WRATE Analysis of Allerton Waste Recovery Park

Final Report to The Parish Councils' Group

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Report for:

The Parish Councils' Group

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EXECUTIVE SUMMARY

AmeyCespa is currently seeking planning permission from North Yorkshire County Council (NYCC) for a waste recovery facility at Allerton Quarry, near Harrogate. The proposed facility includes a mechanical treatment (MT) plant, an anaerobic digestion (AD) plant, and an Energy-from-Waste (EfW) or 'incineration' facility. The Allerton Waste Recovery Park (AWRP) is AmeyCespa's solution to treat all local authority collected (LAC) residual waste collected on behalf of the York and North Yorkshire Waste Partnership (YNYWP) for a contract period of 25 years. [1] [2] AmeyCespa intends to fill any shortfall in LAC waste with further waste sourced from the commercial and industrial (C&I) sectors to ensure the full capacity the plant is utilised.

This study reviews the WRATE modelling undertaken by Fichtner Consulting Engineers ('Fichtner') on behalf of AmeyCespa in support of the latter's application for planning consent for the development of the proposed AWRP.[3]

We have undertaken a review of Fichtners assumptions and, where relevant, amended a small number of these to present modelling of both the AWRP and potential alternative treatment solutions using WRATE's Global Warming Potential (GWP) indicator, with the aim of determining whether the results published by AmeyCespa are plausible.

The key findings from our analysis can be summarised as follows:

- In their three reports, Fichtner do not provide full information relating to many of their model assumptions. These omissions make it difficult to directly replicate (and hence verify) their analyses. Greater transparency would enable the performance of the proposed AWRP to be verified by stakeholders within the consenting process;
- The assumed waste composition used within the Fichtner analysis, which is based on data from 2006/7, is not representative of LAC residual waste today. More importantly, it even less accurate with regard to a representation of the waste composition to be treated throughout the duration of the contract. This is because recycling rates have risen significantly since 2006/7 and are expected to increase further over time, thus altering the concentrations of different materials within the residual waste stream;
- Fichtner's assumptions relating to the recovery of metals (particularly non-ferrous metals) from both the sorting and incineration processes are somewhat optimistic, as is the level of assumed energy recovery via AD;
- Although outside of the scope of this study, use of such a highly contaminated feedstock in a digester, as planned at the AWRP, is likely to result in adverse operational issues;

[1] LAC waste was previously defined as municipal solid waste (MSW), but following clarification of the definition of MSW by the European Commission (EC) to include all commercial wastes, Defra introduced the term LAC waste, and thus the term MSW is no longer relevant in the UK

[2] YNYWP manages LAC waste from the following councils: North Yorkshire County Council, City of York Council, Craven District Council, Hambleton District Council, Harrogate Borough Council, Richmondshire District Council, Ryedale District Council, Scarborough Borough Council and Selby District Council

[3] WRATE (Waste and Resources Assessment Tool for the Environment) is the Life-cycle assessment (LCA) tool developed by the Environment Agency

- The results presented in Fichtner's Report 1 are not likely to be representative of the performance of the AWRP over time by virtue of the anticipated decarbonisation of the electricity grid. This is demonstrated within the scenarios presented in Fichtner's own WRATE Report 3;
- Under our 'future' scenario, we have modelled the AWRP using a probable future electricity grid mix and a more likely residual waste composition, assuming a higher overall level of recycling, Under this approach, the AWRP solution performs worse than landfill (the 'do nothing' option) in terms of GWP;
- Again, under our 'future' scenario, we have also compared the AWRP solution with two other established forms of residual waste treatment; a mechanical biological treatment (MBT) 'Dual Fuel' solution and a MBT 'biostabilisation' solution. The outcome of this modelling shows that the AWRP solution performs significantly worse than each of these MBT solutions in terms of GWP;
- The analysis presented in this report, therefore, shows that potential alternative options for waste disposal would offer more beneficial long-term climate change benefits compared to the AWRP scheme. It also shows that the AD / incineration approach proposed for the AWRP does not perform discernibly better than an 'incineration only' solution; and
- Finally, it is important to acknowledge Fichtner does not claim that any of the three published WRATE reports represents a full options appraisal. This suggests that these reports should not therefore be presented as evidence within the consenting process that the proposed AWRP is an environmentally sound solution.

