Stop, Sort, Burn, Bury?

Independent Review of the Role of Incineration in the Waste Hierarchy in Scotland

Report

May 2022

Foreword from Dr Colin Church, Chair of the Independent Review

I was honoured to be asked in November 2021 to lead the independent review into the role of incineration in the waste hierarchy in Scotland. How we address the challenges of moving from a linear economic model to a low-carbon, more circular economy is a passionate interest of mine, and the role of incineration in that move is one key challenge.

As Scotland seeks to make this move, the prominence of incineration has grown. The ban on landfilling biodegradable municipal waste from 2025 has concentrated many minds, and incineration is rightly a fundamental element of the approach to meet it. At the same time, concerns have been raised about the impacts of incineration on human health and the environment. Modern plants are far from the polluting monstrosities of the past, now being required to meet stringent emissions standards to protect human health and the environment from airborne harm. But burning waste also produces carbon dioxide, a greenhouse gas, so allowing it to be freely emitted in the long term is incompatible with Scotland's desire to reach net zero carbon emissions. There are also concerns as to whether a high level of incineration can act as a constraint on greater waste prevention and recycling.

At the same time, the resource and waste management system is complex and interdependent. It is impossible to consider one aspect of it (such as incineration) properly in isolation from the others (waste prevention, recycling, etc). I must admit to having been more than a little daunted to be asked to do so in a little over four months! It has indeed been a difficult challenge, especially in the light of the lack of data in some crucial areas and whilst other parts of the system are also in motion. However, the Report before you now is as good as it could be in the circumstances, and I believe it offers some clear messages to the Scottish Government and all stakeholders on the current and future role of incineration in the waste hierarchy in Scotland.

I am immensely grateful to all the individuals and organisations who provided input to the Review via submissions to the Call for Evidence and through online and in person meetings. Their insights and evidence, and their willingness to share them with me, enabled this Review to deliver its report within the timescales laid down by the Minister.

Finally, my thanks to the team who supported me so ably in this task and without whom this report would not exist.

Dr Colin Church CEnv FIMMM CRWM MCIWM
Independent Chair of the Review

Executive Summary

The Independent Review of the Role of Incineration in the Waste Hierarchy ('the Review') commenced in November 2021, with this report being delivered in April 2022. The Review, chaired by Dr Colin Church, set out to answer five key questions:

1. Given Scotland's waste management ambitions and current progress towards these, what capacity is required to manage residual waste in Scotland?
2. What are the options for managing residual waste?
3. What are the economic, environmental and social trade-offs of those residual waste management options?
4. How do we decide where capacity should be located, and in what form?
5. What can be done to improve existing residual waste treatment facilities in terms of carbon performance and societal impacts?

The Review was asked by the Minister to prioritise the assessment of national capacity requirements (Topic 1). To respond to these topics, the review considered existing evidence and commissioned additional capacity modelling, an appraisal of waste treatment options and a rapid evidence review of the potential health impacts of incinerating waste. Additionally, the Review opened a Call for Evidence, allowing stakeholders to submit written and verbal evidence and considerations for the Review.

During its review of available evidence, it became apparent to the Review that the accessibility, quality and quantity of some data around waste management in Scotland is lacking in some key aspects. To address this, the Review recommends improvements to the Scottish Government's waste management data and for the Scottish Government, industry and local authorities to improve the transparency of their data (see Recommendation 2 and Recommendation 3).

Capacity to manage residual waste in Scotland

Overall, the capacity analysis completed for the Review suggests that there is likely to be a capacity gap in 2025, when the biodegradable municipal waste (BMW) ban comes into force. This will clearly be exacerbated if the ban is extended to include all non-municipal biodegradable waste. While this capacity gap could be closed by Scotland achieving its waste and recycling targets, stakeholders raised concerns about the likelihood of achieving these targets, drawing on experience and comparisons with other nations as evidence of what could be possible. The Review recommends that Scotland should limit the granting of further planning permissions for incineration infrastructure (see Recommendation 4). Further to this, the Review recommends that an indicative cap for the residual waste treatment needed in Scotland should be developed, and that this should decline over time as Scotland transitions towards a fully circular economy (see Recommendation 5).

The short term nature of the capacity gap, balanced against the long term likelihood of overcapacity, highlighted the difficulty in using infrastructure with long operational lifespans alone to treat residual waste. The Review finds that the risk of lock-in in

waste management contracts is genuine, and recommends that local authorities specifically address this within their contracts (see Recommendation 6).

Residual Waste Management Options

The best form of residual waste treatment is preventing it occurring in the first place, through reducing waste and recycling. The Review recommends that the Scottish Government does more to reduce the proportion of recyclable materials in the residual waste stream (see Recommendation 1).

In terms of managing the remaining residual waste, the Review assessed the feasibility of a number of residual waste treatment options. In consideration of this assessment, along with a further appraisal of social, health and climate considerations relating to waste treatment, the Review finds that incineration's current place within the waste hierarchy, where overall it is preferable to other forms of residual waste treatment, but less desirable than reducing and recycling waste, is correct. It recommends that the most feasible waste treatment options are incineration, landfill and export of waste (see Recommendation 7).

Trade-Offs

The Review considered the health and social impacts of residual waste management in Scotland. This included a Rapid Evidence Review on health impacts from Public Health Scotland, which confirmed its previous view that such impacts were likely to be small. The Review also considered the impacts: on local amenity; the link between deprivation and location of facilities; perception and employment, as well as the Scottish Landfill Communities Fund and heat and energy offtake. The Review additionally heard from stakeholders regarding the difficulties they experienced engaging with planning processes and difficult relationships with local facilities. The Review finds that communities deserve more authentic and committed engagement from local authorities and industry than is currently sometimes the case (see Recommendation 8 and Recommendation 9).

Decarbonisation

The Review has found that currently, incineration is less damaging to the environment than landfill. However, increased incineration, changes to waste composition and wider decarbonisation will make this less favourable over time. To assist in monitoring this, the Review has recommended that greenhouse gas (GHG) emissions from incineration are reported separately from other energy-related emissions. (see Recommendation 12)

Separate work has been commissioned to inform further consideration of opportunities to decarbonise the residual waste treatment infrastructure sector in Scotland, with the main focus on waste incineration (Topic 5). In the meantime, the Review has provisionally recommended improving pre-treatment processes before incineration, with a particular focus on plastics (see Recommendation 13). Additionally the Review has provisionally recommended that combined heat and power should be pursued for as many incineration facilities as possible (see Recommendation 14).

Recommendations

The Review's Recommendations are summarised here for ease of reference, but should be considered in the context both of the discussion around them in the Report and of the Report as a whole.

Recommendation 1: Scottish Government should rapidly seek further reductions in the proportion of recyclable materials in the residual waste stream. It should do this in the forthcoming Route Map.

Recommendation 2: The Scottish Government should develop better waste management data, especially around the composition of all types of waste and the arisings and fate of commercial and industrial waste, and improve its capacity to model future trends across the whole resource and waste management system. The forthcoming Route Map should set out how the Scottish Government will do this.

Recommendation 3: Industry, local authorities and the Scottish Government should do more to make data around waste in general, and around incineration in particular, more transparent and accessible for all stakeholders. This should be done alongside development and implementation of the Route Map.

Recommendation 4: Effective immediately, the Scottish Government should ensure that no further planning permission (i.e. beyond that already in place) is granted to incineration infrastructure within the scope of this Review unless balanced by an equal or greater closure of capacity. The only exceptions to this should be those outlined in Recommendation 10.

Recommendation 5: As part of an overall strategic approach to planning and deploying waste management capacity (see Recommendation 11), the Scottish Government should develop an indicative cap that declines over time for the amount of residual waste treatment needed as Scotland transitions towards a fully circular economy.

Recommendation 6: When negotiating contracts for residual waste management treatment, local authorities should specifically address the risks of lock-in and ensure those contracts are aligned with meeting Scotland's current and future targets on resource and waste management.

Recommendation 7: The most feasible treatment options to manage Scotland's residual waste are incineration, landfill and export of waste. Scottish Government should work with local authorities to ensure they have a solution to manage their residual waste in 2025 based on this.

Recommendation 8: As part of the strategic approach referred to in Recommendation 11, Scottish Government and Local Authorities should ensure that adequate time and resource is dedicated to local and community engagement.

Recommendation 9: Operators of all residual waste treatment facilities should work to significantly strengthen community engagement and trust before, during and after development. Clear guidelines for authentic and effective community engagement

should be co-produced by Scottish Government with community groups and local authorities by the end of 2023.

Recommendation 10: Scottish Government should urgently work with local authorities in remote and rural areas of Scotland without a settled residual waste management solution to meet the Ban to explore options that might, if fully justified, lead to the creation of a small amount of additional capacity.

Recommendation 11: Scottish Government and local authorities should work with industry to develop a strategic approach to planning and deploying waste collection, reprocessing and management facilities by the end of 2023, which takes account of the key issues. The Scottish Government should consider how best to incorporate this into the proposed fourth National Planning Framework.

Recommendation 12: The Scottish Government should report greenhouse gas emissions from incineration separately from other energy-related emissions as soon as possible, ideally from the 2021 data onwards.

Recommendation 13: (Provisional) The Scottish Government should immediately strengthen existing requirements for pre-treatment and work with local authorities and industry to apply them to all existing and future incineration facilities to remove as much recyclable material as feasible, with a particular focus on plastics.

Recommendation 14: (Provisional) The Scottish Government and local authorities should continue to work with industry to deploy combined heat and power for as many existing incineration facilities as possible.

Contents

1 Introduction

1.1 Background To The Review

In May 2021, the Cabinet Secretary for Net Zero, Energy and Transport announced that an independent review of the role of incineration[1] in Scotland's waste hierarchy would be commissioned, with the aim of ensuring that how residual waste is managed in Scotland aligns with Scotland's carbon reduction ambitions. This followed the Scottish Government's update to the Climate Change Plan, which set out the Government's intention to "end landfilling of biodegradable municipal waste by 2025, reduce the percentage of all waste sent to landfill to 5% by 2025 and recycle 70% of all waste by 2025."[2]

A statement to Parliament by Lorna Slater, Minister for Green Skills, Circular Economy and Biodiversity, in September 2021[3], set out the intention for this 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 to act as independent Chair of the Review of the role of incineration in the waste hierarchy in Scotland ('the Review'). Dr Church is CEO at the Institute of Materials, Minerals and Mining (IOM3) and is Chair of the Circular Economy Task Force, a business group led by the Green Alliance. He has previously been the CEO of the Chartered Institution of Wastes Management (CIWM), which is a professional body for the waste management industry in the UK and has been a non-executive director for WRAP, a leading UK sustainability charity. Prior to that, he held several senior roles in Defra, DECC[4] and the Cabinet Office.

As independent Chair of the Review, Dr Church determined the scope and process for the review within the overall parameters and timescale set by the Minister, which are outlined above. Dr Church was supported in the Review by a secretariat consisting of individuals

[1] In the Review, the term "incineration" is used in line with its terms of reference to cover mass burn via moving grate, rotating kiln or fluidised bed; gasification; and pyrolysis, all with or without energy recovery. Elsewhere, the terms "energy from waste" (EfW) or "waste to energy" (WtE) are often preferred and can be considered to be essentially the same as "incineration" in the Review.
[2] *Securing a green recovery on a path to net zero: climate change plan 2018–2032 - update.* Scottish Government. (2020). Chapter 5 Waste and the Circular Economy - 3.5. Waste and the Circular Economy. Available at: Securing a green recovery on a path to net zero: climate change plan 2018-2032 – Scottish Government (accessed March 2022)
[3] Written question and answer: S6W-03436 | Scottish Parliament Website. Available at: Written questions and answers, Scottish Parliament (accessed April 2022)
[4] the former UK Department of Energy and Climate Change

detached from Scottish Government and the Scottish Environmental Protection Agency (SEPA).

1.2 Structure And Process Of The Review

1.2.1 Scope of the review

The Review, through an initial Call for Evidence ('the Call') and a number of stakeholder events, sought input into five main topics which were considered in the context of treatment of household (HH) and commercial and industrial (C&I) waste streams. These waste streams were chosen as they are likely to be captured by the forthcoming ban on sending certain biodegradable waste streams to landfill (see Annex B), they comprise a large proportion of waste incinerated, the incineration of these waste streams has increased significantly since 2013[5], and municipal waste incinerators are often the object of stakeholder concerns.

The five main questions highlighted in the Call were:

1. Given Scotland's waste management ambitions and current progress towards these, what capacity is required to manage residual waste in Scotland?
2. What are the options for managing residual waste?
3. What are the economic, environmental and social trade-offs of those residual waste management options?
4. How do we decide where capacity should be located, and in what form?
5. What can be done to improve existing residual waste treatment facilities in terms of carbon performance and societal impacts?

Certain elements have been excluded from the scope of the Review. These include:

- The incineration of biomass for energy, since the goal of biomass facilities is likely to be energy production (for example, through energy crops), rather than waste treatment.
- Consideration of high-temperature incineration for the treatment of some healthcare and hazardous wastes[6].
- An in-depth review of health impacts of residual waste treatment.

This report largely follows the structure of the five topics. It should be read as a whole; in particular, its Recommendations draw on all of the work of the Review, not just the aspects relevant to their placement in the document.

While the Call encouraged submission in relation to all the topics, the Review prioritised Topics 1-4, with the assessment of national capacity requirements (Topic 1) at its centre. Separate work has been commissioned to inform further consideration of opportunities to decarbonise the residual waste treatment infrastructure sector in Scotland, with the main focus on waste incineration (Topic 5). In the meantime, a brief outline of some of the

[5] *Waste incinerated in Scotland - 2020.* SEPA. (2020). Figure 2 Waste incinerated in Scotland by incineration method 2011 - 2020. Available at: Waste Incinerated in Scotland 2019, SEPA (accessed March 2022)
[6] The Review recognises that the treatment of healthcare and hazardous wastes is an important topic, however the issues for consideration are, in some significant respects, different to those relating to managing other forms of residual waste which are the primary focus for this review.

issues and some provisional conclusions and recommendations are included within this report.

In accordance with its remit, the Review has primarily looked at incineration. However, the Review has also considered options for residual waste treatment beyond incineration, including, but not limited to, landfill, mechanical biological treatment (MBT), and biostabilisation.

