Stop, Sort, Burn, Bury? Independent Review of the Role of Incineration in the Waste Hierarchy in Scotland

Second Report: Decarbonisation of Residual Waste Infrastructure in Scotland

February 2023

Scottish Government
Riaghaltas na h-Alba

FOREWORD FROM DR COLIN CHURCH, INDEPENDENT CHAIR OF THE REVIEW

I was very conscious when I submitted the First Report of the Review that we had not had time to do justice to the topic of decarbonising residual waste management infrastructure in Scotland. I was therefore very happy to be asked to stay on to cover that topic in more depth and produce this Second Report.

Incineration remains a more climate-friendly method of managing residual waste than landfill, and more practical than any other currently available approach. However, without further action, this advantage will erode over a relatively short time. And even if those changes are made, eventually incineration should cease to be a significant management option for residual waste as Scotland makes its economy more circular.

This Second Report therefore looks at how best to reduce the carbon impact of incineration and, to a lesser extent, of landfill. It sets out a series of recommendations, of which the most urgent and potentially most impactful is the cessation this decade of incineration of plastic.

As before, I thank the individuals and organisations who provided input to the Review via written submissions and through online and in person meetings. This material was important in developing this Second Report as it was for the First.

Finally, my gratitude 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

In November 2021, the Minister for Green skills, Circular Economy and Biodiversity 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 delivered his First Report, *Stop, Sort, Burn, Bury?* in April 2022 and the Scottish Government published it and its response in June 2022. As the time for the Review to be completed was short, the First Report was unable to consider the issues around decarbonisation of residual waste management infrastructure in great depth. Dr Church was therefore asked to produce a further report to address this issue in more detail.

This Second Report, as part of the Review, seeks to evaluate the opportunities to decarbonise the residual waste treatment infrastructure sector in Scotland and in doing so considers the following questions:

- What does the current carbon impact of disposal of waste look like?
- What are the possible options to decarbonise residual waste infrastructure?
- What are the most effective and feasible options to improve existing waste management infrastructure in terms of carbon performance?
- What combination of options is the most feasible for Scotland?

The scope of the Second Report is residual waste infrastructure greenhouse gas emissions (primarily carbon dioxide from incinerators and methane from landfill), for the treatment of household (HH), and commercial and industrial (C&I) waste, with a focus on waste incineration infrastructure (including that in construction and likely to be developed). Both technology changes as well as systematic changes to decarbonise infrastructure are considered.

In preparing the Second Report, the Review team considered stakeholder feedback gathered through the initial Call for Evidence, which is summarised in the evidence document published alongside the First Report; two stakeholder events; and a number of additional contributions from stakeholders. The review also received a report from Eunomia, which set out to assess the effectiveness of options to decarbonise existing waste infrastructure. The additional contributions and the Eunomia report are published alongside the Review’s Second Report.

Greenhouse Gas Emission Reporting

The Second Report briefly looks at how greenhouse gas emissions associated with the resource and waste management sector are reported. Its conclusion is that current reporting doesn’t accurately reflect the full picture of the sector’s impact. For example, the Eunomia report identifies four categories of emissions impact for incineration:

1. Direct emissions from the incinerator
2. ‘Recycling credits’ – emissions avoided by using recycled materials rather than virgin ones
3. ‘Energy credits’ – emissions avoided by displacing other forms of energy generation (heat and/or electricity)
4. ‘Biogenic carbon capture credits’ – the allowance for burning biogenic waste and capturing the short-cycle GHGs that are then emitted (sometimes also known as ‘negative emissions’)

Of these, only 1 is generally reported (as an energy emission) and none is attributed to the waste sector.

This can lead to perverse incentives on decision makers and stands in the way of the holistic, systemic view of the resource and waste management that the Review has previously recommended. The Review therefore proposes that emissions reporting be examined and changes made to ensure decision makers can understand the full system impact of their decisions, in particular with respect to biogenic emissions (see Recommendation 15).

Emissions Trading

The Review also notes the current discussions on the extension of the UK Emissions Trading Scheme (UKETS) to cover incineration with energy recovery. Given that this could prove a useful tool to incentivise action, the Review supports this extension as one (but not the only) potential policy tool to drive decarbonisation of incineration (see Recommendation 16).

The Review considers that Recommendation 2 (from the First Report) on the need to consider the resource and waste management system as an inter-dependent system is relevant to this topic and the UK and Scottish Governments will need to consider the impact on that whole system from including incineration in the UKETS.

Options for Decarbonisation

The Review then considers options to decarbonise the sector. As stated in the First Report, the best approach on all levels is to avoid residual waste in the first place. However, for the waste that does require treatment and based on the evidence received, the most feasible and potentially impactful options appear to be:

- advanced sorting to remove recyclable material from residual waste;
- connection to heat networks; and
- deployment of carbon capture use or storage (CCUS).

The Eunomia report therefore assesses the effectiveness of these options to decarbonise existing waste infrastructure in different combinations across three scenarios (business as usual, best efforts focused on plastics and best efforts focused on food).

The Review does not see evidence that biostabilisation of biodegradable waste coupled with landfill was likely to be a major solution in Scotland, though it might offer a route for more remote communities. The Review also looks at waste-to-fuel and chemical recycling technologies. Where these do not have direct greenhouse gas emissions, it considered these to be outside the scope of the Review and its recommendations.

Advanced Sorting

This modelling shows that advanced sorting would have an immediate and significant impact on direct emissions from incinerators (49-56% reduction depending on the scenario) as well as bringing significant additional benefits in terms of recycling credits (enough to offset the remaining direct emissions). The Review therefore confirmed its provisional recommendation that more should be done to remove recyclable material from residual waste (see Recommendation 13).

However, the modelling shows continued direct emissions, a proportion of which will be due to plastic left in the residual waste that may not currently be recyclable. The Review therefore goes further in this Second Report and proposes that by 2030, all plastic should be removed before incineration (see Recommendation 17), by a combination of upstream policies such as bans on certain single-use plastic items, better source separation, and more intensive advanced sorting (see Recommendation 19). In doing this, the Review is conscious that exporting plastic waste should not be encouraged (see Recommendation 18).

Heat Networks

While there should be a diminishing need for residual waste treatment, for as long as there is a need to burn waste to treat it in a sanitary manner, as much as possible needs to be done to pursue all possible ways to decarbonise the incineration sector and to use it to support wider decarbonisation. Heat networks can be expensive and controversial to construct, and in reality offer only a partial solution for the incineration sector, as many facilities will struggle to connect to heat users. However, they do have a wider role to play in decarbonisation, whatever energy source is used, so their connection to incineration plants is beneficial, a finding underpinned by the Eunomia report. Therefore, this Second Report confirms the First Report’s provisional position that they should be pursued where possible (see Recommendation 14), but not seen as a reason to build an incinerator.

Carbon Capture, Use or Storage (CCUS)

Capturing the carbon dioxide emissions from incineration – both fossil and biogenic – is an apparently attractive solution. Indeed, the Eunomia modelling suggests that deployment of CCUS at a (generous) subset of incinerators could improve the direct emissions reduction by two-thirds compared to advanced sorting alone. Added to this is the potential for substantial biogenic carbon capture credits. Therefore, the sooner CCUS can be developed on incineration facilities the greater the impact on carbon emissions there will be. It is therefore prudent, when choosing which of the pipeline of incineration facilities to pursue, to opt for those with the greatest opportunity to decarbonise quickly (see Recommendation 20). However, there are many practical and economic barriers to CCUS deployment and it seems unlikely that deployment to a range of incineration facilities will happen to a significant extent over the next couple of decades. CCUS is therefore more likely to be a longer-term solution and will probably have a limited role to play in meeting Scotland’s current net zero ambitions. There is probably also merit in Scotland looking at emerging carbon capture and use technologies to overcome the challenges faced by incinerators that are less well placed to use existing or planned carbon dioxide transportation infrastructure (see Recommendation 21).

Decarbonising Landfill

Landfill is a significant but declining option for biodegradable waste management in Scotland. The methane produced in landfill gas is often captured and either used to generate energy or flared. The Review did have concerns as to what might happen to sites as the concentration of methane decreased (see Recommendation 22) and as the current financial incentives to capture and use the landfill gas expire in 2037 (see Recommendation 23).

Recommendations

The Recommendations set out below should be considered in the context of the discussion in this Report and the First. Numbering continues from the First Report.

Recommendation 13: 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. (Confirmed.)

Recommendation 14: 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 (Confirmed.)

Recommendation 15: The Scottish Government should consider how biogenic carbon is included in future resource and waste management sector modelling and how this influences decision making.

Recommendation 16: The Scottish Government should support inclusion of incineration (with or without energy recovery) in the UK Emissions Trading Scheme as one important decarbonisation policy tool.

Recommendation 17: The Scottish Government and SEPA should put in place by 2025 robust arrangements to stop fossil-based plastic from being incinerated in Scotland from the beginning of 2030, except where required for hazardous waste disposal.

Recommendation 18: In implementing the recommendations of the Review, the Scottish Government should do what is within its powers to ensure that there is no increase (and ideally a significant decrease) in the export of plastic waste from Scotland.

Recommendation 19: The Scottish Government should implement Recommendation 17 through policies to reduce plastic production and use, promote source segregation of all plastic wastes, and implement advanced sorting of residual waste.

Recommendation 20: In considering which plants with planning permission to construct, financers, developers and planning authorities should prioritise those plants where deployment of currently available CCUS technology is most feasible.

Recommendation 21: The Scottish Government should consider support for emerging carbon capture and use technologies that could overcome challenges to deployment for facilities already in operation, or required for more remote facilities.

Recommendation 22: The Scottish Government and landfill owners and operators should ensure maximum capture of landfill gas for open and closed landfill sites, and develop new approaches to do this as methane levels decrease.

Recommendation 23: The Scottish Government should consult with landfill owners and operators to address the consequences of the withdrawal of current landfill gas management financial incentives after 2037.

CONTENTS

1 Introduction

1.1 Background to the Review

In November 2021, the Minister for Green skills, Circular Economy and Biodiversity appointed Dr Colin Church[1] to act as independent Chair of the Review of the role of incineration in the waste hierarchy in Scotland ('the Review'). Dr Church delivered his First Report, *Stop, Sort, Burn, Bury?* in April 2022 and the Scottish Government published it in June 2022[2].

Dr Church determined the scope and process for the Review within the overall remit[3] and timescale set by the Minister. These included that the Review focused on an assessment of national capacity requirements and 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. The Minister also 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 on landfilling biodegradable municipal waste and consider planning applications as well as for the waste management industry to make investment decisions.

The Review 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?

To approach these questions, the Review considered existing evidence and commissioned additional capacity modelling, an appraisal of waste treatment options and a rapid review of evidence relating to the health impacts of incinerating waste since 2009, conducted by Public Health Scotland[2]. Additionally, stakeholders were consulted on these topics through a Call for Evidence, which was launched in December 2021 and included both a written

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[1] 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. Prior to that, he held several senior roles in Defra, DECC and the Cabinet Office.

[2] *Stop, Sort, Burn, Bury? Independent Review of the Role of Incineration in the Waste Hierarchy in Scotland*, Report. Review of Incineration. (2022). Available at: Stop, Sort, Burn, Bury - incineration in the waste hierarchy: independent review - gov.scot (www.gov.scot)

[3] *Written question and answer: S6W-03436*, Scottish Parliament. (2022). Available at: Questions and answers | Scottish Parliament Website

questionnaire and stakeholder events and meetings[4]. Stakeholder responses to the Call for Evidence were summarised in an evidence document[5].

The Review's First Report[6] was then published by the Scottish Government on 10 May 2022. This set out 12 recommendations regarding the first four questions of the review and two provisional recommendations regarding decarbonisation. Given the timescales, the Review had to prioritise the capacity analysis and consideration of the social, health and economic trade-offs for various waste management options.

The First Report's recommendations on decarbonisation were:

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 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 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.

