drumgray - FCC Recycling (UK) Limited: Drumgray Energy Recovery Centre – PPC Permit application - Scottish Environment Protection Agency - Citizen Space (sepa.org.uk)

Tolvik's statistical analysis of incineration facilities across the UK in 2020 shows that across all continuously monitored emissions27 to air, emissions were 29.1% of the ELV on average and for periodically monitored emissions28, emissions were 8.1% of the ELV on average. This result shows that actual emissions are, on average, well below those used in the dispersion models and risks assessments. This is consistent with the annual reports currently being submitted to SEPA for 2021 – examples can be provided.

Surface water impacts

Modern incinerators are constructed so that all process equipment is located inside the building, this includes the abatement equipment for most of the more recent constructions. This allows uncontaminated surface water to be segregated from any contaminated surface water generated inside the building, for example from washing surfaces.

Outside the process building, uncontaminated surface water is segregated from potentially contaminated surface water associated with tanker offloading and bulk storage of fuels and chemicals by containment/ bunding. Uncontaminated surface water from yard and road areas is treated via interceptors and a Sustainable Urban Drainage System (SUDS) prior to discharging directly, or indirectly, to the water environment.

Fire water containment measures are incorporated into the design for internal and external areas and a penstock valve is typically installed to enable isolation of site drainage in the event of a fire, spill etc.

Any discharge to the water environment of uncontaminated surface water is subject to routine monitoring. Additional surface water conditions include regular inspection of impermeable surfacing, containment structures and pollution control equipment to ensure these remain in good condition, the maintenance of site drainage plans and the implementation of a surface water, drainage and spillage plan to prevent the release of pollutants to surface water or site drains from spills or leaks.

Soil and groundwater impacts

Appropriate techniques must be in place to prevent any pathways for contamination of hazardous substances to soil or groundwater. This is aided by enclosure of most of the process and good design, construction and maintenance standards for concrete hardstanding and storage areas for handling and storage of wastes and residues inside the building, for example, and impervious surfaces and kerbing for site roads, yard areas etc.

A baseline report is also required to identify levels of any hazardous substances in different zones in ground/groundwater prior to commencement of commissioning. Soil and groundwater are then subject to periodic monitoring throughout the life of the Permit and in accordance with sampling plans approved by SEPA. On cessation of operation, the Operator must demonstrate that they have not caused any deterioration to soil and groundwater conditions since the initial baseline report.

Incinerator Permits include a general requirement that there shall be no emission of any pollutants to groundwater or soil from the permitted installation and any records of relevant incidents must be retained for the life of the Permit.

Arisings of solid residues

Incinerators generate residues typically in the form of Incinerator Bottom Ash from the incineration process and Air Pollution Control residues (APCr) which are collected from the abatement equipment and comprise a mix of lime or sodium carbonate to neutralise acid gases, and powdered activated carbon used for treatment of volatile heavy metals and organic compounds including dioxins and furans in exhaust gases, and particulate matter collected from bag filters which will contain traces of pollutants collected on the surface of the bag. Scrap metal may also be collected from the IBA stream following the ash cooling step where it is recovered for recycling. Depending on the technology, other residues may be produced e.g. char or oversize tramp material from pyrolysis or gasification, cyclone ash etc

Significant progress in the last two years has been made in treating IBA so that it can be reused as a secondary aggregate. Where this option is not available then IBA may be sent to non-hazardous landfill. Treatment options are available to convert APCr into an aggregate in England, although there are currently no facilities in Scotland so this may be sent to hazardous landfill for disposal. Research is ongoing into additional options for re-use of IBA and APCr such as in grout as an alternative to pulverised fuel ash from coal-fired power stations.

Summary of BAT review implementation

The BAT Conclusions guidance for waste incineration and co-incineration plants (the WI BATCs) was published on 3 December 2019. This includes a set of 37 BAT Conclusions the majority of which apply to potential environmental impacts of waste incineration although a small number are specific to IBA treatment.

Under Article 21(3) of IED, all new applications for waste incineration and co-incineration plants received after 3 December 2019 must meet the requirements of the WIBATCs for new plants from the issue date of the Permit. All other plants, known as existing plants, must have their Permits reviewed by SEPA so that the requirements of the WI BATCs take effect 4 years from the date of publication, i.e. by 3 December 2023. SEPA is intending to initiate the BAT review for existing plants during Quarter 1 2022. The WI BATCs apply to incineration and co-incineration plants with a capacity exceeding 3 Tonnes per hour or 10 Tonnes per day of non-hazardous or hazardous waste respectively.

A UK Interpretation Document on the WI BATCs has been developed by UK Regulators including SEPA. The UK Interpretation Document explains how the BATCs will be implemented in practice.

Areas where standards are tightening

A key requirement of the WI BATCs is to revise ELVs for Emissions to Air in line with BATAssociated Emission Levels. For the majority of pollutants including NOx, particulate matter, heavy metals and dioxins and furans, this will result in a tightening of the existing ELVs.

Other requirements include implementation of BAT-Associated Energy Efficiency Levels (BAT-AEELs) to ensure that plants meet minimum requirements for energy efficiency. There will also be a requirement for 3 samples to be collected during extractive monitoring. The results are to be averaged for comparison to ELVs – this is to improve the statistical robustness of the data collected.

If existing plants cannot meet any of the requirements of the BAT-AELs they will need to apply for a derogation to SEPA although this would only remain effective until the next BAT review.

Further improvements we’d like to see

SEPA would like to see further reductions in NOx emissions from incineration and co-incineration plants. There is some evidence that new and existing incineration and co-incineration plants can achieve emission levels below the upper end of the BAT-AELs with an ELV of 100 mg/Nm3 being set for applications for new incineration and co-incineration plants received from October 2021 compared to the 120 mg/Nm3 at the upper end of the BAT-AEL for new plants. This is consistent with the approach of all UK Regulators to implementation of the WI BATCs as detailed in the UK Interpretation document on the Waste Incineration BATCs

SEPA would also like to see further support for connection to district heat networks and/or to industrial users to maximise the energy recovery efficiency in line with both the energy recovery targets in SEPA's Thermal Treatment of Waste Guidelines and the BAT-AEELs in the WI BATCs.

Environmental Issues - Landfills

The Landfill (Scotland) Regulations 2003 and their amendments in 2003 and 2013 implement the Landfill Directive and set standards for the design and operation of landfills. Landfill sites must be classified as hazardous, non-hazardous, or inert.

All operational landfills are regulated under PPC and must be fully engineered. There are also older, closed landfills that were previously regulated under WML, but these no longer accept waste. In Scotland, many operational landfills also include older closed phases that are unlined or are not lined in accordance with current standards. This can complicate the management of environmental risks.

Groundwater Impacts

Currently operational landfills must comply with the requirements of the Landfill (Scotland) Regulations 2003. These include minimum requirements for lining system design, capping and leachate management as well as monitoring. However, it is important to recognise that even a fully engineered landfill that has been constructed and operated in accordance with these regulations will still leak, albeit at a much slower rate than the older unlined 'dilute and disperse' landfills. Landfills therefore pose a long-term risk to the water environment, particularly groundwater, but also other receptors such as surface waters or wetlands via groundwater baseflow. Risks to the water environment from landfills are predicted to persist for decades, possibly hundreds of years.