Because of the potential extension[7] of the Ban ('the Extended Ban') to non-municipal biodegradable waste, some aspects of construction and demolition (C&D) waste have also been considered.

1.2.2 Evidence collection and analysis

While there was some evidence and data on the key topics already available to the Review at its commencement, the Review was aware that further important information may be held by stakeholders. Additionally, many groups feel strongly about waste management in their local areas as well as environmental issues on a wider scale. The Review therefore issued a Call for Evidence ('the Call') and organised a series of meetings, which together enabled stakeholders to provide written and verbal evidence, viewpoints and considerations for the Review.

The Review commissioned additional information, research and analysis where necessary. This included capacity modelling and options appraisal by Ricardo and a rapid review of evidence relating to the health impacts of incinerating waste since 2009 from Public Health Scotland. Additionally, the Review has sought extra information and sense checks from stakeholders where appropriate and necessary.

More information on the evidence gathered can be found within the evidence document.

1.2.3 Limitations

The Review has endeavoured to be open and thorough in its scope and process. However, there have been a number of limitations caused by the Review's timeframes and the impacts of Covid-19, both on the Review's activities and other organisations' ability to contribute to the Review.

The Minister for Green Skills, Circular Economy and Biodiversity requested that the Review was delivered as soon after the end of March as possible in order to take account of the need for Local Authorities to make arrangements for the Ban and consider planning applications as well as for the waste management industry to make investment decisions. This timescale has meant that certain parts of the Review had to be prioritised, particularly the capacity analysis and consideration of the social, health and economic trade-offs for various waste management options. In order to allow the Review to give appropriate

[7] The Scottish Government committed to "extend the forthcoming ban on sending biodegradable municipal waste to landfill to include biodegradable non-municipal wastes, subject to appropriate consultation and work to provide assurance around some specific waste streams"
Securing a green recovery on a path to net zero: climate change plan 2018–2032 - update. Scottish Government. (2020). Chapter 5 Waste and the Circular Economy - 3.5. Waste and the Circular Economy. Available at: https://www.gov.scot/publications/securing-green-recovery-path-net-zero-update-climate-change-plan-20182032/documents/ (accessed March 2022)

consideration to the matter of decarbonising existing infrastructure, an additional piece of work has been commissioned for this, which is expected to take a further six to nine months. The Review and its Chair do not expect this to delay the publication of the existing Report or accompanying evidence document, nor inhibit the Scottish Government's decision making ability based on this Report.

The Covid-19 pandemic has also impacted on the Review. While many of the impacts, such as the inability to hold in-person meetings and stakeholder events, have been mitigated through the use of video calls, other limitations in terms of the capacity of other organisations have resulted in minor adjustments to the scope of the Review and the evidence available for analysis. Additionally, the Review has taken care with the data used for the capacity analysis, due to the potential for the 2020-22 data to not be representative.

Finally, some data that the Review would have preferred to assess (such as full data on waste arisings and fate since 2018) has not been available due to the impacts of the recent cyber-attack on SEPA.

1.2.4 Review publications

There are currently five elements to the Review's outputs:

- Call for Evidence, December 2022[8] – This invited stakeholders to provide comments on initial analysis from ClimateXChange (CXC) and evidence on a range of questions relating to the Review.
- Review Report, submitted April 2022 – This document outlines the key considerations of the review and the recommendations the Review is making.
- A summary of the main recommendations of the Review to date (to follow).
- Evidence Report, submitted April 2022 – This report summarises the evidence considered by the Review, including responses to the Call and further evidence.
- Call for Evidence responses – As far as possible, the Review has published in full the responses received to the Call. Further information on the publication of responses can be found within the evidence document.

[8] *Call for Evidence.* Review of Incineration (2021). Available at: https://consult.gov.scot/environment-forestry/incineration-review-call-for-evidence/

2 General Themes From The Review

The remainder of this document considers the different questions the Review considered in seeking to provide advice to the Scottish Government. However, during its work, several cross-cutting themes emerged which apply across the topic of the role of incineration in managing residual waste in Scotland. These are set out in this section.

2.1.1 Avoid residual waste

The best form of residual waste treatment is preventing it occurring in the first place. This can be through preventing waste at all or by recycling it when it arises. For Scotland to meet its resource and waste management and climate mitigation targets, more will need to be done in this area. The Review understands that the Scottish Government is working with stakeholders to develop a route map to deliver Scotland's resource and waste management targets ('the Route Map') and it is to be hoped that this will address making further progress on this.

Recommendation 1 Scottish Government should rapidly seek further reductions in the proportion of recyclable materials in the residual waste stream. It should do this in the forthcoming Route Map.

- The primary focus should be on upstream measures to reduce the amount of recyclable material entering residual waste by waste prevention and source separation.
- Given the high proportion of recyclable material in residual waste, the Scottish Government should work with local authorities and the waste industry to remove recyclable material from the residual waste stream.

2.1.2 Community engagement

As set out in the draft fourth National Planning Framework (NPF4)[9], community engagement at all stages of a major project is essential to 'respect, protect and fulfil human rights'. Experience and anecdotal evidence suggest that meaningful and ongoing community engagement is also vital to help deliver a better, more successful project, especially for waste management. However, the Review received evidence that the standard of community engagement by both public and private entities varied greatly and it is clear that the general level should be improved. (See Section 5.4 and Section 5.5 for more details and specific recommendations.)

2.1.3 Data

The Review found the relatively poor quality and scope of some data that was available to it a limiting factor in its work, a concern shared by many stakeholders. Whilst data on household (HH) waste arisings and fate is generally good, data on its composition is not. For other types of waste, most aspects are much less well understood. There were also uncertainties about the real-life capacities of existing and planned incineration facilities.

[9] *Draft fourth National Planning Framework.* Scottish Government. (2021). Part 3, Policy 4. Available at: https://www.gov.scot/publications/scotland-2045-fourth-national-planning-framework-draft/pages/5/ (accessed April 2022)

Beyond data quality and availability, the Review has relied on consultant support for detailed modelling. This will bring challenges for Scottish Government if it wishes to use the same model in the future rather than expanding its in-house resource. There needs to be significant investment in both data collection and in the capacity to analyse it and draw conclusions, ideally in a manner that enjoys broad stakeholder support. (See Recommendation 2.)

2.1.4 Systems thinking

No part of the resource and waste management system can be considered in isolation. Changes to one part of it have impacts on others, which can be hard to predict. In turn, improvements in one area are often dependent on changes happening in others. It is therefore essential for decision makers to consider the whole system wherever possible when making changes. For example, both stakeholders and the Review found it hard to assess the likely or expected impacts of upstream measures on future residual waste quantities and composition, which has hindered the ability to make firm predictions.

Recommendation 2 The Scottish Government should develop better waste management data, especially around the composition of all types of waste and the arisings and fate of commercial and industrial waste, and improve its capacity to model future trends across the whole resource and waste management system. The forthcoming Route Map should set out how the Scottish Government will do this.

2.1.5 Transition

Incineration should be thought of as a transitional technology that helps Scotland bridge the gap from mass landfill to a low waste, low carbon, more circular economy. We are currently in the growth phase, but as set out by several stakeholders, if Scotland is to meet its resource and waste management and climate change mitigation targets, there will be a corresponding future phase down. Planning by central and local government for how to manage this is essential to avoid unnecessary expense or environmental damage. (See also: Section 3.6, Recommendation 4 and Recommendation 5.)

2.1.6 Transparency

Greater transparency around the data that does exist would help build greater trust in the incineration industry and support more robust decision making. Some data may legitimately need to be kept confidential for commercial reasons but given the environmental and social considerations the test for this should be reasonably stringent. Transparency also means presenting the data in an accessible and coherent manner with appropriate explanations.

Recommendation 3 Industry, local authorities and the Scottish Government should do more to make data around waste in general, and around incineration in particular, more transparent and accessible for all stakeholders. This should be done alongside development and implementation of the Route Map.

3 Capacity To Manage Residual Waste In Scotland

Given Scotland's ambitions and current progress towards these, what capacity is required to manage residual waste in Scotland?

3.1 Introduction

The capacity analysis conducted by Ricardo[10] builds upon previous work[11] using information gathered through the Review. The purpose of this analysis is to establish future capacity requirements to treat residual waste in Scotland to 2050.

The analysis assumes that the facilities identified will only manage waste quantities generated within Scotland. This high-level analysis does not quantify any waste tonnages being managed that are from England or other areas and other waste types not included within the assessment such as small quantities of hazardous waste that may be managed using this capacity.

3.2 Waste Management In Scotland

3.2.1 Waste generated in Scotland

Scotland produced around 11.5 million tonnes (Mt) of waste in 2018 from households (2.4 Mt), C&I sources (3.2 Mt) and C&D activities (5.8 Mt)[12].

Waste generated in Scotland has reduced by 4.2% since 2011. While there has been a general reduction in HH (7% between 2011 and 2018) and C&I waste (22% between 2011 and 2018), the amount of C&D waste generated fluctuates year on year.[12]

3.2.2 Waste management in Scotland

Producers and managers of waste have a duty to treat waste according to the waste hierarchy[13]. This means avoiding waste generation is the first priority, followed by reusing products and materials. Where this is not possible, waste should be recycled. The majority of waste generated in Scotland is recycled. In 2018, 60.7% of waste from all sources was recycled. For HH waste specifically, 42.0% of waste was recycled in 2020[14].

Residual waste is waste that cannot be recycled. This is often called 'black bag' waste since it includes the mixed materials generally collected in black bags or bins. Black bag

[10] *Incineration Review: Capacity Analysis.* Ricardo Energy and Environment. (2022). Available at: http://www.gov.scot/ISBN/9781804353912/documents/
[11] *Implementing Scotland's landfill ban.* ClimateXChange. (2022). Available at: https://www.climatexchange.org.uk/research/projects/implementing-scotlands-landfill-ban/ (accessed March 2022)
[12] *Waste from all sources data tables 2018.* SEPA. (2019). Prevention tab. Available at: https://www.sepa.org.uk/media/500275/waste-from-all-sources-waste-data-tables-2018.xlsx (accessed March 2022)
[13] For more detail on the waste hierarchy, see *Applying the waste hierarchy: guidance.* Scottish Government. (2017). Part 1. Available at: https://www.gov.scot/publications/guidance-applying-waste-hierarchy/pages/3/ (accessed March 2022)
[14] *Household Waste Summary Data.* SEPA. (2020). Table 7. Available at: https://www.sepa.org.uk/media/594041/2020-household-statistics-data-tables-final-v2b.xlsx

waste often contains recyclable material; evidence suggests that around 60% of material in black bags is recyclable.[15] However, material in black bag waste is often not recycled since mixing materials reduces their quality, and separation and cleaning is often not economically viable under the current market conditions.

The waste hierarchy gives preference to recovering value from residual waste, for example through incineration with energy recovery, with disposal (for example in landfill) being the least preferable option.

The total quantity of waste incinerated in Scotland in 2020 was 1.26 Mt, an increase of 0.38 Mt (3.1%) from 2019, consistent with the longer term trend of an increase of 0.86 Mt (208%) from 2011[16].

Due both to a reduction in residual waste generated and in line with the increase in waste incinerated, the amount of waste disposed of to landfill has generally decreased steadily since 2007. In 2020, Scotland sent 2.6 Mt to landfill, a reduction of over 4.4 Mt (63%) since 2005[17]. Figure *1* shows the arisings and fate data for 2014-18.

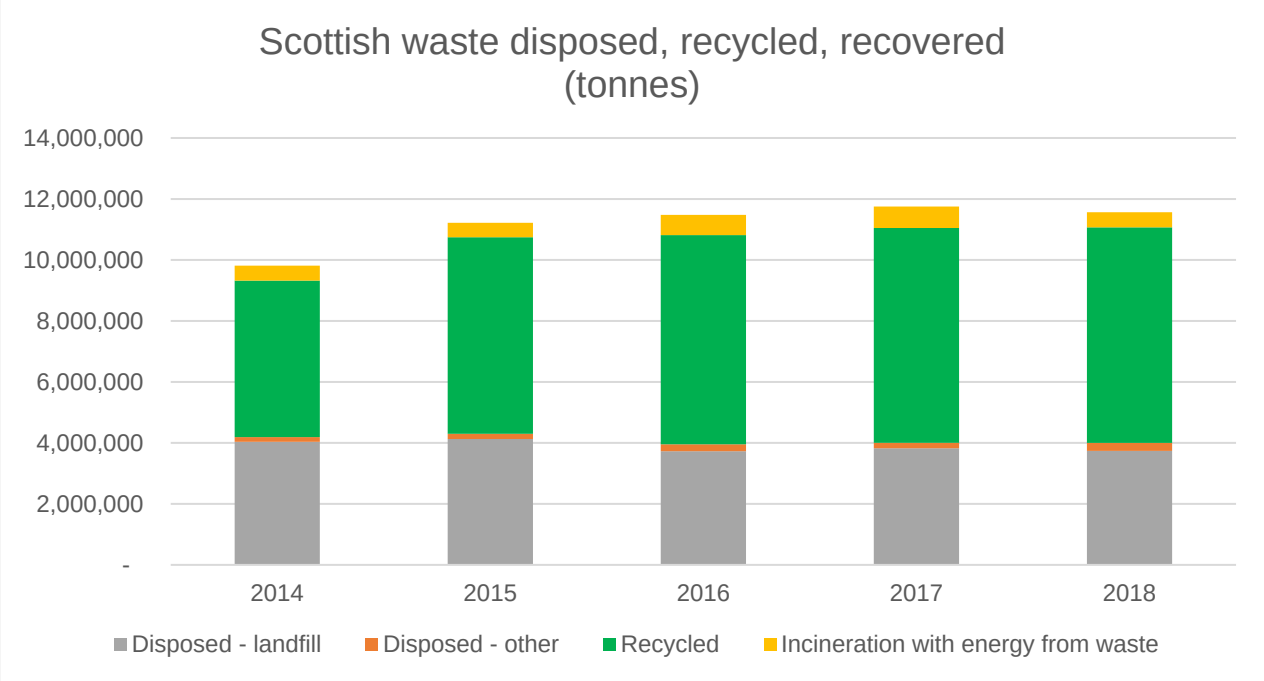

Figure 1: Scottish waste 2014-18

[15] *The composition of household waste at the kerbside in 2014-15,.* Zero Waste Scotland. (2017). Page 12. Available at: https://www.zerowastescotland.org.uk/composition-household-waste-kerbside (accessed April 2022)
[16] *Waste Incinerated in Scotland Data Tables.* SEPA. (2021). Table 2. Available at: https://www.sepa.org.uk/media/594033/2020-waste-incinerated-in-scotland-data-tables-release.xlsx (accessed March 2022)
[17] *Waste Landfilled in Scotland Data Tables.* SEPA. (2021). Table 2. Available at: https://www.sepa.org.uk/media/594033/2020-waste-incinerated-in-scotland-data-tables-release.xlsx (accessed March 2022)

3.2.3 Current residual waste infrastructure

With waste policy[18] generally diverting waste away from landfill (especially through application of the Scottish landfill tax and the forthcoming Ban) resulting in a general decrease in waste landfilled, the number of landfill sites in Scotland has decreased. In 2005 Scotland landfilled over 7 Mt of waste at 129 active landfill sites compared to 2.6 Mt at 41 sites in 2020[19].