Contents

1.0 Introduction, Scope and Objectives

Eunomia Research and Consulting Ltd. ('Eunomia') is pleased to present this report to the Parish Councils' Group regarding the life-cycle assessment (LCA), using the Environment Agency's Waste and Resources Assessment Tool for the Environment ('WRATE') tool, of the proposed Allerton Waste Recovery Park (AWRP).[4]

Eunomia is a consultancy specialising in waste management and renewable energies. Our expertise covers economic analysis, due diligence, environmental assessment, strategy development, policy design, partnership development and procurement. The company prides itself on the interdisciplinary nature of its work, and its critical perspective on key waste management issues.

We have considerable experience in providing information to support both internal businesses cases and external due diligence exercises for proposed waste treatment infrastructure development. We have recently worked on such projects on behalf of The Cooperative Bank, Nord LB, New Earth Solutions, Shanks Waste Management, FCC, Ludgate Environmental Fund and Scottish & Southern Energy (SSE). We have also undertaken 'gate fee' surveys on behalf of the UK Waste and Resources Action Programme (WRAP) for each of the last five years. Furthermore, we publish a national 'Residual Waste Infrastructure Review' on a six-monthly basis, which provides a regular update to industry on the status of the development of waste treatment facilities on a regional basis.

AmeyCespa is currently seeking planning permission from North Yorkshire County Council (NYCC) for a waste recovery facility at Allerton Quarry, near Harrogate. The proposed facility includes a mechanical treatment (MT) plant, an anaerobic digestion (AD) plant, and an Energy-from-Waste (EfW) or 'incineration' facility. The AWRP is AmeyCespa's solution to treat all local authority collected (LAC) residual waste collected on behalf of the York and North Yorkshire Waste Partnership (YNYWP) for a contract period of 25 years.[5] [6] AmeyCespa intends to fill any shortfall in LAC waste with further waste sourced from the commercial and industrial (C&I) sectors to ensure the full capacity the plant is utilised.

This report presents a review of the WRATE modelling undertaken by Fichtner Consulting Engineers ('Fichtner') on behalf of AmeyCespa in support of the latter's application for planning consent for the development of the proposed AWRP. The

[4] See http://www.environment-agency.gov.uk/research/commercial/102922.aspx

[5] LAC waste was previously defined as municipal solid waste (MSW), but following clarification of the definition of MSW by the European Commission (EC) to include all commercial wastes, Defra introduced the term LAC waste, and thus the term MSW is no longer relevant in the UK

[6] YNYWP manages LAC waste from the following councils: North Yorkshire County Council, City of York Council, Craven District Council, Hambleton District Council, Harrogate Borough Council, Richmondshire District Council, Ryedale District Council, Scarborough Borough Council and Selby District Council

WRATE studies undertaken by Fichtner consider the environmental impacts of two alternatives for the treatment of North Yorkshire and the City of York's waste:

- Front end 'sorting' to remove metals and plastic, with a biomass-rich feedstock going to AD, digestate and remaining waste going to incineration ('combined 'Incin / AD' solution), i.e. the solution proposed for the AWRP; and
- The incineration of all of the contracted waste without any pre-treatment ('Incin only' solution).

Fichtner then compare the results with the 'do nothing' scenario of landfill. Their report concludes that the AWRP offers the least environmental impact of these three options.

This study examines the assumptions and results relating to Fichtner's WRATE modelling. The environmental analysis undertaken by Fichtner considers a range of environmental indicators, including toxicity impacts as well as eutrophication and acidification.