Surface Water Impacts

Once a landfill site has been constructed and waste deposited, the key tool for protection of the water environment comprises active leachate management to maintain leachate levels within the cells to permitted levels. Leachate extracted from landfills is typically either treated on site and discharged to the water environment or discharged to sewer for treatment at a nearby wastewater treatment works. A few landfill sites in Scotland tanker their leachate for off-site treatment. In the past, leachate treatment in Scotland has focussed primarily on addressing biological loading and key contaminants such as ammoniacal nitrogen. In recent years, there has been increasing awareness of the potential limitations of traditional leachate treatment systems for managing the risks associated with persistent contaminants. Treated leachate effluent may therefore still potentially pose a risk

	to the water environment. The scale of the risk will depend on the level of treatment and the sensitivity of the receiving water environment. <u>Gas Management</u> Landfill capping and gas management systems help manage the risks posed by landfill gas. As well as methane and carbon dioxide from degradation of biodegradable wastes, landfill gas may include other volatile contaminants. Whilst gas generation rates remain sufficient to make gas utilisation commercially viable, the gas risks will usually be actively managed. However, as landfills age, gas generation rates reduce and consequently the technical and commercial feasibility of active gas generation will lessen. Passive gas risk management measures are required during aftercare. Note that gas management is required at landfills for the safety of site users and neighbouring communities with respect to explosion and asphyxiation risks as well as due to consideration of climate change. The environmental risks associated with landfills persist for many years, well beyond the operational period. Once cells are full, capped and restored, active site management will be required. This phase of aftercare may last for several decades. Passive mitigation measures are then required to manage the longer-term risks prior to permit surrender. Other impacts associated with landfills include odour, noise, dust, litter, and vermin. These impacts are of greatest concern whilst landfill sites are operational. Closed and fully restored landfills are less likely to cause nuisance. <u>Additional considerations</u> Incineration is potentially a more effective treatment method than landfilling for some persistent organic pollutants (POPs) that may be present in residual wastes. The environmental risks posed by POPs in landfill leachate are expected to continue for decades, potentially hundreds of years.
Other	Other aspects that the Review may wish to consider in regards of Residual Waste treatment options would include: MBT – the scale and availability of markets for both recyclates and Residual Waste recovered from MBT processes; MBT – the carbon impact of the equipment and machinery used in processing Residual Waste at MBT plants; Cement Kilns – the use of Solid Recovered Fuel (SRF) at Cement Kilns in the UK and/or Europe as an alternative fuel for making of cement products.

Individual	The individual states that they do not have such information, but that SEPA should have more power to regulate.
Individual	The individual states that the Environmental Impact Assessment of the local proposed incinerator development stated that emission fallout would impact our local SSSI and a designated site of wildlife and landscape importance. Without carrying out a detailed field based Ecological appraisal the conclusion was reached that the emissions would not significantly change already impacted sites. The local Health Authority representatives have objected to the proposed incinerator stating great concerns on respiratory effects. The individual states that the local landfill has been reported on numerous occasions relating to the release of Methane. SEPA have responded and remedial work has been carried out.
Individual	The revisions to the BAT conclusions in the BREF for Waste Incineration are relevant for e.g., NOx. These were issued late in 2019. It would be useful to understand how many permits of existing facilities have been revised, and whether all permits for new facilities have reflected / will reflect these updated limit values. In particular, given its relevance to air quality, how have permits been updated / issued to reflect the new limit values for NOx, and have the permits for all new facilities required the use of selective catalytic reduction to abate NOx? A matter which the BREF addressed inadequately, in the individual's opinion, is the threat from brominated dioxins and furans. These are not currently regulated (only the chlorinated ones are). There are good reasons to be concerned about this given the use of chemicals that may be precursors as, for example, flame retardants. The arrangements for handling ash residues of various types from incineration facilities also deserve closer inspection, though they may also offer additional opportunities for value extraction. In terms of operating landfill sites, the approach that the UK deployed to interpret the term 'treatment' under the Landfill Directive was, in the individual's view, a disgrace. As climate scientists consider the effects of so-called short-lived climate pollutants in contributing to (short-term) climate change, it seems clear that landfilling should occur only where wastes are treated (where they need it) so that the extent to which they generate methane can be reduced such that the residual flux can be largely eliminated using suitable cover layers. In terms of closed landfill sites, ones in coastal locations are increasingly at risk of discharging pollutants and wastes into seas. The aftercare requirements should be rigorously enforced (and relevant financial provisions required).

10.8 Call For Evidence: Question 16 Summary

Category	Q16: Do you have any evidence that the Review should consider in comparing the other (non-climate) environmental risks of options for residual waste treatment in Scotland?
Local Government	None.
Local Government	No information to add.
Local Government	No evidence to provide.
Local Government	N/A.
Local Government	Of the current technologies available, EfW offers the most comprehensive treatment measure for all forms of biodegradable wastes. Other technologies, e.g., composting, anaerobic digestion, MBT etc. can offer improved biostability but are likely to have varied degrees of performance depending on material type.
Local Government	The operational and financial viability of alternatives to EfW that are capable of meeting our carbon reduction targets need to be carefully considered.
Local Government	No evidence.
Local Government	Non-climate environmental risks of treatment options have been considered widely over many decades and the current regulatory system addresses these for proven technologies, especially thermal treatment. Bio-aerosols from bio-stabilisation processes are less well studied because of the relative rarity of these activities, however, the authority is not aware of any evidence that the current regulatory system is insufficient in this respect.

Local Government	The authority is not aware of any evidence that the current regulatory system is insufficient in this respect.
Local Government	No response.
Professional body, trade organisation or governing body	It is not entirely clear what value there is in presenting a comparison of compliance scores of landfills against EfW. All this will show is that there are far more permitted landfill sites in Scotland than EfW plants and that landfill sites have multiple emission points over a much larger footprint. Also there is inherently greater scope for non-compliance at landfill sites than at EfW plants. Points to consider when comparing options are: • Reliability of technology • Availability • By products • Raw and auxiliary materials • Safety record • Maintenance • Decommissioning • Aftercare in terms of landfill • Accident risk – fire, explosion etc • Health issues i.e. bioaerosols at MBT and ultra-fine particles at other facilities
Professional body, trade	It is not entirely clear what value there is in presenting within the review a comparison of compliance scores of landfill against EfW. This only serves to show that there are far more permitted landfill sites in Scotland than EfW

organisation or governing body	and, as sites with multiple emission points over a larger footprint, there is inherently great scope for non-compliance at landfill than at EfW.
Professional body, trade organisation or governing body	Both of the following studies are typical of LCAs on this question. Both demonstrate the need for system specific LCA. Both suggest value from MBT but like almost all LCAs we have noted on, neither addresses the issue of residual waste management in an evolved system of integrated recycling systems covering kerbside DMR collections, green waste collection and food waste collections evident in Scotland. These are factors that affect the financial viability and performance of MBT. MBT therefore needs to be considered in terms of a Scottish specific context, and there are no studies we have seen that do this. It is also worth noting that many older studies are comparing EfW in terms of emission limits that have undergone further iterative limit reductions under the BREF process. 1. Review of life-cycle environmental consequences of waste-to-energy solutions on the municipal solid waste management system Resources, Conservation and Recycling Volume 157, June 2020, 104778 2. Life Cycle Assessment for Landfill, Incineration and Mechanical Biological Treatment of Residual Waste for Krakow City (Poland)
Professional body, trade organisation or governing body	No response.
Professional body, trade organisation or governing body	Maximising the recycling of residual waste in cement manufacture in Scotland delivers social and economic benefits, as well as environmental ones. Cement production at Dunbar reduces demand for imports, supporting security of supply, cutting carbon and contributing to homegrown economic prosperity. Cement manufacturing provides training and development opportunities for young people, leading to high skill jobs. Cement mainly finds use in concrete. Concrete is essential to delivering social and economic infrastructure and vital to the continued strength of local and national economies. As concrete is in demand and available throughout Scotland, it creates jobs and supports communities all over the country. The national and local economies could not function without concrete products which touch virtually every aspect of our lives in housing, schools, hospitals, roads, rail, power stations, ports and airports.