Scotland currently has 7 operational municipal waste incinerators (Table 1). There are two main technologies employed in Scotland: mass burn and gasification (a type of advanced thermal technology, ATT). Scotland also has several pre-treatment facilities. These are listed as MBT facilities in Table 1, although, some may operate only as mechanical sorting facilities while some will undertake biological treatment, such as composting or anaerobic digestion.

Table 1. Operational residual waste facilities in Scotland in 2022

Facility Name	Technology Type	Annual permitted Capacity/t	Operational Date
DERL (MVV Baldovie)	Mass burn	150,500	1994
Lerwick	Mass burn	26,000	2000
Levenseat	Pre-treatment and gasification	250,000	2018
Glasgow Recycling and Renewable Energy Centre	Pre-treatment and gasification	200,000	2019
Millerhill	Mass burn	189,500	2019
Dunbar ERF	Mass burn	325,000	2019
Dundee ERF	Mass burn	110,000	2021
Total Incineration Capacity		1,251,000	
Moleigh	Composting / MBT	24,999	1998
Dalinlongart Compost	Composting / MBT	20,515	2001
Lingerton Compost	Composting / MBT	36,500	2001
Eco Deco Dumfries	MBT	70,000	2006
Total MBT capacity		152,014	

[18] See Annex B for more detail on the policy context for Scotland
[19] *SEPA response to Incineration Review Call for Evidence.* SEPA. (2022). Available at: Incineration in the waste hierarchy review: call for evidence - Scottish Government - Citizen Space (consult.gov.scot)

3.3 Outline Of Methodology

A brief overview of the modelling is given here and more detail is available in the *Incineration Review: Capacity Analysis* report by Ricardo[20]. Data and evidence gathered through the Call was used to update an existing Residual Waste Model.

3.3.1 Waste arisings

To forecast residual waste arisings, the modelling took the latest available data, which is for 2018[21] (the 'baseline' year) and filtered this for specific waste streams. These were generally HH waste and C&I waste. In selecting these waste streams it was assumed that this would cover all of the waste that will be captured under the Ban in 2025, as well as the vast majority of waste captured under the Extended Ban[22], should this be introduced.

The modelling also considered C&D waste as some sorting residues from C&D waste could well be biodegradable and therefore may be captured by a ban on landfilling of biodegradable non-municipal waste. However, while some stakeholders felt it sensible to include all possible waste which may be captured by a ban within the capacity analysis, some stakeholder feedback noted that much of these sorting residues is unlikely to be suitable for incineration[23]. The model was therefore run both without and with C&D waste.

Best fit growth assumptions were then applied to each type of waste to assess how quantities may change in the future. Three scenarios were then modelled to assess the impact of a range of potential future performance scenarios:

- **Business As Usual (BAU)**: This scenario projects historical trends forward into the future[24], to examine what the future could look like if there are no significant changes to current trends.
- **Meeting Targets (MT)**: This scenario amends historical trends in order to meet Scotland's waste reduction and recycling targets for 2025.
- **Best Efforts (BE)**: This scenario examines what Scotland's future could look like if it improved its recycling rates in line with what has been achieved by some of the best performing European nations[25].

3.3.2 Infrastructure capacity and pipeline

Once waste arisings data had been established, the infrastructure capacity of existing and planned ('pipeline') facilities was established. Although this is given in tonnes of waste, and this is the basis for planning permission and permitting, in reality the throughput limit for an incineration plant is set by its thermal capacity, and therefore the calorific value (CV)

[20] *Incineration Review: Capacity Analysis.* Ricardo Energy and Environment. (2022). Available at: http://www.gov.scot/ISBN/9781804353912/documents/
[21] *Waste from all sources data tables 2018.* SEPA. (2019). Available at: https://www.sepa.org.uk/media/500275/waste-from-all-sources-waste-data-tables-2018.xlsx (accessed April 2022)
[22] The analysis considers waste likely to be captured by the Ban plus an additional 37.1 kt of C&I waste that would also be covered by an Extended Ban, using the assumed waste streams set out in Appendices 2 and 3 in the Ricardo analysis.
[23] For example, sorting residue particles are often too fine to be put through a moving grate incinerator
[24] An annual half percentage point increase in recycling rate for target materials
[25] An annual percentage point increase in recycling rate for target materials

of the waste is crucial. Generally, the presence of more plastic will increase the CV and therefore reduce the tonnage that can be treated.

Residual waste infrastructure capacities for facilities were reported by a number of stakeholders. The permitted capacity for sites is unlikely to be the operational capacity and stakeholder estimates of operational capacity varied. For sites that are operational, a realistic capacity was established by considering recent waste data returns for these sites and sense checking this with stakeholder evidence. However, this approach also has limitations since some recently opened sites are unlikely to have been operating at their full capacity. For sites that are not yet operational, 85% of the consented or planned capacity was used as a proxy for the operational capacity[26,27]. Table 1 shows the permitted capacities of operational sites which were adjusted for modelling purposes. Table *2* sets out the pipeline facilities and their modelled capacities.

Table 2 - Pipeline facilities and their status, modelled capacity and assumed operational dates

Facility Name	Technology Type	Modelled Capacity (t/y)*	Status	Assumed Operational Date
Earls Gate	Mass burn	201,000	In Construction	2023
Aberdeen Recycling & Energy Recovery (NESS)	Mass burn	127,500	In Construction	2022
Westfield	Mass burn	212,500	In Construction	2025
Glenfarg (Binn Group)	Mass burn	71,400	Planning Granted	2025
Oldhall (Doveryard)	Mass burn	153,000	Fully Consented**	2026
South Clyde (Fortum)	Mass burn	299,200	Fully Consented	2026
Drumgray (FCC)	Mass burn	255,000	Fully Consented	2026
Avondale MRF/MBT	MRF[28] / MBT	60,000	Fully Consented	2026

[26] This was based upon reviewing the modelled capacity outlined for the operational facilities against the sites consented capacity, factoring in the assumption that newer facilities would be more efficient and operating closer to their actual consented capacity. This was also cross-referenced with information submitted during the call for evidence. For example, stakeholder feedback suggested that a reasonable estimate of availability could be around 86% or 86.4%-91%. For more information see: *Incineration Review: Capacity Analysis.* Ricardo Energy and Environment. (2022). Available at: http://www.gov.scot/ISBN/9781804353912/documents/

[27] Additionally, Tolvik suggest that based on turbine operations, the average availability was 85.9%. For example see: *UK Energy from Waste Statistics.* Tolvik UK. (2020). Available at: https://www.tolvik.com/wp-content/uploads/2021/05/Tolvik-UK-EfW-Statistics-2020-Report_Published-May-2021.pdf (accessed March 2022)

[28] Materials recovery facility – a mechanical sorting process used to separate out different materials and formats for recycling.

Facility Name	Technology Type	Modelled Capacity (t/y)*	Status	Assumed Operational Date
Inverurie (Agile Energy)	Mass burn	170,000	Planning Granted	2027
Avondale EfW	Mass burn	127,500	Planning Granted	2027
Killoch EfW***	EfW	141,100	Proposed	2027
Levenseat 2	Mass burn	267,800	Planning Granted	2027

*This is an 85% weighting of the consented capacity. Where facilities do not yet have a permit, the expected capacity is used.
**Note, facility does not have a permit, but has achieved financial close and is therefore categorized as “fully consented” for modelling purposes
***This facility has planning granted for gasification and has put in a further application for mass burn. It has been included in the modelling on the basis of the new planning application.

These values are a source of uncertainty in the modelling. The Review sought additional feedback from relevant stakeholders on the estimates for capacity and the timelines for pipeline facilities to come online. Where the feedback commented on these numbers, it largely agreed with the suggested estimates; however, some estimated capacities were increased as a result of the feedback[29].

A sensitivity analysis (using the highest and lowest capacity estimates from stakeholders for operational facilities and 80% and 90% availability for pipeline facilities) suggests that the uncertainty in the capacity estimates could mean that the total annual capacity for operational facilities could be between 140,300 t lower and 42,100 t higher. With pipeline facilities, with the 80% and 90% availability this would result in between 119,150 t lower and 119,200 t higher. This uncertainty is likely to be small in comparison to the uncertainty around which facilities may or may not be built in the future. It does not change the overall conclusions or recommendations of this Review.

3.4 Capacity Analysis Results

3.4.1 Overview

Figure 2 shows the results of the capacity analysis taking account of the full pipeline capacity, i.e. facilities at all stages of the development process. It includes all capacity in the pipeline, although it is unlikely that all facilities in the pipeline will be built, especially those that have not yet secured full financial backing (‘financial close’), which in turn often depends on securing local authority ‘anchor’ contracts.

The assumed future waste quantities are shown for each of the modelled scenarios and projected forwards to 2050.

[29] For example, one operator told us they would be expecting to operate close to their permitted capacity, and would be likely to come online sooner than the original estimate.

The infrastructure capacity is shown as stacked line columns. At the bottom of each column is the modelled operational capacity[30]. Over the projected period, some of these capacities decrease as infrastructure is anticipated to close. Pipeline infrastructure is then categorised by the current development stages (’in construction’, ‘fully consented’, ‘planning granted’, ‘proposed’.) and each facility’s estimated operational commencement date based upon the information available and the assumptions provided.

3.4.2 Capacity requirements

Figure 2 (which excludes C&D waste) suggests that there is likely to be insufficient residual waste treatment capacity in Scotland in 2025 by 590-680 kt where policy targets are not achieved. Where Scotland meets its policy targets, there would not be an expected capacity gap from 2024. If all the facilities that are categorised in the model as fully consented are built as anticipated, then there is likely to be overcapacity from 2027 in all scenarios modelled. An overcapacity could also exist in 2025, if Scotland meets its policy targets and all pipeline facilities scheduled to come online by then do become operational as planned.

Following an initial build phase, the infrastructure capacity is expected to reduce with the anticipated closure of some operational facilities in 2028, 2031, 2039.

In all three scenarios, facilities currently with a status of "planning granted” or “proposed” would not be required if the other pipeline facilities that are fully consented or under construction become operational.

[30] As MBT is a pre-treatment technology, not an end treatment, the ‘capacity’ for it used in the model is the volume reduction achieved due to the pre-treatment (mainly removal of recyclables and moisture loss).

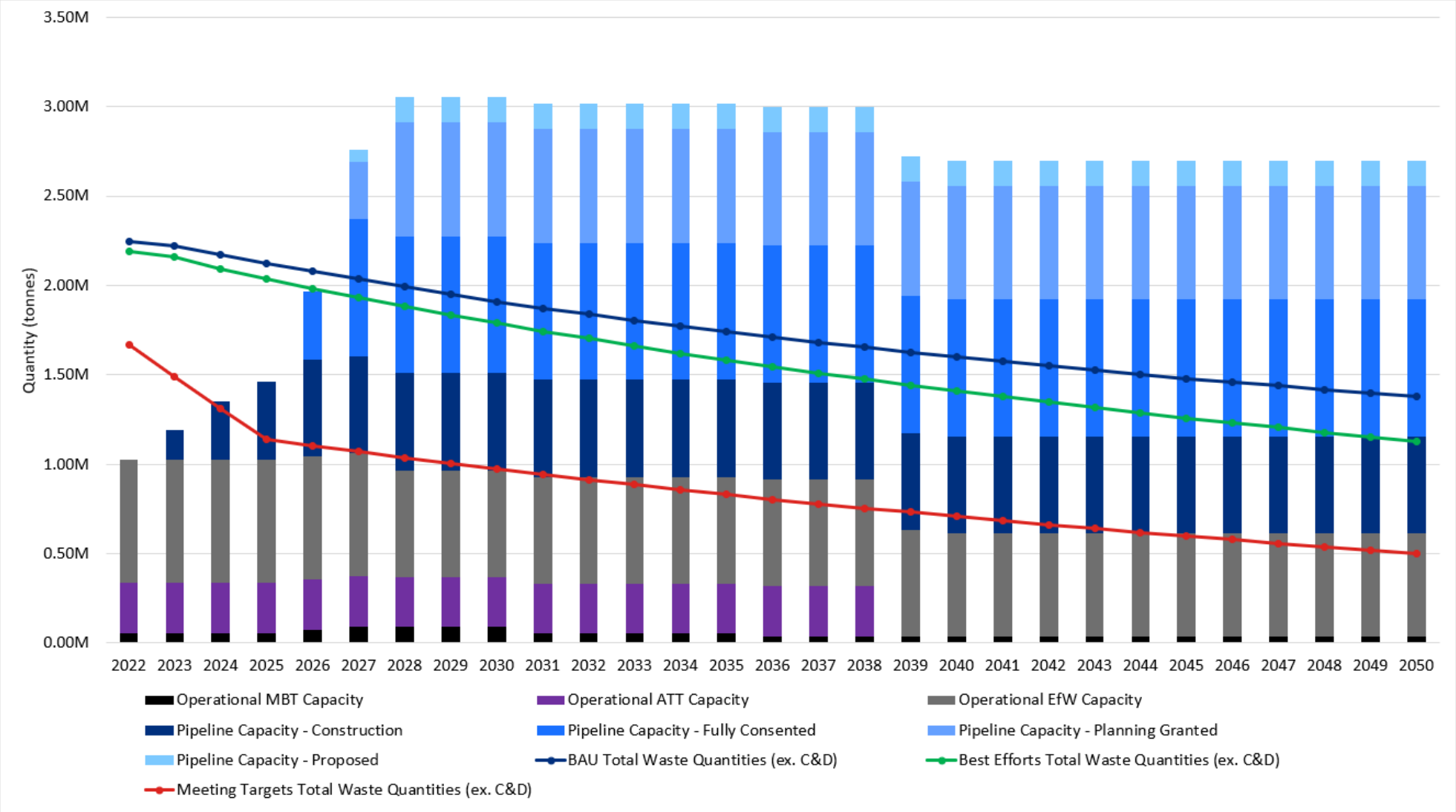

Figure 2 - Capacity Analysis results (all scenarios and full pipeline) excluding C&D waste

3.4.3 Other capacity considerations

The Review considered the inclusion of C&D waste within the capacity analysis carefully, since the extended landfill ban could include sorting residues from C&D waste. Whilst the model was run with and without these streams, the final recommendations are based on the run without them. This is because most of them are unlikely be suitable for incineration, either because of their composition or because of their size (sorting residues are often in the form of fine particles that cannot practically be treated by a conventional moving grate incineration facility). Nevertheless, some sorting residues may be suitable for incineration. The analysis suggests that if all C&D sorting residues were captured by the ban and suitable for incineration then approximately an additional 50 kt of additional capacity in 2025 may be required.