Recommendations 13 and 14 were provisional in the First Report. In order to allow the Review to give appropriate consideration to the matter of decarbonising existing infrastructure, a further report was commissioned in May 2022.

Dr Church was supported in the Review by a secretariat consisting of individuals detached from the Scottish Government and the Scottish Environment Protection Agency (SEPA).

1.2 Review Publications

There are six main elements to the Review's outputs:

1. Call for Evidence, December 2021[7] – This invited stakeholders to provide comments on initial analysis from ClimateXChange (CXC) and evidence on a range of questions relating to the Review.
2. Review First Report, submitted April 2022 – This document outlines the key considerations of the review and the recommendations the Review is making.

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[4] *Call for Evidence.* Review of Incineration. (2021). Available at: Incineration in the waste hierarchy review: call for evidence - Scottish Government - Citizen Space (consult.gov.scot)

[5] *Evidence Document.* Review of Incineration. (2021). Available at Supporting documents - Stop, Sort, Burn, Bury - incineration in the waste hierarchy: independent review - gov.scot (www.gov.scot)

[6] *Stop, Sort, Burn, Bury? Independent Review of the Role of Incineration in the Waste Hierarchy in Scotland, Report*, Review of Incineration. (2022). Available at: Stop, Sort, Burn, Bury - incineration in the waste hierarchy: independent review - gov.scot (www.gov.scot)

[7] *Call for Evidence.* Review of Incineration. (2021). Available at: Incineration in the waste hierarchy review: call for evidence - Scottish Government - Citizen Space (consult.gov.scot)

3. Evidence Report, submitted April 2022 – This report summarises the evidence considered by the Review, including responses to the Call and further evidence.
4. Call for Evidence responses – As far as possible, the Review published in full the responses received to the Call. Further information on the publication of responses can be found within the evidence document.
5. Review Second Report (this document), submitted to Scottish Ministers in December 2022 – This outlines the recommendations on decarbonising residual waste infrastructure in Scotland.
6. Additional evidence, obtained for the Second Report, including both stakeholder contributions (published on Citizen Space[4] where permitted by their providers) and the Eunomia modelling report.

2 Approach to the Second Report

2.1 Overview of the Second Report Process

This Second Report, as part of the Review, seeks to evaluate the opportunities to decarbonise the residual waste treatment infrastructure sector in Scotland and in doing so considers the following questions:

- What does the current carbon impact of disposal of waste look like?
- What are the possible options to decarbonise residual waste infrastructure?
- What are the most effective and feasible options to improve existing waste management infrastructure in terms of carbon performance?
- What combination of options is the most feasible for Scotland?

The scope of the Second Report is residual waste infrastructure, for the treatment of household (HH), and commercial and industrial (C&I) waste[8], with a focus on waste incineration infrastructure (including that in construction and likely to be developed). Both technology changes as well as systematic changes to decarbonise infrastructure are considered. In preparing the Second Report, the Review team considered stakeholder feedback gathered through the initial Call for Evidence, which is summarised in the evidence document[9] published alongside the First Report, and two stakeholder events. The review also received a report from Eunomia, which set out to assess the effectiveness of options to decarbonise existing waste infrastructure.

2.2 The Eunomia Report

In December 2022, Eunomia presented the results of its commissioned work, and that report is published alongside the Review's Second Report[10]. This work assessed the effectiveness of options to decarbonise existing waste infrastructure (the 'Eunomia modelling report'). The overarching objectives for this work were to:

- Evaluate (GHG) emissions for existing residual waste management facilities within scope;
- review additional and alternative technologies to the current systems in use, with particular focus on the existing incineration facilities, by assessing the viability and potential impact of each option – including its technical, environmental, economic and social impacts, together with its limitations and risks; and
- provide a high-level commentary of each of these options to decarbonise the existing residual waste facilities, and how these paths would change over time.

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[8] 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 A), they comprise a large proportion of waste incinerated, the incineration of these waste streams has increased significantly since 2013, and municipal waste incinerators are often the object of stakeholder concerns

[9] See the *Evidence Document.* Review of Incineration. (2022). Available at: [Supporting documents - Stop, Sort, Burn, Bury - incineration in the waste hierarchy: independent review - gov.scot (www.gov.scot)]

[10] *Opportunities to Decarbonise the Waste Treatment.* Eunomia. (2022). Published alongside this report (See Supporting Documents

To compare the carbon impact of implementing options to decarbonise the residual waste sector, Eunomia developed a baseline for carbon impacts associated with residual waste treatment, covering:

- Direct emissions such as those arising from the combustion of waste streams;
- Impacts arising from energy use at facilities;
- Avoided emissions arising as a consequence of energy being generated via the waste management process (e.g. energy generation at incinerators) which therefore negates the requirement for energy to be generated elsewhere and emissions avoided by dry recycling (for incinerators, this relates to the recovery of metals from bottom ash).

The baseline and scenarios also included sequestration of biogenic carbon in landfills.

The baseline examined the current carbon impacts of managing residual waste, and the carbon impacts of managing residual waste in 2035 under three scenarios, Business as Usual (BAU), Best Efforts Scenario - Food (BES-F), and Best Efforts Scenario - Plastics (BES-P). The BAU scenario predicts increases in recycling rates comparable to the BAU scenario in the capacity modelling undertaken in the First report. The BES-F and BES-P scenarios mirror the improvements in recycling rates of the 'Best Efforts Scenario' from the capacity analysis in the First Report, but acknowledge that there are multiple ways to achieve improvements in recycling rates. The BES-F scenario forecasts greater improvements in food waste recycling, and the BES-P scenario forecasts greater improvements in plastics recycling. These scenarios thus act as a sensitivity analysis for the impact of potential options.

Each scenario was modelled to 2035. This year was selected to balance the desire to forecast as far into the future as possible to enable policy impacts to take effect and facilities and infrastructure (e.g. heat networks) to feasibly be developed with the increasing uncertainty in future years, particularly due to changes in waste composition and quantities, and the energy grid impacts. Figure *1* shows the estimated annual residual waste emissions of the baseline scenarios (2020 and 2035), before any pathways were applied.

The first draft of the Eunomia report was also considered by the Climate Change Committee (CCC) and revised in light of the comments received.

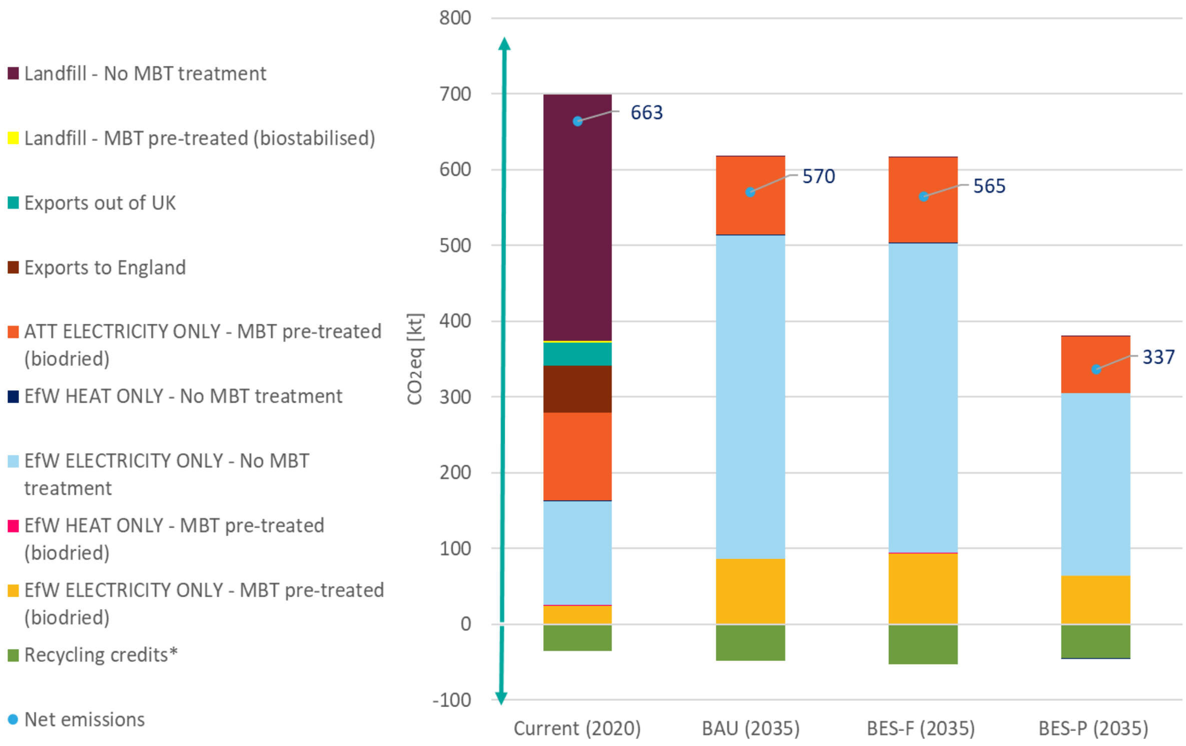

Figure 1: Current and future baseline annual residual waste emissions, split by treatment route[10]

The Review considered a long-list of options to decarbonise the residual waste sector, discussed below in Section 4, and from this, identified four pathways which, based on stakeholder feedback and evidence, it considered could most feasibly decarbonise the sector:

- Advanced sorting;
- Advanced sorting and the deployment of heat networks;
- Advanced sorting and the deployment of CCUS; and
- Advanced sorting and the deployment heat networks and CCUS.

The deployment of heat networks and of CCUS was modelled on a best case basis – this represents the most these could do to help decarbonise incineration.

The results of the Eunomia report underpin the discussion in Section 4 and are set out in more detail in Section 5.

3 Greenhouse Gas Emissions from Residual Waste Management

What does the current carbon impact of disposal of waste look like?

3.1 Residual Waste Management in Scotland

As previously noted[11], Scotland produced around 11.5 million tonnes (Mt) of waste in 2018 from households (HH, 2.4Mt), Commercial & Industrial sources (C&I, 3.2Mt) and Construction & Demolition activities (C&D, 5.8Mt). Waste generated in Scotland has reduced by 4.2% since 2011. While there has been a general reduction in household (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].

The majority of waste generated in Scotland is recycled. In 2018, 60.7% of waste from all sources was recycled. For HH waste specifically, 42.7% of waste was recycled in 2021[13]. Residual waste is waste that is not collected for reuse or recycling, or that is rejected from those processes. This is often called ‘black bag’ waste since it includes the mixed materials generally collected in black bags or bins. Black bag waste often contains recyclable material; evidence suggests that just under 60% of material in black bags is recyclable[14]. 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, after reuse and then recycling, 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 2021 was 1.35Mt, 612kt of which was HH waste[13], an increase of 0.93Mt (7.4%) from 2020, consistent with the longer-term trend of an increase of 0.94Mt (230%) from 2011[15]. The amount of waste disposed of to landfill has generally decreased steadily since 2007. In 2020, Scotland sent 2.6Mt to landfill, a reduction of over 4.4Mt (63%) since 2005[1], similarly, the amount of household waste sent to landfill decreased by

[11] *Stop, Sort, Burn, Bury? Independent Review of the Role of Incineration in the Waste Hierarchy in Scotland Report.* Review of Incineration. (2022). Section 3.2. Available at*:* Stop, Sort, Burn, Bury - incineration in the waste hierarchy: independent review - gov.scot (www.gov.scot)

[12] *Waste from all sources Summary Document and Commentary text.* SEPA. (2019). Available at: Waste data for Scotland | Scottish Environment Protection Agency (SEPA)

[13] *Summary data and text.* SEPA (2022). Available at: Household waste data | Scottish Environment Protection Agency (SEPA)

[14] *Response to the Call for Evidence.* Zero Waste Scotland. (2022). Available at: Response 904363792 to Incineration in the waste hierarchy review: call for evidence - Scottish Government - Citizen Space (consult.gov.scot)

[15] *Waste Incinerated in Scotland Statistical Commentary.* SEPA. (2022). Available at: Waste data for Scotland | Scottish Environment Protection Agency (SEPA)

54.4% between 2011 and 2021 when 664kt was sent to landfill[13]. From 31 December 2025, biodegradable municipal waste in Scotland will be banned from landfill[16] ('the Ban').