The focus of our study, however, is on the assessment of the climate change impacts of the proposed AWRP. These are modelled within WRATE using the Global Warming Potential (GWP) indicator. The rationale for focusing on the GWP indicator can be summarised as follows:

- The global dimension of climate change impacts, such that the results from the GWP indicator are typically accorded the highest weighting by local authorities during the procurement process for residual waste treatment solutions;[7]
- Of the six 'default' assessment criteria within WRATE assessments, the GWP indicator is that for which the data is most accurate. This is because the related input data is more likely to be known by plant operators (for example, tonnage of recycled materials recovered, energy used and generated etc) than for other indicators; and
- Relatively few variables affect results for the GWP indicator. In contrast, results for the other criteria are affected by a large number of process variables and assumptions. As a result, any attempt to verify the precise modelling undertaken by Fichtner is not possible without obtaining the actual WRATE models or user-defined processes (UDPs) developed to generate the results.

In Section 2.0, we undertake a review of the Fichtner assumptions, in an effort to replicate (as best we can, without the UDPs used within their modelling), the modelling presented in their reports. Our analysis is focused on the assumptions that have the most significant impact on the results of the GWP indicator, with the aim of determining whether the published results are plausible.

[7] Eunomia has undertaken many such WRATE reviews on behalf of bidders within local authority procurement processes

Subsequently in Section 3.0, we propose a range of revised assumptions that we consider more appropriate for this modelling exercise. Using these, we present a comparative analysis of AmeyCespa's proposed solutions against alternative approaches for the treatment of residual LAC waste within the YNYWP area. We have selected technology configurations and solutions for the management of outputs from these configurations based on what we believe is both technically and commercially feasible within the current marketplace for treatment of residual wastes in the UK.

In Section 5.0, we present the results from the comparative analysis before summarising the key findings from the study within Section 6.0.

2.0 Review of AmeyCespa WRATE Assumptions

2.1 Overview of AmeyCespa WRATE Reports

Several WRATE reports have been submitted to NYCC by AmeyCespa during the consenting process. Those made publicly available and reviewed by Eunomia for the purposes of this study are summarised below. These have not been consistently numbered in chronological order, and we have therefore used our own labelling system as follows:

1. Report 1 - 'Issue 3' of the report published as Appendix 2 to the Planning Statement. The analysis presented in Report 1 considers the environmental performance of the 'Incin / AD' (AWRP) solution only in comparison to landfill (the 'do nothing' option).[8] The year modelled is 2015, with an assumed electricity mix (and associated carbon intensity) for electricity generation which is 'displaced' (i.e. that is no longer required) due to generation at the AWRP, developed accordingly;
2. Report 2 - 'Issue 4' of the report published as Appendix B4, following subsequent queries from the Planning Authority.[9] Report 2 includes additional analysis of the 'Incin only' option. The assumed electricity generation displaced in this report is intended to represent the situation in 2020; and
3. Report 3 - Appendix B5 ('Issue 1') of the report published as additional information for the Planning Authority.[10] Report 3 considers results from the 'Incin / AD' (AWRP) solution, but assumes all 'displaced' electricity is generated using hydroelectricity. This again followed a request from the planning authority to use an electricity mix representative of the situation in 2030.[11]

The reports show only a high level interpretation of key outputs from the WRATE modelling, although some detail regarding the assumptions is presented in the Appendices to each report. As described below, accurate interpretation of some of the results and assumptions is therefore sometimes challenging.

It is important to acknowledge Fichtner does not claim that any of the three reports represents a full options appraisal. This suggests that they should not therefore be presented as evidence that the proposed AWRP is an environmentally sound solution.