Stakeholders also highlighted other opportunities in Scotland for processing waste, particularly incineration of waste (for example, SRF) at cement works, which would also support the decarbonisation of the cement industry. Dunbar Cement Plant (Tarmac) is a potential opportunity. Currently the plant treats around 12 kt of rubber waste each year and opportunities to burn other wastes could support Scotland's residual waste treatment infrastructure. The Scottish Leather Group also drew attention to its own facility, which processes tannery waste from their production processes, highlighting opportunities to treat specific waste streams with smaller facilities.

The existing and planned capacity shown in Figure 2 may also be filled by waste arising outside of Scotland. For example, CIWM suggested that around half of the capacity of the Oldhall (Doveryard) facility may be contracted to waste from Northern Ireland.

Finally, stakeholders also observed the need to allow additional capacity for unexpected circumstances such as unplanned maintenance or facility breakdown. There could be scope for some existing facilities (such as the Dunbar Cement Plant) to be re-tasked for a short period to help manage this through burning refuse derived fuel (RDF) or solid recovered fuel (SRF). In addition, in all scenarios modelled, there is likely to be more capacity available than needed for Scotland's residual municipal waste from 2027 onwards, which will reduce the risk from such unexpected circumstances. The Scottish Government and SEPA will need to consider how best to work with local authorities and industry to manage such eventualities.

3.4.4 Comparisons with other capacity estimates

Stakeholders provided some capacity estimates and recommendations. These capacity estimates were generally up to 2025, reflecting the timeline for the Ban. As with the infrastructure capacity, comparing capacity estimates is difficult due to the assumptions and scenarios used in each analysis. However, there was some broad

agreement with the range of scenarios presented in Figure 1. For example, RMAS[31] predicted a potential capacity gap in 2025 of 250-680 kt, while UKWIN[32] and SESA[33] identified a potential for either overcapacity (530-455 kt) or undercapacity (550-635 kt).

SEPA took a different approach to modelling the capacity requirements. SEPA used a‘ bottom-up ’approach, using data on the amount of waste landfilled in Scotland in 2020[34]. This contrasts the capacity analysis above which starts with waste arisings data. The SEPA analysis suggests that around 1.05 Mt of waste that would be captured by the Ban was landfilled in 2020, resulting in a capacity gap of around 500 kt in 2025[35].

In general, most stakeholders did not fundamentally disagree with the modelling approach. Industry stakeholders, while disagreeing with some assumptions, agreed with the outcomes of the original capacity analysis set out in the Call. NGO stakeholders generally considered that there would not or should not continue to be enough residual waste arisings to produce a capacity gap.

3.4.5 Limitations and areas for further development

In the time and with the data available, the Review has done the best it can to model residual waste supply and treatment capacity in Scotland. However, limitations remain. These include:

- Detailed consideration of the potential changes in the composition of the waste and its impact on capacity and appropriate treatment solutions. An initial assessment has been made by Ricardo, however, there is a lack of data on the potential impacts of future policies, such as deposit return scheme (DRS) and changes to packaging recycling rule to produce a meaningful analysis. SEPA notes that Dunbar has applied to extend its permitted capacity, which has become possible due to a lowering of the calorific value (CV) of its residual waste. In contrast, FCC noted the opposite effect is possible, if the CV of residual waste increases.
- Uncertainty about whether some waste streams are suitable for incineration facilities. For example, some waste classified as sorting residues (EWC 19 12 12) may be unsuitable for incineration with the dominant moving grate technology.

[31] *RMAS Homepage.* Resource Management Association Scotland. Available at: https://rmascotland.co.uk (accessed March 2022)
[32] *UKWIN Homepage.* United Kingdom Without Incineration Network. Available at: https://ukwin.org.uk (accessed March 2022)
[33] *SESA Homepage.* Scottish Environmental Services Association. Available at: http://www.esauk.org/about-us/sesa (accessed March 2022)
[34] *Waste Landfilled in Scotland Dataset.* SEPA. (2020). Available at: https://www.sepa.org.uk/media/594032/2020-waste-landfilled-in-scotland-data-tables-release.xlsx (accessed March 2022)
[35] SEPA response to Incineration Review Call for Evidence. SEPA. (2022). Available at: Incineration in the waste hierarchy review: call for evidence - Scottish Government - Citizen Space (consult.gov.scot)

- Inability of the model to shed light on the balance between larger centralised facilities and smaller decentralised facilities, such as the economics and carbon emissions of transporting waste.

3.5 Risk Of Lock-In And Stranded Assets

Lock-in is where the development of residual waste treatment infrastructure with a long operational life, such as incineration, limits the treatment of waste further up the hierarchy. This can come about nationally if more capacity is built than, over time, is needed as an economy moves towards a more circular model.

This emergence of excess capacity over time has been the experience of some northern European countries[36]. This has been handled in many cases by importing RDF from elsewhere to make up volumes. However, doing this in Scotland would not be consistent with the overall resource and waste management policy.

It can also happen on a more local basis because, in order to finance the infrastructure, long term residual waste supply contracts with local authorities may have guaranteed minimum amounts with either financial penalties for not meeting them or bonuses for meeting them. If set at too high a level, this can constrain local recycling or waste prevention activities as the penalties (or missed bonuses) that might result are viewed as too expensive.

The Review received some stakeholder contributions that suggested there is a potential for lock-in effects, including examples where rising rates of incineration were accompanied by declining rates of recycling[37,38]. Others suggested that the market dynamics would mean that financiers would not invest where there was likely to be insufficient waste. However, where there are high guaranteed minimum tonnages, it is the local authority that carries the risk, not the financier, so this argument does not always stand.

One evidence contribution[39] provided the results of some unpublished analysis of English data showing the relationship between rates of incineration and rates of recycling over the past ten years (a period of significant growth in incineration capacity in England). For most combustible materials, this shows an inverse relationship (that is, recycling is dropping and incineration is growing) which might be an indication of the impact of lock-in.

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[36] *SEPA response to Incineration Review Call for Evidence.* SEPA. (2022). Available at: Incineration in the waste hierarchy review: call for evidence - Scottish Government - Citizen Space (consult.gov.scot)
[37] *Friends of the Earth Scotland response to Incineration Review Call for Evidence*. FOES. (2022). Available at: Incineration in the waste hierarchy review: call for evidence - Scottish Government - Citizen Space (consult.gov.scot)
[38] *UKWIN response to Incineration Review Call for Evidence.* UKWIN. (2022). Available at: Incineration in the waste hierarchy review: call for evidence - Scottish Government - Citizen Space (consult.gov.scot)
[39] Email correspondence between Prof Phil Purnell (University of Leeds) and the Review

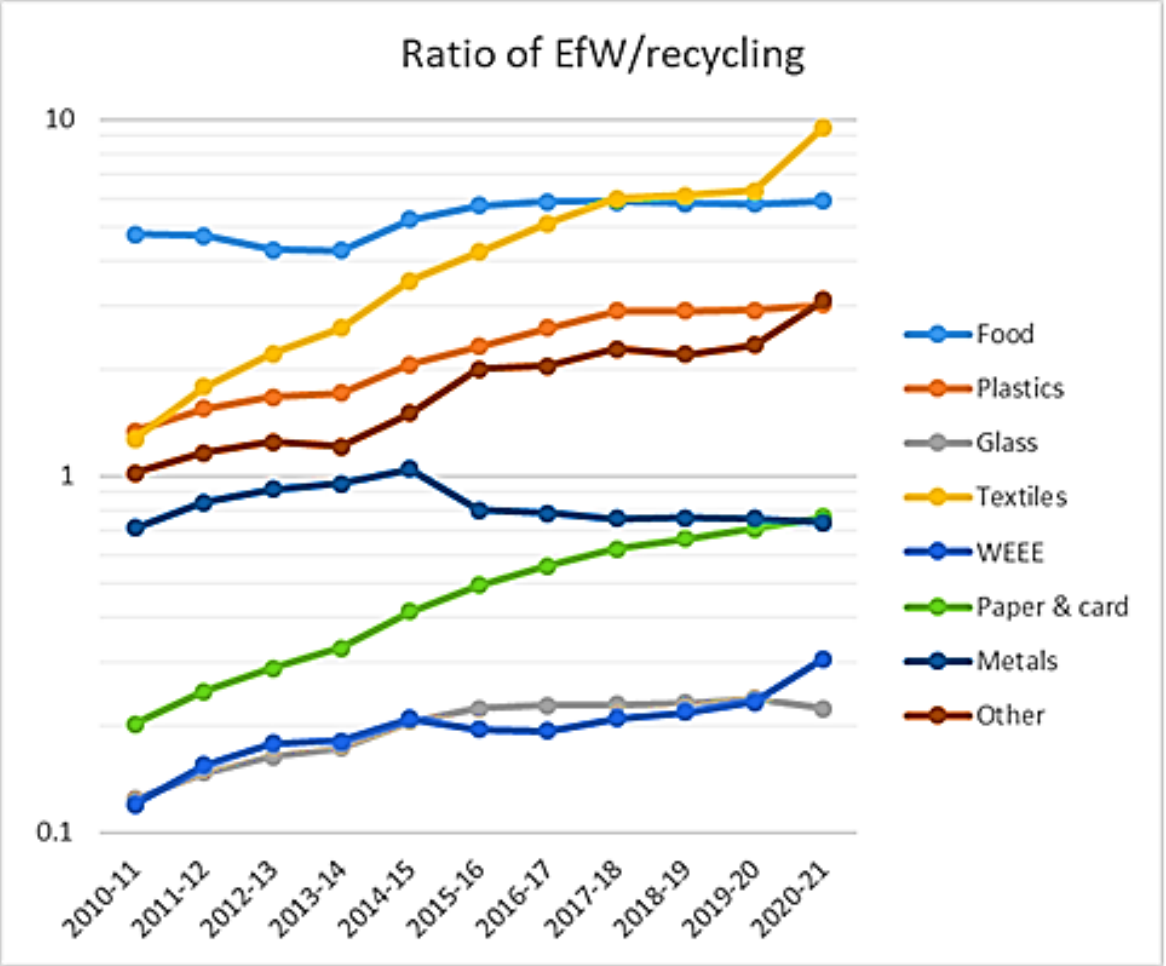

Figure 3: Rates of incineration versus recycling in England, Prof P Purnell (University of Leeds)

The Review was unable to analyse whether or not existing local authority contracts in Scotland contained guaranteed minimum tonnages (or other conditions) that might be problematic in terms of lock-in as it was informed that such contracts were commercially confidential and would not be shared.

Stakeholders generally associated lock-in effects with incineration. For example, one stakeholder suggested that MBT or biostabilisation would avoid lock-in associated with residual waste treatment facilities such as incinerators which cost hundreds of millions of pounds to build. However, the evidence received by the Review suggests that MBT facilities require a consistent feedstock to operate effectively and their costs can range from £50m to £125m, suggesting the potential for similar lock-in effects, or stranded assets if the composition of feedstocks does change.

Stakeholder feedback also raised concerns about the increased risks of lock-in or stranded assets with a reliance on expensive carbon capture and storage solutions to reduce the carbon impacts of incineration.

3.6 Conclusions On Capacity

Despite the uncertainties outlined above, the capacity analysis suggests that there is likely to be a residual waste treatment capacity gap in 2025, when the Ban comes into force. This will clearly be exacerbated if the ban is extended to include non-municipal biodegradable waste. While this capacity gap could be closed by Scotland achieving its waste and recycling targets, a few stakeholders raised concerns about the likelihood of achieving these targets, drawing on experience and comparisons with other nations as evidence of what could be possible.

The capacity analysis also shows there is a risk of long-term overcapacity beginning from 2026 or 2027, if all or most of the incineration capacity in the pipeline is built, notwithstanding the predicted closure of some facilities in the future.

The analysis demonstrates the difficulty in using infrastructure with long operational lifespans alone to treat residual waste. Scotland appears to have more than enough capacity (in operation and in the development pipeline) to manage its residual waste beyond 2025. Given the risks of overcapacity, Scottish Government should limit the amount of national capacity that is developed. Care will be required to ensure any limits are appropriate and waste can be managed during planned or unexpected events (e.g. from routine maintenance to pandemics) which temporarily reduce capacity or increase waste arisings. For example, additional ‘buffer’ capacity beyond the availability assumed in this model may be necessary.

The Review has considered whether it would be possible to comment on which of the pipeline facilities should be built and which should not, but has decided that in the time and, with the evidence available to it, is unable to do so with sufficient robustness. However, it would point to the discussion in Section 6 for some principles that might be applied.

Recommendation 4 Effective immediately, the Scottish Government should ensure that no further planning permission (i.e. beyond that already in place) is granted to incineration infrastructure within the scope of this Review unless balanced by an equal or greater closure of capacity. The only exceptions to this should be those outlined in Recommendation 10. This change could be embedded in the final version of the fourth National Planning Framework.