With waste policy generally diverting waste away from landfill (especially through application of the Scottish landfill tax and the forthcoming Ban), the number of landfill sites in Scotland has decreased. In 2005 Scotland landfilled over 7Mt of waste at 129 active landfill sites compared to 2.6Mt at 41 sites in 2020[17].

Scotland currently has 6 operational municipal waste incinerators. 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, although some may operate only as mechanical sorting facilities while some will undertake biological treatment, such as composting or anaerobic digestion. All of these methods of managing residual waste emit greenhouse gases (GHGs) in different orders of magnitude.

3.2 Greenhouse Gas Emissions from Residual Waste Management

The main GHGs of concern in waste management are carbon dioxide (CO_2) and methane (CH_4). Carbon dioxide is emitted when a material containing carbon is burned in the presence of oxygen, for example in a waste incinerator. Methane is emitted when biodegradable material[18] decomposes in a landfill in the absence of oxygen[19]. Estimates of the proportion of HH waste that is made up of biodegradable material vary, but most suggest it is at least half, if not more. GHG emissions are generally reported in terms of "tonnes of carbon dioxide equivalent", abbreviated to "tCO_2e". Methane is approximately 25 times more potent a GHG than carbon dioxide[20], which means that a tonne of the former will equate to ~$25tCO_2e$. These factors together help explain why Scotland is moving its residual waste treatment away from landfill and towards incineration – each amount of biodegradable waste that is incinerated rather than landfilled will reduce total GHG emissions significantly.

The Scottish Government's Climate Change Plan sets out a target of reducing emissions by 75% by 2030 and finally to net zero by 2045[21]. The Climate Change Plan sets out target 'emissions envelopes' that each sector will need to reach to achieve Net Zero. Table *1*

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[16] *Delivering Scotland's circular economy - route map to 2025 and beyond: consultation,* Scottish Government*. (2022). Available at:* [Package 6: Minimise the impact of disposal - Delivering Scotland's circular economy - route map to 2025 and beyond: consultation - gov.scot (www.gov.scot)]

[17] *Response to the Call for Evidence.* SEPA. (2022). Available at: [Response 539587232 to Incineration in the waste hierarchy review: call for evidence - Scottish Government - Citizen Space (consult.gov.scot)]

[18] That is, material that can rot, such as food, paper, natural textiles, and wood.

[19] Methane is also produced when food waste is treated in an anaerobic digester, however this is then captured and burned to generate electricity and/or heat so the end emission is also CO_2

[20] This is a simplification, because methane's lifetime in the atmosphere is different to that of carbon dioxide and so their relative strength also varies over time.

[21] *Update to the Climate Change Plan.* Scottish Government. (2020). Available at: [Securing a green recovery on a path to net zero: climate change plan 2018–2032 - update - gov.scot (www.gov.scot)]

illustrates the main sources of GHG emissions for Scotland's residual waste management infrastructure in 2021.

Table 1: Reported greenhouse gas emissions from different residual waste treatment methods in Scotland (2021)[22]

Source	CO_2 emitted (tonnes)	CH_4 emitted (tonnes)	CO_2 equivalent (tonnes)[23]
Landfill	324,664	19,772	817,714
Energy from Waste	660,618	Below reporting threshold	660,618

Figure 2 shows the carbon impact[24] of HH waste landfilled and incinerated between 2011 and 2021. While the overall emissions from HH waste disposed of by landfill and incineration has decreased, the relative carbon impact from incineration has increased, particularly since 2017.

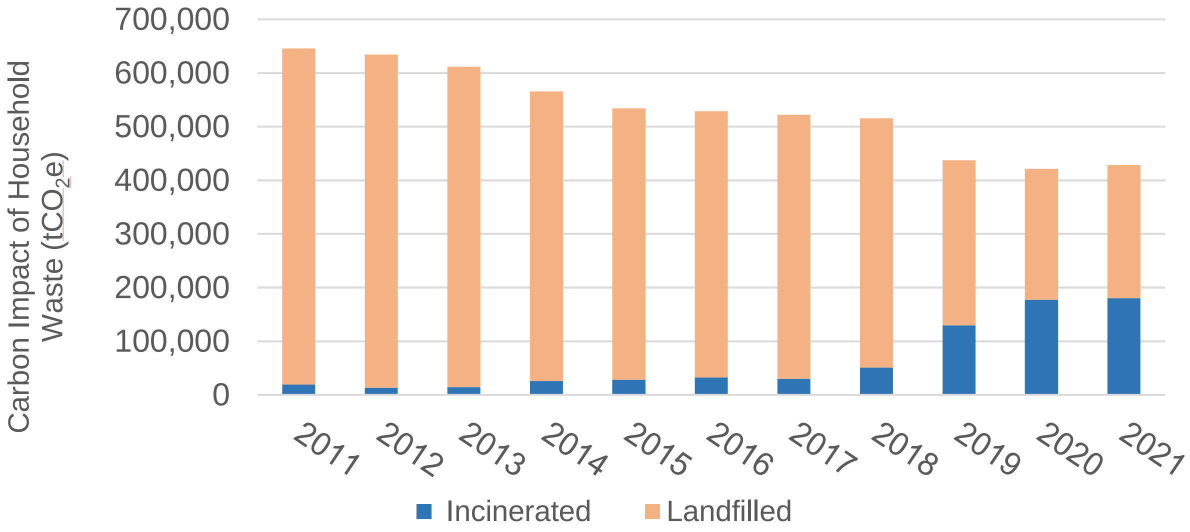

Figure 2: Carbon impact of HH waste sent for incineration and landfill[25]

Emissions from and therefore the carbon impact of waste sent to landfill are expected to continue to decline as Scotland moves towards the Ban and as incineration capacity

[22] Data from *Scottish Pollutant Release Inventory for 2021*. SEPA. (2022). Available at: [SPRI | Scottish Environment Protection Agency (SEPA)]

[23] Based on methane having 25 times Greenhouse Gas Equivalent using *Greenhouse Gas Equivalence calculator.* USEPA. (2022). Available at: [Greenhouse Gas Equivalencies Calculator | US EPA]

[24] The carbon impact is a measure of the whole-life carbon impacts of waste, from resource extraction and manufacturing emissions, right through to waste management emissions. See *Scottish Household waste data and text*. SEPA. (2021). Available at: [Household waste data | Scottish Environment Protection Agency (SEPA)]

[25] Table 14 *Household Waste Summary Data Tables.* SEPA. (2022). Available at: [Household waste data | Scottish Environment Protection Agency (SEPA)]

increases with more facilities coming online[26]. However, this is likely to lead to further increases in the carbon impact of HH waste incinerated. While this should result in a continued net reduction in the carbon impact of HH waste treatment overall, this will very much depend on the amount of residual waste produced, and the composition of waste[27].

The Scottish Government has set out several targets and policies which could reduce greenhouse gas emissions from the Waste Management sector[28]. Since publication of *Stop, Sort, Burn, Bury?,* the Scottish Government has also consulted on a Route Map to 2025 and beyond, which proposes further policies, including additional policies to reduce emissions from incineration, which are summarised in Annex C – Policy Context. The UK also signed up to the Global Methane Pledge at COP26, which aims to collectively reduce global emissions by at least 30% below 2020 levels by 2030.

3.2.1 Current Inventory Approach

Currently, internationally-agreed methodology counts the methane emissions from landfill as being due to the waste sector. Waste incineration with energy recovery has its carbon dioxide emissions accounted for under energy, not waste. Only the emissions from incineration without energy recovery (eg some forms of hazardous waste incineration) count under waste. Using this approach, emissions attributed to the waste management sector largely comprise methane from landfill and have decreased from around 6 $MtCO_2e$ in 1995 to 1.4$MtCO_2e$ in 2020 (Figure 3). This is mainly due to diversion of waste away from landfill as a result of Scottish Landfill Tax and preparations for the forthcoming ban on landfilling biodegradable municipal waste. (Note that further reductions are required to achieve the Waste Sector emissions envelopes, which are 0.9 and 0.7$MtCO_2e$ for 2025 and 2032 respectively[21]).

[26] *Stop, Sort, Burn Bury?* Review of Incineration. (2022). 3.4 Capacity Analysis Results. Available at: Supporting documents - Stop, Sort, Burn, Bury - incineration in the waste hierarchy: independent review - gov.scot (www.gov.scot)

[27] *The Climate Impacts of Burning Municipal Waste in Scotland.* Zero Waste Scotland. (2020). Available at: The climate change impact of burning municipal waste in Scotland | Zero Waste Scotland

[28] The policy context is summarised in *Stop, Sort, Burn Bury?* Review of Incineration. (2022). Annex B (Pg 55). Available at: Supporting documents - Stop, Sort, Burn, Bury - incineration in the waste hierarchy: independent review - gov.scot (www.gov.scot)

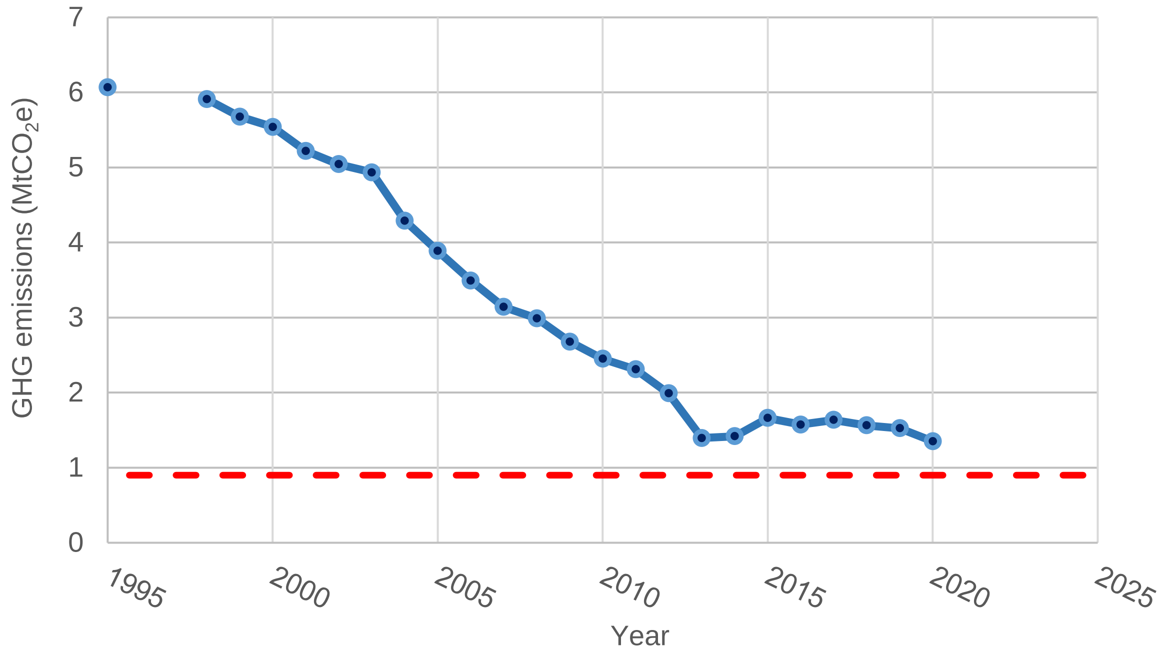

Figure 3: Greenhouse gas emissions from the Waste Management Sector in Scotland, and the 2025 emissions 'envelope' target (denoted by the red dashed line) [29]

Another specific aspect of the current inventory approach is how it treats GHG emissions from the incineration of "biogenic" material. Historically, the release of carbon dioxide from the 'slow domain carbon cycle' – fossil fuels which, although they originally came from plants and animals, have stored the carbon for tens of thousands of years – has been of concern for climate change measurements. The release of carbon dioxide from 'fast domain carbon cycle' – atmospheric reactions, plants, animals, oceans, etc over tens or hundreds of years – has been considered neutral.