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[8] Fichtner Consulting Engineers (2011) Appendix 2A WRATE Report - AmeyCespa: City of York and North Yorkshire PFI WRATE model, Report for AmeyCespa, March 2011, Issue 3

[9] Fichtner Consulting Engineers (2012) Appendix B4 WRATE Model Update Report - AmeyCespa: City of York and North Yorkshire PFI WRATE model, Report for AmeyCespa, 27 April 2012, Issue 4

[10] Fichtner Consulting Engineers (2012) Appendix B5 WRATE Model Update Report - AmeyCespa: City of York and North Yorkshire PFI WRATE model, Report for AmeyCespa, 19 April 2012, Issue 1

[11] Letter to AmeyCespa from Shaun Robson, Team Leader Development Control, North Yorkshire County Council Business and Environmental Services, 28th February 2012

2.2 Approach to Review of Assumptions

The climate change impacts of waste treatment solutions are influenced by the following three key variables:

1. The composition of waste assumed to be treated;
2. The recovery of materials for recycling both during pre-treatment as well as from the bottom ash from incinerators; and
3. The generation and consumption of energy by the facilities which comprise the technical solution.

The review of the AmeyCespa reports, therefore, focuses on assumptions made across these three key variables.

Furthermore, in our analysis, a distinction has been made between:

- 'General' assumptions - which apply to all scenarios considered (see Section 2.3), which during procurement processes are likely to be prescribed by the local authority;
- 'Specific' assumptions used within the UDPs developed for bespoke treatment facilities such as the proposed AWRP. These assumptions are detailed in Section 2.4.

2.3 General Assumptions

2.3.1 Waste Composition

The waste composition used in the WRATE analysis is presented in AmeyCespa Report 1 (see Figure 1). The same composition is used in all three submitted reports cited in Section 2.1 and is a combination of commercial, household and household waste recycling centre (HWRC) waste.

The composition data is not easy to determine accurately from any of the reports as it is presented in pie charts rather than in a table of precise numbers. Our visual interpretation of these charts is presented in Table 1.

There are several points to note in respect of this data:

- It relates to composition analyses undertaken in 2006 and 2007. During the intervening period, recycling rates have continuously increased in North Yorkshire and City of York (and indeed, nationally), and are projected to increase further throughout the lifetime of the contract. This has an impact on the composition of waste accepted for treatment at the plant, which will affect its claimed environmental performance;
- As recycling increases, those types of materials which are not captured become increasingly concentrated within the residual waste stream. As such, the composition presented in Table 1 is very unlikely to be representative of waste treated in the plant during even the earlier years of contract operation;
- The composition contains a very large proportion (23.5%) of 'miscellaneous waste' in the form of unspecified 'combustible' materials. Assumptions

relating to the composition of this stream, and the proportions of biomass and plastic present, might vary significantly, thus presenting a wide range of potential results.

The impact of these factors upon the outcomes of the modelling is discussed in more detail in Section 3.1.1.

Table 1: Composition Data – Overall Waste Composition Used By Fichtner

Material	Proportion of Waste Stream
Paper & card	19.4%
Film	4.7%
Dense plastic	5.8%
Textiles	2.5%
Wood	0.7%
Combustibles	23.5%
Non combustibles	7.5%
Glass	1.5%
Organic	28.9%
Ferrous metal	2.4%
Non-ferrous metal	0.7%
Fines	0.3%
WEEE	1.3%
Hazardous	0.8%

2.3.2 Carbon Intensity of Displaced Electricity Generation

The analysis undertaken by Fichtner uses electricity generation mix data for 2015 (Report 1) and 2020 (Report 2). This data is shown in Table 2. The 'baseline' mix columns refer to what has been used by Fichtner to calculate the carbon dioxide equivalent (CO2e) emissions associated with electricity used by the plant, whilst the 'marginal' mix columns refer to the electricity generation which is 'displaced' (i.e. that is no longer required) due to generation at the AWRP.