The Review recognises that it is not straightforward to terminate or revoke planning permission once it has been granted. However, as a consequence of the Review and the acceptance of Recommendation 4:

- Developers of the schemes categorised as “planning granted” in the capacity analysis report should consider whether there will in fact be sufficient residual waste available to operate as currently foreseen.
- Local authorities should consider using the powers under section 61 of the Town and Country Planning (Scotland) Act 1997 or other powers to terminate existing planning permissions for incineration facilities that have not been pursued.

Finally, the Scottish Government should consider how best it can discourage undesirable imports of RDF to Scotland that might drive otherwise unnecessary infrastructure capacity development.

Recommendation 5 As part of an overall strategic approach to planning and deploying waste management capacity (see Recommendation 11), the Scottish Government should develop an indicative cap that declines over time for the amount of residual waste treatment needed as Scotland transitions towards a fully circular economy.

To do this, Scottish Government should:

- Consider what other options are available to manage waste (see Recommendation 7) and the regional demand and resilience of residual waste infrastructure (see Recommendation 10).
- Remain cognisant that there may be a justification for local or regional capacity, even where no national capacity requirements are needed.
- Define the scope of the Extended Ban carefully to consider the best management option for specific waste streams (e.g. C&D sorting residues)
- Develop its own modelling capabilities to rapidly update this modelling with new data.
- Work with SEPA, local authorities and the waste industry to improve waste data (for example, C&I waste arisings) and reduce uncertainty in future capacity analyses (see also Recommendation 2).
- Work more closely with developers of pipeline infrastructure to understand the timelines for development, capacity and other needs.
- Consider what buffer capacity may be required in the future and how to provide it.

This work should be carried out with stakeholders.

Some of the biggest problems in recommending a level for the cap are the uncertainties in the data and the lack of a clear understanding of the likely trajectory of residual waste arisings. This in turn depends fundamentally on the policy choices of the Scottish Government within the context of the whole resource and waste management system. It is to be hoped that the forthcoming Route Map to deliver Scotland's resource and waste management targets will provide greater clarity on this.

In the meantime, given the data and modelling issues noted earlier, it is hard to recommend a definitive figure. Clearly, though, it should be on a declining trajectory over time and be below the projected residual waste arisings in the BAU scenario.

Recommendation 6 When negotiating contracts for residual waste management treatment, local authorities should specifically address the risks of lock-in and ensure those contracts are aligned with meeting Scotland's current and future targets on resource and waste management.

4 Residual Waste Management Options

What are the options for managing residual waste?

4.1 Feasibility Of Options

The capacity analysis (Section 3) noted the need for careful consideration of waste management options to overcome a short-term capacity gap as well as management options to mitigate risks to overcapacity in the medium to long-term.

In considering the feasibility of waste management options in Scotland, the vast majority of stakeholders noted that waste prevention and recycling should be prioritised. Zero Waste Scotland notes that around 60% of residual waste is recyclable[40]. There will be greater carbon and environmental benefits to reducing and recycling this waste compared to residual waste treatment.

Where materials do become residual waste, the Review's analysis suggests that incineration and landfill are both feasible options for its medium to long-term management . However, for BMW streams, landfilling in Scotland will not be an option after 2025.

Analysis[41] suggests that biostabilisation is unlikely to be a feasible option for the short or medium-term management for residual waste treatment in Scotland. It seems to be technically feasible to stabilise waste to achieve the landfill ban criteria[42], using an MBT plant with in-vessel composting as a biological treatment step, and this may be lower carbon than other options (see Section 7.1). However, the evidence also suggests the UK market is moving away from MBT and the reported technical difficulties associated with MBT facilities are unlikely to make this technology appealing to investors. MBT also appears to require stable feedstocks to achieve consistent performance and Scottish Government policies are seeking to change the nature of residual waste. Therefore, there appears to be similar risks of lock-in effects or stranded assets (see Section 3.5).

It is difficult to compare the cost of MBT and other treatment options, however, from the available evidence MBT appears to be a costly treatment option for local authorities. It is also worth noting that another economic barrier to biostabilisation is likely to be the exclusion of biostabilised waste from the list of wastes[43] that incur the lower rate of Scottish Landfill Tax (currently £3.15/t). Biostabilised wastes would therefore be subject to the standard rate (currently £98.60/t).

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[40] *The composition of household waste at the kerbside in 2014-15,.* Zero Waste Scotland. (2017). Page 12. Available at: https://www.zerowastescotland.org.uk/sites/default/files/The%20composition%20of%20household%20waste%20at%20the%20kerbside%20in%202014-15.pdf (last accessed April 2022)

[41] *Operational Assessment of Alternative Residual Waste Treatment Technologies Report.* Zero Waste Scotland (Pre-peer review, unpublished). (2022)

[42] Further information can be found at: *Biodegradable Municipal Waste Landfill Ban.* SEPA. (2018). Available at: https://www.sepa.org.uk/media/352595/sepa_bmw_landfill_ban_guidance_note.pdf (accessed April 2022)

[43] *The Scottish Landfill Tax (Qualifying Material) Order 2016.* Available at: https://www.legislation.gov.uk/ssi/2016/93/contents/made (accessed April 2022)

For the short-term management of residual waste, for example to fill the immediate capacity gap identified in the analysis, the export of waste appears to be the most feasible option. This could include export of waste to England for landfill or export of RDF or SRF for energy recovery to England or further afield. Scotland has two significant MBT facilities, which both produce RDF (though one supplies only the co-located gasification plant). As noted above, MBT appears to be a costly waste management option, so export of waste is likely to only be desirable as a temporary measure.

One potential benefit of MBT facilities is that they can be designed to remove recyclable waste from the residual waste stream. Similarly, some incineration facilities in Scotland have sorting facilities which can remove recyclable materials. However, as some stakeholders note, due to the poor quality of the materials produced it is often difficult to find suitable outlets for them at this time, meaning incineration or landfill can be the most economically favourable option. This often results in only metals being recovered from the residual waste stream in the UK.

Some emerging technologies which are in pilot and demonstration stages were highlighted by the analysis. These include waste to hydrogen technology and hydrothermal liquefaction. While these are unlikely to provide short-term options, these or other emerging technologies may provide medium to long-term options as they develop.

4.2 Conclusion On Options

In conclusion, the Review considers that overall, incineration's place in the waste hierarchy is appropriate. Incineration in a properly regulated and operated facility remains the most appropriate treatment route for residual biogenic and BMW, especially once everything that can be extracted for recycling has been taken out and where waste prevention and reuse have been maximised.

Recommendation 7 The most feasible treatment options to manage Scotland's residual waste are incineration, landfill and export of waste. Scottish Government should work with local authorities to ensure they have a solution to manage their residual waste in 2025 based on this.

- This may involve shorter term solutions such as export of waste to bridge an expected capacity gap in 2025.
- Following the introduction of the BMW ban, landfill should be considered as a specialised waste treatment option only, where it provides the best environmental outcome and not for the routine disposal of active waste.

5 Trade-Offs

What are the environmental and social trade-offs of those residual waste management options?

5.1 Climate Change Impacts

Many stakeholders were concerned about the climate change impacts of residual waste management and options for managing them. This topic is discussed in Section 7 – IMPROVING CARBON PERFORMANCE along with the Review's initial thoughts on addressing decarbonisation of incineration.

5.2 Health Impacts

5.2.1 Incineration

A number of stakeholders raised concerns about the potential health impacts of incineration in all forms. Historically, the main issue has been air quality. The developments in regulation of incineration plants through European and Scottish law have continued to reduce emissions of most pollutants. However, increasingly, stakeholders are raising questions around ultrafine airborne particles (smaller than 2.5nm) as these are known to have negative health impacts and there is concern that modern air pollution control processes do not stop these from being emitted. Some stakeholders have also raised the wider mental health and wellbeing impacts of living near an incinerator.

The Review commissioned Public Health Scotland (PHS) to consider whether the conclusion from a previous Health Protection Scotland review on the health impacts of incineration[44] should be amended in light of more recent evidence. PHS undertook a Rapid Evidence Review ('the 2022 PHS Review'), which reaffirmed the original conclusions of the 2009 work:

> "the body of evidence for an association with (non-occupational) adverse health effects is both inconsistent and inconclusive. However, more recent work suggests, more strongly, that there may have been an association between emissions (particularly dioxins) in the past from industrial, clinical and municipal waste incinerators, and some forms of cancer, before more stringent regulatory requirements were implemented.
>
> For individual incineration waste streams (clinical, hazardous, industrial and municipal), the evidence for an association with (non-occupational) adverse health effects is inconclusive.

[44] *Incineration of Waste and Reported Human Health Effects*. Health Protection Scotland. (2009). Available at: https://hpspubsrepo.blob.core.windows.net/hps-website/nss/2407/documents/1_incineration-of-waste-and-reported-human-health-effects.pdf

> The magnitude of any past health effects on residential populations living near incinerators that did occur is likely to have been small.
>
> The majority of research work in this field is of historical relevance but tells us little about the current risk of (non-occupational) adverse effects potentially associated with incineration plants in operation now.
>
> Levels of airborne emissions from individual incinerators should be lower now than in the past, due to stricter legislative controls and improved technology. Hence, any risk to the health of a local population living near an incinerator, associated with its emissions, should also now be lower."

The 2022 PHS Review also stated that any risks to human health related to newer incinerators were very likely to be lower than they were previously. However it also confirmed that evidence continued to be absent, inadequate or limited. Additionally the 2022 PHS Review stated that:

> "Commitment to limiting the total amount of waste destined for energy recovery via thermal treatment, as well as the use of existing planning controls, should also continue to minimise public exposure to potential adverse health impacts of incineration."

The Review has addressed the need to limit residual waste in Recommendation 1.

While the 2022 PHS Review did not consider the issue in detail, stakeholders raised concerns around the potential psychological or mental health impacts of living close to an incinerator. The Review did not find any specific studies considering this. One study 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".[45] There is scope for further research into this area.

5.2.2 Landfill

The health impacts of landfill can be difficult to quantify as they vary based on location, design and waste composition for each location. A study considered the cancer risks of populations living close to landfills in Great Britain, finding that there were no excess risks of cancer for those living within 2km of landfill sites compared to those living more than 2km from a landfill[46]. An initial study of landfills in Great Britain in 2001 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[47]. A follow-up study of the risk of adverse birth outcomes in

[45] *Environmental Stressors: The Mental Health Impacts of Living Near Industrial Activity.* Downey, L. & van Willigen, M. (2005). *J Health Soc Behav, 46(3), pp. 289-305.*
[46] *Cancer risks in populations living near landfill sites in Great Britain.* Jarup, L. et al. (2002). British Journal of Cancer, Volume 86, pp. 1732-1736.
[47] *Risk of adverse birth outcomes in populations living near landfill sites.* Elliott, P. et al. (2001). British Medical Journal, Volume 323

populations living within 2 km of special (hazardous) waste landfill sites found that there were no statistically significant excess risks of congenital anomalies or low birth weight in populations living near special waste landfill sites.[48]

A more recent study by Eunomia[49] on behalf of ClientEarth investigated the air quality impacts of landfill in comparison to incineration through a literature review and modelling and showed that, of the health impacts considered from landfill, ammonia has the greatest impact on human health. Biostabilisation reduced this impact slightly but also increased particulate emissions modelled as $PM_{2.5}$. Overall, the report concluded that landfill had a smaller impact on local air quality than incineration.

5.2.3 Mechanical Biological Treatment and bio-stabilisation

Defra explains that no studies had specifically looked at the health effects of MBT facilities at the time of its guidance document being produced[50]. Within its document, Defra states that the health effects are expected to be comparable to those from in-vessel composting (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 has been public concerns that open composting operations could in theory affect the health of those living in close proximity. Research undertaken by Defra suggests that communities located more than 250m away from composting facilities are unlikely to be exposed to harmful levels of bio-aerosols[51]. However, they may experience odours associated with the process as these can travel much further.

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

5.2.4 Conclusion on the health impacts

The evidence suggests that all feasible options for managing residual waste in Scotland have some risks to public health that must be managed appropriately through robustly-enforced regulation. The evidence does not suggest that these impacts are more severe from incineration than from landfill, export or MBT. However, these conclusions need to be kept under constant review as the evidence on health impacts evolves.

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[48] *No Excess Risk of Adverse Birth Outcomes in Populations Living near Special Waste Landfill Sites in Scotland.* Morris, S. E. et al. (2003). Scottish Medical Journal, 48(4).
[49] *Greenhouse Gas and Air Quality Impacts of Incineration and Landfill.* Eunomia. (2020). Available at: https://www.eunomia.co.uk/reports-tools/greenhouse-gas-and-air-quality-impacts-of-incineration-and-landfill/ (accessed April 2022)
[50] Mechanical biological treatment of municipal solid waste. Defra. (2013). Available at: https://www.gov.uk/government/publications/mechanical-biological-treatment-of-municipal-solid-waste
[51] *Exposure-response relationships for bioaerosol emissions from waste treatment processes.* Defra. (2008). Available at: http://sciencesearch.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=15140 (accessed March 2022)

5.3 Community And Social Impacts

This section focuses on considerations specific to populations in the areas local to waste treatment facilities.

Community groups and members of the public concerned about incinerators in their local areas have engaged with all elements of the Call[52]. While responses were focused on incineration, new waste facilities of whatever type are rarely welcomed by residents close to where the facility is to be located[53]. With the awareness that many may become engaged in the debate around waste management in their local community but not in the conversation at a national level, the Review has sought out additional information regarding the number of objections posed to SEPA and local authorities around specific plants, in order to better understand this level of engagement which may not have reached the Review directly. This showed a large range in the number of objections received depending on the site, with some receiving very low numbers and other receiving well over a thousand.

5.3.1 Local amenity

Impacts on local amenity are often cited as concerns relating to waste management facilities. These include light pollution, noise, odours, vibration, chimney plume and increases in local traffic.

In its response to the Call, SEPA noted it was more likely to receive complaints regarding dust, odour and vermin relating to landfills and more about noise for incineration facilities. The planning and permitting application processes consider the potential impacts on local amenity in the context of the specific location, type and size of the facility. However, a number of stakeholders raised concerns around the process of community engagement undertaken as part of planning. This is discussed further in Section 5.4.