However, especially for the resource and waste management sector, this may no longer be adequate for several reasons. Firstly, given how little time is left for humanity to reduce its GHG emissions if it is to keep climate change below 1.5°C, even emissions on a cycle of a few hundred years could become important. Secondly, Scotland has ambitious plans to reduce the amount of food waste that is treated by residual waste infrastructure. As this starts to happen, the life cycle of the biogenic waste coming to incinerators will increase as more of it is made up of textiles (~5 years) paper and card (~20 years) and wood (tens or hundreds of years) rather than food (<1 year). Finally, given the scope for incinerators to operate with carbon capture, it may become increasingly important to consider short cycle biogenic carbon.

Without consensus on how to include biogenic carbon in future modelling, it will continue to be difficult for stakeholders and policy makers to make informed decisions and recommendations for the decarbonisation of the waste sector. As an initial position, we would suggest that biogenic carbon should be included in all parts of future modelling for the resource and waste management sector. Therefore, this Second Report recommends that:

[29] *Scottish Greenhouse Gas Statistics 2020*. Scottish Government. (2022). Available at: [Scottish Greenhouse Gas Statistics 2020 - gov.scot (www.gov.scot)](https://www.gov.scot)

Recommendation 15 The Scottish Government should consider how biogenic carbon is included in future resource and waste management sector modelling and how this influences decision making.

This is also strongly related to the Review's Recommendation 2[30] on the need to improve data and to understand better how the whole resource and waste management sector operates as an inter-dependent system.

3.3 Wider GHG Implications of Resource and Waste Management

Resource and waste management activities have much wider implications for GHG emissions than those traditionally captured by the current GHG accounting practices. For example, the waste management sector figures do not include emissions from incineration with energy recovery; these are reported as being emissions due to energy production. For this reason, the First Report recommended that the carbon dioxide emissions from incinerators with energy recovery should be reported separately. The CCC has made the same recommendation, and the Scottish Government has committed to do so[31].

Another 'gap' is that of the emissions avoided by recycling. Producing a tonne of recycled aluminium, for example, uses only 5% of the energy needed to produce the same amount of virgin aluminium[32]. However, the associated GHG savings are not recorded as being due to actions by the resource and waste management sector.

As many stakeholders have argued[33], this can lead to odd policy choices that do not reflect the true GHG emissions generated and saved through resource and waste management activities.

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[30] "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." See *Stop, Sort, Burn, Bury?* (2022)*, Available at:* Supporting documents - Stop, Sort, Burn, Bury - incineration in the waste hierarchy: independent review - gov.scot (www.gov.scot)

[31] In response to the Review's Recommendation 12, the Scottish Government noted its intention to amend this and explore the potential to provide a separate energy from waste source in future GHG emissions publications. *Independent review of the role of incineration in the waste hierarchy: Scottish Government response*. Scottish Government. (2022). Para 43. Available at: Supporting documents - Independent review of the role of incineration in the waste hierarchy: Scottish Government response - gov.scot (www.gov.scot)

[32] *Enabling the circular economy with aluminium*. European Aluminium. (2022). Available at: Enabling the circular economy with aluminium - European Aluminium (european-aluminium.eu)

[33] See for instance the analysis by Dominic Hogg at Why reporting on greenhouse gas emissions from waste management needs to change — Equanimator (dominichogg.com) and *Problems in the Reporting of GHG Emissions from 'Waste': Indicators and Inventories.* Equanimator Ltd. (2022). Available at the same page

4 Decarbonisation Options

What are the possible options to decarbonise residual waste infrastructure?

What are the most effective and feasible options to improve existing waste management infrastructure in terms of carbon performance?

What combination of options is the most feasible for Scotland?

4.1 Emissions Trading and Taxation

Any policy measure that places a cost on emitting GHGs could be used to promote the various approaches to decarbonising residual waste management infrastructure. One example that is currently under discussion is the proposed expansion of the UK emissions trading scheme (UK ETS)[34] to include incineration. Inclusion of incineration in the UK ETS could play a role in incentivising the three main options to decarbonise the incineration sector (preventing the incineration of plastics, the deployment of heat networks and the use of CCUS).

Another approach would be to introduce a wider carbon tax across the full economy. This could be economically the most efficient approach, but without some form of carbon border adjustment mechanism (CBAM)[35] could have negative impacts on Scottish and UK industrial competitiveness and seems currently unachievable for political and administrative reasons. While the relative merits of a carbon tax or ETS approach are debatable, the UK ETS is the main approach for carbon pricing across the UK and there is currently an opportunity to extend the scope of the ETS to waste.

The Review therefore concludes that extension of the UK ETS to incineration should be supported by the Scottish Government as one element of the approach to decarbonising incineration:

Recommendation 16 The Scottish Government should support inclusion of incineration (with or without energy recovery) in the UK Emissions Trading Scheme as one important decarbonisation policy tool.

However, as noted in the First Report, the waste sector is a complex system, and no part can be considered in isolation. Applying an ETS to the incineration sector is likely to have impacts on other parts of the waste management system and some consideration of what those impacts may be and how to mitigate those impacts is warranted, including further expansion of the UK ETS to other parts of the waste sector.

[34] *Developing the UK Emissions Trading Scheme (UK ETS) (2022): A joint consultation of the UK Government, the Scottish Government, the Welsh Government and the Department of Agriculture, Environment and Rural Affairs for Northern Ireland.* BEIS. (2022). available at: Developing the UK Emissions Trading Scheme (UK ETS) - GOV.UK (www.gov.uk)

[35] An import levy on imports of key industrial inputs such as electricity, cement, aluminium, fertiliser and iron and steel products, the level of which depends on the emission content of production and the difference between the UK carbon price and any carbon price paid in the production country.

4.2 Preventing Residual Waste

As noted in the First Report, the best form of residual waste treatment is preventing it from occurring in the first place. Where waste does occur, preventing it from entering the residual waste stream by collecting it for reuse or recycling is preferable to any disposal option. When a product is made from virgin materials, significant GHG emissions are associated with that production process from extraction, refining, transport, manufacture and distribution. If a product is made from recycled materials, there is no extraction; refining is generally lower energy; and often (but not always) transport distances are lower. This means using recycled materials creates lower GHG emissions than using virgin materials.

Where residual waste enters landfill, the degradation of biodegradable waste is responsible for the majority of emissions (as methane) and where it is incinerated, burning fossil carbon is particularly important for emissions[36]. Fossil carbon in residual waste is largely contained in plastics such as that from packaging, toys, building products and clothing.

Preventing biodegradable (e.g. food waste) and plastics from entering the residual waste is, therefore, likely to be the most impactful and reliable strategy to reducing the carbon impact of residual waste management[37].

4.3 Advanced Sorting

The Scottish Government accepted the First Report final recommendations, including the need to rapidly seek further reductions in the proportion of recyclable material entering the residual waste stream to the greatest extent possible[38].

However, even with improved kerbside collections, it is likely that a proportion of recyclable material will enter the residual waste stream with current collection methodologies. Data from households suggest currently that up to 60% of what is put into general waste bins can be recycled using existing recycling services[39]. In addition, contamination of materials collected for recycling makes managing recycling collections more costly and in extreme cases can mean all collected recycling in that load has to be diverted for incineration or landfill. For example, just under a fifth of everything put out for recycling by householders is currently non-recyclable[40].

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[36] The IPCC estimate that every tonne of waste incinerated releases 0.7-1.2 tCO_2e, depending on its composition.

[37] Compositional analyses estimate that food waste makes up around 37% of residual waste, and plastic films, despite their relatively low density, make up 11% of residual waste by weight. See *Household Waste composition 2017.* WRAP. (2019). Available at: [Quantifying the composition of municipal waste | WRAP]

[38] Recommendation 1, *Stop, Sort, Burn, Bury?* Review of Incineration. (2022). Available at: [Stop, Sort, Burn, Bury - incineration in the waste hierarchy: independent review - gov.scot (www.gov.scot)]

[39] *The composition of household waste at the kerbside in 2014-15*. Zero Waste Scotland. (2017). Page 12. Available at: [Composition household waste at the kerbside 2014-15 | Zero Waste Scotland]

[40] *Recyclate Quality Reporting Tool.* SEPA. (2022). Available at: [Recyclate Quality (sepa.org.uk)]

Therefore, where efforts to prevent waste occurring and prevent materials entering the residual waste stream have been unsuccessful, advanced sorting[41] to recover recyclable materials may play a role in decarbonising the sector. Moreover, separating these different elements will allow a greater recovery of valuable materials, the amount of material sent to landfills to be minimised, and recyclable materials to find a new purpose. It also supports Scotland in reaching its recycling targets, particularly in areas where recycling targets might be more difficult to reach, for example in more rural areas or those with a high density of flatted properties.

A wide range of sorting and separating technologies can be used to separate key recyclable material streams, based on characteristics of the targeted items. Overall, most technologies are well established across Europe[10]. It can help to reduce climate change emissions in two ways:

- Emission benefits from the recycling activity – which results in avoided emissions from the primary production of materials
- For materials that contain fossil carbon (mostly plastics), emissions benefits also arise because of the reduction in this material within the incinerator feedstock.

The removal of plastics from the residual waste stream is likely to be the priority for decarbonisation of incineration infrastructure since fossil carbon in residual waste is largely from plastics[42]. Almost all plastic is fossil carbon locked up in polymer form[43]. Composition changes and the reduction of plastic in residual waste can, therefore, have a significant effect on incineration carbon emission.

One stakeholder noted that removing plastic from the residual waste stream prior to combustion is a promising route towards reducing EfW emissions and increasing the material available for recycling. Trials at two of their facilities in Scotland have indicated an ability to remove 16% of waste (70% in the form of plastics), thereby reducing the fossil emissions of a tonne of black bag waste by up to 281kgCO2e i.e. it reduces the fossil emissions by more than half[44]. However, the trials also reinforce some of the challenges associated with Advanced Sorting, such as the poor quality of contaminated materials.

The Eunomia report therefore looked at advanced sorting to remove recyclable plastic. It found (Pathway 1) that advanced sorting alone would reduce annual direct GHG emissions from incineration by 56% from the modelled business as usual (BAU) baseline of 747ktCO_2e to 329ktCO_2e. Even where significantly less plastic is ending up in residual

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[41] In this Second Report, the term "advanced sorting" is used to describe the process of removing plastics and other materials from residual waste before it is incinerated.

[42] *National municipal waste composition-England 2017*. WRAP. (2017). Available at: Quantifying the composition of municipal waste | WRAP; *The composition of household waste at the kerbside in 2014-15.* Zero Waste Scotland. (2017). Available at: Composition household waste at the kerbside 2014-15 | Zero Waste Scotland; *The climate change impacts of burning municipal waste in Scotland.* Zero Waste Scotland. (2021). Available at: The climate change impact of burning municipal waste in Scotland | Zero Waste Scotland.

[43] See for example *Fossil Fuels & Plastic*. CIEL. (2015). Available at: Fossil Fuels & Plastic - Center for International Environmental Law (ciel.org)

[44] *Response to the Call for Evidence.* Viridor (2022). Available at: Response 778305103 to Incineration in the waste hierarchy review: call for evidence - Scottish Government - Citizen Space (consult.gov.scot)

waste (the BES-P scenario), the reduction from advanced sorting is 49% 496 to 252ktCO_2e.

The arguments for advanced sorting to remove recyclable plastic are clear. Therefore, this Second Report confirms the First Report's provisional position:

Recommendation 13: 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 possible, with a particular focus on plastic.