There is much debate as to the grid mix and associated carbon intensity, which should be used for such analysis. With regard to the marginal mix, some studies do not assume a 'mix' at all; rather they consider the type of facility which is likely not to be constructed as a result of the proposed new generation capacity. The most recent guidance published by the Department of Energy and Climate Change (DECC) in this regard suggests that for options appraisal studies within the public sector, such as the AmeyCespa proposal, an emissions factor of 373 g CO2 per kilowatt hour (gCO2/kWh) should be used, which is broadly equivalent to the emissions from a combined cycle gas turbine plant (CCGT) plant.[12]

In the current situation of major Electricity Market Reform (EMR) in the UK, it is extremely challenging to forecast either future 'baseline' or 'marginal' carbon intensities. Fichtner, within Reports 1 and 2, however, appears to have *specifically chosen* to ignore the aforementioned Guidance published by DECC and to instead assume that an average grid mix will be displaced (rather than CCGT capacity) by the proposed AWRP. This key assumption has the effect of reducing the predicted emissions of CO_2 associated with the AWRP.

In Report 3, however, Fichtner models the displacement of hydroelectric capacity only. Whilst this situation is unlikely in reality, it does provide a means to explore the impacts of the proposed AWRP should the UK grid become fully decarbonised in the future.

These issues are explored further in Section 3.1.2, in which we set out our own preferred approach to modelling the marginal mix of electricity generation.

[12] DECC & HM Treasury (2011) Valuation of energy use and greenhouse gas emissions for appraisal and evaluation, October 2011

Table 2: Fichtner Assumptions relating to Electricity Use and Displacement

Energy Source	2015 (Report 1)		2020 (Report 2)	
	Baseline Mix (%)	Marginal Mix (%)	Baseline Mix (%)	Marginal Mix (%)
Coal	32	46.8	26.4	33.8
Oil	0.3	0	0.3	0
Gas	3.4	4.2	3.4	4.2
Gas CCGT	36.9	49.9	47.6	62
Nuclear	12.9	0	9.7	0
Waste	0.2	0	0.2	0
Thermal other	0.8	0	0.8	0
Renewable thermal	2.3	0	2.4	0
Solar PV	0.2	0	0.3	0
Wind	9.3	0	11.3	0
Tidal	0.2	0	0.3	0
Wave	0.2	0	0.3	0
Hydro	1.3	0	1.4	0
Geothermal	0	0	0	0
Renewable other	0	0	0	0
Total	100	100	100	100

2.4 Specific Assumptions used in Treatment Models

WRATE contains standard, default models which are intended to be representative of typical waste treatment processes, including incineration, AD and landfill. The assumptions contained within these standard models can be modified, such that an 'Expert' user of WRATE can create UDPs that are considered to be more representative of the treatment solution offered by the specific technology provider or plant operator.

Fichtner has developed three UDPs in their WRATE modelling undertaken for AmeyCespa:

- A 'pre-treatment' (or mechanical separation) UDP, based on the WRATE standard process 11089;
- An AD UDP, based on standard process 11312; and
- An incineration UDP, based on standard process 12300.

In WRATE, a Background Table for each UDP must be set up to show the annual impact of the treatment facility based on a typical input composition. Formulae included within the model allow for various impacts to be calculated for different, 'user-entered' waste compositions. These formulae are known within WRATE as 'Allocation Rules'. In developing UDPs for non-standard processes, Expert Users can make modifications both to the quantities of waste and Allocation Rules included within the Background Table. In developing the UDPs for the proposed AWRP, Fichtner have made both types of amendments, as is discussed for each element of the plant within Sections 2.4.1 to 2.4.3.

2.4.1 Pre-Treatment UDP

The pre-treatment process is aimed at recovering recyclables from the LAC input stream and producing a fraction that is sent for AD. In the Reports, Fichtner indicate that they have modified assumptions relating to:

- The level of recovery of recyclable materials; and
- The amount of energy used by the pre-treatment (sorting) process.

Both of these assumptions have an impact on the GWP of the proposed plant.