5.3.2 Social deprivation

A frequently stated concern is that low income areas are more acutely exposed to the impacts of residual waste management as these facilities are more likely to be located in areas where these populations live. There is good evidence that socially deprived areas are disproportionally exposed to municipal landfill sites. This suggests that area deprivation may have preceded disproportionate siting to some extent, but landfill siting also preceded a relative increase in deprivation[54]. There is a similar distribution of incineration facilities in England[55], however, it is difficult to

[52] The review received 57 responses and emails from individuals and local community groups and an email campaign of over 1000.
[53] *Mechanical biological treatment of municipal solid waste*. Defra. (2013). Available at: https://www.gov.uk/government/publications/mechanical-biological-treatment-of-municipal-solid-waste
[54] *The Mechanism behind Environmental Inequality in Scotland: Which Came First, the Deprivation or the Landfill?,* Richardson, E., Shortt, N. & Mitchell, a. R. J. (2010). Environment and Planning, 42(1), pp. 223-240.
[55] *Incineration Review: Options Appraisal.* Ricardo Energy and Environment. (2022). Available at: http://www.gov.scot/ISBN/9781804353912/documents/

assess this in Scotland due to the small sample size of operational facilities. The location of operational and pipeline facilities in relation to the Scottish Index of Multiple Deprivation (SIMD) is in Table *3*.

Table 3. Scottish Index of Multiple Deprivation (SIMD)[56] deciles for areas and proposed areas of operational and pipeline facilities, respectively.

Facility Name	Status	SIMD Decile
GRREC	Operational	1
Earls Gate	In Construction	3
Lerwick	Operational	3
South Clyde (Fortum)	Fully Consented	3
Aberdeen Recycling & Energy Recovery (NESS)	In Construction	4
Oldhall (Doveryard)	Fully Consented*	4
Westfield	In Construction	4
Drumgray (FCC)	Fully Consented	5
DERL (MVV Baldovie)	Operational	6
Dundee ERF*	Operational	6
Glenfarg (Binn Group)	Planning Granted	6
Inverurie (Agile Energy)	Planning Granted	6
Millerhill	Operational	6
Avondale EfW	Planning Granted	7
Dunbar ERF	Operational	7
Killoch EfW	Planning Granted	7
Levenseat	Operational	7
Levenseat 2**	Planning Granted	7

*Same location as existing facility (DERL (MVV Baldovie)) assumed
** Same location as existing facility (Levenseat) assumed

This table shows that there is not a strong relationship between a location's decile on the SIMD and the likelihood that an incinerator will be located or planned in that area. Indeed, ten (56%) are in the less deprived half of the distribution.

[56] The Scottish Index of Multiple Deprivation (SIMD) is a relative measure of deprivation which ranks 6,976 small areas (called data zones). The SMID 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. More information can be found at: *Scottish Index of Multiple Deprivation.* Scottish Government. (2020). Available at: https://www.gov.scot/collections/scottish-index-of-multiple-deprivation-2020/ (accessed March 2022)

5.3.3 Perception

Another element for consideration in terms of community and local impacts of waste treatment facilities is the perception of such facilities. The Review received evidence of lived experience, and contributions of community groups, regarding concerns relating to incineration in particular.[57] Examples given included concerns around a decrease in house prices local to incineration facilities, impacts on the ability of local businesses to sell products, and the potential psychological impacts of worry and anxiety about a local incineration facility. While some perceived harms may be difficult to verify with external evidence, the Review regards the perceptions themselves as essential to understanding the community and social impacts of waste treatment methods.

5.3.4 Employment

There could also be some positive impacts of residual waste treatment facilities on local areas. Employment opportunities in operating and constructing incineration facilities was raised by multiple stakeholders as an example of a positive impact[58], with some stakeholders highlighting that there are likely to be more employment opportunities generated from an incineration facility compared to landfill. However, one piece of evidence suggested that there were six jobs available in landfill for every one in incineration, while also indicating the opportunity for further employment within the circular economy[59]. In terms of MBT, a guidance document from Defra provides an employment guide based on current and proposed facilities (at the time of the report) of about one employee per 6-7000tpa processed[60].

5.3.5 Scottish Landfill Communities Fund

One vector for positive or mitigating impacts for communities local to landfill sites is the Scottish Landfill Communities Fund (SLCF). Established in 2015, it is funded by operators giving a percentage of their landfill tax liability to an 'approved body', which then distributes funding to community and environmental projects. A review of the performance of the fund was undertaken in 2020 by SEPA and found that 55% of landfill operators have contributed to the SLCF and it had funded over 1,400 projects with £32.7m of funding[61]. The SLCF is expected to receive declining contributions in future years due to a reduction in reliance on landfills and because of the Ban in 2025.

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[57] The preponderance of evidence relating to incineration compared to other waste treatment options could be explained by the Review's focus on waste and possibly the differences in lifecycle stages and planning processes

[58] For example, a typical ATT plant of 50,000 t/y capacity would employ approximately 25-35 permanent staff

[59] *Briefing on job creation potential in the re-use sector.* rreuse. (2015). Available at: https://rreuse.org/re-use-has-higher-employment-potential-than-recycling/.(accessed April 2022)

[60] *Mechanical biological treatment of municipal solid waste*. Defra. (2013). Available at: https://www.gov.uk/government/publications/mechanical-biological-treatment-of-municipal-solid-waste

[61] *Scottish Landfill Communities Fund Five Year Review.* SEPA. (2020). Available at: https://www.sepa.org.uk/media/590266/201201_public_slcf_5yearreview.pdf (accessed April 2022).

5.3.6 Heat and energy offtake

Heat and energy offtake are often cited as positive examples of the impact of incineration facilities on their local communities. In Lerwick, Shetland, heat from the energy recovery plant supplies approximately 1200 customers and, according to Shetland Heat Energy & Power, around £1,000,000 per annum of the income from these sales remains in Shetland[62]. However, stakeholders have expressed concern about the implementation of heat and energy from other waste incineration facilities and the likelihood of these benefits materialising in other areas (see Section 7)

5.3.7 Conclusion on community and social impacts

The planning and permitting processes for residual waste treatment facilities consider and seek to address a range of community and social impacts (but see also Section 5.4 – PLANNING CONSIDERATIONS for some issues with the former). Landfill facilities are more likely to receive complaints than incineration facilities, with the exception of noise. There is not a strong link in Scotland between the location of incineration facilities and deprivation. Perceptions of incineration facilities can though be quite negative. Residual waste management facilities can provide employment opportunities to local communities and some funding for community activities.

5.4 Planning Considerations

It has become clear from the Review's engagement with stakeholders that planning processes and poor engagement between operators and local communities present their own concerns.

Community stakeholders raised the fact that they had difficulty having their voices heard. Within the stakeholder events, roundtable meetings and subsequent meetings, stakeholders raised issues they had faced engaging with the planning processes. This included struggling to find information on how to engage effectively, feeling that their engagement was not regarded widely and frustration with the lack of a right to third party appeal.

Recommendation 8 **As part** of the strategic approach referred to in Recommendation 11, Scottish Government and Local Authorities should ensure that adequate time and resource is dedicated to local and community engagement.

This should include:

- Providing greater clarity on how community and local groups can engage with waste planning processes effectively.
- Ensuring opportunities for local and community groups to be heard within meetings where waste management is discussed and that they are given appropriate time and genuine consideration

[62] *About Shetland Heat Energy and Power.* Shetland Energy Heat and Power. https://sheap-ltd.co.uk/technical-information (accessed April 2022).

- Planning authorities reviewing commitments made in the planning process on a regular basis to ensure they are always upheld, especially in terms of community benefits

These proposals could be integrated into the final version of NPF4.

5.5 Effective Engagement With Local Communities

In addition to difficulties local communities may face engaging with planning processes, relations between operators themselves and the local communities, particularly around planned sites, can be poor.

It is clear from the response to the Call that among certain groups there is mistrust and concern around the operators of residual waste treatment facilities. Concerns were raised about gaps in data as well as the accessibility and clarity of information relating to emissions. There was also some concern that operators have failed or will fail to follow through on benefits promised at planning stages. Additionally, there was some frustration expressed at the use of language and branding by individual operators, with claims that it was misleading.

There are, however, positive examples available of community engagement from waste treatment operators. An example was provided verbally to the Review, in which an operator took a local community council to visit a site to explain its workings, which then provided reassurance to members of that council who could see the site from their homes.

Recommendation 9 Operators of all residual waste treatment facilities should work to significantly strengthen community engagement and trust before, during and after development. Clear guidelines for authentic and effective community engagement should be co-produced by Scottish Government with community groups and local authorities by the end of 2023.

This engagement needs to be genuine and it will not be viewed as such if promises are made which are then not kept. The guidelines should be determined within the co-production process, however the Review would recommend that the following elements are considered:

- Transparency in construction processes and operations.
- Follow-through on community benefits referred to in planning stages.
- The accessibility of data around a plant's operations, including emissions data.
- Ensuring local voices are heard at every stage of the process.
- Engaging with local concerns, providing evidence and reassurance relating to impacts of waste management without being misleading or engaging in 'greenwashing'.

6 Location

How do we decide where capacity should be located, and in what form?

The Review's analysis indicates that the currently planned incineration capacity in Scotland is sufficient for managing current and projected residual waste at a national level. However, it is clear that the location of that capacity has emerged in an unstructured manner, with some areas being better served than others. This is particularly problematic for some of the more remote or rural areas of Scotland, including islands, though for example the Shetlands have been able to address this successfully with the Lerwick heat plant (see Figure , generated for the Review by Scottish Government).

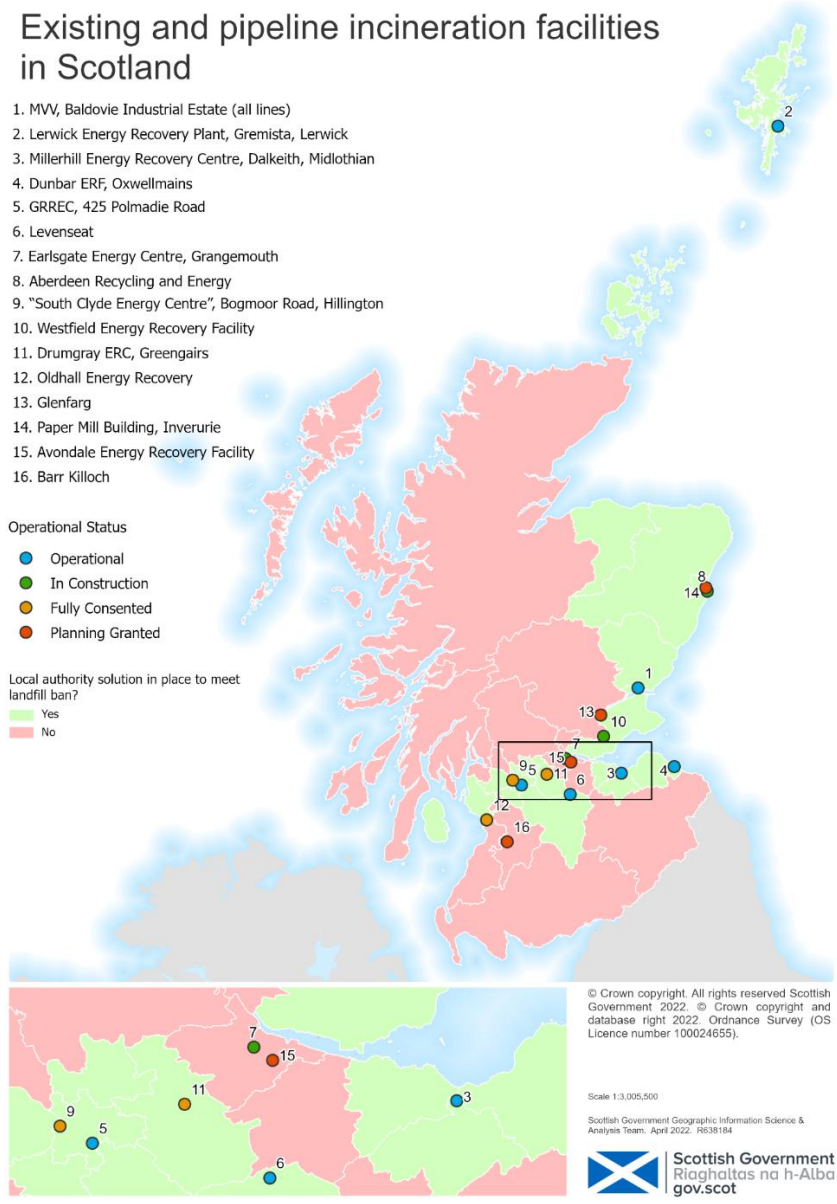

Figure 4: Existing and pipeline incineration facilities in Scotland

The Scottish Government will need to work with local authorities in these areas to explore options to manage their residual waste. If no better option is available that might, if fully justified, lead to the creation of a small amount of additional capacity. This work will need to recognise the potentially greater residual waste management costs faced in remote and rural areas.

Recommendation 10 **Scottish** Government should urgently work with local authorities in remote and rural areas of Scotland without a settled residual waste management solution to meet the Ban to explore options that might, if fully justified, lead to the creation of a small amount of additional capacity.

Notwithstanding the current capacity situation, over time, existing residual waste infrastructure will need to be replaced to some reducing extent as it reaches end of life. In addition, if Scotland is to meet its wider resource and waste management targets, other infrastructure will need to be developed. It would be unfortunate if the same unstructured approach were allowed to recreate similar issues in the future. This is particularly true because of the complex, interdependent nature of resource and waste management, which emphasises the importance of treating it as a whole system. The Review therefore recommends that the Scottish Government and local authorities should work with industry to develop a strategic approach to planning and deploying waste collection, reprocessing and management facilities by the end of 2023, which takes account of the issues set out below.

Recommendation 11 Scottish Government and local authorities should work with industry to develop a strategic approach to planning and deploying waste collection, reprocessing and management facilities by the end of 2023, which takes account of the key issues. The Scottish Government should consider how best to incorporate this into the proposed fourth National Planning Framework.

Stakeholders proposed a range of criteria that could be used to decide where to place residual waste capacity going forward. Drawing on that, the Review suggests that the following should be considered as key issues in developing the strategic approach in Recommendation 11:

- Proper appreciation of resource and waste management as a complex and interdependent system.
- Application of the proximity principle (that waste should generally be managed as near as possible to its place of production) at a sub-national level.
- Consideration of access to low-carbon transport, especially where longer distances are involved.
- Opportunities for synergy with other activities. For incineration, this should prioritise access to heat offtake and, in due course, carbon dioxide offtake options.
- Local environmental and social impacts.
- Wider environmental impacts, such as the carbon and other benefits from recycling to avoid virgin raw material production.