Professional body, trade organisation or governing body	No comment.
Business that operates one of more incineration facilities in Scotland	No comment.
Business that operates one of more incineration facilities in Scotland	No response.
Business that operates one of more incineration facilities in Scotland	A suitable route for ash "disposal" - i,e., recovery must be considered. De-regulation of "ash” as waste, towards being seen as a resource (mineral source, precious metals) may see a commercial switch to "recovery", currently prohibited by the complexities of "waste classification".
Business that operates one of more incineration facilities in Scotland	No comment.

Business that operates other (non-incineration) residual waste treatment facilities outside of Scotland	No specific comment.
Business that does not operate a residual waste treatment site but produce waste that ultimately is treated at one	No comment.
Not for profit environmental organisation	Once developed, SWEFT could be an option for considering these risks.
Environmental Group	Failure to extract the maximum achievable volume of reusable and recyclable materials from the waste stream before incineration will lead to the loss of valuable resources, many of which are finite on this planet, alongside the climate impacts. So it is a double whammy against our future on the planet.
Environmental Group	No response.
Environmental Group	Incineration has non-climate environmental risks. Some of these, such as air pollution, dioxins and hazardous ash are well understood and documented. Emissions include dioxins, NOx and ultrafine particulate matter that can be harmful to both human health and the natural environment.

	Importantly, the societal risks of CCS are rarely discussed. Piping CO2 poses risks similar to those associated with fossil fuel pipelines, from land disturbance and water contamination to the danger of explosions and other accidents. The IPCC recognizes that “carbon dioxide leaking from a pipeline forms a potential physiological hazard for humans and animals”.
Environmental Group	There is evidence that heat networks based on incinerators are expensive and unreliable for the communities forced to use them, for example heat supplied by London’s Beddington incinerator. Which has produced a paper setting out a number of recommendations to Government, including improved regulation of the market and fair pricing, to ensure that consumers with district heating are getting a fair deal.
Environmental Group	Response covered in the other questions.
Other	Nothing up to date.
Other	See response to question 15.
Other	No response.
Individual	N/A.
Individual	The individual refers to the Ayrshire and Arran NHS response to the planning proposals for a Waste to Energy Park.
Individual	See attached documents to my response.

10.9 Call For Evidence: Question 17 Summary

Category	Q17: Do you have evidence or experience of the community impacts (positive and negative) of different residual waste treatment options, e.g. landfilling compared to incineration, that you could share?
Local Government	There is a view amongst residents that an MBT facility is a ‘recycling facility’, rather than a residual waste processing facility. It may not be clear to residents that MBT is the first step in processing residual waste, and that only a small proportion of residual waste is actually recycled.

Local Government	The authority undertook a desktop assessment of continuing the status quo with regard to residual waste management (landfilling) against creating an EfW facility and using the electricity and heat outputs. The methodology (multi criteria analysis) used was that outlined in the Scottish Government's Guidance on Strategy Level Socio-Economic Assessments. Weightings, however, were adjusted to reflect corporate priorities. The assessment suggested a more positive socio-economic impact through creating a local EfW CHP facility and utilising its heat and electricity outputs to support subsequent development. This initial report considers that there could be the potential, based on a cornerstone EfW CHP development in the local area, for subsequent ancillary developments including, a heat network to augment development to the east of the city, the possibility of re-siting depots and creating electric vehicle charging infrastructure, and looking into whether it is feasible to develop hydrogen production from the EfW outputs. A development programme to take forward the necessary analysis and assess the feasibility of this package of potential opportunities is intended, subject to the outcome of this current Scottish Government review.
Local Government	The authority mentioned that they receive community benefits as part of the residual waste contract, however we are unable to share this information as it is subject to commercial and operational sensitivity or to legal restrictions.
Local Government	N/A.
Local Government	No direct experience of incineration. Operation of AD Plant and (historic) in-vessel composting treatment facility has had little of no community impact.
Local Government	Landfill Positive: rarely close (meaning operationally effective in terms of waste delivery), can be a source of energy production through Methane capture, income generation for Scottish Government through landfill tax, planting of trees in aftercare projects enhancing Carbon production, highly regulated (SEPA) Landfill Negative: odour issues, wind-blown litter issues, dust and detritus issues, rarely close meaning constant operation of large vehicles in and around local area. Incineration Positive: vastly reduced odour, no wind-blown litter, no dust or detritus, high in energy production as a source of income and the potential for heat off takes. Incineration Negative: no income generation for Scottish Government (affecting potential budget allocation), rarely close meaning constant operation of large vehicles in and around local area.

Local Government	No evidence.
Local Government	Members of the local authority team have worked in many areas of residual waste treatment and have experienced situations where even well-run landfill sites have inflicted severe amenity impacts on local communities, e.g., malodour, vermin, traffic on rural roads and noise. There is little evidence that this is the case for EfW. Dundee and Lerwick (both long term operations) demonstrate that there is little public concern or objection voiced about these facilities once they are operational. Often the prospect appears to be much worse than the reality. Correctly sites EfW facilities also have the potential to help communities suffering from fuel poverty through the provision of low and stable cost heat. EfW, through public procurement activities, often deliver structured and extensive community benefits throughout the contract period; such requirements are less evident in landfill contracts.
Local Government	The authority has experience of many areas of residual waste treatment including landfill, RDF and incineration. It is difficult to accurately understand what the community impacts are, either for those living near to a waste facility, or further away. There is a perception that waste is bad and harmful, and that can be the case of course, however, the authorities experience is that the perception is usually much worse than the reality with communities quickly accepting new facilities once they are up and running. The lack of understanding and knowledge of the technicalities and practicalities of waste management from the public is a factor in this and more could be done to share information and knowledge and raise the awareness of this activity. The authority does not have any evidence to suggest that the community impact of one type of facility/treatment is any worse or better than others.
Local Government	Historically landfill sites have resulted in a negative impact on local communities in the form of odour, dust, noise vermin and traffic and due to operating models and procurement of services there was very little community benefits received from the operator. In relation to EfW's there is little or no evidence to support the negative impact of facilities to the local communities however with the public procurement process for new treatment and EfW facilities there are extensive community benefits such as education, training etc delivered through the contract period.

Professional body, trade organisation or governing body	Socio-economic benefits arising from the development and operation of EfW facilities are well documented. During construction, these facilities create many hundreds of skilled and semiskilled jobs. While some of these require specialist contractors, who move from project to project across the world, there are many jobs for locals either on site or through supply chain opportunities. With an increased development pipeline across the world, local experience can result in significant social mobility. During operating years, around 40 on-site high skilled and professional jobs are created and sustained. With EfW plants being long-term investments with secure futures, there is long-term job stability, which does not exist in many other sectors. Major Local Authority contracts have a requirement to include community benefits within their contracts. This has resulted in the existing Scottish EfW plants building good relationships with their local communities offering funding and labour to local groups, as well as education/ training opportunities.
Professional body, trade organisation or governing body	The generic impacts associated with any residual waste treatment are well documented and are broadly similar across both treatment options. EfW presents greatest employment opportunities of the two, with a typical sized Scottish EfW plant (150-200kt) expected to generate around 40 permanent jobs, and with approx. 300 jobs in construction. There are also generally opportunities for apprenticeships, as well as local supply chain opportunities. Local authority contracts tend to stipulate that EfW operators demonstrate community benefit, and which has resulted in EfW operators establishing and maintaining good relationships with their local communities, offering funding and support to local groups as well as education/training opportunities.
Professional body, trade organisation or governing body	Only empirical evidence on the direct impacts from landfill. Odour from landfill has impacted many communities proximate to landfills. The complex composition of landfill gas has significant potential for health impacts and is one of the many reasons landfill should be restricted as a residual treatment option. MBT facilities also have odour risk issues as well as the potential for ‘fly’ problems which can impact local communities. On the benefits side we would suggest that society at large benefits from the safe management of residual waste given its regularity and scale. Anything impeding the safe management of residual waste would have immediate impacts on communities in general. More could be delivered in terms of direct financial benefits to local communities from schemes similar to those operating for wind farms. The body would support a consistent approach to community benefit payments from incinerators based on the scale of the facility.

