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Zero Waste Scotland - climate change report

Environmental Services Association

Rebuttal

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Document approval

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Management Summary

Zero Waste Scotland (ZWS) published a report titled "The climate change impacts of burning municipal waste in Scotland – Technical Report" (the ZWS report) in October 2020. Due to concerns about the accuracy and methodology of this report, the Environmental Services Association (ESA) has commissioned Fichtner Consulting Engineers Ltd (Fichtner) to comment on the report in detail.

Fichtner considers that the ZWS report uses a flawed methodology and contains errors and inconsistencies which mean that the results are not dependable.

Methodology Concerns

ZWS has calculated the carbon intensity of power generation from waste and compared this with other forms of power generation, without giving any credit for the displacement of landfill. This is incorrect, as energy from waste serves a dual purpose unlike other forms of power generation, and is inconsistent with government guidance.

ZWS has also carried out a life cycle assessment to compare energy from waste with landfill. However, the approach is unreasonable, for two main reasons.

1. In Scotland, the management of municipal waste takes place at a number of levels. Waste is sorted by the householder, depending on the type of kerbside collection provided. The local authority then sorts the waste, to a varying degree, to remove recyclates and this can be done at dedicated facilities or at facilities co-located with landfill sites or energy from waste sites. The remaining residual waste is then either sent to landfill or used for energy recovery.

   A life cycle assessment for residual waste should start with residual waste. ZWS does not take this approach. Instead, the life cycle assessment boundary includes pre-treatment at some, but not all, energy from waste plant and at the landfill site. This approach penalises energy from waste plants which receive sorted waste, even those these plants are operating in accordance with Scottish legislation and SEPA guidance. It also overstates the degree of recycling carried out at typical landfill sites in Scotland.
2. The lifecycle assessment is based on operational data for six EfW plants from 2018, including two gasification plants. At the time four of the six EfW plants were undergoing commissioning. This means that the data is not representative of future operations, particularly for the gasification plants which operated for limited hours and, when operating, were primarily SRF/RDF production facilities in 2018.

Calculation Errors and Inconsistencies

1. Due to a clear mathematical error, the report overstates the benefits of electrical generation from landfill sites by a factor of three.
2. In the lifecycle assessment, ZWS has given credit for electricity generation using the carbon intensity figure for industrial consumption of electricity, rather than the (higher) figure for marginal generation which ZWS claimed to have used.
3. ZWS appears to have used different waste compositions to calculate the carbon emissions from EfW plants and landfill. Furthermore, the assumptions on electricity generation from EfW plants are not consistent with the waste composition used.

Fichtner has used data in the ZWS report to recalculate the headline figures, correcting the methodological concerns and the calculation errors. Fichtner concludes that the net carbon intensity of one of the electricity-only plants, taking account of landfill displacement, is actually negative, at -96 gCO_2e/kWh, compared to ZWS's figure of 565 gCO_2e/kWh, and that the benefit of sending 1 tonne of residual waste to energy from waste compared to landfill was around 202 kgCO_2e, compared to ZWS's figure of about 30 kgCO_2e.

Contents

1 Introduction

1.1 Background

Zero Waste Scotland (ZWS) published a report titled "The climate change impacts of burning municipal waste in Scotland – Technical Report" (the ZWS report) in October 2020. Due to concerns about the accuracy and methodology of this report, the Environmental Services Association (ESA) has commissioned Fichtner Consulting Engineers Ltd (Fichtner) to comment on the report in detail.

The Scottish Environmental Services Association (SESA) met with the ZWS team on 5 November 2020, along with a number of industry representatives, and presented a number of the points made in this report. ZWS did not agree with most of the points raised, although it did undertake to produce a revised version with some updates due to a mathematical error.

1.2 Objective

The objective of this report is to set out, in detail, why Fichtner considers that the ZWS report is flawed.

1.3 Qualifications

The author of this report, Stephen Othen, is a chartered chemical engineer with over 20 years of experience in the waste industry. He has been the responsible author for a number of climate change assessments of energy-from-waste plants and has given evidence at planning inquiries on this topic.

2 Conclusions

For the following reasons, Fichtner considers that the ZWS report is flawed and cannot be used for determining future policy.

