Comments on submissions received at D4

UKWIN'S D5
GHG SENSIVITY ANALYSIS

Proposed Development:
Medworth EfW CHP

Proposed Location:
Land on the Algores Way Industrial Estate to the west of Algores Way in Wisbech, Fenland, Cambridge

Applicant:
Medworth CHP Limited

Planning Inspectorate Ref:
EN010110

Registration Identification Ref:
20032985

JUNE 2023

UKWIN
United Kingdom
Without Incineration
Network

FINDINGS OF UKWIN'S SENSITIVITY ANALYSIS

1. UKWIN undertook sensitivity analysis based on a spreadsheet provided by the Applicant at Deadline 4 (D4), as referred to by the Applicant in their REP4-023 submission.
2. For this analysis UKWIN followed the approach and assumptions set out below, making use of the Applicant's GHG spreadsheets and considered the following sensitivities to the assumptions applied:
    - Waste composition and level of biogenic carbon
    - Electricity generation emissions factor
    - Biogenic carbon sequestration credit
    - Level of energy production
    - Landfill gas recovery rate
    - Proportion of methane in landfill gas
3. The results of this analysis reinforce UKWIN's case, set out in REP4-037 and in REP2-066, that the Medworth NSIP application is in a very similar position to Wheelebrator Kemsley North (WKN) where the Secretary of State agreed with the ExA that "the available evidence casts considerable doubt on whether the 'net [climate] benefit' can be ascertained with any great certainty, given it is highly sensitive to the assumptions applied" and that as such "the matter should carry little weight in the assessment".

UKWIN'S APPROACH TO GHG SENSITIVITY ANALYSIS

General principle

4. UKWIN's approach is to assess a range of sensitivities using the Applicant's core case – as set out in APP-088 Table 14C.2 ('Comparative sensitivity analysis of net annual emissions savings') – alongside a number of alternative waste composition cases and electricity generation emissions factors, with results expressed in net tonnes of CO_2e/year.
5. A deep red background is used in the results tables below to show negative results (i.e. where the plant would be worse than the landfill base case) in UKWIN's base sensitivity analysis. In some of the additional sensitivities further cases also yielded negative results, and these are displayed using a light red (pink) background.

Application of correction value to scope-in stages omitted by the Applicant

6. When validating our replication of the Applicant's APP-088 Table 14C.2, using the spreadsheets supplied by the Applicant, it became clear that the Applicant's core figure of net benefit in APP-088 Table 14C.2 is inconsistent with the 40-year figure they provided in APP-041 Table 14.31 ('GHG emission estimates during the lifecycle of the Proposed Development case and without Proposed Development case').

7. Analysis of the Applicant's spreadsheets revealed that this discrepancy was due to the Applicant's sensitivity analysis omitting some of the stages that are scoped into their main analysis.

8. When these omissions are added back in, the claimed benefits of the facility proposed for Medworth as set out in APP-088 Table 14C.2 are shown to be around 9,683 tonnes of CO_2e per annum lower for every single result shown. This is explained in the technical appendices at the end of this analysis.

9. UKWIN's sensitivity analysis corrects for these omissions by subtracting 9,683 tonnes of CO_2e per annum from the results in the Applicant's spreadsheets to provide consistency with the results from the Applicant's main analysis.

Electricity generation emissions factors

10. APP-088 Table 14C.2 provides four scenarios for electricity generation emissions factors, and an additional scenario is provided by the Applicant in their REP1-036 Table A.3 ('GHG emission estimates during the lifecycle of the Proposed Development case and without Proposed Development case, and comparison against the sensitivity analysis for forecast grid mix decarbonisation').

11. For the purpose of looking at future grid averages UKWIN has used the November 2022 version of the BEIS/DESNZ Treasury Green Book – Data Tables 1-19 rather than the older version from June 2021 historically used by the Applicant.

12. The November 2022 version of Data Tables 1-19 uses lower figures, because the Government now assumes a greater degree of decarbonisation of the electricity grid.

13. UKWIN's sensitivity analysis considers the Applicant's **Current Gas (380g/kWh)** and **Current UK Grid Average (182g/kWh)** cases to allow for a better understanding of the sensitivity of the Applicant's analysis. However, we maintain our previous concerns about the relevance of these cases to the assessment given the decarbonisation of the electricity supply.