	In comparative terms to landfill or MBT, incineration facilities offer significantly greater employment opportunities and the opportunity to drive co-located business opportunities (and further employment) from private grid power and heat supply services.
Professional body, trade organisation or governing body	No response.
Professional body, trade organisation or governing body	There have been a number of extensive studies that show there are negligible air quality and public health impacts from the use of residual wastes in cement manufacturing. For example, the Committee on Medical Effects of Air Pollutants (COMEAP) concluded that the use of waste derived fuels during cement manufacturing does not have additional health impacts when effective controls were in place. Public Health Wales concluded that the health indicators around the Padeswood cement plant were as good or better than the average for Wales. The use of waste derived fuels in cement manufacturing is considered a 'Best Available Technique' for cement manufacturing and therefore is advocated under Integrated Pollution Prevention and Control legislation.
Professional body, trade organisation or governing body	No comment.
Business that operates one of more incineration facilities in Scotland	A typical sized Scottish EfW plant (150-200kt) could be expected to generate around 40 permanent jobs, and approximately 300 jobs in construction.
Business that operates one of more incineration	Consideration of community impacts from waste management infrastructure needs to take into account both economic and environmental factors. In considering economic impacts, it's important to acknowledge the positive contribution made to communities through the Scottish Landfill Communities Fund, which is linked to the Scottish Landfill Tax (SLfT). This sees

facilities in Scotland	landfill site operators provide contributions to Approved Bodies, who can then pass the funds onto community and environmental projects. Contributions totalled £40.3m between 2015 and 2020. As a landfill operator, the business has a long history of providing benefits to community organisations and projects through our participation in this scheme. The impending landfill bans scheduled by Scottish Government for 2025 will see a sharp reduction to this income stream and the associated community benefits it generates. By contrast, energy from waste facilities are not subject to taxation in the same way as landfill - but still have the potential to generate significant economic benefits to the communities in which they operate over the long term. For example, Barr's proposals for the Killoch Energy Recovery Park in East Ayrshire represent an inward investment of around £100m, representing opportunities for local suppliers of goods and services both during construction and then many years of operation. The cascade of this significant investment can be shown in our current planning application (Planning Application 21/0369/PP) to be of economic benefit to communities locally and regionally. In addition, once operational, our facility will contribute significant levels of business rate payments to the local authority each year and add further value to the local economy through the creation of new, long-term and well-paid jobs. In the case of our proposal, economic benefits of energy from waste must also be considered in light of the opportunity costs should local authorities not develop regionally accessible energy from waste capacity. The alternative would be for authorities to either transport its waste further afield, to an energy from waste facility elsewhere in Scotland, or send it to landfill in England, both of which will significantly increase their costs - that in turn will be placed on to the communities they serve. This, of course, assumes capacity is available elsewhere – local authorities may not be able to secure the capacity they need and - if their waste is being dealt with outside of their own local authority area, then they would be paying to have their waste managed in a different local authority area. The impact of this on the community would be the resulting loss of local jobs, the potential for local power and heat use, or other direct community benefits, such as support for local groups and organisations. Turning to the environmental impacts of waste management, it should be considered that the community impact of energy from waste represents a moment in time, at the point the waste is collected and processed. The environmental impacts of landfill (in terms of emissions to air, for example) last for decades.

	In a scenario whereby insufficient local residual waste management capacity is available to East Ayrshire post 2025, we have already acknowledged within this response that waste will need to be transported further to its point of processing. Transporting this waste further from its point of arising leads to an unnecessarily larger carbon footprint, due to increased road traffic emissions, as well as putting a greater volume of HGV traffic on the road. Both will have a long term impact on local communities across the region
Business that operates one of more incineration facilities in Scotland	EfW positive response, increasingly welcomed vs landfill (once unfounded fears over emissions are overcome).
Business that operates one of more incineration facilities in Scotland	The business can point to the detailed studies carried out for the purpose of seeking planning permission and which include 'Human Health Risk Assessment Report' which is publicly available.
Business that operates other (non-incineration) residual waste treatment facilities outside of Scotland	Many more employment opportunities are likely to be increased and improved recycling services that residual waste treatment. This would include all stage of recycling collections by Local Authorities, sorting and segregation at MRFs and then at reprocessing sites.
Business that does not operate a residual waste	No comment.

treatment site but produce waste that ultimately is treated at one	
Not for profit environmental organisation	No response.
Environmental Group	No evidence to share.
Environmental Group	See UKWIN report.
Environmental Group	No response.
Environmental Group	No response.
Environmental Group	Job creation can be considered a positive community impact, and in light of this it would be useful for the Review to consider evidence of how options other than incineration and landfill can result in the creation of far more by way of jobs (especially when account is taken of the land take associated with incineration facilities and landfill sites). There are numerous studies showing that many employment opportunities could arise from a more circular economy. A small selection of recent studies include: • 'Levelling up through circular economy jobs' (August 2021) by Green Alliance, which shows how "Greater government ambition for an effective and expanded circular economy by 2035 would create hundreds of thousands of new jobs… we estimate that the government could help to create over 450,000 jobs in the circular economy by 2035". • 'Effects of the Circular Economy on Jobs'104 (November 2020) by the International Institute for Sustainable Development, which refers to many other studies.

• ‘London's circular economy route map’ (March 2021) by Circular London (ReLondon, formerly known as the London Waste and Recycling Board), which states: “By 2036, the circular economy could provide London with net benefits of at least £7bn every year. These benefits would be in the sectors of built environment, food, textiles, electricals and plastics. The circular economy could also generate 12,000 net new jobs in the areas of re-use, remanufacturing and materials innovation”.

‘Zero waste and economic recovery: The Job Creation Potential of Zero Waste Solutions’ (February 2021) by GAIA similarly highlights the job creation potential of the circular economy and states: “…zero waste approaches create orders of magnitude more jobs than disposal-based systems that primarily burn or bury waste. Indeed, waste interventions can be ranked according to their job generation potential, and this ranking exactly matches the traditional waste hierarchy based on environmental impacts (Figure 1). These results demonstrate the compatibility of environmental and economic goals and position zero waste as an opportune social infrastructure in which investments can strengthen local and global economic resilience. This study also finds evidence for good job quality in zero waste systems. Multiple studies of zero waste systems cite higher wages and better working conditions than in comparable fields, and opportunities to develop and use varied skills, from equipment repair to public outreach.”

Communities living near incinerators have many complaints that arise during construction, pre-operational testing (commissioning) and full operation, including:

Noise, vibration, plume, flies and odours – These disamenities are often downplayed by operators during the planning and permitting application stages, however when problems do occur some of these same operators dismiss the problems as inevitable or unavoidable. Press coverage reflecting some of these problems with incinerators include:

• In Runcorn, where waste is delivered by rail, it was reported that: “one resident said she faced daily noise from cargo trains en route to deliver the waste to be burned, well into the evening” and that: “It’s unbelievable – you can lie in bed at night and feel the vibration of the train as it goes past but it goes that slow it takes about two to three minutes to come past through the station.”

• It was also reported in Runcorn that: “Around 100 people attended a meeting…to protest over the noise, smell, steam and pollution from the plant.” quoting one resident saying: “I’ve been awake most of the night and I’m losing the will to live. Then wagons beeping their horns this morning followed by banging of containers“. The organiser of the meeting is quoted as stating: “People feel trapped. It’s gone from a place where they could sit in their garden to closing doors and windows because it stinks”. This report also quoted the local MP as follows: “People have been complaining about a droning noise disturbing their sleep. These are genuine concerns about the vapour, noise and smells.”