1. Due to a clear mathematical error, the report overstates the benefits of electrical generation from landfill sites by a factor of three.
2. ZWS has calculated the carbon intensity of power generation from waste without giving any credit for the displacement of landfill. This is incorrect, as energy from waste serves a dual purpose unlike other forms of power generation. ZWS's approach is inconsistent with government guidance; and also inconsistent with the second part of the ZWS report.
3. ZWS has also carried out a life cycle assessment, which does compare energy from waste with landfill. However, the boundaries for the life cycle assessment include pre-treatment of waste for landfill sites but not for most of the EfW plants. This is unreasonable.
    a. Many EfW plants in Scotland receive waste which has already been sorted, in accordance with Scottish legislation and SEPA guidance. ZWS's approach penalises these plants.
    b. ZWS has used a "representative" landfill site with 10% recycling. This does not appear to be representative of all Scottish landfill sites and is only reasonable for some landfill sites which are co-located with civic amenity sites or transfer stations.
    c. The life cycle assessment should be considering the treatment of residual waste.
4. In the lifecycle assessment, ZWS has given credit for electricity generation using the carbon intensity figure for industrial consumption of electricity, rather than the figure for marginal generation which ZWS claimed to have used.
5. The lifecycle assessment is based on data from 2018, when four of the six plants were undergoing commissioning. This means that the data is not representative of future operations, particularly for the two gasification plants which were primarily operating as SRF/RDF production facilities in 2018.

Fichtner has used data in the ZWS report to recalculate the headline figures.

1. The carbon intensity has been recalculated using ZWS's figures and concluded that the net carbon intensity of one of the electricity-only plants is actually negative, at –96 gCO_2e/kWh, compared to ZWS's figure of 565 gCO_2e/kWh.
2. It is estimated that the net greenhouse gas emissions of sending one tonne of residual waste to landfill are 432.7 $kgCO_2e$, compared to ZWS's figure of 257 $kgCO_2e$.
3. It is estimated that the net greenhouse gas emissions of sending one tonne of residual waste to electricity-only conventional energy from waste are 230.9 $kgCO_2e$, compared to ZWS's figure of 227 $kgCO_2e$. (This is because the various errors cancel each other out).
4. Hence, Fichtner considers that the benefit of sending 1 tonne of residual waste to energy from waste compared to landfill is around 202 $kgCO_2e$, compared to ZWS's figure of about 30 $kgCO_2e$.

3 Discussion

3.1 Mathematical Error

Table 6 of the ZWS report states, that electricity generated from the collection of landfill gas displaces 122 $kgCO_2e$/tonne of waste; and the ZWS report states in table 5, that electricity generated from the combustion of waste in a conventional energy from waste plant displaces 97-127 $kgCO_2e$/tonne of waste. However, EfW plants generate considerably more electricity than landfill sites per tonne of waste, so these figures cannot be right.

We consider that the problem is equation 3 in the report, which has been calculated as follows:

$$\begin{gathered}\textit{Power generated per tonne of waste landfilled} \\ = \textit{Volume of methane captured and burnt} \\ \times \textit{Density of gas} \times \textit{NCV of gas}\end{gathered}$$

This equation correctly calculates the total energy in the landfill gas used to generate electricity. However, not all of this energy is converted to electricity. The equation should take into account the efficiency of the landfill gas engine, which is typically around 36%[1]. This means that the benefit from energy displacement should be approximately 44 $kgCO_2e$/tonne.

It is noted that this is a fairly clear error in the data, as it should be well known that an EfW plant generates more power than a landfill site, and it is surprising that this was not identified through the peer review process undertaken by the Scottish Waste Data Strategy Group.

3.2 Carbon Intensity

Within the Introduction, page 7 of the ZWS report, the basis of the report is set out:

> *"Climate change impacts are measured in two ways in this study;* ***carbon intensity*** *and* ***greenhouse gas emissions****. Carbon intensity is a standard approach for comparing the climate change impacts of different energy generation technologies, such as gas fired power stations. EfW plants are classified as power stations for national emissions reporting purposes and while their primary purpose is waste treatment, part of their function is to provide energy.* *<u>Therefore, a comparison to other energy generating technologies is appropriate.</u>* *Life Cycle Analysis (LCA) methodology is used to assess the greenhouse gas emissions and savings of sending one tonne of municipal waste to a waste disposal route. It can be used to compare the climate change impact of waste management technologies with similar boundaries. In this study, EfW is compared to landfill." (*our emphasis)

ZWS then proceeds to carry out two separate assessments. However, the basis for the first of these assessments, concerning the carbon intensity of power generated, is flawed.