14. UKWIN also assesses the development against the:

- **2027 UK Grid Average (66.8g/kWh).** This indicates the currently anticipated grid average at the time of the earliest year when the plant might start operation. As noted on REP3-050 paragraph 70, the facility proposed for Medworth could not reasonably be expected to become operational until 2027 at the earliest.
- **2027-2066 UK Grid Average (13.442g/kWh)**. While the Applicant's REP1-036 Table A.3 assesses the proposal against an average for 2026-2065, UKWIN uses the average over the period 2027-2066 based on a more realistic first year of operation.
- **2050 UK Grid Average (2.283g/kWh)**. In line with Applicant's use of 2050 (including applying electricity generation emissions factor value to CHP heat offset) but using the lower figure from the November 2022 version of BEIS/DESZN tables. The 2050 grid average remains constant for 2050-2066.

Waste composition cases

15. In addition to considering the Applicant's core 'current waste' case, which is based on around **57% biogenic content**, UKWIN has also modelled two other scenarios to show the potential impact of feedstock compositions with lower biogenic content:

- **50% Biogenic content**. This scenario considers significant reductions in food and garden waste and lower levels of reductions in paper and card. This results in around half of carbon content of the feedstock being biogenic, which is the standard 'rule of thumb' assumption for mixed residual waste [REP1-096, UKWIN Good Practice Guidance, internal page 80].
- **40% Biogenic content**. This assumes biogenic content of around 40.2% to show the mirror impact of the Applicant's assumed 17 percentage point <u>increase</u> in biogenic from their 'Reduced Food and Plastic' scenario in line with UKWIN's D4 Post-hearing Submission [REP4-042]. This reduced biogenic case has a Total NCV of around 10.9 MJ/kg and so the sensitivity analysis uses the 531,200 tonnes per annum tonnage figure set out by the Applicant in their REP3-040 on electronic pages 93-94.

BASE ANALYSIS OF COMPOSITION/GRID SENSITIVITY

16. As per paragraphs 111-112 of UKWIN's Written Representation [REP2-066], the Examining Authority for the WKN decision stated (and the SoS accepted) that "key uncertainties and limitations" that justified giving little weight to claimed climate benefits of the EfW scheme included "the carbon intensity of marginal electricity generation and the proportions of waste types to be managed…"

17. This highlights the importance of considering a range of potential sensitivities with respect to electricity generation emissions factors and to waste composition.

18. Below is a summary of the results of assessing the sensitivity of the proposed Medworth development to changes in waste composition and electricity generation grid factors following the methodology set out above, with no other changes to the assumptions used by the Applicant.

BASE SENSITIVITY ANALYSIS SHOWING COMPOSITION/GRID SENSITIVITY

	Electricity generation emissions factor (CO_2e/kWh)				
Waste composition	**Unabated CCGT** 380g	**Current Grid (Applicant Core)** 182g	**2027 Grid Average** 67g	**2027-2066 Grid Average** 13g	**2050+ Grid Average** 2g
Energy export option: *Electricity only*					
57% Biogenic (Applicant Core)	129,593	64,270	26,266	8,660	4,978
50% Biogenic	57,655	-10,907	-50,795	-69,274	-73,138
40% Biogenic	-30,568	-103,583	-146,062	-165,742	-169,856
Energy export option: Electricity & Steam					
57% Biogenic (Applicant Core)	149,066	93,563	61,273	46,314	5,296
50% Biogenic	77,128	18,387	-15,788	-31,620	-72,820
40% Biogenic	-11,095	-74,290	-111,055	-128,087	-169,538

19. This shows that when assessing the proposal using the Applicant's core assumptions, the results are highly sensitive to the electricity grid emissions factor and to the composition of the waste to be used as the feedstock.

20. It also shows that a reduction of 7 percentage points in the biogenic proportion of the carbon could be more than sufficient to result in the Medworth proposal having an adverse GHG impact compared to landfill in the Applicant's core electricity generation emissions factor case in electricity only mode.

21. When lower levels of grid electricity are assumed and/or when lower levels of biogenic waste are assumed, then the level at which the Medworth proposal would be worse than landfill increases.

22. In the 40% biogenic carbon case the proposal would be worse than landfill across all electricity generation scenarios, including when modelled in the Applicant's CHP ('Electricity and Steam energy export') case.

23. At 50% biogenic carbon content, the Medworth proposal would be worse than landfill when applying the 2027 Grid Average rather than the Applicant's 'Current Grid' figure.