• In Derby, one resident stated: “Where we are, the stench is really strong and smells like rotting food. We have been getting loads of flies around here as well. The summer has been horrendous, we have had to keep our windows closed in the hot weather because when we open them it is just awful.” It was also reported that: “Bad smells from the controversial Sinfin waste treatment plant are still plaguing residents almost a year after the stink first started. Last August, residents and businesses near to the plant complained to the Environment Agency about a compost-like smell shortly after waste arrived for pre-opening commissioning. They were told the smell would disappear and was due to waste being stored on the site ahead of testing. But the smell has continued to plague residents – especially during the recent warmer weather – despite earlier promises from the operators that there would be no smell off-site from the facility”.

In Derby, the operator stated: “we acknowledge…that some nuisance has been caused especially overnight when background noise levels are lower, and the warm weather leaves residents understandably wishing to have windows open”.

• In Gloucestershire, the operator stated in relation to hot commissioning that: “During this period, up until the facility is fully operational in summer 2019, there will be occasional loud noises, which sound similar to when you bleed a radiator, and plumes of steam as the first combustion gases are pushed through the ducting to test all systems”.

• An incinerator in Plymouth has also generated numerous complaints from local residents, with one commenting to the Plymouth Herald that: “The summer was awful, all the flies, the rubbish, the smell. I am looking to move because we have had enough of it”, and another stating: “It smells, it makes me feel sick”. According to an ITV report: “Residents nearby have complained about the smell, the noise and flies in their homes. They say their worst fears have been realised”. It was also reported that: “A ‘rotten smell’ was frequently emitted when first constructed, and still occurs in the summer”.

Light pollution – Bright lights are typically placed towards the top of the incinerator stack to reduce the risk of aircraft collision. This is a constant reminder of the incinerator and a source of distress to many residents. For example, it was reported in Runcorn that one resident: “said she now lives with her curtains drawn at night to block the lights from the site, which include a pair of red lights like eyes peering from the top of the main chimney stack, from shining into her home and bedroom, having previously enjoyed looking out at the trees behind her home and the site”.

Visual impact of the chimney stack and building – Incinerators are often seen as a blot on the local landscape and a constant reminder of the pollution that they cause. For example, one local newspaper article about an incinerator in North Yorkshire described the Allerton plant as one which "dominates the skyline of the main road to the North" quoting a councillor as stating: "A lot of people do feel it is a blot on the landscape, I'm astonished that it can be seen from so many places".

Traffic – In addition to increases in the general volume of traffic and the pollution that this brings, some of those living near incinerators have observed HGVs ignoring planning conditions designed to control adverse impacts.

For example, lorries delivering feedstock sometimes travel along routes that are disallowed by planning conditions, despite assurances made at the planning application stage that this would not happen. In other instances, after planning permission is granted on the basis of strict controls over when and where the HGVs can travel, it is not unusual for operators to seek to change the arrangement to enable increases in the number of vehicles, extensions of the time these vehicles are permitted, and expansion of the routes that they are allowed to take. Such changes are often allowed under delegated powers without any community consultation, even in circumstances where the changes directly break promises made to the community about how traffic impacts will be strictly controlled.

Broken promises, misinformation and lack of transparency – In addition to the broken promises referred to above in relation to disamenities, there are various other instances where operators behave differently to how they said they would during consultations or where operators have not acted with full candour. For example:

• Operators routinely state that inverse pressure will be used in buildings to avoid noise and odour issues, with doors being mostly shut, but then too often the operators end up leaving doors open for operational reasons which results in disamenities to neighbours.

• Areas have faced real-world reductions in recycling rates despite assurances that the incineration plant would only be used for "non-recyclable" waste. In some cases, this is a result reduced recycling services once the incinerator is in place.

• Liaison groups set up with the stated purpose of engaging with the community are often not informed of forthcoming changes to planning permissions and environmental permits, e.g. proposals to increase capacity. Those who ask tough questions are often excluded from liaison groups, and applicants often use participation in the liaison group as evidence of 'community support' for the facility (even in circumstances where the operator promised that they would not do so). In many cases, liaison groups are given the promise of helping to design the proposal but end up having influence over the location, capacity and technology choices adopted by the operator.

	• Operators often try to give the impression that all emissions are continuously monitored when in most cases emissions of concern, such as dioxins, are only monitored a few times a year. Even in cases where operators have carried out compositional analysis of what they are burning, they often do not publish this information and will not release it to the public when this information is requested. Inadequate responses to complaints – When communities face serious nuisance from an incinerator, residents who reach out to the operator are too often greeted with denials that the problems are caused by the incinerator. Even when the operator is subsequently found to be at fault, these operators rarely apologise for having denied the issues were their responsibility. It is extremely rare for an operator to provide any compensation for the nuisances that they cause. Property values – Whether or not the loss of property value is a material planning consideration, it is not unusual for houses prices to fall when there is a proposed or actual incinerator. There are numerous instances where residents have reported experiencing difficulty selling their property due to the threat of an incinerator. Operators do not tend to compensate residents who have suffered financially as a result of incinerators or incinerator proposals. Problems with district heating schemes including: • Outages, where residents are left in the cold due with no heating or hot water, e.g. because of an unplanned incinerator shut-down. • Costs, where residents may be tied into paying above-market-rate prices for their heating. Residents often do not have alternative means of powering their heating system (e.g. they have no boiler), and they are contractually obliged to pay for the heating network. • For an account of some of the problems associated with the Sutton Decentralised Energy Network (SDEN) associated with London's Beddington incinerator as conveyed by Elliot Colburn MP to Parliament on the 4th of February 2022 see the Hansard record.
Other	Nothing up to date.
Other	The numbers of complaints due to odour, dust and vermin are likely to be significantly lower for waste incineration or co-incineration than for a landfill site. Numbers of noise complaints may be higher due to the presence of more potential sources of noise. Community impacts and numbers of complaints will vary from site to site depending on their proximity to sensitive receptors as well as how well these are designed, maintained and operated.

Landfill

Odour

Landfills can result in community impact throughout their life cycle. During the operational phase, when wastes are deposited, communities can be negatively impacted by nuisance issues such as odour, dust, noise and vermin.

Odour is a significant environmental cause of public complaints of people living near waste treatment facilities and negatively affects quality of life and wellbeing. Odour can be a cause of stress and anxiety, even when the substances causing the odours are not harmful to health at the levels detected at waste treatment locations.

Landfills, and specifically landfill odour, account for a significant proportion of public environmental event complaints made to SEPA. In extreme cases, where sites are poorly operated, or have specific gas management issues to address, this has resulted in several hundred public complaints in a single day.

Three operational landfills are currently classified by SEPA as sites of ongoing community impact. In 2021, these sites alone accounted for 987 substantiated complaints to SEPA.

In 2010, SEPA published guidance for dealing with odour29. The Guidance relied on scientific evidence gathered from systematic literature review study. Page 7 outlines SEPA's view of the health impacts of odour after a systematic review of evidence.

Waste Incineration

Odour

Whilst odour complaints are occasionally received for incineration or co-incineration plants these are usually low numbers, e.g. typically below 5 per annum with few being substantiated.

The key source of odour is from the handling and storage of incoming waste. This is tipped from refuse collection vehicles or articulated lorries into a below ground waste bunker or a ground-level storage area inside an enclosed waste reception building which is fitted with fast acting doors which remain closed except when a vehicle is entering or exiting and which is kept under negative pressure to prevent escape of odour emissions outside the building.

During normal operation potentially odorous air inside the waste reception hall is extracted by the primary air fan and used as combustion air in the incineration process so that any odours are destroyed during incineration.

Permits include a requirement for an Odour Management Plan and have a standard odour condition which requires that "All emissions to air from the Permitted Installation shall be free from offensive odour, as perceived by an Authorised Person, outside the Site Boundary" – this provides SEPA with a mechanism by which to assess whether there is a breach of Permit condition due to odour.