An energy from waste (EfW) plant carries out two functions, both of which have implications for carbon emissions. It diverts residual waste from landfill, and it generates electricity. Any assessment of the carbon benefits or costs of EfW needs to consider both of these functions, and ZWS does this in the life cycle assessment section of the report. However, ZWS does not do this in the carbon intensity section.

[1] DEFRA – Review of landfill methane emissions modelling (2014)

Fichtner agrees that it could be helpful to compare the carbon intensity of power generated by an EfW plant with the carbon intensity of power generated by other means. However, the carbon intensity calculation needs to consider the avoided emissions from landfill, as other forms of power generation, such as CCGTs, wind or solar, do not displace waste from landfill. The calculation also needs to take account of the power which would have been generated if the waste had been sent to landfill.

A more correct approach is to calculate the following quantities for a fixed amount of waste:

1. The direct carbon emissions from the EfW plant. (C_{EFW})
2. The power exported by the EfW plant. (E_{EfW})
3. The direct carbon emissions from landfill. ($C_{landfill}$)
4. The power exported by the landfill. ($E_{landfill}$)

This means that:

- the effective increase in direct carbon emissions from sending waste to an EfW plant is C_{EFW} - $C_{landfill}$;
- the effective increase in power generation is E_{EFW} - $E_{landfill}$; and
- The effective carbon intensity of the additional power is $\frac{C_{EfW}-C_{landfill}}{E_{EfW}-E_{landfill}}$.

This effective carbon intensity is a fairer reflection of the carbon performance of an EfW plant when compared to other forms of power generation.

Fichtner attempted to use data from the ZWS report to illustrate the effect of this point for plant EOP1. Fichtner has focused on plant EOP1 as this plant has no heat export and no upfront MRF, which reduces the complexity of the calculation and makes it easier to extract the relevant data.

- As presented in Table 5 in the ZWS report, it has direct fossil carbon emissions of 412 $kgCO_2e/t$ and energy displacement of 127 $kgCO_2/t$. Furthermore, as presented in Table 3, it has a carbon intensity of 565 $kgCO_2e/MWh$.
- As presented on page 18 of the ZWS report, the energy displacement is based on the UK carbon factors for marginal electricity generation, taken from the BEIS 'Valuation of energy use and greenhouse gas', dated 2019. The value of this carbon factor is not stated, but it can be calculated from the values above:
  - $Carbon\ intensity\ = \frac{Carbon\ Emissions}{Power\ Generated}$; hence $Power\ Generated\ = \frac{Carbon\ Emissions}{Carbon\ Intensity}$
  - $Power\ Generated\ x\ Carbon\ Factor = \ Energy\ Displacement$;
  - Hence $Power\ Generated\ = \frac{Energy\ Displacement}{Carbon\ Factor} = \frac{Carbon\ Emissions}{Carbon\ Intensity}$.
  - Hence,

    $Carbon\ Factor\ = \frac{Carbon\ Intensity}{Carbon\ Emissions} x\ Energy\ Displacement\ = \frac{565}{412} x127\ = 174.2$
  - Hence, Power Generated = 412/565 = 0.729 MWh/t or 729 kWh/t.
- Therefore, as an aside, it appears that ZWS has used a value of 174 kg CO_2e/MWh, or 0.174 $kgCO_2e/kWh$, which is the figure for industrial consumption in 2018, rather than the long run marginal generation-based figure of 0.291 $kgCO_2e/kWh$. (The equivalent calculation for EOP3 gives the same result, which tends to confirm this.)
- As presented in Table 6 of the ZWS report, landfill has carbon emissions of 458 $kgCO_2e/te$ and energy displacement of 122 $kgCO_2e/te$. As explained in section 3.1, this value should have been 44 $kgCO_2e/t$. Assuming that ZWS has used the same carbon factor of 174 $kgCO_2e/MWh$, this implies that landfill generates 44/174 = 0.252 MWh/t or 252 kWh/t.

- Therefore, the effective carbon intensity of the additional power generated by plant EOP1 compared to sending waste to landfill is $\frac{412 - 458}{729 - 252} = -0.096$ kgCO_2e/kWh. In other words, the effective carbon intensity is negative, based on ZWS's own figures.