ANALYSIS OF BIOGENIC CARBON SEQUESTRATION

24. In UKWIN's Good Practice Guidance for Assessing the GHG Impacts of Waste Incineration (July 2021) – which was included as part of REP1-096 – UKWIN set out the importance of considering how, when biogenic material is sequestered in landfill, it should be credited for sequestering carbon that would be released as CO_2 if the same material were to be landfilled.

25. This set out evidence set out the theoretical basis for why it is correct and appropriate to account for biogenic carbon sequestration, including statements from Defra's Carbon Based Modelling Approach report.

26. The Guidance also set out numerous real world examples of GHG modellers who considered this impact, either in their core analysis or their sensitivity analysis, including for planning applications to build new incinerators.

27. Information on the importance of this consideration and the significance of the Medworth Applicant's failure to take it into account is set out by UKWIN in REP2-066 paragraphs 79-106, REP3 paragraphs 61-66, and REP4-037 paragraphs 85-90.

28. Equanimator provides an estimate for the impact of accounting for this effect in REP2-064 Appendix 5. To assess this impact against the cases outlined above UKWIN replicates the exercise by modifying the Applicant's spreadsheet to allow for a credit to be made for biogenic carbon sequestration in landfill.

29. The results of this analysis are as follows:

FULLY ACCOUNTING FOR BIOGENIC CARBON SEQUESTRATION IN LANDFILL

Waste composition	**Electricity generation emissions factor (CO_2e/kWh)**				
	Unabated CCGT 380g	**Current Grid (Applicant Core)** 182g	**2027 Grid Average** 67g	**2027-2066 Grid Average** 13g	**2050+ Grid Average** 2g
Energy export option: ***Electricity only***					
57% Biogenic (Applicant Core)	-42,255	-107,578	-145,582	-163,188	-166,869
50% Biogenic	-88,654	-157,217	-197,105	-215,584	-219,448
40% Biogenic	-57,256	-130,272	-172,751	-192,430	-196,545
Energy export option: Electricity & Steam					
57% Biogenic (Applicant Core)	-22,782	-78,284	-110,575	-125,534	-166,551
50% Biogenic	-69,182	-127,923	-162,098	-177,930	-219,130
40% Biogenic	-37,784	-100,978	-137,744	-154,776	-196,227

30. This shows that, based on the Applicant's assumptions for the proposed Medworth facility, if credit is given for biogenic carbon sequestration then the proposed Medworth facility would perform worse than landfill even for the Applicant's unabated CCGT case and their core waste composition, even with CHP.

31. With respect to 'tipping points', even if only 87% of the credit for biogenic sequestration were accounted this would still be sufficient to produce an adverse result across all the cases modelled by UKWIN, as can be seen from the table overleaf:

ACCOUNTING FOR 87% OF THE BIOGENIC CARBON SEQUESTRATION IN LANDFILL

Waste composition	**Electricity generation emissions factor (CO_2e/kWh)**				
	Unabated CCGT 380g	**Current Grid (Applicant Core)** 182g	**2027 Grid Average** 67g	**2027-2066 Grid Average** 13g	**2050+ Grid Average** 2g
Energy export option: ***Electricity only***					
57% Biogenic (Applicant Core)	-19,914	-85,238	-123,242	-140,848	-144,529
50% Biogenic	-69,634	-138,196	-178,085	-196,564	-200,428
40% Biogenic	-53,787	-126,802	-169,281	-188,960	-193,075
Energy export option: Electricity & Steam					
57% Biogenic (Applicant Core)	-442	-55,944	-88,234	-103,193	-144,211
50% Biogenic	-50,161	-108,903	-143,078	-158,910	-200,110
40% Biogenic	-34,314	-97,509	-134,274	-151,306	-192,757

ANALYSIS OF IMPROVED LANDFILL PERFORMANCE

32. One of the "key uncertainties and limitations" highlighted by the ExA on paragraph 4.14.64 of the WKN decision was the "the estimate of GHG emissions from landfill".

33. For Medworth, the Applicant adopts a 68% landfill gas recovery rate based on a 2014 assessment of historic landfill sites (which uses data from 2011, as per the Applicant's APP-088 Climate Appendices, internal page 14B.2).

34. However, if waste were to be landfilled it would likely go to a future modern landfill which maximised the level of landfill gas recovery.

35. A figure of 75% landfill gas recovery rate has been used as the default both for WRATE and MELMod and in Defra's Carbon Based Modelling Approach and this 75% figure is often used for analysis, either as the central figure or as a sensitivity.