However, it is also the case that burning fossil-based plastics[45] – whether recyclable or not – creates climate-impacting GHG emissions and needs to be avoided if Scotland is to reach its net zero targets. In other words, for some or all incineration plants (depending on the deployment of carbon capture technologies, see Section 4.7), net zero is not possible if plastic remains in the feedstock.

This Second Report therefore goes further:

Recommendation 17 The Scottish Government and SEPA should put in place by 2025 robust arrangements to stop fossil-based plastic from being incinerated in Scotland from the beginning of 2030, except where required for hazardous waste disposal.

Industry and local authorities have the ability and direct levers (e.g. through contracts) to prevent the incineration of fossil-based plastics and should take action as soon as possible to do so. However, it will necessarily fall to Scottish Government and SEPA to ensure that robust arrangements are in place to prevent plastics from being incinerated in Scotland.

Currently, Scotland and the rest of the UK are heavily reliant on exports[46] for managing plastic waste. Recent estimates suggest that the UK exports around 60% of its packaging waste[47]. While some exports currently ensure the value of material is maximised, this trade is fraught with problems and is increasingly seen as unsuitable[48]. It is also not consistent with Scotland's desire to be self-sufficient in its waste management for it to send any significant quantity of its waste out of the country.

Recommendation 18 In implementing the recommendations of the Review, the Scottish Government should do what is within its powers to ensure that there is no increase (and ideally a significant decrease) in the export of plastic waste from Scotland.

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[45] That is, plastic that has been made from fossil sources such as coal, natural gas or oil, as opposed to bio-based plastic made from recently-living material.

[46] In the Review, "exports" is used to mean moving waste outside Scotland to other parts of the UK as well as across international boundaries.

[47] *The price of plastic: ending the toll of plastic waste*. House of Commons Committee report. (2022). Available at: The price of plastic: ending the toll of plastic waste - Environment, Food and Rural Affairs Committee (parliament.uk)

[48] See, for example, *Closing the loop: Viridor's roadmap to a truly circular plastics economy*. Viridor (2022). Available at: Viridors roadmap to a truly circular plastics economy and *The Reality Check 2022.* Biffa. (2022). Available at: Publications | Biffa

Plastics fractions contained in complex waste streams may not be easily sortable or available in sufficient amounts or at the sufficient quality to make mechanical recycling a viable solution from both an economic and environmental standpoint. Black plastics are particularly hard to sort as their colour makes them difficult for machines to spot, plastic films are problematic due to their capacity to jam sorting machinery, and low-density polythene needs to be chemically recycled.

There are also limited options for off-takes of the lower quality plastics that are sorted from residual waste. Industry experience of plastics recovered from residual waste in Scotland has highlighted that they are very poor quality with low market acceptability[49]. Furthermore, alternative options such as chemical recycling also come with technical complexities and other challenges.

Overcoming the barriers to handling plastic waste domestically will require action and investment across the plastics supply and management chain. The UK Plastics pact Annual Report 2021/22[50] suggests that although the UK's plastics reprocessing capacity has grown 50% over the past 5 years, it will require an additional 440,000t/y of domestic plastics reprocessing capacity to achieve the UK Plastic Pact target of boosting plastics recycling to 70% by 2025. It also notes that certainty on key policy is needed to ensure this capacity will be available to the market in time.

Costs for advanced sorting are highly variable and dependent on facility size – with smaller facilities tending to be more expensive on a per tonne basis. The overall balance of costs depends on material revenues and avoided disposal costs – not just the cost of installing and operating sorting processes. Furthermore, transporting, storing, and potentially upgrading intermediates can add significant operational and capital costs.

Given these constraints, implementation of the Review's Recommendations implies that plastic that is currently not recyclable will need to be stored until a suitable recycling route is developed and implemented. Such storage will need to be regulated appropriately to ensure it is done safely in terms of risks to human health and the environment as well as to enable it to be easily and economically retrieved once recycling is feasible.

Because it is likely that advanced sorting technologies will not be able to deliver Recommendation 15 alone, additional approaches should be examined. Clearly, global work to reduce plastic production and use may have an impact, as will the deployment of extended producer responsibility schemes for packaging and other plastic uses, bans on certain single-use items, etc. In addition, a change to waste collection practices could be beneficial. For example, businesses and households could be required to place **all** end-of-life plastic items into one 'bin', which would then be taken to specialist plastics sorting, recycling and storage facilities that would divert it all away from incineration. This could be easier for waste producers to understand and comply with than other approaches, though would also require investment in the appropriate infrastructure.

[49] For example, see Viridor's response to the Call for Evidence, *Response to the Call for Evidence.* Viridor. (2022). Available at: [Response 778305103 to Incineration in the waste hierarchy review: call for evidence - Scottish Government - Citizen Space (consult.gov.scot)]

[50] *The UK Plastics pact -Annual Report 2021/22.* WRAP. (2022). Available at: [The UK Plastics Pact Annual Report 2021-22 | WRAP]

Recommendation 19 The Scottish Government should implement Recommendation 17 through policies to reduce plastic production and use, promote source segregation of all plastic wastes, and implement advanced sorting of residual waste.

The point of this recommendation is that all these policy approaches are likely to be relevant and necessary – it is unlikely that any one alone will give the desired result for Scotland.

4.4 Biostablisation

Biostabilisation processes that use in-vessel composting may be able to stabilise waste to a level that is compliant with the landfill ban. However, as noted in the First Report, while it may be technically feasible to stabilise waste to achieve the landfill ban criteria, biostabilisation is unlikely to be a practical treatment option for the majority of residual waste in Scotland.

However, as the First Report highlighted, there are geographies in Scotland where residual waste treatment options may be limited, such as remote and rural areas. In such cases, biostabilisation may have a role as a small-scale treatment option, particularly where food waste collections are limited.

Since biostabilisation is unlikely to be a practical treatment option for the majority of Scottish residual waste, it is unlikely to provide a solution or alternative route to support the decarbonisation of existing and planned infrastructure in Scotland. It was therefore not included in the detailed modelling of options[10].

4.5 Waste to Fuel and Chemical Recycling Technologies

Stakeholder feedback noted the potential for ATT processes to develop products other than electricity, which might be beneficial to support decarbonisation of other activities, especially as the power grid decarbonises and so the carbon benefit of this kind of electricity generation reduces.

Waste to fuel is an umbrella term for a range of technologies, typically gasification or pyrolysis, that convert mixed municipal waste or single waste streams (eg plastics) into fuel sources such as hydrogen and bioethanol. These have been labelled ‘low carbon fuels’, since they typically displace fossil fuels derived directly from extracted oil.

Scotland currently has two gasification plants in operation, none in development and one with planning permission for the treatment of municipal waste. We understand that it would be difficult for these facilities to convert to waste to fuel processes. It is therefore, unlikely that waste to fuels technologies would be viable options for the decarbonisation of existing and planned infrastructure, particularly for the processing of mixed municipal waste.

Chemical recycling is also an umbrella term for technologies that seek to recycle plastics by changing their material structure[51], for example, converting them back to their

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[51] *Chemical Recycling State of Play Report.* Eunomia. (2020). Available at: Eunomia State of Play Report

monomers for reformulation into plastics. One form of chemical recycling involves pyrolytic techniques, and there is therefore a cross-over in the type of technologies used in chemical recycling, waste to fuels and in the incineration of mixed municipal waste, considered by the Review.

Waste to fuel and chemical recycling technologies could play a role in allowing the sector to support wider decarbonisation by offering a route for plastics that are difficult (practically or economically) to mechanically recycle and are collected at source or recovered from the residual waste stream. This could facilitate the implementation of recommendations in this Second Report, including the collection of plastics not currently recycled.

We would not expect chemical recycling or waste to fuel technologies to be caught under Recommendation 4[52] so long as they do not directly emit GHGs. Although they add a small amount of treatment capacity, they will ultimately reduce the need for municipal waste incineration capacity, which could be reflected in a faster reduction in any future capacity cap (Recommendation 5[53]).

4.6 Heat Networks

The majority of incineration plants in Scotland 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 efficiency is required for the process to be better in GHG emission terms than landfill.

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%.

Currently, only one operational incinerator in Scotland is connected to an operational heat network, Gremista in Lerwick, Shetland, which is owned and operated by Shetland Council. This was constructed alongside the heat network for the town of Lerwick and the plant does not generate electricity. Its operation is as a waste solution for the Shetland Islands due to limited available options for recycling and as a source of heat for the heat network. As such its indicative efficiency is greater than other incinerators in Scotland (see Table *4*, Annex B – Recovery Status (R1 value)).

The Millerhill incinerator operated by FCC in partnership with the City of Edinburgh and Midlothian Councils has plans to connect to a heat network in the Shawfair development in Southeast Edinburgh. Construction of the initial district heating network, supplying around

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52 “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.” See *Stop, Sort, Burn, Bury?* (2022), Available at: Supporting documents - Stop, Sort, Burn, Bury - incineration in the waste hierarchy: independent review - gov.scot (www.gov.scot)

53 “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.” See *Stop, Sort, Burn, Bury?* (2022), Available at: Supporting documents - Stop, Sort, Burn, Bury - incineration in the waste hierarchy: independent review - gov.scot (www.gov.scot)

3,000 homes, education and retail properties at Shawfair Town in the north of Midlothian Council area is expected to begin soon and deliver heat to homes by 2024. This initial phase is expected to save over 2,500 tonnes of CO_2 per year. The project will benefit from up to £7.3m from the Scottish Government's Low Carbon Infrastructure Transformation Project (LCITP)[54].

The Ness incinerator which is currently under construction in Aberdeen is planning to connect to a heat network providing heat to Local Authority buildings and houses in the Torry area of Aberdeen providing up to 10MWth of heat energy from 2025[55].

Heat networks can therefore be a viable method to allow the sector to support wider decarbonisation. However the examples above show how close collaboration with developers, local authorities and plant operators is required to ensure heat networks can be utilised for new developments and existing infrastructure. This can be difficult to achieve. For example, the incinerator operated by MVV MEB in Baldovie, Dundee has not been able to find a customer for its excess heat. The plant is located adjacent to the former Michelin tyre factory, which was a potential customer before its closure. Finding a viable alternative since then has not been successful.

Incineration facilities are subject to minimum efficiency requirements. SEPA's 'Thermal Treatment of Waste Guidelines'[56] (TTWG) updated in 2014 sets a 20% energy efficiency target for municipal waste incinerators, over 25kt annual capacity, at start-up (generally achievable as electricity only) and require a credible Heat and Power Plan showing how the facility could meet a minimum of 30-35% efficiency.

As per the TTWG, all SEPA permits for incineration plants contain a requirement stating:

> Within 7 years from the date of First Operation of the Permitted Installation, the total quantity of energy recovered in the form of electrical or heat energy or a mix of electrical and heat energy shall exceed the amount of energy equivalent to a Combined Heat and Power Quality Assurance (CHPQA[57]) Quality Index value of 93 or an indicative efficiency of 35%.

Every incineration plant in Scotland in operation or in the planning pipeline is required to prepare a Heat and Power Plan to ensure compliance with the TTWG to demonstrate how they can connect to a heat network or how they demonstrate being 'CHP ready' should the option to connect to a heat network become a viable option. Although the TTWG places an

[54] *News: From waste to low-carbon heating for Midlothian homes.* FCC. (2022). Available at: From waste to low-carbon heating for Midlothian homes – Millerhill (fccenvironment.co.uk)

[55] *Energy from Waste Facility Non-Technical Summary Acciona Industrial.* NESS. (2019). Available at: Ness EfW Limited: Ness EfW facility - permit application - Scottish Environment Protection Agency - Citizen Space (sepa.org.uk)

[56] *Thermal Treatment of Waste Guidance.* SEPA. (2014). Available at: SEPA| Thermal Treatment of Waste Guidelines

[57] The CHP Quality Assurance programme (CHPQA) is a UK government initiative providing a practical, determinate method for assessing all types and sizes of Combined Heat and Power (CHP) schemes throughout the UK. CHP, the simultaneous generation of heat and power in a single process, provides one of the most cost-effective approaches for making carbon savings and plays a crucial role in the UK Climate Change programme. *Combined Heat and Power Quality Assurance Programme*. UK Government. (2014). Available at: Combined Heat and Power Quality Assurance Programme - GOV.UK (www.gov.uk)

obligation on incinerator operators to provide heat and/or steam to a heat network, the availability of a heat network is not within their control and they are reliant on local authorities, developers and other outside stakeholders to develop a viable network.