However, this calculation does not take account of other potential carbon costs and benefits. This is done in the full life cycle assessment, which has been considered in section 3.3.

3.3 Life Cycle Assessment

3.3.1 Boundary

The system boundaries for the life cycle assessment are shown in section 2.3 of the ZWS report. In all three cases (incineration, gasification and landfill), the boundary includes sorting or pre-processing at the same site as the main process. However, this means that the assessment is not really comparing processes for residual waste. This is because, in some cases, companies or local authorities choose to co-locate sorting, recycling and treatment facilities with EfW plants or landfills, and in some cases the sorting, recycling and treatment facilities are located elsewhere.

The management of household and commercial waste in Scotland, and indeed elsewhere in the world, is carried out by a number of parties and at a number of stages. It starts with the householder separating waste into different types, depending on the different collection services (and deposit services) provided. The element of household waste which is not sorted is then managed by the local authority, or its contractor. Depending on the collection service provided, the unsorted waste can be sent directly to landfill or incineration for final treatment, or more commonly sent via some form of sorting process or mechanical/biological treatment to extract further recyclable materials. The sorting process can happen at a dedicated facility, local to the waste source, or at a more centralised dedicated facility, or at a facility co-located with the landfill site or energy-from-waste plant.

The point is, after the collection and sorting processes have been completed, the remaining residual waste has two potential routes for final treatment – energy from waste or landfill. Therefore, the life cycle assessment of these two alternatives needs to start with the residual waste.

3.3.1.1 Pre-treatment of waste at EfW Plants

ZWS has set a boundary at an earlier point in the process, but this means that the plants are not treated consistently.

- EOP1 (Dunbar) and EOP3 (Miller Hill) are both stand-alone EfW plants with no pre-treatment onsite. This is because any source segregation or pre-treatment is carried out elsewhere.
  - At EOP1, the waste is delivered from two local councils. In one case, the waste is pre-treated at a waste treatment centre to remove ferrous metal, non-ferrous metals and dense plastics. The other council operates a kerbside collection scheme which removes these materials.
  - The waste for EOP3 comes from three local councils. All three of the councils operate separate kerbside collections, including food waste collections. All of the councils specifically have derogations under the Waste (Scotland) Regulations 2012 to confirm that dense plastics have already been removed and so do not need to be removed before incineration and two have the same derogation for metals.

  - All of the waste delivered from councils to both plants has been confirmed, by SEPA, to comply with the pre-treatment requirements of the Thermal Treatment of Waste Guidelines.
- EOP2 (Dundee) has a small amount of pre-treatment to prepare the waste for the fluidised bed.
- GAS1 (Glasgow) has a MRF on-site but it was barely operational in 2018.
- GAS2 (Levenseat) has a MRF to prepare the fuel.
- HOP1 (Shetland) has no pre-treatment.

3.3.1.2 Landfill comparator

In the ZWS report, the comparator to EfW is a landfill site at which around 10% of the incoming waste is removed for recycling. This is based on an unnamed "representative" landfill site in Scotland. We have reviewed the site returns data for 2018, published by SEPA[2], to see whether this is representative.

- There were 39 operational landfill sites listed for household and commercial waste. Some of these have other waste management activities present as well, such as civic amenity sites or transfer stations. Only 13 are listed as only landfill sites.
- Looking at the 39 sites overall, they received 3,754,872 tonnes of waste in 2018 and exported 438,966 tonnes, or 11%. However, 272,198 tonnes of the export was landfill leachate, so the actual export of solid waste was only 166,768 tonnes, or 4.4% of the input.
- The 13 sites which are only landfill sites received 990,627 tonnes of waste and only exported 1,695 tonnes of solid waste. This is reasonable, as these sites are purely disposal facilities. The other 26 sites received 2,764,245 tonnes of waste and exported 165,072 tonnes, or 6.6%, of solid waste. This may not all have been recycled.
- This suggests that the landfill site selected by ZWS as "representative", which separated about 10% of its waste as recycling, may not have been typical. In fact, three of the sites had very high waste exports (50% or more), which suggests that they were operating more as waste transfer and waste treatment facilities, and only eight other sites had exports of 10% or more.