36. UKWIN's sensitivity analysis found that an increase in landfill gas recovery rates from 68% to 75% (used to provide sensitivity analysis of other EfW proposals) would be sufficient to result in the Medworth plant having negative (i.e. adverse) climate impacts even for the Applicant's core waste composition and electricity generation emissions factor electricity only case.

SENSITIVITY OF INCREASING LANDFILL GAS RECOVERY RATE TO 75%

	Electricity generation emissions factor (CO_2e/kWh)				
Waste composition	**Unabated CCGT** 380g	**Current Grid (Applicant Core)** 182g	**2027 Grid Average** 67g	**2027-2066 Grid Average** 13g	**2050+ Grid Average** 2g
Energy export option: *Electricity only*					
57% Biogenic (Applicant Core)	62,454	-625	-37,324	-54,325	-57,880
50% Biogenic	494	-66,158	-104,935	-122,899	-126,655
40% Biogenic	-74,013	-145,577	-187,211	-206,499	-210,532
Energy export option: Electricity & Steam					
57% Biogenic (Applicant Core)	81,927	28,668	-2,317	-16,671	-57,562
50% Biogenic	19,967	-36,864	-69,928	-85,245	-126,337
40% Biogenic	-54,540	-116,283	-152,204	-168,845	-210,214

37. Furthermore, as per the Applicant's APP-088 Climate Appendices, internal page 14B.2, the Applicant assumes that "The ratio of methane to carbon dioxide in UK landfill gas is calculated to be 57:43% rather than the generally assumed 50:50%".

38. When the 'generally assumed' 50%:50% ratio is applied, even with the 68% landfill gas recovery rate, the results are significantly worse than the Applicant's baseline.

Impact of assuming 50%:50% ratio of methane to carbon in landfill with the Applicant's assumed 68% landfill gas recovery rate

Waste composition	Electricity generation emissions factor (CO_2e/kWh)				
	Unabated CCGT 380g	Current Grid (Applicant Core) 182g	2027 Grid Average 67g	2027-2066 Grid Average 13g	2050+ Grid Average 2g
Energy export option: ***Electricity only***					
57% Biogenic (Applicant Core)	99,456	31,456	-8,105	-26,433	-30,265
50% Biogenic	31,997	-38,844	-80,059	-99,152	-103,144
40% Biogenic	-50,069	-124,817	-168,304	-188,450	-192,662
Energy export option: Electricity & Steam					
57% Biogenic (Applicant Core)	118,929	60,749	26,902	11,221	-29,947
50% Biogenic	51,470	-9,551	-45,052	-61,498	-102,826
40% Biogenic	-30,597	-95,523	-133,297	-150,796	-192,344

39. If one combines the two impacts, the resulting impact is even greater:

Impact of assuming 75% landfill gas recovery rate and 50%:50% ratio of methane to carbon in landfill

Waste composition	Electricity generation emissions factor (CO_2e/kWh)				
	Unabated CCGT 380g	Current Grid (Applicant Core) 182g	2027 Grid Average 67g	2027-2066 Grid Average 13g	2050+ Grid Average 2g
Energy export option: ***Electricity only***					
57% Biogenic (Applicant Core)	40,562	-25,469	-63,886	-81,683	-85,404
50% Biogenic	-18,145	-87,310	-127,550	-146,191	-150,089
40% Biogenic	-88,179	-161,653	-204,399	-224,202	-228,342
Energy export option: Electricity & Steam					
57% Biogenic (Applicant Core)	60,035	3,824	-28,879	-44,029	-85,086
50% Biogenic	1,328	-58,017	-92,543	-108,537	-149,771
40% Biogenic	-68,707	-132,360	-169,392	-186,548	-228,025

40. This indicates that the climate impact of alternatively sending the feedstock to landfill could be significantly overstated by the Applicant, in their 'Without Development' case, even before the potential for biostabilisation (e.g. in-vessel composting (IVC) pre-treatment) is considered, and that this can impact on the results of the analysis across a range of waste composition and electricity generation emissions factor cases.

ANALYSIS OF REDUCTION IN POWER GENERATION

41. As noted by UKWIN in REP4-037 paragraph 42: "To assess the potential impacts of the sort of suboptimal electricity generation set out above, we believe it would be reasonable to assess electricity generation being on average 15% lower than the claimed headline MW generation figure, i.e. 51MW and not 60MW".