This approach could also be applied in co-operation with local authorities and industry to determine which of the pipeline facilities would be best to build and which might be deprioritised in the light of the overcapacity predicted in Section 3.

7 Improving Carbon Performance

What can be done to improve existing residual waste treatment facilities in terms of carbon performance?

7.1 Climate Change Impacts

Burning residual waste releases carbon dioxide. The IPCC estimates that every tonne of waste incinerated releases 0.7-1.2 tCO_2e[63], a range that is consistent with the figure adopted by UKWIN[64] of ~1 tCO_2e per tonne of waste. For global climate reporting purposes, only "climate-relevant" GHG emissions are considered. These come from the combustion of fossil carbon, which for residual waste is normally in the form of plastic. Emissions from biogenic[65] carbon (paper, card, food, natural textiles, etc) are not counted. Therefore, the greater the proportion of plastic in the residual waste, the worse the outcome for climate change from incinerating it.

By contrast, biodegradable waste decomposes anaerobically[66] in landfill sites, leading to the release of methane, which is a many times more potent GHG than carbon dioxide. Plastics and other forms of fossil carbon generally do not decompose in landfill to release GHGs.

One of the major drivers therefore of whether incineration or landfill emits the least climate-relevant GHG is the proportion of the waste that is biogenic. According to figures from Defra, in 2011 the biogenic content of municipal residual waste in England was 51%, down from 68% previously[67], though data from WRAP[68] in 2017 put it at 63%. The study by Zero Waste Scotland[69] suggests that the biogenic fraction in Scotland in 2018 was 15% and the fossil content 11%; another study showed HH waste only in Scotland[70] was 74% biogenic content in 2014-15. Given that the relative carbon impact of different options depend on it, this uncertainty in the composition of residual waste is unhelpful (see Recommendation 2).

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[63] *Emissions From Waste Incineration.* IPCC. Available at: https://www.ipcc-nggip.iges.or.jp/public/gp/bgp/5_3_Waste_Incineration.pdf (accessed April 2022)
[64] *Evaluation of the climate change impacts of waste incineration in the United Kingdom.* UKWIN. (2019). Available at: https://ukwin.org.uk/files/pdf/UKWIN-2018-Incineration-Climate-Change-Report.pdf (accessed April 2022)
[65] That is, come from natural materials that were in living organisms in the last hundred years
[66] That is, in the absence of oxygen
[67] *An assessment of the biodegradable content of mixed municipal and commercial and industrial waste.* Defra. (2012). Available at: http://randd.defra.gov.uk/Document.aspx?Document=12266_WR1003BiodegradabilityofMSWReportfinal.pdf (accessed April 2022)
[68] *National municipal waste composition - England 2017.* WRAP. (2017). Available at: https://wrap.org.uk/sites/default/files/2020-11/WRAP-National%20municipal%20waste%20composition_%20England%202017.pdf (accessed April 2022)
[69] *The climate change impact of burning municipal waste in Scotland,.* Zero Waste Scotland. (2021). Available at: https://www.zerowastescotland.org.uk/content/climate-change-impact-burning-municipal-waste-scotland (accessed April 2022)
[70] *The composition of household waste at the kerbside in 2014-15,.* Zero Waste Scotland. (2017). Available at: https://www.zerowastescotland.org.uk/composition-household-waste-kerbside (accessed April 2022)

The difference between the amount of GHG emitted for the energy generated via incineration and that generated by other sources is also relevant. Therefore, as the electricity grid decarbonises, the relative carbon benefit of incineration (without additional measures) decreases.

Currently, where energy is recovered, GHG emissions from incineration are categorised alongside other forms of energy generation in line with international standards. However, as pointed out by stakeholders, this obscures the true contribution of incineration to Scotland's GHG emissions. If policy and technology choices are made on this basis, those choices may not in fact be the right ones[71]. To address this situation, these emissions should be identified separately, a point already made by the Climate Change Committee[72].

Recommendation 12 The Scottish Government should report greenhouse gas emissions from incineration separately from other energy-related emissions as soon as possible, ideally from the 2021 data onwards.

7.2 Decarbonisation Of Existing Residual Waste Management Infrastructure

Unfortunately, given the short timescale of the Review, it has not yet been possible to explore fully all the issues related to decarbonisation of residual waste treatment in Scotland. The Review is grateful to the stakeholders who have provided evidence on this topic and has sought to draw some provisional conclusions and recommendations based on that. However, an additional piece of work has been commissioned on this Topic, which is expected to take a further six to nine months and which will be subject to review by the Climate Change Committee. This evidence will be made public in due course and may justify revision of these provisional recommendations at that point. However, the Review and its Chair do not expect this to delay the publication of the existing Report or accompanying evidence document, nor inhibit the Scottish Government's decision making ability based on this Report.

This section must not be taken as providing reasons to build more incineration facilities. Rather, it is considering how to deal with the GHG emissions from those facilities that, for waste management reasons, need to exist.

7.3 Incineration

Historically, incineration facilities have been a better option for treating residual waste than landfill in terms of GHG emissions[69], which is one reason why energy recovery appears higher up the waste hierarchy than disposal. However, as more organic waste is either avoided or separately collected for recycling, and other

[71] See for example *Problems in the Reporting of GHG Emissions from 'Waste': Indicators and Inventories,* Equanimator Ltd (2022). Available at: https://www.dominichogg.com/research
[72] *Progress reducing emissions in Scotland – 2021 Report to Parliament, Climate Change Committee.* The Climate Change Committee. Available at: https://www.theccc.org.uk/publication/progress-reducing-emissions-in-scotland-2021-report-to-parliament/ (accessed April 2022)

sources of energy generation decarbonise, this balance will continue to change and may well flip at some point without other action. Additionally, as noted above, we are currently in the growth phase, but if Scotland is to meet its resource and waste management and climate change mitigation targets, there will be a corresponding future phase down. For at least some electricity-only facilities, this could start before their currently planned end of life[73].

At a strategic level, it could be advantageous for incineration to be included in the UK Emissions Trading Scheme, as this would help provide a set of incentives on operators to reduce their GHG emissions. Indeed, the four UK administrations have recently opened a consultation including this very question[74].

At a practical level, based on the evidence the Review has considered, the following practical options for decarbonising incineration facilities exist:

1. Reducing the proportion of residual waste that is made up of carbon from fossil sources. In most practical senses, this means ensuring less plastic is present in the material when it is burned.
2. Ensuring that all possible wastes and by-products of combustion are recycled or reused.
3. Extracting the maximum energy from each tonne of waste incinerated through harnessing both power and heat (Combined Heat and Power, CHP) wherever possible.
4. Where practicable, using carbon capture technology to ensure the GHGs are not released to the atmosphere (Carbon Capture, Use and Storage, CCUS).

7.4 Removing Fossil Carbon

Fossil carbon in residual waste is largely from plastics[75,76, 77] such as used in packaging, toys, building products and clothing. As emphasised before, avoiding this material entering residual waste in the first place is best, but where that has been unsuccessful, pre-treatment before incineration can play a role[78], as for example at Levenseat. Because this can be applied to any incineration facility (either on site or before delivery) and uses well-established sorting technology that can be put in

[73] *Energy recovery for residual waste: A carbon based modelling approach.* Defra. (2014). Available at:http://randd.defra.gov.uk/Document.aspx?Document=11918_WR1910Energyrecoveryforresidualwaste-Acarbonbasedmodellingapporach.pdf (accessed April 2022)
[74] *Developing the UK Emissions Trading Scheme (UK ETS)*, BEIS et al (2022). Available at: https://www.gov.uk/government/consultations/developing-the-uk-emissions-trading-scheme-uk-ets
[75] *National municipal waste composition - England 2017.* WRAP. (2017). Available at: https://wrap.org.uk/sites/default/files/2020-11/WRAP-National%20municipal%20waste%20composition_%20England%202017.pdf (accessed April 2022)
[76] *The composition of household waste at the kerbside in 2014-15,.* Zero Waste Scotland. (2017). Available at: https://www.zerowastescotland.org.uk/composition-household-waste-kerbside (accessed April 2022)
[77] *The climate change impacts of burning municipal waste in Scotland*, Zero Waste Scotland (2021). Available at: https://www.zerowastescotland.org.uk/content/climate-change-impact-burning-municipal-waste-scotland
[78] *Greenhouse Gas and Air Quality Impacts of Incineration and Landfill.* Eunomia. (2020). Available at: https://www.eunomia.co.uk/reports-tools/greenhouse-gas-and-air-quality-impacts-of-incineration-and-landfill/ (accessed April 2022)

place fairly rapidly, it is the most feasible of the options to implement reasonably quickly. Regulation 29[79] of the Pollution Prevention and Control (Scotland) Regulations 2012 already tasks SEPA to require a degree of pre-treatment to extract hard plastics and non-ferrous metals from municipal waste destined for incineration 'where practicable'. However, since SEPA's Thermal Treatment of Waste Guidelines 2014[80] describes hard plastics as PET and HDPE, not all plastics are covered. In addition, exemptions can also be granted for various reasons.

Several stakeholders who commented on the decarbonisation of incineration, including Friends of the Earth Scotland (FOES) and SESA, agreed that reducing the amount of plastics in residual waste (both by stopping them entering it or by pre-treatment once they have) before incineration was essential for this purpose.

Recommendation 13 (Provisional) The Scottish Government should immediately strengthen existing requirements for pre-treatment and work with local authorities and industry to apply them to all existing and future incineration facilities to remove as much recyclable material as feasible, with a particular focus on plastics.

Clearly, there needs to be reprocessing options for the recyclable material obtained through pre-treatment, and this must be considered as part of the wider resource and waste management system. This might well be an area where so-called 'chemical recycling'[81] of plastics could help, though that too can have its issues[82].

7.4.1 Recycling more by-products

Incinerator bottom ash (IBA) is increasingly recycled into secondary aggregate or other construction materials and the metals found in it can also generally be extracted and recycled. Uses for boiler or fly ash are also being developed, as are approaches to recycle air pollution control residues (APCR). If each of these replaces a higher-carbon virgin resource, this will help improve the carbon balance for incineration. However, some of these materials can contain hazardous substances so care must be taken in how they are recycled and it may not always be the best environmental outcome to do so.

7.4.2 Higher efficiency through Combined Heat and Power

Most incineration plants in Scotland (and the UK more broadly) use the heat from combustion to create steam that then drives a turbine to generate electricity. This process is not hugely efficient, with efficiency percentages in the low twenties being considered normal. As the ratio of fossil carbon to biogenic carbon increases, greater

[79] *Pollution Prevention and Control (Scotland) Regulations 2012.* Available at:https://www.legislation.gov.uk/ssi/2012/360/regulation/29 (accessed April 2022)
[80] *Thermal Treatment of Waste Guidelines.* SEPA. (2014). Available at: https://www.sepa.org.uk/media/28983/thermal-treatment-of-waste-guidelines_2014.pdf (accessed April 2022)
[81] *Chemical Recycling 101,* British Plastics Federation. Available at: https://www.bpf.co.uk/plastipedia/chemical-recycling-101.aspx
[82] *Chemical Recycling: State of Play*, Eunomia (2020). Available at https://chemtrust.org/chemical-recycling/.

efficiency is required for the process to be better in climate-relevant GHG emission terms than landfill. Figure shows the relationship graphically.

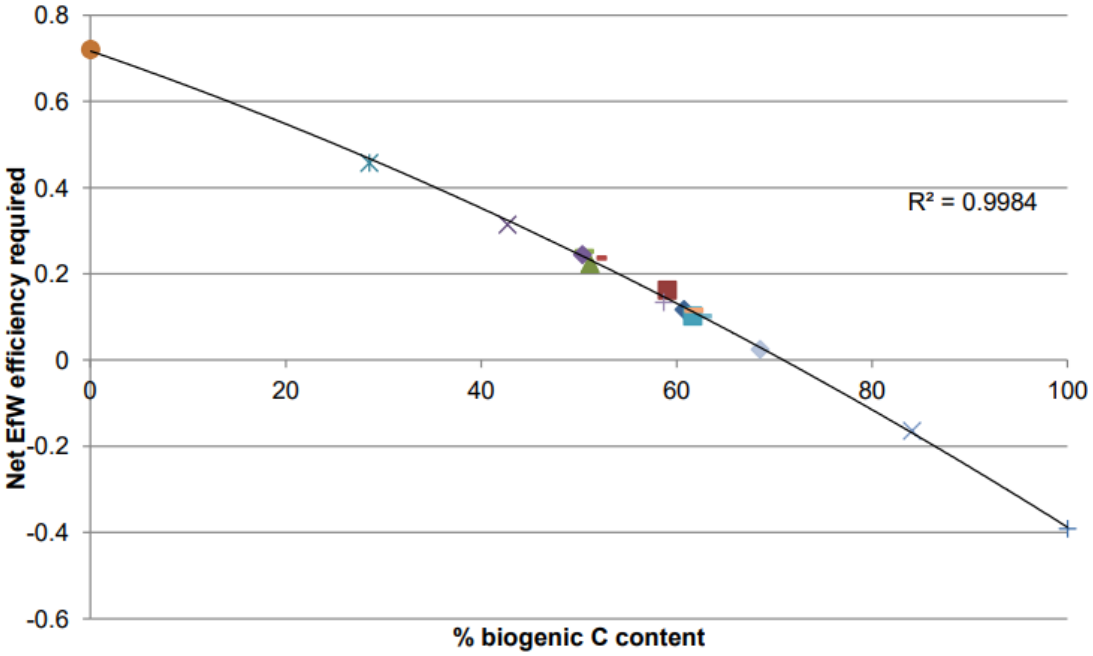

Figure 5: Net efficiency of EfW required as a function of biogenic C content of a range of waste[83]

The most common and practicable method to improve efficiency is to use the steam to provide heat to another user, such as a district heat network or a large industrial facility. In this mode, efficiency can be doubled or more, reaching 55-65%. Almost all incineration plants in Scotland in operation[84] or in planning are required to be 'CHP ready'. However, historically in the UK very few have then gone on to actually be connected to some form of heat user. Stakeholders generally agreed that this is for several reasons, many of which apply to any district heat network but some of which are specific to incineration:

Specific

- The planning process and other factors can mean incineration plants are often not sited near potential heat users.
- The incineration operator's responsibility for CHP ceases at the facility boundary, so if there is not an organisation prepared to make the running, often nothing will happen.
- Operating a heat network requires a different skill set than operating and incineration plant, so even if the plant operator is keen they may not be equipped to do so.
- Heat demand is often seasonal, but waste production happens all year round.