3.3.1.3 Implications

It is clear from this discussion that ZWS's approach to the boundary is unreasonable.

- It penalises EOP1 and EOP3 specifically, as these plants manage their feedstock in line with SEPA's Thermal Treatment of Waste Guidelines by accepting a pre-processed residual waste, so that only residual waste is processed within the waste incineration plant.
- It gives too much credit to landfill sites by giving them credit for separate of recyclates carried out at waste treatment sites which happen to be co-located with landfill sites.

Fichtner considers that allowing extra benefit for the pre-treatment of the waste to remove recyclates puts an unfair disadvantage on those facilities which arrange for the recyclates to be removed off-site. It is also illogical, as it means that an EfW plant with an on-site pre-treatment plant performs much better than an EfW plant where pre-treatment is undertaken off-site, or where the waste is segregated at source.

Fichtner considers that it would be more appropriate to set the life cycle assessment boundary after the waste separation processes, so that the assessment is specifically considering options for treating residual waste.

[2] https://www.sepa.org.uk/data-visualisation/waste-sites-and-capacity-tool/ [Accessed in December 2020]

The numerical implications of this are significant. Carbon savings from recycled materials were estimated to be 84 $kgCO_2e$/tonne of waste processed in a landfill (using carbon factors from the Scottish Carbon Metric). The equivalent figures for the three conventional EfW plants considered are 14, 78 and 20 $kgCO_2e$/tonne of waste for plants EOP1, EOP2 and EOP3 respectively, with an average of 37.3 $kgCO_2e$/tonne of waste. However, the figures for EOP1 and EOP3 are only for metals recovered from the bottom ash, so the contribution from the pre-treatment of waste is only around 60 $kgCO_2e$/tonne for EOP2.

The ZWS report suggests that 10% of waste sent to landfill is removed for recycling. This suggests that the Greenhouse Gas Emissions in Table 6, apart from the pre-landfill removals, are for 900 kg of waste rather than 1 tonne. Hence, the GHG emissions per tonne of residual waste have been recalculated, also correcting the mathematical error identified in section 3.1:

- Methane releases = 458 kg CO2e for 900 kg of waste, or 458/0.9 = 508.9 $kgCO_2e$/te
- Process emissions = 5 kg CO_2e for 900 kg of waste, or 5/0.9 = 5.6 $kgCO_2e$/te
- Energy displacement = 44 kg CO_2e for 900 kg of waste, or 44/0.9 = 48.9 $kgCO_2e$/te
- Hence, Net GHG Emissions per tonne of residual waste = 508.9 + 5.6 – 48.9 = 465.6 $kgCO_2e$/te

The ZWS report doesn't confirm how much waste was exported from EOP2. However, the same waste input was used for all of the EfW plants but the direct carbon emissions from EOP2 were only 78.2% of the direct carbon emissions from EOP1 and EOP2. This suggests that only 782 kg of each tonne of waste was residual waste processed by incineration. Hence, the GHG emissions per tonne of residual waste has been recalculated, as follows:

- Fossil carbon embedded in waste = 412 kg CO_2e/te
- Process activities = 35 kg CO_2e/te[3]
- Energy displacement = 101 / 0.782 = 129 kg CO_2e/te
- Metals recovery = 17 kg CO_2e/te (average of EOP1 and EOP3).
- Hence, Net GHG Emissions per tonne of residual waste = 412 + 35 – 129 - 17 = 301$kgCO_2e$/te

Therefore, the average figure from EOP1 (297), EOP2 (301) and EOP3 (332) would be 310 $kgCO_2e$/te.

This implies that the benefit of electricity-only energy from waste plants over landfill should have been calculated as 465.6 – 310 = 165.6 $kgCO_2e$/te. This can be compared to the ZWS headline conclusion of 30 $kgCO_2e$/te.

3.3.2 Correction for carbon intensity

As noted in section 3.2, it appears that the ZWS report has used a carbon intensity value for electricity generation of 174 kg CO_2e/MWh, or 0.174 $kgCO_2e$/kWh, which is the figure for industrial consumption in 2018, rather than the long run marginal generation-based figure of 0.291 $kgCO_2e$/kWh. The Net GHG emissions have been recalculated to correct for this error.