SENSITIVITY TO LEVEL OF POWER GENERATION

	Electricity generation emissions factor (CO_2e/kWh)				
Waste composition	**Unabated CCGT** 380g	**Current Grid (Applicant Core)** 182g	**2027 Grid Average** 67g	**2027-2066 Grid Average** 13g	**2050+ Grid Average** 2g
Energy export option: ***Electricity only***					
57% Biogenic (Applicant Core)	102,233	51,166	21,456	7,692	4,814
50% Biogenic	30,295	-24,011	-55,605	-70,242	-73,303
40% Biogenic	-57,928	-116,687	-150,872	-166,709	-170,021
Energy export option: Electricity & Steam					
57% Biogenic (Applicant Core)	118,785	76,065	51,212	39,698	5,084
50% Biogenic	46,847	889	-25,849	-38,236	-73,032
40% Biogenic	-41,376	-91,788	-121,116	-134,703	-169,750

42. Reducing electricity and heat export by 15% reduces the modelled benefit of energy (electricity / heat) exported from the Medworth plant. The degree of impact depends on the assumed electricity generation emissions factor.

43. If power output was reduced by 16% then this would be sufficient to tip the Applicant's Core Current Grid Case for 50% biogenic and with electricity & steam output into being worse than landfill.

COMBINATION OF SENSITVITIES

44. These sensitivities have been considered in isolation above.

45. When these sensitivities are combined then a lower level of deviation from the Applicant's core approach for each of the sensitivities considered would be necessary to result in negative (adverse) net GHG emissions across all of the waste composition and electricity generation emissions factor cases considered in this sensitivity analysis.

46. The table below shows the impact of reducing energy production from the Medworth facility by 5%, crediting the plant for 60% of its total biogenic carbon sequestration benefit, and assuming a landfill gas recovery rate of 72% (with the Applicant's 57% methane:CO_2 ratio for landfill gas).

CUMULATIVE SENSITIVITY TO A COMBINATION OF FACTORS

	Electricity generation emissions factor (CO_2e/kWh)				
Waste composition	**Unabated CCGT** 380g	**Current Grid (Applicant Core)** 182g	**2027 Grid Average** 67g	**2027-2066 Grid Average** 13g	**2050+ Grid Average** 2g
Energy export option: *Electricity only*					
57% Biogenic (Applicant Core)	-21,001	-80,290	-114,783	-130,763	-134,104
50% Biogenic	-71,914	-134,633	-171,121	-188,025	-191,560
40% Biogenic	-80,527	-147,960	-187,192	-205,367	-209,167
Energy export option: Electricity & Steam					
57% Biogenic (Applicant Core)	-2,501	-52,461	-81,526	-94,991	-133,802
50% Biogenic	-53,415	-106,804	-137,865	-152,254	-191,258
40% Biogenic	-62,028	-120,132	-153,935	-169,596	-208,865

Application correction value to scope-in omitted stages

47. The two sets of values in APP-041 Table 14.31 highlighted in yellow and in cyan (below) were omitted by the Applicant from APP-088 Table 14.C.2:

Table 14.31 GHG emission estimates during the lifecycle of the Proposed Development case and without Proposed Development case

Stage of the Proposed Development	Main stage of Proposed Development life cycle	Estimate emissions 'without Proposed Development' case ($ktCO_2e$)	Estimate emissions 'with Proposed Development' case ($ktCO_2e$)
Construction	A1 – A2 – A3 – Raw materials supply, transport and manufacture	-	35.55
	A5 – Construction process stage	-	4.90
	A4 – Construction Transport	-	7.93
Operation	B2 – B5 – Maintenance, repair, replacement and refurbishment [a]	-	4.91
	B6 – Operational energy	25.04	10,933.05
	B7 – Operational water	-	0.24
	B8 – Other operational processes: Landfill	11,489.35	-
	B8 – Other operational processes: Operational transport	103.85	271.68
	B8 – Other operational processes: IBA and APCr	-	142.60
Decommissioning	C1 – C2 – C3 – C4 – End of life, including deconstruction, transport, waste processing for recovery and disposal *	-	48.38
General	D – Avoided emissions	-801.42	-3,203.20
TOTAL		10,816.83	8,246.03
Net change in GHG emissions resulting from the Proposed Development ($ktCO_2e$)		-	-2,570.80

* Assumed to be equivalent to construction.