Plants that cannot meet the TTWG requirements due to circumstances outside of the plant's control, must submit to SEPA in writing the details of those circumstances and the reasons for the likely non-compliance, with reference to the provisions of the TTWG and the most recently agreed Heat & Power Plan, together with information on the Operator's proposals on how and when the requirements of said guidelines will be met.

Where this occurs the CHPQA and indicative efficiency requirements are dis-applied from the plant's permit until such time as the Operator has received written confirmation from SEPA that either the requirements of TTWG continue to apply, or the requirements of the TTWG are varied by issue of a variation notice by SEPA.

This effectively means that the regulatory pressure on an incinerator operator to connect to a heat network is not great, and in many cases will not be strong enough to overcome the problems identified above.

Operational facilities are required to update their Heat and Power Plan annually[17]. Table *4*: Current estimated efficiency values, CHQQA and R1 values for Energy from Waste plants in Scotland (Annex B – Recovery Status (R1 value)) summarises the efficiency levels and CHPQA quality index reported up to 2022 by existing and proposed sites in Scotland. Plants operational before 2014 are not required to calculate these values.

The Eunomia report noted that the addition of heat recovery resulted in a modest reduction of net emissions (around 27 – 35 ktCO_2e per annum), compared to CCUS and advanced sorting. This is in part due to assuming that only five additional facilities (Millerhill, GRREC, Aberdeen, Dundee and Earls Gate) will implement heat recovery and connect to heat networks by 2035 given the issues outlined above.

In addition, while increasing the efficiency of a plant results in avoided emissions by displacing other sources of energy, it doesn't reduce direct emissions. As the wider energy sector decarbonises, there will be less of a displacement effect. So, while heat networks can be an effective way of capturing excess heat from an incineration plant, this is not a reason to construct a new one.

Nonetheless, as heat networks have a wider role to play in decarbonisation, whatever energy source is used, their connection to incineration plants, where possible, is beneficial. Therefore, this Second Report confirms the First Report's provisional position that:

Recommendation 14 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.

4.7 Carbon Capture, Use, or Storage (CCUS)

Several technologies[58] 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. For now, the most suitable capture technology for incineration is likely to be post-combustion removal of CO_2 from the flue gases, which is expected to be carried out by carbon scrubbing with amines, as this is the only capture technology that has been used industrially[59]. Amine-based carbon capture is a regenerative process using an amine solvent to remove CO_2 from flue gas post combustion. Reversing the reaction releases pure CO_2 for capture and frees up the solvent for re-use. Amine-based post-combustion capture (PCC) is a well-proven and commercially available technology, having been used in the petroleum sector since 1996 and in the coal-fired power industry since 2014[60].

Less well-developed approaches include membrane separation and chemical looping. Increasingly, technologies that convert the carbon dioxide on site into a useful material[61] are being developed.

The capture and compression of CO_2 incurs an energy loss (parasitic load) in the form of the provision of steam and/or power. The size of this loss will depend on the efficiency of the capture process but can be as much as 20% of the energy output from the facility. This will impact on the efficiency values stated previously but will improve a plant's R1 status (see Annex B – Recovery Status (R1 value)). Typically, within an incinerator, CO_2 represents 10-12% of the flue gases; higher concentrations of CO_2 make the capture of CO_2 more efficient. The absorber tower can be made smaller, and the solvent used to capture the CO_2 in the flue gas can be used more efficiently.

CCUS technologies have the potential to capture emissions from both fossil carbon and biogenic carbon released from the incineration of residual waste. The additional work undertaken by Eunomia, following discussion with the CCC, therefore included emissions reductions due to the capture and storage of biogenic carbon emissions. This modelling suggests that the deployment of CCUS in Scotland could have a marked impact on decarbonisation, noting that the addition of CCUS (Pathway 3) would reduce annual net GHG emissions from waste treatment by around 80% (79 – 82% depending on the scenario) compared to the modelled Pathway 1 (Advanced sorting only) in all scenarios (64-68% reduction in direct emissions). The scenarios that examined increased food waste avoidance compared to increased plastics recycling had little impact on the modelled results since CCUS was assumed to capture both biogenic and fossil carbon. In this modelling the sequestration of biogenic carbon in landfill is also included as an assumption, however, emissions from the incineration of biogenic carbon are not included

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[58] *About CCUS: Playing an important and diverse role in meeting global energy and climate goals.* IEA. (2021). available at: About CCUS – Analysis - IEA

[59] *Facilities Database.* Global CCS Institute. (unknown). Available at: Facilities - Global CCS Institute (co2re.co)

[60] *Amine-based post-combustion capture.* Global Cement and Concrete Association. (2022). Available at: Amine-based post-combustion capture : GCCA (gccassociation.org)

[61] See for example, Carbon8. (2022). Available at: Carbon8

in the baseline (2020) scenario. While this is in line with wider carbon accounting practices, it may be beneficial to consider whether reporting biogenic carbon in all aspects of future modelling for the waste sector could be beneficial (see Section 3.2.1 and Recommendation 15).

4.7.1 Development of CCUS

The modelling undertaken by Eunomia is intentionally optimistic about the potential for Scotland to deploy CCUS, presenting what could be considered a best case scenario. CCUS was not modelled on its own without other options (Advanced Sorting or Heat Networks) as it is currently the least feasible option and there are a number of potential barriers to deployment of CCUS.

The development of CCUS is anticipated to occur in a phased manner, led by the location of incineration facilities (and wider industry) which strongly influence technical and economic viability. There is recognition that large CO_2 emitters close to each other and to a transport and storage solution will likely form into a CCUS ‘cluster’. Incineration facilities are suitable candidates to join such clusters and are already aligning themselves with such projects.

Proposals for a CCUS cluster in Scotland are led by the Acorn Project[62], a consortium of companies backed by the UK & Scottish Governments and the EU. This proposes to use existing and new pipelines, ships and other containers to move CO_2 emissions from projects in Scotland, across the UK and internationally to permanent storage 2.5km (1.5miles) under the North Sea.

Those plants most likely to overcome the barriers, and therefore be able to deploy CCS first are anticipated to be those along the east side of Scotland initially and within 30km of an identified cluster or pipeline. Following this, it is anticipated that facilities that are within 30km of potentially suitable port facilities to be developed next (second phase). This is on the basis that given existing infrastructure, these ports would likely represent the most likely future 'hubs' through which captured carbon would be transported (via ship) to cluster locations.

Transport solutions for the remaining incinerators away from the cluster and port locations are likely to be expensive due to their remote locations. If current CCUS technologies are applied to these, it will require substantial wider learning and cost reductions from earlier phases. For some of these incinerators the costs of applying CCUS may be prohibitive.

The operational sites in Scotland within 30 km of the Acorn cluster are:

- Earls Gate Park, Grangemouth
- MVV Environment Baldovie, Dundee
- FCC Millerhill, Edinburgh

The sites within 30 km of suitable ports are:

- Dunbar ERF - Forth port is well located to access the Acorn Cluster storage site.

[62] For more information see *Acorn.* Acorn. (2022). Available at: [Acorn | Growing Our Decarbonised Future (theacornproject.uk)](theacornproject.uk)

Earls Gate Energy Centre in Grangemouth, Westfield Incinerator in Fife, Ness Incinerator in Aberdeen and Inverurie Incinerator are likely to be within 30 km of the Acorn Cluster when operational.

All other sites are considered to be away from suitable clusters or port locations.

We asked incineration operators if they had plans for CCUS on site. Of those that responded, several are actively considering CCUS (e.g. through feasibility studies) and one operator noted that it is likely to depend on the Net Zero strategy of the contractual authority.

The sooner CCUS can be developed on incineration facilities the greater the impact on carbon emissions there will be. It is therefore prudent, when choosing which of the pipeline of incineration facilities to pursue, to opt for those with the greatest opportunity to decarbonise quickly. The Review recommends that:

Recommendation 20 In considering which plants with planning permission to construct, financers, developers and planning authorities should prioritise those plants where deployment of currently available CCUS technology is most feasible.

This Recommendation is not intended to over-rule Recommendation 10[63], especially if it is possible to use newer technologies to allow carbon capture and use.

Recommendation 21 The Scottish Government should consider support for emerging carbon capture and use technologies that could overcome challenges to deployment for facilities already in operation, or required for more remote facilities.

While there should be a diminishing need for residual waste treatment, for as long as there is a need to burn waste to treat it in a sanitary manner, we should pursue all possible ways to decarbonise the incineration sector, including through CCUS, particularly given the potential to capture biogenic carbon. Current barriers, such as access to the Acorn Pipeline, may be overcome by emerging carbon capture and use technologies, especially those that remove the need for transport of carbon dioxide.

4.8 Recycling More By-Products

The Review has received no new information on this aspect and therefore has nothing to add to the First Report.

4.9 Decarbonising Landfill

Landfill is a significant but declining option for biodegradable waste management in Scotland. It is currently associated with higher GHG emissions in comparison to other forms of residual waste treatment and is a significant source of anthropogenic methane

[63] "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."

emissions[64] from the degradation of biodegradable material[65]. For example, the Eunomia modelling found that sending waste to landfill without pre-treatment was between 381 and 408ktCO_2e per kt of household waste landfilled for the BES-F and BES-P scenarios, respectively.

When biodegradable waste is deposited in a landfill, biological decomposition can be hastened or delayed depending on the amount of oxygen, temperature, and moisture available. Waste in a landfill can take anywhere between 10 days (eg for a banana) and 800 years (eg for sanitary products) to decompose and is dependent on the waste composition and other factors. This long term emission means that even if no more biodegradable waste is deposited in Scotland's landfill sites, there will nonetheless be an ongoing need to capture the significant GHG emissions for years to come.

Other impacts associated with landfills include groundwater and surface water risks, odour, noise, dust, litter, and vermin. Furthermore, some active and historical landfill are in coastal and alluvial areas prone to flooding and/or erosion and this is likely to increase in the future because of risks associated with climate change such as increased frequency of extreme rainfall events and sea level rise. These risks need to be better understood and managed in the future.

Therefore, while the environmental risks associated with landfill, including GHG emissions, are most acute during the operational phase, they may persist for many decades, well beyond the operational period. Once landfills are full, capped and restored, active site management is required to mitigate the longer-term environmental risks.

4.9.1 Gas Management

Landfill capping and gas management systems help manage the risks posed by landfill gas, but many older, closed sites in Scotland passively vent landfill gas to the atmosphere with little or no collection infrastructure. As well as methane and carbon dioxide from degradation of biodegradable wastes, landfill gas may include other volatile contaminants. Gas management is required at landfills to mitigate risks to human health and the environment, including to reduce climate change impacts.

The landfill gas capture rate across the UK is estimated to be between 59% and 63%, which is lower than that reported in other countries[66]. Increasing the proportion of landfill gas captured is, therefore, likely to play a part in decarbonising the residual waste sector[67].

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[64] Methane has 28-34 times the global warming potential (GWP) compared to CO_2 over a 100-year period (this increases to 84-86 times measured over 20 years). *The Challenge*. UNEC. (2022). Available at: The Challenge | UNECE

[65] Some biogenic material is likely to be sequestered in landfill sites, and could therefore act as a small carbon sink.