1. For landfill, the benefit of electricity displacement per tonne of residual waste should be 48.9 x 0.291/0174 = 81.8 $kgCO_2e$/te, giving Net GHG emissions of 508.9 + 5.6 – 81.8 = 432.7 $kgCO_2e$/te.
2. A similar calculation for EOP1, EOP2 and EOP3 gives the following results:
   a. EOP1 – 211.8 $kgCO_2e$/te.
   b. EOP2 – 214.1 $kgCO_2e$/te.
   c. EOP3 – 266.9 $kgCO_2e$/te

[3] ZWS assumed that the process emissions for the three EOP plants would be the same, even though EOP2 has additional separate equipment. This seems unlikely, so we have not changed this figure.

   d. Average = 230.9 $kgCO_2e/te$

This implies that the benefit of electricity-only energy from waste plants over landfill should have been calculated as 432.7 – 230.9 = 201.8 $kgCO_2e/te$.

3.3.3 Use of 2018 data

The ZWS report uses operational data from 2018 and draws conclusions from this data for future policy. However, 2018 was not a representative year. As ZWS notes in Table 1, only two of the plants (EOP2 and HOP1) were fully operational in 2018.

- EOP1 and EOP3 were both commissioned in 2018 and so the data reflects partial operation. It is likely that the plants will have operated less efficiently during commissioning.
- GAS1 and GAS2 were also being commissioned in 2018. The waste pre-treatment plants were operating earlier than the gasification plants, so both sites were primarily operating as RDF/SRF production facilities, exporting 70% and 82% of input waste as RDF/SRF respectively. Hence, any comments on the performance of GAS1 and GAS2 are not relevant for future operations.

3.4 Internal Inconsistencies

It is important, when carrying out a life cycle assessment to compare two alternatives, that the comparison is carried out on a consistent basis. In this case, where ZWS is comparing two alternatives for treating residual waste, it is important that both alternatives are assessed using the same waste and that all of the calculations use this waste. This is because the performance of an EfW plant will vary depending on the waste composition. For example, if the calorific value of the waste is higher, then the EfW plant will generate more power per tonne of waste, and the ash production will vary depending on the as content of the waste.

As explained in section 3.3.1, the boundary selection introduces inconsistencies. However, the details of the life cycle assessment are also inconsistent.

1. Section 2.1 of the ZWS report presents the waste composition used in the study in terms of waste fractions. ZWS does not state the calorific value or ash content of this waste.
2. Section 2.2 of the ZWS report calculates a method for calculating carbon intensity of EfW plants. As explained in section 3.2, this is considered to be misleading. However, it is also inconsistent.
   a. The carbon emissions from burning waste are calculated from the fossil carbon content of the waste stated in section 2.1 of the ZWS report.
   b. The power generated from waste is calculated, in effect, by assuming that the net calorific value of the waste is 9.5 GJ/t for electricity-only incinerators and 12.1 GJ/t for gasifiers. Clearly, one of these values (possibly both) must be inconsistent with the waste composition from section 2.1.
   c. The other input for the power generation is the efficiency of the plant, taken from the relevant heat and power plan. This is reasonable, but means that the power generation, in this calculation, is not linked to the actual performance of the plant.
3. Section 2.3 of the ZWS report presents the life cycle assessment methodology.
   a. The carbon emissions from burning waste use the waste composition from section 2.1 and the waste throughput reported to SEPA. It appears that ZWS has assumed that the waste composition is the same for all plants.
   b. The emissions avoided from energy displacement appear to use the same electricity generation figures as for section 2.2. If so, they are based on plant efficiency figures which

may or may not represent actual operation and waste NCV which is inconsistent with the actual or design waste composition.

4. Section 2.4 of the ZWS report presents the life cycle assessment methodology for landfill. The parameters for landfill gas are based on a waste composition from a DEFRA study from 2014. This waste contained 12.1% fossil carbon and 13.6% biogenic carbon, which is inconsistent with the waste composition used for the EfW plants of 10.9% fossil carbon and 14.7% biogenic carbon.

   The sensitivity assessment carried out by ZWS, and illustrated in figure 13 of the ZWS report, show that using waste with a higher fraction of biogenic carbon results in landfill emissions increasing. Hence, if ZWS had used the same waste composition for the landfill assessment as for the EfW assessment, the landfill emissions would have been higher.

These inconsistencies between and within the calculations mean that the results cannot be considered to be dependable.

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