Noise

The key sources of noise from an incineration plant are from operation of process equipment, steam venting and vehicle movements. General BAT requirements for vehicle reversing at SEPA regulated sites requires that a risk assessment is carried out to determine whether alternatives to standard tonal reversing alarms (STRAs) can be used as STRAs have the potential to cause annoyance at nearby receptors. Measures to prevent and/or minimise noise emissions from operational equipment are assessed during Permit determination to confirm that proposed noise attenuation techniques e.g. silencers and acoustic enclosures are consistent with BAT requirements.

A noise assessment is provided to confirm the impact of the incinerator at noise sensitive receptors such as the closest residential receptors. A key requirement of the noise assessment is to demonstrate that the proposed plant will not cause noise emissions significantly above existing background levels during the day or the more sensitive night-time period.

Noise due to steam venting associated with start-up and shutdown and occasionally due to emergency conditions should be infrequent but can cause high levels of noise nuisance. This is minimised by good design featuring silencers on steam vents and through optimising operating procedures and preventative maintenance to minimise the frequency and duration of steam venting.

Permit conditions for noise include requirements for a regular noise survey to assess the impact at noise sensitive receptors, this is typically repeated once every 2-4 years depending on the proximity to receptors of the individual site. A Noise Management Plan may also be required to set out the steps to be taken by the Operator to prevent and reduce emissions of noise and vibration at all times. This includes details of how they will follow up complaints from local residents.

Dust and litter

Dust and litter should not be a significant issue for a well-managed incineration plant due to the enclosed nature of the process, the use of covered vehicles delivering waste and collecting waste residues from the site and the use of covered skips for external storage. There is usually a procedural requirement to check lorries do not have any waste residues/ litter etc attached before they are allowed to leave the Tipping Hall once they have tipped their load. Dust emissions from point sources are unlikely during normal operation due to the high efficiency of dust

	abatement (bag filters) fitted to the exhaust gas from incineration and similar controls on silo's used for storage of solid raw materials and residues. Permit conditions include requirements for operations to be carried out to prevent and minimise the potential escape of dust and litter from the site and for any litter to be removed on a daily basis. There is also a standard requirement to ensure that all roads and surfaces within the site are kept free from mud and other debris to the extent necessary to prevent fouling of the public highway. Due to the control measures described, numbers of dust or litter complaints from incineration plants are typically very low or are unsubstantiated following investigation. <u>Vermin</u> Birds (seagulls etc) would not be expected to be a concern at an incineration plant, e.g. compared to a landfill site, due to the enclosed nature of the process particularly around waste storage. Some sites do have an allowance for storage of baled waste outside although these would be subject to restrictions in number and storage duration with regular checks on bale integrity being required to identify and resolve damage etc. The Permit requires operations to be managed to minimise the potential presence of vermin and regular inspections for the presence of insects, birds or vermin, with implementation of a prompt treatment programme to deal with any identified infestation. Typically the numbers of complaints about vermin from incineration and co-incineration sites are either low or non-existent.
Other	During 2021 Tolvik assessed the number of direct employees at 20 EfW plants in the UK. The largest site employed 85 people, the smallest of the sample employed 23 people and the average was 49 people. The average employee cost was in the region of £50k pa. The nature of the roles at such sites requires high levels of electrical, instrumentation and mechanical engineering qualifications.
Individual	The individual states that their only experience was with a large cluster of cancers in individuals living and working in the vicinity of an incinerator. If incinerators are located near to "economically poorer" communities or rural, less populated areas, there will probably be less feedback.
Individual	The individual refers to poor Landfill management and waste disposal at a site. The releases of Methane and subsequent investigations revealed poor waste cell construction and deliberate deceit relating to submissions to SEPA and refers to a tribunal report.

Individual	Do you mean 'other than to the extent that people hate them'? There have been studies regarding the disamenity effect of landfills and incineration facilities. The UK itself has undertaken some such studies on landfills (hedonic pricing studies on the effect of landfills on house prices). In the early 2000s, UK government committed to undertake such a study on the disamenity associated with incineration. It never undertook that study. A meta-analysis was undertaken by Eftec as part of a review by HM Customs and Excise (as it then was). The evidence, such as it exists, and such as one can reasonably apply benefits transfer techniques, would suggest that the disamenity effect of incineration far exceeds that of landfills. That is because the populations living close by incinerators tends to be larger because of their (usually more urban) location, so the disamenity is experienced across a larger number of houses. The effect on the value of housing assets, therefore, is significant as far as this can be discerned. The individual states that they would go so far as to suggest that appreciation that this would be the likely outcome of any such study was the prime reason why none was ever undertaken by Government despite its announcement of its intent to do so.

10.10 Call For Evidence: Question 18 Summary

Category	Q18: Do you have evidence (reports, studies, data) that could help to inform consideration of the public health implications of different treatment options?
Local Government	None.
Local Government	No information to add.
Local Government	No response.
Local Government	N/A.

Local Government	None.
Local Government	No.
Local Government	No evidence.
Local Government	No additional evidence to that already in the public domain. As for Q16, in the case of thermal treatment, there has been extensive research undertaken that underpins the regulatory framework that currently exists.
Local Government	No additional evidence.
Local Government	No response.
Professional body, trade organisation or governing body	Official guidance published in Scotland and across the UK consistently point to the same conclusions; emissions from EfW plants make only a small, if detectable, contribution to local concentrations of pollutants, such that any impact on health from reduced air quality is negligible. Emissions from EfW are among the most heavily scrutinised and regulated in Europe. Operators have very strict emissions limits imposed upon them and performance against these limits is closely monitored by SEPA. In practice, modern, well-run, facilities operate well within their permitted levels across a range of emissions factors. The latest BREF guidance with further reduced emissions limits will continue to push the EfW sector to comply with lower levels of emissions. However, NOx emissions are now at a level where achieving them through Semi Non-Catalytic Reduction Measures can result in elevated releases of ammonia, which can be damaging to local biodiversity. Therefore, any further reductions in NOx levels will demand a different form flue gas treatment, which will place additional costs on existing EfW plants that may eventually lead to some closures in the future.
Professional body, trade organisation or governing body	Official guidance published in Scotland and across the UK consistently point to the same conclusions: emissions from EfW make only a small, if detectable, contribution to local concentrations of pollutants, such that any impact on health from reduced air quality is negligible. (12)

	Emissions from EfW are among the most heavily scrutinised and regulated in Europe. Operators have very strict emissions limits imposed upon them and performance against these limits is closely monitored by SEPA. In practice, modern, well-run, facilities operate well within their permitted levels across a range of emissions factors. The body do, however, welcome continued rigorous and peer reviewed academic research in this area so both operators and the public alike can be assured over the safety of these operations. Our sector will strive to deliver continual improvement by appraising and utilising the best available technologies and techniques. References (12) https://www.hps.scot.nhs.uk/web-resources-container/incineration-of-waste-and-reported-human-health-effects/ https://www.imperial.ac.uk/news/191653/major-study-finds-conclusive-links-health/ https://phw.nhs.wales/services-and-teams/environmental-public-health/air-quality/incineration-and-health-view/ https://www.gov.uk/government/publications/municipal-waste-incinerators-emissions-impact-on-health/phe-statement-on-modern-municipal-waste-incinerators-mwi-study
Professional body, trade organisation or governing body	The body of evidence on this is significant and well published, though at times contradictory. For this reason, the RMAS declines to provide links to specific studies, to avoid any risk of selective bias. However, we believe most studies to date have identified limited health impacts of concern. Studies have highlighted the impact of particulates on the interactions of air quality on health outcomes and the risk of dioxin and furans. This is significantly influenced by the location of facilities. In urban areas these emissions are dwarfed by those of transport. In rural areas the dilution of emissions significantly reduces any air quality impacts. Since the early 1990's there has been a series of changes restricting the emission and other health impacts from incineration. These include • Progressive European directive-based restriction on emission standards from incineration (Directive and Guidance based) focused on environmental permitting regimes. • A gradual de-pollution of materials including control on heavy metals in the packaging, WEEE and ELV directives. Incineration as a technology, is strictly regulated. However, the RMAS supports greater public transparency on emissions monitoring and would support real time monitoring for public access where practicable. R&D on real