[83] *Energy recovery for residual waste: A carbon based modelling approach.* Defra. (2014). Available at:http://randd.defra.gov.uk/Document.aspx?Document=11918_WR1910Energyrecoveryforresidualwaste-Acarbonbasedmodellingapporach.pdf (accessed April 2022)
[84] Except the Lerwick plant, which operates in heat-only mode with a stated efficiency of 85%

General

- Building a heat network (which essentially means installing a lot of pipe work) can be disruptive and expensive.
- Depending on the funding model and what fuel is being replaced, switching to district heat can be more expensive for the user than sticking with their existing solution (for example, natural gas).
- There is a lack of widespread cultural experience and acceptance of district heating for housing and a perceived loss of individual control.
- Unplanned downtime for the heat source needs alternative (often expensive) cover.

The provisions on CHP for incineration in the draft NPF4[85] represent a toughening of current requirements and seek to address some of the issues above. However, these will not be relevant for incineration projects that already have planning consent. It will be feasible for some of those to develop heat recovery to boost their overall efficiency, though this will require focused attention from the Scottish Government and local authorities, which are uniquely placed to bring together the different actors needed to make CHP a reality.

Recommendation 14 (Provisional) The Scottish Government and local authorities should continue to work with industry to deploy combined heat and power for as many existing incineration facilities as possible.

For others, where the planning and location decisions already taken make it unlikely that heat recovery will be possible, removal of fossil carbon from their feedstocks is vital if they are to remain beneficial in carbon terms.

7.4.3 Carbon capture

Several technologies[86] have been proposed to capture the carbon dioxide emitted from combustion processes so that it can either be used elsewhere or sent for long term storage underground. Chemical absorption using an amine is the most mature, and physical separation through a range of processes is also already in use for some industrial processes. Less well developed approaches include membrane separation and chemical looping.

Stakeholders raised a number of issues with the application of CCUS to incineration facilities, including:

- Construction Cost – adding CCUS is thought to require an additional 20-25%.
- Efficiency – current CCUS technologies require significant amounts of electricity to run. This would mean a reduction in electricity available for export by about a quarter by some estimates.

[85] *Draft fourth National Planning Framework.* Scottish Government. (2021). Part 3, Policy 20(i). Available at: https://www.gov.scot/publications/scotland-2045-fourth-national-planning-framework-draft/pages/5/ (accessed April 2022)
[86] *About CCUS: Playing an important and diverse role in meeting global energy and climate goals.* IEA. Available at: https://www.iea.org/reports/about-ccus (accessed April 2022)

- Transport – moving captured carbon dioxide by tanker is very expensive, so either close proximity to a carbon dioxide user or a connection to some form of pipeline is preferable. Only a subset of incineration sites will be well-placed to take advantage of any such users or pipelines.
- Lead time – the industry's own target is to have CCUS fitted to all incineration plants 'where feasible' by 2040[87].

One recent report[88] suggests that capture costs will range from £66 to £110 per tonne of carbon dioxide captured. Using the figure of ~1 tCO_2 per tonne of waste, this could see gate fees increasing by a similar amount, from current levels of £91-£110[89] to £157-£220.At least two projects are underway to deploy CCUS on large incinerators in England[90] and the UK Government is supporting the one in Teesside[91]. Other operators are also looking closely at CCUS options including Viridor for its facility in Dunbar.[92] However, from the evidence received so far, it seems that carbon capture alone is unlikely to be able to deliver the required level of decarbonisation of incineration in time to meet Net Zero. Further research has been commissioned by the Review to investigate this. In the meantime, removal of fossil carbon from the feedstock is a no regrets move, since if CCUS is then implemented it could result in net carbon dioxide removal (also called negative emissions).

7.5 Other Residual Waste Treatment Options

The focus of the Review is on the role of incineration so in its limited time, it has not looked at decarbonisation of other residual waste treatment options such as landfill. However, the additional research it has commissioned will consider this further.

[87] *The ESA Net Zero Emissions Strategy*, ESA (2021) https://www.esauk.org/what-we-say/publications/net-zero-strategy-report-registration-form (accessed April 2022)
[88] *CCUS Development Pathway for the EfW Sector.* Eunomia. (2021). Available at: https://www.eunomia.co.uk/reports-tools/ccus-development-pathway-for-the-efw-sector/ (accessed April 2022)
[89] *EfW, landfill, RDF 2022 gate fees.* letsrecycle.com. Available at: https://www.letsrecycle.com/prices/efw-landfill-rdf/efw-landfill-rdf-2022-gate-fees/ (accessed April 2022)
[90] Cory Riverside (https://www.corygroup.co.uk/media/news-insights/cory-announces-plans-worlds-biggest-energy-waste-decarbonisation-project/) and Suez Tees Valley (https://resource.co/article/suez-teesside-carbon-capture-plans-take-step-forward) (accessed April 2022)
[91] https://www.gov.uk/government/publications/cluster-sequencing-phase-2-eligible-projects-power-ccus-hydrogen-and-icc/cluster-sequencing-phase-2-eligible-projects-power-ccus-hydrogen-and-icc (accessed April 2022)
[92] *Decarbonising our waste: Viridor's Roadmap to net zero and net negative emissions*. Viridor. (2021). https://www.viridor.co.uk/siteassets/document-repository/viridor-decarbonisation-strategy-ebook-artwork-v4-hr.pdf

7.6 Provisional Conclusion On Improving Carbon Performance

Reporting of GHG emissions from incineration under the wider energy sector makes sensible decision making more difficult for policymakers and less transparent for stakeholders and should be changed.

Currently, incineration releases fewer climate-relevant GHG than landfill and is therefore the better option from a carbon perspective. However, this balance is dependent on the proportion of residual waste that is biological versus fossil in origin and has probably been shifting in an unfavourable direction over the past decade. The balance is also affected by the comparison of emissions from incineration with emissions from the rest of the energy system. As that wider system decarbonises, the balance becomes less favourable for incineration.

The four routes to redress the balance for incineration are removal of plastics from the waste before burning; greater use of by-products; improved efficiency through use of the waste heat; and capturing carbon emissions. All can play a role, but only the first two are currently applicable to all operational and planned facilities in Scotland. Using waste heat depends on a suitable location and customer. Capturing carbon will take a long time to deploy and it is expensive and probably only worthwhile on larger facilities that are near carbon dioxide users or transport pipelines.

8 Overall Conclusions

Based on the evidence considered by the Review, its conclusions are:

1. Avoiding residual waste generation is vital and Scotland needs to do even more than it is already.
2. Properly regulated incineration has an important role to play as part of the waste hierarchy in managing Scotland's unavoidable, unrecyclable residual waste in a sanitary manner.
3. The demand for this capacity is currently growing, so the supply is rightly planned to grow too. However, the planned supply will, in all scenarios modelled, be more than Scotland will need in 4-5 years' time to (at least) 2050.
4. The locations of operational and planned incineration facilities have emerged organically and are not necessarily in the right places strategically. This is a particular issue for rural and remote communities, whose waste may need to be transported significant distances as a result.
5. Whilst it is too late for the location of these incineration facilities, future waste capacity of any kind should be placed more strategically.
6. All forms of residual waste treatment pose risks to human health and the environment, so all need to be properly regulated to manage those risks. There is no compelling evidence that incineration is any worse than the other options when this is done. Indeed, with current stringent emissions standards, the evidence is that the air quality impacts are probably small.
7. However, given the risks that incineration poses to human health and the environment, and the risk of lock-in, Scotland should not construct more capacity than it needs and only some of the currently planned capacity should be built.
8. Communities deserve more authentic and committed engagement from local authorities and industry than is currently sometimes the case. This includes making more data more accessible.
9. Incineration releases greenhouse gases, but the current reporting does not identify either the total or the 'climate-relevant' amount. This needs to change.
10. Incineration is currently less climate damaging than landfill. However, the growth of incineration, changes to waste composition and wider decarbonisation will make incineration less favourable over time, which if unaddressed will have implications for Scotland's net zero ambitions.
11. Stopping plastic from being incinerated is the quickest and most reliable route to reduce the carbon impact of incineration.

12. Combined Heat and Power and Carbon Capture, Use and Storage both could play a decarbonising role for some incineration facilities in the longer term, but given their respective challenges should not be relied on.
13. Resource and waste management is a complex system with many interdependencies. Navigating it successfully to meet Scotland's targets on this and on net zero will require a strategic approach with all stakeholders.
14. Data gaps and a lack of central modelling capacity are hindering progress in resource and waste management policy and practice.

Annex A – Definitions

ATT	Advanced Thermal Treatment
Anaerobic decomposition	Rotting in the absence of oxygen
BAU Scenario	Business as Usual – Scenario within Review's Capacity Analysis which projects historical trends forward into the future to examine what the future could look like if there are no significant changes to current trends.
BE Scenario	Best Effort – Scenario within Review's Capacity Analysis which examines what Scotland's future could look like if it improved its recycling rates in line with what has been achieved by some of the best performing European nations
Biodegradable waste	Any waste capable of undergoing decomposition such as food, garden waste, paper and cardboard
Biodegradable Municipal Waste	Municipal waste that is also biodegradable.
C&I	Commercial & Industrial waste – waste from commercial and industrial sources. Includes waste from business and industrial premises in Scotland, but excludes waste from the construction and demolition industry
C&D	Construction & Demolition waste - waste from the construction and demolition industry.
CIWM	Chartered Institution of Wastes Management
CV	Calorific Value
CXC	ClimateXChange
DRS	Deposit Return Scheme
FOES	Friends of the Earth Scotland
HH	Households
IOM3	Institute of Materials, Minerals & Mining
Landfilling	The deposition of waste onto or into land.
Municipal waste	Waste from households as well as other waste which because of its nature or composition is similar to waste from households.

MBT	Mechanical biological treatment. A group of solid waste management systems, typically used for the pre-treatment of waste, that combines a sorting facility with a form of biological treatment such as composting or anaerobic digestion. Unless specified, MBT is used in this Call to specifically mean processes that produce a high calorific fuel called Refuse Derived Fuel (RDF) or Solid Recovered Fuel (SRF), which can be used in cement kilns or power plants.
MT Scenario	Meeting Targets – Scenario within Review's Capacity Analysis which amends historical trends in order to meet Scotland's waste reduction and recycling targets for 2025.
Residual waste	The material left that cannot be reused or recycled and thus must be disposed of safely.
RDF	Refuse derived fuel
SEPA	Scottish Environmental Protection Agency
SESA	Scottish Environmental Services Association
SLCF	Scottish Landfill Communities Fund
SRF	Solid recovered fuel
The Ban	The biodegradable municipal waste to landfill ban in Scotland, due to be implemented at the end of 2025.
The Call	The Call for Evidence for this Review.
The Extended Ban	The extension of the biodegradable municipal waste to landfill ban to include biodegradable non-municipal wastes, as per Scottish Government Commitment in updated Climate Change Plan.
The Review	Unless otherwise specified, the review of the role of incineration in the waste hierarchy in Scotland.
The Route Map	The planned route map to deliver Scotland's resource and waste management targets
UKWIN	United Kingdom Without Incineration Network

Annex B - Policy Context

Current Policies

In conducting the analysis and considering its recommendations, the Review considered the relevant policy landscape. For example, whether Scottish Government has policies that will result in changes to the residual waste stream.

The Scottish Government has set several targets related to resources and waste for 2025, including:

- Reducing the amount of waste produced by 15% compared to 2011 levels
- Reducing food waste by one third by 2025 (against a 2013) baseline, supported by the Food Waste Reduction Action Plan[93].
- recycling 70% of all waste by the same year
- Ending the practice of landfilling of biodegradable municipal waste (BMW) and
- Landfilling less than 5% of remaining waste.

In addition, the Scottish Government has agreed to extend the Ban to include biodegradable non-municipal waste, subject to appropriate consultation and work to provide assurance around some specific waste streams

The Scottish Government's Climate Change Plan sets out a target of ending Scotland's contribution to climate change and reduce emissions by 75% by 2030 and finally to net zero by 2045. To achieve this target the waste sector has a target to reduce greenhouse gas (GHG) emissions to 1.2 million tonnes of carbon dioxide equivalent ($MtCO_2e$) by 2025 and 0.8 $MtCO_2e$ by 2030 from the current baseline of 1.9 $MtCO_2e$ per year. However, the waste sector emissions do not include incineration as these are reported through the power sector.

There are several implemented and planned policies that are applicable to this review including:

- Scottish landfill tax applies at two different rates, a standard rate and a lower rate for less polluting materials[94].
- A ban on the landfilling BMW from 31 December 2025.
- Extending this ban to include biodegradable non-municipal waste, subject to appropriate consultation and impact assessments [95].

[93] *Food waste reduction: action plan.* Scottish Government. (2019). Available at: https://www.gov.scot/publications/food-waste-reduction-action-plan/

[94] In 2022, the standard rate applied to active waste is £98.60 per tonne and the lower rate applied to inactive waste is £3.15 per tonne. More detail is available at: https://www.gov.scot/policies/taxes/landfill-tax/ (accessed March 2022)

[95] *Securing a green recovery on a path to net zero: climate change plan 2018–2032 - update.* Scottish Government. (2020). https://www.gov.scot/publications/securing-green-recovery-path-net-zero-update-climate-change-plan-20182032/pages/

- Implementing a Deposit Return Scheme by 16 August 2023[96]
- Working with UK Government to implement reforms to the Extended Producer Responsibility Scheme.

The Climate Change Plan also notes the Scottish Government also intends to develop a route map to achieve its waste and recycling targets and how the waste and resources sector will contribute towards net zero up to 2030 and beyond[97].

[96] *Deposit and Return Scheme for Scotland Regulations 2020.* Available at: https://www.legislation.gov.uk/ssi/2020/154/contents/made
[97] *Route Map: A plan for waste targets to 2025 and beyond.* Zero Waste Scotland. (2021). Available at https://www.zerowastescotland.org.uk/content/route-map-plan-waste-targets-2025-and-beyond

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