[66] *UK Greenhouse and Gas inventory 1990 to 2020 Annual Report for submission under the Framework Convention on Climate Change.* NAEI. (2022). Available at**:** Report: UK Greenhouse Gas Inventory, 1990 to 2020: Annual Report for submission under the Framework Convention on Climate Change - NAEI, UK (beis.gov.uk)

[67] The CCC has recommended that methane capture rates increase to 80% by 2050 to address fugitive emissions from landfill. See *2021 Progress Report to Parliament.* CCC. (2021). Available at: 2021 Progress Report to Parliament - Climate Change Committee (theccc.org.uk)

Gas that is collected can be used to generate electricity or, in a combined heat and power (CHP) system, to provide both electricity and heat, or flared to the atmosphere to convert the methane to carbon dioxide. Though landfill gas production generally reaches a peak in five to seven years, a landfill can continue to produce gases for more than 50 years. Whilst gas generation rates remain sufficient to make energy recovery from the landfill gas commercially viable, the gas risks will usually be actively managed. However, as landfills age, gas generation rates reduce[68] and consequently the technical and commercial feasibility of generating energy from landfill gas will lessen. Where energy generation is not economically or practically possible, for example due to waste composition changing to less biodegradable waste (less methane produced), it can be flared and where this is not possible, it can be managed passively, for example by an appropriate choice of plant cover.

Recommendation 22 The Scottish Government and landfill owners and operators should ensure maximum capture of landfill gas for open and closed landfill sites, and develop new approaches to do this as methane levels decrease.

Stakeholders have raised concerns around the future incentives to capture landfill gas for energy production or flaring. The Renewables Obligation (RO), covering England and Wales and the Renewables Obligation (Scotland) (ROS), have supported most of the renewable capacity built across the UK since their introduction in 2002. Under these schemes, certificates (ROCs) are issued to operators of accredited renewable generating stations for the eligible renewable electricity they generate, including landfill gas renewable technologies[69]. However, since April 2017 and the closure of the RO to new entrants, new landfill gas generation capacity has not qualified for any subsidy support, and support for existing landfill gas generation ceases from April 2037.

The RO/ROS withdrawal could result in the potential loss of a significant revenue stream and an increase in the volume of gas being flared. Consideration of the impacts of the removal of the ROS and how to incentivise landfill operators and their renewable technology partners to maximise the efficiency of landfill gas management would seem beneficial[70].

Recommendation 23 The Scottish Government should consult with landfill owners and operators to address the consequences of the withdrawal of current landfill gas management financial incentives after 2037.

4.9.2 Further Decarbonisation Options

There may also be opportunities for further incentives and opportunities to support decarbonisation of the sector, as the number of Scottish landfills in the restoration phase continues to increase. These include:

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[68] The amount of landfill gas produced is dependent on number of factors including volume and biodegradable content of waste, compaction, and moisture.

[69] In 2020- 21, 308,950 ROCS were issued in Scotland for landfill gas renewable technology. See *Renewables Obligation Annual Report 2020-21.* OFGEM. (2022). Available at: Renewables Obligation (RO) Annual Report 2020-21 | Ofgem

[70] Previous study noted a similar recommendation for landfill aftercare, See *Landfill After Care Scoping Study..* Defra. (2019). Available at: Science Search (defra.gov.uk)

- Options to use energy on-site instead of exporting to the grid;
- Opportunities for mobile flaring technology which could be used for flaring on a part-time basis as the gas generation rates fall;
- Opportunities for heat recovery from the landfill;
- Improvements in capture technology such as improved containment liners or using biosolids (containing microorganisms) that convert methane into carbon dioxide.

5 Eunomia Report Results

This section summarises the results from the Eunomia report[71]. These results are also integrated into the discussions above.

5.1 Eunomia Report Results – Overall

The Eunomia report provides a substantial amount of information on how the modelled pathways would affect decarbonisation of incineration in Scotland in each of the three scenarios. This is summarised in Figure *4*.

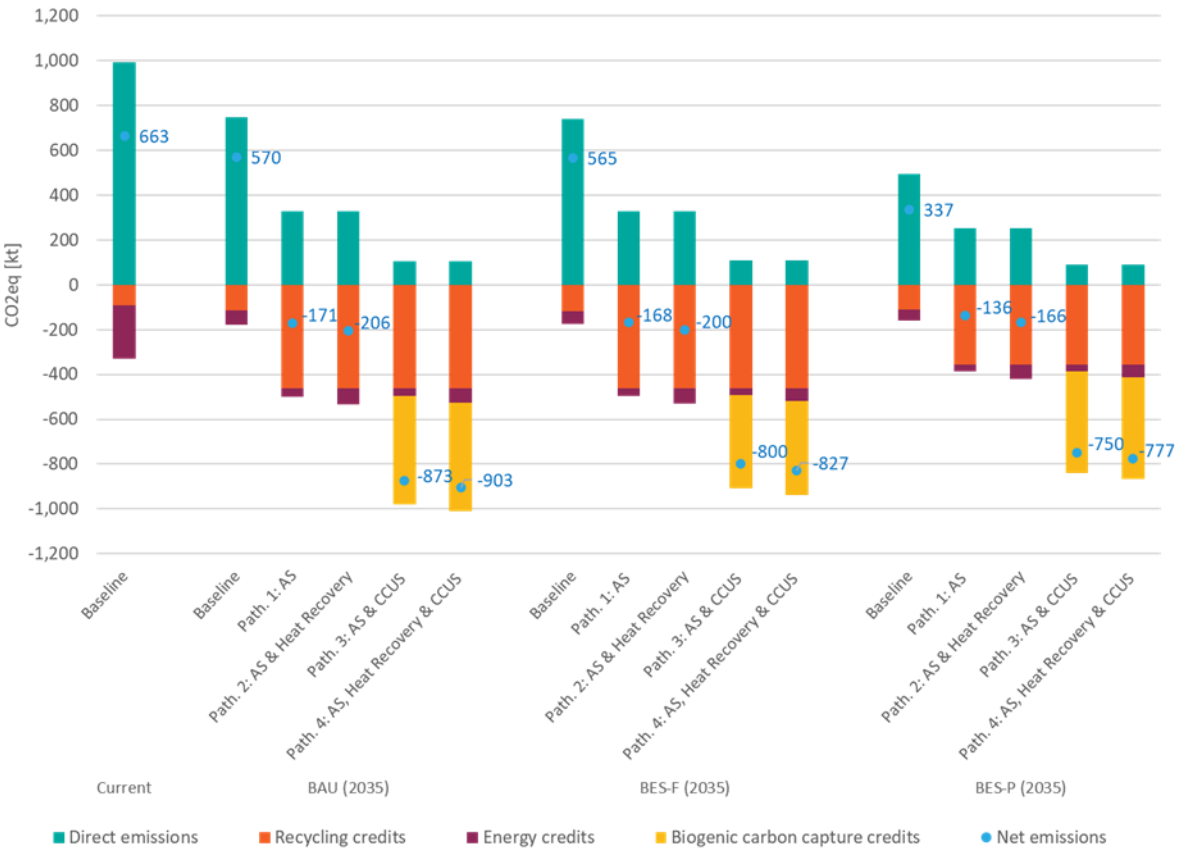

Figure 4: Carbon emissions associated with the baseline and the pathways for each scenario by direct emissions and carbon credits

There are four types of impact on emissions that emerge from this work:

1. Direct emissions from the incinerator (teal)
2. 'Recycling credits' – emissions avoided by using recycled materials rather than virgin ones (orange)
3. 'Energy credits' – emissions avoided by displacing other forms of energy generation (heat and/or electricity) (dark pink)
4. 'Biogenic carbon capture credits' – the allowance for burning biogenic waste and then capturing the short-cycle GHGs that are then emitted (yellow)

[71] All the data and figures presented in this section come from the Eunomia report unless otherwise stated, see 10

As discussed in Section 3.2.1, none of these currently score as waste sector emissions and only the first type is generally reported (under energy). However, when considering the resource and waste management system as a whole, and when seeking to reach a net zero and more circular economy, they are clearly relevant to enable policy makers to take fully-informed decisions. This is made even more clear by Figure 5, which shows the emissions associated with the production of materials that eventually become the waste that has to be treated, alongside the waste treatment impacts. When such impacts are included, all the scenarios for all the pathways have a net contribution to climate change. End-of-life benefits arising from techniques like CCUS therefore need to be seen in the wider waste and resources systems context.

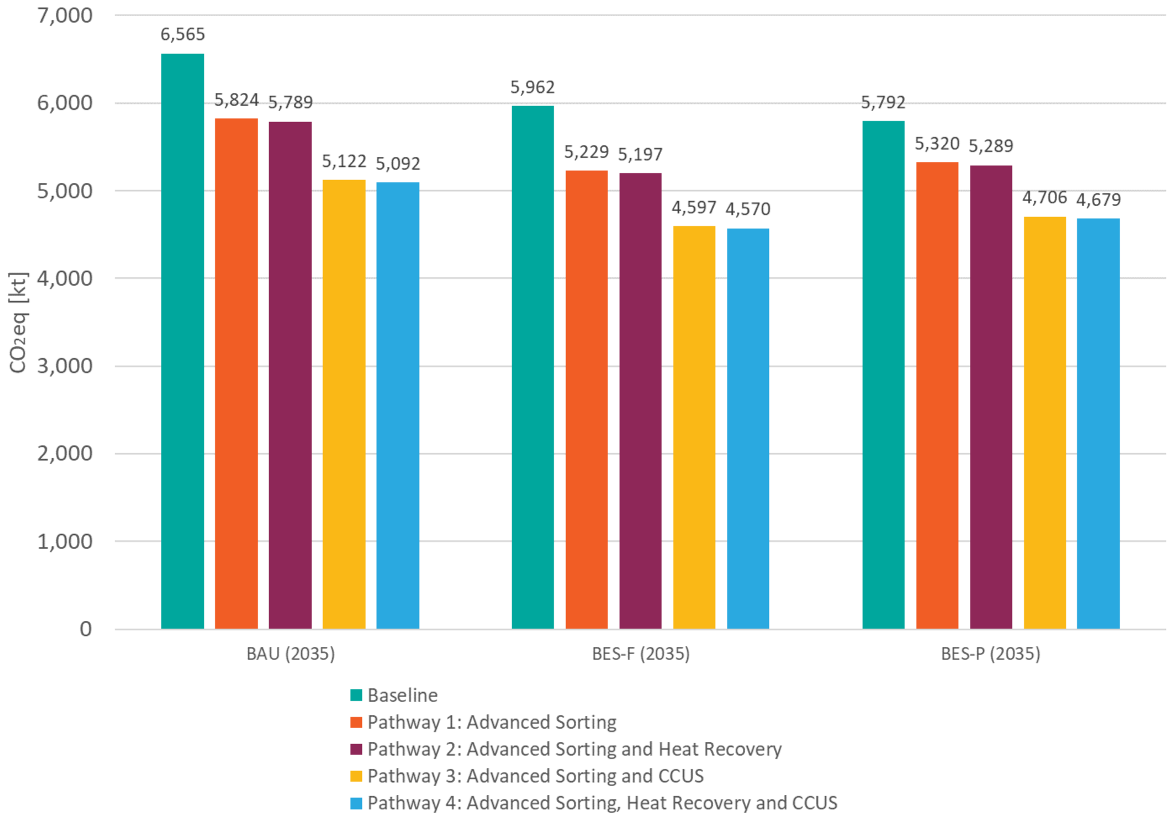

Figure 5: Carbon emissions associated with the baseline and the pathways for each scenario including material production emissions

In all three scenarios and all pathways, the modelling makes an allowance for energy credits. For the baseline and Pathways 1 and 3 this is from electricity generation (29-61ktCO2e) and for Pathways 2 and 4 both electricity and heat (56-72ktCO_2e).

5.2 Eunomia Report Results – Advanced Sorting

Removing most of the recyclable plastic from incinerator feedstock via advanced sorting has a substantial and immediate impact on direct emissions as summarised in Table 2. There are also significant (355-463ktCO_2e) recycling credits across the three scenarios from advanced sorting.