48. This means that the Applicant's sensitivity analysis omitted 128.89ktCO_2e (over 40 years) in their 'without Proposed Development' (landfill) case (i.e. the sum of the column 3 values shown in yellow above) and the Applicant omitted 516.21ktCO_2e (over 40 years) in their 'with Proposed Development case' (i.e. the sum of the column 4 values shown in cyan above) which represents a total difference to the Net change in GHG emissions over 40 years resulting from the Proposed Development of -387.32ktCO_2e (i.e. 128.89 - 516.21).

49. Because the values in APP-088 Table 14.C.2 are presented on a per-year basis (expressed as tonnes of CO_2e), the 40-year values from APP-041 Table 14.31 (which are in ktCO_2e) have to be divided by 40 and multiplied by 1,000 to make them equivalent.

50. To be consistent with APP-041 Table 14.31 every result in APP-088 Table 14.C.2 needs to be around 9,683tCO_2e/year lower (i.e. 387.32/40 x 1000).

51. The per-year figure was calculated directly from the equivalent columns in the Applicant's 'GHG Assessment 1.xlsx' summary sheet which is of higher precision than the values displayed in APP-041 Table 14.31.

52. As a general practice, UKWIN uses the highest degree of precision whilst presenting these values in rounded form for the purpose of readability.

Waste composition cases

53. The analysis shows the potential impact of the Medworth facility treating a lower proportion of biogenic waste than assumed in the Applicant's core case.

54. There is uncertainty about the extent to which the Applicant's original feedstock composition case is representative of their anticipated feedstock, and as such changing a material stream in one direction or another does not necessarily indicate a shift in the composition of residual waste to that degree.

55. In modelling the 50% biogenic case UKWIN matched the 9.53MJ/kg Total NCV used in the Applicant's core case, which enabled the model to maintain the original quantities of waste to be processed (i.e. 625,600 tonnes per annum).

56. In modelling the 40% biogenic case UKWIN matched the Total NCV to around 10.9MJ/kg to be in line with the Applicant's Design Load Case (DLC) set out in APP-041 Graphic 14.2, resulting in the lower annual tonnage of 531,200 tonnes per annum (as per the Applicant's assumed optimal feedstock rate for the associated Total NCV of around 10.9MJ/kg).

50% BIOGENIC CASE (625,600 TONNES/YR):

Waste Stream	Current Residual Waste: Commercial and Household (% by weight)	Reduction in proportion	Equivalent weight of residual waste (tonnes)	Future Residual Waste: (% by weight)	Biogenic Carbon (% of waste stream)	Non-Biogenic Carbon (% of waste stream)	Net Calorific Value (MJ/kg)	Biogenic Carbon (% by weight)	Non-Biogenic Carbon (% by weight)	Total Carbon (% by weight)	Total NCV (MJ/kg)
Recyclable Paper	5.9%	50.0%	0.030	4.0%	31.27%		10.749	1.25%		1.25%	0.43
Card	6.3%	50.0%	0.032	4.3%	31.27%		10.749	1.34%		1.34%	0.46
Non-recyclable Paper	8.9%		0.089	12.1%	28.69%		9.735	3.46%		3.46%	1.18
Dense Plastic	7.8%		0.078	10.6%		54.76%	24.682		5.80%	5.80%	2.61
Plastic film	8.2%		0.082	11.1%		48.11%	21.279		5.35%	5.35%	2.37
Textiles	5.5%	78.0%	0.012	1.6%	19.93%	19.93%	14.327	0.33%	0.33%	0.65%	0.24
Misc. Combustible	9.3%	65.0%	0.033	4.4%	23.69%	15.79%	14.612	1.05%	0.70%	1.74%	0.65
Misc. Non-Combustible	3.6%		0.036	4.9%	2.94%	4.05%	2.573	0.14%	0.20%	0.34%	0.13
Other Wastes	0.3%		0.003	0.4%	2.94%	4.05%	2.573	0.01%	0.02%	0.03%	0.01
Glass	2.6%		0.026	3.5%	0.31%		1.414	0.011%		0.011%	0.05
Ferrous Metals	2.4%		0.024	3.3%							
Non-Ferrous Metals	1.1%		0.011	1.5%							
Food Waste	27.0%	28.0%	0.194	26.4%	13.46%		3.460	3.55%		3.55%	0.91
Garden Waste	2.7%	57.0%	0.012	1.6%	17.17%		4.210	0.27%		0.27%	0.07
Other Organic	2.3%		0.023	3.1%	17.17%		4.210	0.54%		0.54%	0.13
Wood	2.3%		0.023	3.1%	17.17%		4.210	0.54%		0.54%	0.13
WEEE	1.1%		0.011	1.5%		15.81%	7.060		0.24%	0.24%	0.11
Hazardous	0.5%		0.005	0.7%	0.61%	19.76%	0.000	0.00%	0.13%	0.14%	0.00
Fines	2.2%	35.0%	0.014	1.9%	13.75%		3.479	0.27%	0.00%	0.27%	0.07
Total	100.0%		0.737	100%				12.8%	12.8%	25.5%	9.53
								50.00%	50.00%		