	time dioxin and furan emission technologies would also be useful as assessing and reporting these results are time delayed from the time of emission.
Professional body, trade organisation or governing body	No response.
Professional body, trade organisation or governing body	See response to question 17.
Professional body, trade organisation or governing body	No comment.
Business that operates one of more incineration facilities in Scotland	Official guidance published in Scotland and across the UK consistently points to the same conslusions: emisisons from EfW make only a small, if detectable, contribution to local concentrations of pollutants, such that any impact on health from reduced air quality is negligible. Emissions from EfW are among the most heavily scrutinised and regulated in Europe. Operators have very strict emission limits imposed upon them and performance against these limits is closely monitored by SEPA. In practice, moder, well-run facilities oprate well within their permitted levels across a range of emission factors. We welcome continure rigorous and peer reviewed academic research in this area so both operators and the public alike can be assured over the safety of these operations. Our sector wills trive to deliver continual improvement by appraising and utilising the best available technologies and techniques.
Business that operates one of more incineration	No response.

facilities in Scotland	
Business that operates one of more incineration facilities in Scotland	The business states that they are recipients of ROSPA Presidents award (Operational staff wellbeing, H&S, worker health surveillance). Fears raised (historical) re emissions have been proven false (e.g., 'what about dioxins etc?"). The business indicates that their annual reports are in the public domain.
Business that operates one of more incineration facilities in Scotland	The businesses project EIA contains a supporting document on the 'Human Health Risk Assessment' which is publicly available. This references a number of studies and essentially draws the same conclusions that the risk to human health is minimal. The project has ensured that the best available technology will be employed to ensure minimal emissions at source from the plant without chemical treatment and in the application of to minimise sub 2.5 micron particulates and enhance energy recovery.
Business that operates other (non-incineration) residual waste treatment facilities outside of Scotland	No specific comment.
Business that does not operate a residual waste treatment site but produce waste that	No comment.

ultimately is treated at one	
Not for profit environmental organisation	No response.
Environmental Group	No evidence to provide.
Environmental Group	There have been numerous reports of negative health impacts from incinerators with nearby residents forced to keep windows closed, especially in warm weather, despite assurances that there would be no odours and minimal emissions at the planning stage. Once the facility is built Councils have very little way of remedying this. Emissions are concentrated around a facility and add to other pollutants. If sited near where people exercise the exposure will be greater. Vigorous exercise results in 15-20 times the amount of air breathed compared to someone at rest. From a respiratory Consultant. 70 litres/minute would be a reasonable figure. Minute ventilation can be 15-20 times greater during exercise. The proposed Inverness Incinerator site is very close to Inverness Caledonian Football stadium which is already exposed to vehicle emissions from the A9. PM 2.5 and below are a particular issue and the smallest particles which are often the worst for respiratory effects are not caught by incinerator filters and not adequately monitored. This incinerator site is also very close to a traveller site. Other incinerators have been refused on the basis of their health impact on traveller communities.
Environmental Group	The recent and numerous reports on the health impacts on incineration, even within EU limits, should be considered seriously. The moratorium on new applications should not be lifted until full consideration of the health impacts of incineration are reviewed fully. It is important to take into consideration, that when any waste plastics containing PVC are burned they will produce particularly toxic and long lived combustion by-products, including carcinogens, such as dioxins and dibenzofurans. Such by products are associated with incinerator flue emissions.
Environmental Group	The All Party Parliamentary Group on Air Pollution's report entitled 'Pollution from Waste Incineration A Synopsis of Expert Presentations on Health and Air Quality Impacts: A Synopsis of Expert Presentations on Health and Air Quality Impacts.

	Prof. Vyvyan Howard found that, even though incinerator filters stop small particulates like PM2.5 they allow ultrafine particulates into the local environment which at scale constitute a significant health hazard. Ruggero Ridolfi MD found heavy metals in the toenails of children living near incinerators linked with childhood leukaemia. Kirsten Bouman's found dioxins in chicken eggs up to 10 kilometres away. This research is of particular relevance to our members who live on the Black Isle, which would be in the direct path of emissions from the proposed incinerator in Inverness. Land use on the fertile Black Isle consists of smaller farms and crofts raising livestock towards the 'mainland' western end of the Black Isle, with larger, mainly arable farms towards the eastern end. The main annual crops are wheat, oilseed rape, seed potatoes, malting barley and carrots. Many of the residents keep chickens and grow their own fruit and vegetables. We note that the All Party Parliamentary Group on Air Pollution has called for a moratorium on large-scale incinerators.
Environmental Group	Incineration can be a significant source of air pollution in a local community, and as with the climate change impacts of incineration these costs are not reflected in the price of treatment and can therefore be considered 'externalities'. The March 2021 ClientEarth report provides evidence on quantifying the adverse health impacts of Municipal Waste Incineration and other waste treatment options based on values from Defra's air quality appraisal damage costs toolkit. While the 'Central' values from Table 2-5 are used for Figure 2-3 and Table 2-6 we suggest that the 'high sensitivity' values are likely to be more accurate, as the current evidence and historic precedent indicate that adverse impacts of air pollution have often been underestimated rather than over-estimated. While the values for incineration are based on PM2.5, it is expected that a higher value would have been achieved if the calculation had been based on the adverse impacts of PM<1s which could be a large proportion of the particulates released from incineration as filter efficiency tends to be lowest in the 0.05 to 0.5 range.118 Other relevant sources of information on the adverse impacts of incineration include: • The All Party Parliamentary Group on Air Pollution's December 2021 report entitled 'Pollution from Waste Incineration A Synopsis of Expert Presentations on Health and Air Quality Impacts: A Synopsis of Expert Presentations on Health and Air Quality Impacts' .

	• ‘The health impacts of waste incineration: a systematic review’ (Tait, 2020). • Health concerns about incineration expressed by NHS Ayrshire and Arran MCN (October 2021). • Health concerns about incineration raised by doctors in London (June 2020). • ‘Toxic Falluot: Waste Incinerator Bottom Ash in a Circular Economy (GAIA / Zero Waste Europe, January 2022). • ‘The True Toxic Toll: Biomonitoring of incineration emissions’ (Zero Waste Europe, January 2022). As Aidan Farrow, a researcher at the Greenpeace International Science Unit, summarised the matter: "There’s really strong evidence that even small increases in particulate pollution can have a measurable impact on health...Anything that is going to produce more air pollution in places where people are going to breathe it, there will be a health impact. It’s effectively a political decision of how big you’re willing that impact to be". This conclusion is supported by statements on the harmfulness of pollutants relevant to incineration from Government and other leading sources. For example: • According to Defra, Public Health England and Local Government Association: "...the latest epidemiology demonstrates that harm occurs at pollution levels below EU limit values, so if your area doesn’t have an AQMA it doesn’t mean there isn’t a public health issue to consider… There is no safe level for particulate matter (PM10, PM2.5), while NO2 is associated with adverse health effects at concentrations at and below the legal limits". • According to European Parliament (Directorate General for Internal Policies): "Although WHO AQGs [World Health Organisation Air Quality Guidelines] are based on health considerations, exposure even below the guideline values may constitute health risks that cannot be excluded. This is especially true for pollutants such as PM [Particulate Matter] for which it has been found that there is no threshold level below which adverse effects can be excluded. Also, mixtures of pollutants might have additive effects; highly sensitive groups might also be affected when exposed to levels at or below the WHO AQG". • According to World Health Organisation (WHO): "PM [Particulate Matter] is a widespread air pollutant, present wherever people live. The health effects of PM10 and PM2.5 are well documented. There is no evidence of a safe level of exposure or a threshold below which no adverse health effects occur. Since even at relatively low concentrations the burden of air pollution on health is significant, effective management of air quality aiming to achieve WHO AQG [World Health Organisation Air Quality Guidelines] levels is necessary to reduce health risks to a minimum".
Other	Nothing up to date.