Table 2: Modelled direct emissions impact for advanced sorting

2035 Scenario	Modelled Direct Emissions $ktCO_2e$			
	Baseline	+ AS	Reduction	
BAU	747	329	418	56%
BES-F	741	328	413	56%
BES-P	496	252	244	49%

This strongly supports the argument that implementation of advanced sorting, along with other measures to avoid plastic waste being incinerated (such as waste prevention and better source segregation as set out in Section 4.3) is a vital decarbonisation solution for incineration. In addition, unlike the other options examined, this is applicable to all current and potential incineration facilities, irrespective of location or technology.

5.3 Eunomia Report Results – CCUS

The Eunomia work also indicates that the application of CCUS could deliver substantial carbon savings by capturing fossil GHG emissions (Table *3*), based on the optimistic deployment assumptions used.

Table 3: Modelled direct emissions impact for CCUS

2035 Scenario	Modelled Direct Emissions $ktCO_2e$				
	Baseline	+ AS	+ CCUS	Reduction	
BAU	747	329	106	641	86%
BES-F	741	328	110	631	85%
BES-P*	496	252	90	406	82%

*The savings in scenario BES-P are lower because this scenario assumes less plastic is in the residual waste due to upstream policies.

In addition to the recycling credits described above, CCUS could also deliver biogenic carbon capture credits. These are also potentially significant (417-482$ktCO_2e$), though again accounting for them is not currently straightforward.

However, as Section 4.7 sets out, the barriers to deployment of CCUS are considerable, so these reductions are a best case scenario by 2035 that depends on a number of things falling into place. These results underpin the Review's position that CCUS should continue to be pursued because of its significant potential, but it cannot be relied upon to decarbonise incineration quickly enough to meet Scotland's ambitions.

5.4 Eunomia Report Results – Heat Networks

Using excess heat from incinerators for other users has a relatively small impact (and once more is not strictly attributed to the waste sector). This supports and confirms the Review's position that the deployment of heat networks is unlikely to be a major element in incinerator decarbonisation, though it can still play a useful role in improving the overall efficiency of the facilities that are connected in this way.

6 Overall Conclusions

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

1. Current greenhouse gas emissions reporting needs to reflect the full system picture if the data is to be used to drive developments in the best overall direction.
2. Stopping all plastic from being incinerated is the quickest and most reliable route to reduce the carbon impact of incineration.
3. Carbon Capture, Use or Storage has the potential to play a significant role in meeting Scotland’s net zero ambitions and should be pursued. However, many barriers stand in the way of CCUS deployment and it is far from clear how quickly any contribution can be realised, nor how extensively. Therefore, it should not be relied upon to deliver Scotland’s net zero ambitions.
4. Combined Heat and Power connected to a heat network or other local heat user can play a role in improving the carbon performance of incinerators. However, because of a number of factors, that role is limited and will almost certainly decrease over time. It is not a reasonable justification for incineration.
5. The forthcoming end to landfill gas capture incentives could, if not addressed, lead to reductions in abatement in this sector.

7 Annex A – Definitions

Advanced Sorting	Treatment of 'black bag' residual waste that removes recyclable materials (such as metals, plastic, etc) before final treatment via incineration or landfill
AS	Advanced Sorting
ATT	Advanced Thermal Treatment
Anaerobic decomposition	Rotting in the absence of oxygen
BAU Scenario	Business as Usual Scenario within the Eunomia report, based on the First Report, which models the carbon implications of this **OR** 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 the 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
BES-F	Best Effort Scenario – Food within the Eunomia report, which extends the First Report BES to consider better food waste recycling and avoidance and models the carbon implications of this
BES-P	Best Effort Scenario – Plastic within the Eunomia report, which extends the First Report BES to consider better plastic recycling and waste avoidance and models the carbon implications of this
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.
Biogenic waste	Waste made up of material that was recently alive, such as food, paper, card, wood and natural textiles
Biostabilisation	The controlled processing of biodegradable waste to reduce or eliminate its potential for anaerobic decomposition
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.
CCC	Climate Change Committee
CIWM	Chartered Institution of Wastes Management
CV	Calorific Value
CXC	ClimateXChange
DRS	Deposit Return Scheme
FOES	Friends of the Earth Scotland
GWP	Global Warming Potential
HH	Households or Household
Incineration	The combustion of material in the presence of air or oxygen. In this report, this includes ‘traditional’ incineration and advanced thermal treatment options such as gasification
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, which 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 Environment Protection Agency

SESA	Scottish Environmental Services Association
SLCF	Scottish Landfill Communities Fund
SRF	Solid recovered fuel
The Ban	The ban on biodegradable municipal waste to landfill 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

8 Annex B – Recovery Status (R1 value) and CHP

Incineration facilities are classified as disposal operations (D10) facilities, unless they can demonstrate a sufficient energy recovery score[72]. Incinerators can be re-classified as a recovery operation (R1) if they can demonstrate a suitable R1 value. To do this, plants must calculate the energy efficiency factor of the incinerator value using the method in the European Commission's Guidance to obtain the R1 value.

The Revised Waste Framework Directive specifies that Energy from Waste plants dedicated to the processing of municipal solid waste can be classified as a Recovery operation only where their calculated energy efficiency score is:

- 0.60 for EfW permitted and in operation before 1 January 2009
- 0.65 for EfW permitted and in operation after 31 December 2008

The energy efficiency is calculated as

$$(Ep - (Ef + Ei))/(0.97 \times (Ew + Ef))$$

in which:

- Ep = annual energy produced as heat or electricity. It is calculated with energy in the form of electricity being multiplied by 2,6 and heat produced for commercial use multiplied by 1,1 (GJ/year)
- Ef = annual energy input to the system from fuels contributing to the production of steam (GJ/year)
- Ew = annual energy contained in the treated waste calculated using the net calorific value of the waste (GJ/year)
- Ei = annual energy imported excluding Ew and Ef (GJ/year)
- 0.97 is a factor accounting for energy losses due to bottom ash and radiation.

Plants must collect operational data each year to confirm whether the plant is still achieving R1 status.

If the data shows that they're not achieving R1 status at the end of the year plants can ask for more time to take action to fix the problem. An extension will be based on the:

- previous 3 years' performance levels
- length of time it will take to fix the problem
- probability of achieving the minimum threshold

R1 status is withdrawn if the incinerator cannot meet the minimum requirements in the following year. They would then revert to being a disposal operation.

R1 status is needed for plants to import and use waste from other Member States, however, UK plants do not currently import waste[73].

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[72] *Waste Framework Directive 2008/98/EC,* EC (2008). Available at: EUR-Lex - 32008L0098 - EN - EUR-Lex (europa.eu)

[73] *Consultation on changes being made to UK legislation to reflect amendments to the Waste Framework Directive from Commission Directive (EU) 2015/1127 Government response.* Department for Environment, Food and Rural Affairs/ Welsh Government. (2016). Available at: Consultation on changes being made to UK legislation to reflect amendments to the Waste Framework Directive from Commission Directive (EU) 2015/1127: Government response (publishing.service.gov.uk)

Table 4: Current estimated efficiency values, CHPQA and R1 values for Energy from Waste plants in Scotland

Site	Date commissioned	Estimated Indicative Efficiency	Estimated QI value	R1 status*	Comments
MVV MEB	Lines 1 & 2 – Pre 2014 Line 3 - 2021	13%	46	None	Based on Electric for lines 1 & 2 only - commissioned in advance of SEPA TTWG. No data for Line 3
Viridor Dunbar	2019	21.1%	73.88	0.72	Electric only
Gremista Lerwick	1998	64.9%	90.85	None	Heat only - commissioned in advance of SEPA TTWG
FCC Millerhill	2019	24.5%	85	Expected in Early 2023	Electric only – proposed heat network not currently commissioned R1 applied for in 2022, plant designed to meet R1 requirements
Viridor Polmadie (GRREC)	2019	20.6%	65.2	None	Electric only
Levenseat	2020	23.20%	86	R1 Status applied for	Electric only
Ness	In construction	34%		None	Based on 2025 estimate of electric and at least 3MWth of heat network, proposed heat network has the potential for up to 10 MWth offtake. Plant designed to meet R1 status and anticipated that value would be 0.788 on electricity only, expected to rise with heat network offtake use
Westfield	In construction	27.80%	63.9	None	Electric only Plan to apply for R1 status in 2023
Earls Gate	In construction	48.70%	103.95	None	Based on electric and expected average heat uptake to existing heat network Plan to apply for R1 status in 2023
Fortum, South Clyde	In construction	33.30%	97.12	None	Electric only Entered into discussions regarding R1 status and expect approval to be granted
FCC Drumgray, Airdrie	In construction	39.1%	68.3	0.77	Based on electric and expected average heat network load, with no heat network efficiency is 25%.

					R1 value based on electricity only, rises to 0.83 if 8.93 MWth heat export is utilised.
Barr Killoch, Ayrshire	Proposed	44.50%	60.8	None	Based on electric only, with proposed heat network efficiency rises to 44.5% and CHPQA to 77.3. R1 status has not been stated by the operator.
Oldhall, Ayrshire	Proposed	-	-	None	Not calculated yet Will progress R1 status as project develops
Thainstone, Inverurie	Proposed	-	70.02	None	CHPQA expected value when operational R1 status not yet applied for, but expect to qualify with significant margin when application made

9 Annex C – Policy Context

In conducting the analysis and considering its recommendations, the Review considered the relevant policy landscape. Relevant policies were summarised in Annex B of *Stop, Sort, Bury, Burn?* This summary noted that 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[21]. The Scottish Government's targets related to resources and waste for 2025, include:

- 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.
- 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.

Since publication of *Stop, Sort, Bury, Burn?* The Scottish Government has consulted on the proposed priorities and actions for the Route Map to 2025 and Beyond[74], which includes policies relevant to the decarbonisation of the residual waste sector.

In relation to residual waste specifically, the Route Map to 2025 and Beyond notes ongoing work, including:

- The ban on landfilling biodegradable municipal waste coming into force from 31 December 2025;
- Extending the ban to include biodegradable non-municipal wastes;
- Publication of a review of biostabilisation of waste commissioned by Zero Waste Scotland; and
- Expanding the existing landfill gas capture programme.

The further work on residual waste proposed in the consultation on the Route Map to 2025 and Beyond, include:

- Developing a residual waste plan, which encompasses a range of proposed policies such as:
    - exploring options to use Scottish Landfill Tax and the Aggregates Levy, separately or jointly, to drive further recycling and develop secondary markets;
    - researching potential uses and treatment options for alternative pathways for sorting residues; and
    - investment to transition to lower emission residual treatment options;
- Facilitating the development of a sector-led plan by 2024 to restrict the carbon impacts of incineration; and
- investigating further fiscal measures to incentivise low-carbon disposal, which includes proposals to investigate the potential of an incineration tax and inclusion of energy from waste within the scope of the UK Emissions Trading Scheme.

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[74] *Delivering Scotland's circular economy A Route Map to 2025 and beyond.* Scottish Government. (2022). Available at: [Delivering Scotland's circular economy - route map to 2025 and beyond: consultation - gov.scot (www.gov.scot)]

Beyond residual waste, there are proposals for new policies further up the waste hierarchy, including:

- to reduce waste, including continuing to support food redistribution in Scotland. in 2022, introduce a charge for single-use disposable cups
- to improve recycling from households, such as co-designing high quality, high performing household recycling and reuse services with households
- to improve recycling from commercial businesses, such as co-design measures to improve commercial waste service provision and researching and piloting commercial waste zoning approaches.

The consultation on the Route Map to 2025 and Beyond is part of a twin consultation alongside the development of a Circular Economy Bill expected to be introduced to the Scottish Parliament this parliamentary session.

Beyond waste policy, the UK and Scottish Governments have been developing further regulations and policies to address barriers and support the development of heat networks (Including the Scottish Government’s Energy Strategy in 2017, National Planning Framework 4 (2021 draft) and the Heat Networks (Scotland) Act 2021 and associated regulations)[17].

Scottish Government
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