40% BIOGENIC CASE (531,200 TONNES/YR):

Waste Stream	Current Residual Waste: Commercial and Household (% by weight)	Reduction in proportion	Equivalent weight of residual waste (tonnes)	Future Residual Waste: (% by weight)	Biogenic Carbon (% of waste stream)	Non-Biogenic Carbon (% of waste stream)	Net Calorific Value (MJ/kg)	Biogenic Carbon (% by weight)	Non-Biogenic Carbon (% by weight)	Total Carbon (% by weight)	Total NCV (MJ/kg)
Recyclable Paper	5.9%	80.0%	0.012	1.9%	31.27%		10.749	0.59%		0.59%	0.20
Card	6.3%	80.0%	0.013	2.0%	31.27%		10.749	0.63%		0.63%	0.22
Non-recyclable Paper	8.9%	44.0%	0.050	8.0%	28.69%		9.735	2.29%		2.29%	0.78
Dense Plastic	7.8%		0.078	12.5%		54.76%	24.682		6.83%	6.83%	3.08
Plastic film	8.2%		0.082	13.1%		48.11%	21.279		6.31%	6.31%	2.79
Textiles	5.5%		0.055	8.8%	19.93%	19.93%	14.327	1.75%	1.75%	3.51%	1.26
Misc. Combustible	9.3%	40.0%	0.056	8.9%	23.69%	15.79%	14.612	2.11%	1.41%	3.52%	1.30
Misc. Non-Combustible	3.6%		0.036	5.8%	2.94%	4.05%	2.573	0.17%	0.23%	0.40%	0.15
Other Wastes	0.3%		0.003	0.5%	2.94%	4.05%	2.573	0.01%	0.02%	0.03%	0.01
Glass	2.6%		0.026	4.2%	0.31%		1.414	0.013%		0.013%	0.06
Ferrous Metals	2.4%		0.024	3.8%							
Non-Ferrous Metals	1.1%		0.011	1.8%							
Food Waste	27.0%	66.0%	0.092	14.7%	13.46%		3.460	1.98%		1.98%	0.51
Garden Waste	2.7%	50.0%	0.014	2.2%	17.17%		4.210	0.37%		0.37%	0.09
Other Organic	2.3%		0.023	3.7%	17.17%		4.210	0.63%		0.63%	0.15
Wood	2.3%	40.0%	0.014	2.2%	17.17%		4.210	0.38%		0.38%	0.09
WEEE	1.1%		0.011	1.8%		15.81%	7.060		0.28%	0.28%	0.12
Hazardous	0.5%		0.005	0.8%	0.61%	19.76%	0.000	0.00%	0.16%	0.16%	0.00
Fines	2.2%		0.022	3.5%	13.75%		3.479	0.48%	0.00%	0.48%	0.12
Total	100.0%		0.625	100%				11.4%	17.0%	28.4%	10.94
								40.19%	59.81%		

Accounting for biogenic carbon sequestration

57. In the Applicant's APP-088 Climate Appendices, at internal page 14B.2, their 'LFG' (Landfill Gas) parameters specify a value for "Biogenic carbon in residual waste converted to landfill gas (LFG)" of 50%. This is used in the Applicant's model to determine "Total carbon converted to LFG [landfill gas] (tonnes carbon)".

58. That is to say, the Applicant assumed that 50% of the biogenic carbon is turned into landfill gas.

59. Determining how much CO_2 is sequestered is therefore a simple process of determining how much biogenic carbon remains (i.e. the other 50%) and then determining how much CO_2 that remaining biogenic carbon would emit if it were incinerated instead of landfilled (which is 44/12 tonnes of CO_2e per tonne of carbon sequestered, as that is how much the weight/mass of carbon increases when the carbon is combined with oxygen as part of the combustion process).