Other	We do not have sole responsibly for public health from waste management. We work in collaboration with a range of partners with respect to public health including; • Consultants in public health medicine • Health Protection Scotland • UK Health Security Agency (formerly Public Health England) • UK Committee on Toxicology • World Health Organisation We base this approach to regulation and human health risk assessments on systemic literature reviews of scientific evidence, not individual studies. Below is a list of available studies, the most recent of which is from 2011. Systematic Literature Reviews of Scientific Papers In 2005, the Environment Agency (EA) published a report on health impacts of various waste management options including incineration, MBT and landfill. This is not available online and a pdf version can be forwarded separately. In 2006, DEFRA commissioned a study comparing the health impacts of various residual waste management options. In 2009, SEPA in association with former Health Protection Scotland (HPS), jointly published a report and briefing note on incineration of waste and reported human health effects. We considered the reported evidence on outcomes associated with the incineration of all forms of waste including: hazardous, clinical, industrial, municipal wastes. In 2010, former Health Protection Agency (HPA) carried out a review of evidence relating to waste incineration. The HPA concludes that ”modern, well managed incinerators only make a small contribution to local concentrations of air pollutants. It is possible that such small additions could have an impact on health but such effects, if they exist, are likely to be very small and not detectable”. In 2011, former Health Protection Agency (HPA) carried out a review of evidence relating to landfill. This review encompasses the results of several epidemiological studies and concludes that there has been no new evidence to change the previous advice that living close to a well-managed landfill site does not pose a significant risk to human health.

Although we base regulatory approaches on systematic reviews of evidence and not individual studies, the scale of the Imperial College Small Areas Health Statistics Unit study published in 2019 make it worth highlighting. Health Protection England made a statement reflecting this study.

Human health impact assessments

Incineration applications include a detailed Human Health Impact Assessment. This takes a conservative approach using worst case scenarios. Example summaries can be found in the decision documents for the most recent permit determinations.

• Westfield - 1181922 | Scottish Environment Protection Agency (SEPA)

• Earls Gate - 1157446 | Scottish Environment Protection Agency (SEPA)

• FCC Drumgray - FCC Recycling (UK) Limited: Drumgray Energy Recovery Centre – PPC Permit application - Scottish Environment Protection Agency - Citizen Space (sepa.org.uk)

Dioxins

Dioxins, furans and dioxin-like Polychlorinated biphenyls (PCBs) are amongst the main potential substances of public health implications released from incineration plant. In 2018 the European Food Standards Agency (EFSA) expert Panel on Contaminants in the Food Chain (CONTAM) completed and published a comprehensive review of the risks to human and animal health from these substances in food and feed. In 2021, the UK Committee on Toxicity (COT) issued an interim position statement on EFSA's dioxins risk benchmark and wants to review the benchmark in UK context.

Odour

Odour remains a significant environmental cause of public complaints of people living near waste treatment facilities and has negative effect on quality of life and wellbeing in affected communities, particularly landfills.

Odour can be a cause of stress and anxiety, even when the substances causing the odours are not harmful to health at the levels detected at waste treatment locations.

The World Health Organisation (WHO) derived a low air quality health-based guideline for hydrogen sulphide, the major substance that causes landfill odour. The former Health Protection England (HPE) notes, in its report referenced above, that where levels of releases are lower than threshold, one would still expect long-term health consequences.

	In 2010, SEPA published a guidance for dealing with odour. The Guidance relied on scientific evidence gathered from systematic literature review study.
Other	No information other than exists in the public domain.
Individual	No.
Individual	The individual refers to previously referenced documents.
Individual	The individual states that they are completely non-plussed by the study of heath effects of incineration by public health bodies and the relevant environment agencies. Taking NOx as an example. Incinerators emit NOx (more than they need to). Bodies such as COMEAP have established damage costs based on source to receptor modelling of emissions, and they nowhere indicate that emitting NOx has zero impact on health. These 'externalities' represent impacts on health. Whether or not the contributions to 'background concentrations' is large or small, it is not zero. The pollution does not, somehow, consume itself. Similarly, even if it were demonstrated that there is no effect of PM10 on fetal growth, stillbirth, and other specified health outcomes, that does not indicate an absence of any effect of PM10 on health, even if the contribution to atmospheric concentrations is small. The emphasis of many of public heath studies tends to be on the links between modelled exposures and specified acute health outcomes, or on an attempt to demonstrate the small size of their contribution to ambient concentrations of specific pollutants. Neither of these indicates absence of effect. In order to demonstrate absence of effect, then either a) the links between the emission and any change in any health outcome would need to be demonstrated to be absent, or b) the contribution of the emissions of a pollutant to concentrations to which people are exposed would have to be shown to be zero. Since for may of the pollutants concerned, a) is clearly a dead-end, then the argument around absence of effect would need to rest on b). No one, the individual believes, is countering the view that the changes in concentration are zero, whatever the absolute magnitude of the change. Finally, expressing changes in concentration relative to prevailing levels might not be especially insightful if those prevailing levels are themselves already harmful.

10.11 Summary Of Responses Outside Of The Allocated Questions

Category	Evidence Submitted
Business that operates one of more incineration facilities in Scotland	The business provided a corporate brochure which provided information on EfW and the businesses facilities.
Other	This review is timely as we are seeing increasing incineration in Scotland and many communities feel under threat, including areas that I represent in Central Scotland. Incineration rates in Scotland have tripled over the last eight years with longer term consequences. These developments are locking councils and communities into polluting practices for decades to come, undermining the necessary and overdue transition to a circular economy. The notification direction issued by the Chief Planner to planning authorities is a welcome step, requiring them to notify new applications and decisions to Scottish Ministers. This falls short, however, of a moratorium. The Scottish Government should make this a permanent ban and commit to an exit strategy for existing plants. Scotland does not need more incinerators. I agree with many of my constituents around Central Scotland region that we need to reduce and recycle waste, not burn it. Scotland's laws, policies and practices should align with these goals. I am also concerned that plastics are being incinerated. This is producing carbon emissions. Plastics should be recycled and the best and quickest way to reduce emissions from existing plants is to put a stop to the burning of plastics. We also need to be honest about the hype about incinerators. Evidence shows that incinerators have failed to deliver in energy efficiency promises to deliver local heat networks. There is a risk that carbon capture and storage would create further lock-in to an expensive and polluting waste management system. As a local councillor (2012-2017) and as an MSP (2016 -), I have supported community campaigns in opposition to speculative incinerator proposals in various parts of Lanarkshire. I want to pay tribute to the Hamilton Energy Recovery Action Group, Monklands Against Pyrolysis Plant and the Dovesdale Action Group for their longstanding commitment to environmental protection, waste reduction and a circular economy. I commend to the review the submission by Dovesdale Action Group. The group have been persistent in calling for an end to the building of new incinerators and represent communities impacted by incineration. Incineration is neither clean nor

	green and should not be considered as having a positive role in the circular economy. Incinerators contribute to climate change by emitting greenhouse gases from the waste they burn. They are not a transitional solution to waste management. Incineration should not be used as an alternative to recycling. Once material is burned the opportunity to recycle is lost. Incineration is avoidable for most wastes and the alternatives, such as recycling and reuse, are preferable economically, environmentally and socially. Scotland enjoys success as a world leader in many areas of policy. To be seen as a world leader in waste management with a clear commitment to eliminating incineration would set a standard not only across the UK but internationally
Environmental Group	Provided their response to the Route Map discussions.
Environmental Group	Report containing information covering the main topics.

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