60. This means that the quantity of biogenic carbon sequestered in landfill is dependent on the waste composition, and so an assessment has to be made about how much biogenic carbon would be sequestered depending on the quantity of total carbon in the waste, the biogenic fraction of that total carbon, and the amount of that biogenic fraction that is assumed to be sequestered in landfill (rather than converted into landfill gas).

61. Using the Applicant's assumption for the factors outlined above, the impact for the different waste cases considered within this sensitivity analysis are as follows:

    - **57% Biogenic (Applicant Core Case):**
      -171,847 tonnes of CO_2e per annum (-46,867 carbon × 44/12).
    - **50% Biogenic:**
      -146,310 tonnes of CO_2e per annum (-39,903 carbon × 44/12).
    - **40% Biogenic (at 531,200 tonnes of waste per annum):**
      -26,688 tonnes of CO_2e per annum (-7,279 carbon × 44/12).

62. As can be expected, waste compositions with lower levels of biogenic waste result in lower levels of biogenic carbon being sequestered.

63. The amount of biogenic CO_2e sequestered in the 40% biogenic case would be a higher figure of -31,431 tonnes of CO_2e per annum if it was assumed that 625,600 tonnes of waste per annum would be processed in line with the assumptions used for the other waste composition cases considered in the sensitivity analysis.

64. The quantity of biogenic CO_2e sequestered in the 57% Biogenic (Applicant Core) case is in line with Equanimator's conclusion set out in Table 2 of Appendix 5 of REP2-046 which provided a value for 'Carbon Sequestration in Landfill' of 171,836 tonnes of CO_2e with the 1 tonne difference due to rounding.

65. The quantity of biogenic CO_2e sequestered in the 57% Biogenic (Applicant Core) case is 46,867.47 tonnes of carbon, which in Table 2 of Appendix 5 of REP2-046 was rounded down to 46,867 – this produced a slightly lower result when subsequently multiplied by 44/12.

66. The reason that the results are similar is that they both follow the same methodology and are both based on the Applicant's assumed level of biogenic carbon sequestration in landfill.

Further rationale for sensitivity analysis of the assumed proportion of methane in landfill gas

67. As per the Applicant's APP-088 Climate Appendices, internal page 14B.2, the Applicant assumes that "The ratio of methane to carbon dioxide in UK landfill gas is calculated to be 57:43% rather than the generally assumed 50:50%".

68. The 50:50% figure is the default value from the IPCC guidance and is sometimes expressed as a 1:1 mix of methane (CH_4) to carbon dioxide (CO_2) by volume, or as a CH_4 fraction of 0.5 (i.e. 50%).

69. The 50:50% value was used in Defra's Carbon Based Modelling Approach report, which notes that: "Landfill gas produced by decomposition of biogenic waste is a mixture of methane and carbon dioxide. The proportions of each will be dependent upon the exact biological processes being undergone but a reasonable assumption would be that landfill gas is approximate 1:1 mix by volume".

70. The November 2014 report entitled 'Review of Landfill Methane Emissions' (Ref WR1908) produced for Defra produced by Golders Associates was cited by the Applicant in APP-041 footnote 57 on internal page 14-22 of their Climate Assessment as the basis for the Applicant's assumption of a 57% proportion of methane in landfill gas rather than the more generally assumed IPCC value of 50%.

71. According to the official peer review at the start of the aforementioned WR1908 document: “The peer review opinion was divided on the recommendation to amend the proportion of methane produced from IPCC default value of 50% (IPCC 2006) to 57% for modelling. The underlying question is whether the methane to carbon dioxide ratio observed during monitoring i.e. at point of release is reflective of the molar concentration rates assumed during landfill gas generation, and or whether there are any secondary processes that significantly change the ratio prior to landfill gas emissions monitoring”.

72. This implies that there was some uncertainty from experts in the field as to whether or not to deviate from the ‘generally assumed’ IPCC default value of 50:50%, making this an appropriate focus for sensitivity analysis.

Summary of sensitivity scenarios

Parameter	Applicant assumption	UKWIN main sensitivity assumption	UKWIN cumulative sensitivity assumption
Reduced energy production	0%	15% (and 16%)	5%
Biogenic carbon sequestration credit	0%	100% (and 87%)	60%
Landfill gas recovery rate	68%	75%	72%
Proportion of methane in landfill gas	57%	50%	57%