We consider that the latter assumption – effectively amounting to an energy consumption of 25 kWh per tonne of sorted waste treated – is reasonable. As explained below, however, we think that the assumptions relating to level of recovery of materials are somewhat optimistic.

Fichtner modify the Allocation Rule that calculates the amount of materials recovery based on the user-entered waste composition. The assumptions used in this respect are presented in Table 3 below, which draws upon Table 3 within Report 1.

We consider that Fichtners assumptions for the recovery of metals (87% for both ferrous and non-ferrous streams) are over-optimistic in respect of what is achievable at even 'best-of-breed' plant. Data obtained by Eunomia from a range of operating mechanical-biological treatment (MBT) facilities (with similar separation technologies) suggests recovery rates are at best 70% for ferrous metals and 45% for non-ferrous metals.[13] The avoided CO_2 emissions via use of recovered metals in manufacturing

[13] Based on data provided to Eunomia by a number of pre-treatment operations including those operated by New Earth Solutions, H W Martin, Orchid Environmental, Premier Waste and GRL; this data is also in line with recovery rates included in standard process models contained within WRATE which

processes for steel (ferrous) and particularly aluminium (non-ferrous) are significant. As a result, Fichtners assumptions in this regard ascribe a far higher benefit to the AWRP than should be the case in reality.

The assumptions regarding the potential CO_2 benefit attributed to recycling of different materials are not detailed in any of the Fichtner reports. It is unlikely, however, that paper recovered through the sorting of a residual waste stream would result in the same benefit that would be attributed to that of a 'clean' stream such as that which would come from a source-separated kerbside collection scheme. To fully assess the impact of Fichtner's assumptions in this regard, therefore, it is necessary to see the detail of these assumptions.

Table 3: Data on Recovery of Recyclable Materials (Report 1)

	Annual tonnage captured for recycling	Recovery rate assumption in Allocation Rule
Dense plastic	3,442	28%
Ferrous metal	4,422	87%
Non-ferrous metal	1,535	87%
Paper and card	2,101	7%

2.4.2 AD UDP

In Report 3, Fichtner amend the following assumptions in their UDP for the AD element of the proposed AWRP plant:

- Amount of energy generated by the AD process;
- Amount of energy used by the AD process; and
- Method of treatment of output digestate.

It is first important to note that, largely, the standard models within WRATE relate biogas generation to the total biogenic carbon content of the material. The degradation of biogenic carbon, however, varies considerably depending on the *type* of carbon - whilst sugars, fats and proteins all degrade readily, lignin barely degrades under anaerobic conditions and so produces little biogas. Detailed data on the chemical constituents of the material going to the AD process would therefore be required in order to robustly understand biogas generation from a 'mixed' waste stream.

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are also based on data from operating plant collected by the Environment Agency during the development of WRATE.

2.4.2.1 Assumed Input Composition to the AD Plant

Fichtner provide a high-level indication of the composition of material to be treated by the AD plant at the AWRP in Report 3 and this is presented in Table 4. This shows that about 20% of the stream is made up of 'combustibles'; by its nature, a highly heterogeneous stream. WRATE assumes a chemical characteristic of this stream that reflects a mixture of furniture items, carpet, shoes and other composite source items that contain both fossil as well as biogenic carbon. As discussed further in Section 2.4.2.2, it is unlikely such a material stream would degrade and produce biogas in the short period spent in the digester. Furthermore, an additional 18% of the input to the plant is 'non-combustible' material, which can be assumed to be completely non-degradable.

Fichtner indicate in their analysis that all non-degradable (or barely degradable) material is expected to pass through the digestion system. Consideration of the technical viability of such an approach is outside the scope of this study, but our experience indicates that the treatment of a significant quantity of non-degradable material within an AD plant will cause significant operational problems including the 'clogging' of digester vessels.

The organic waste and paper fractions would be expected to degrade in the digester, and these two streams together account for 62% of the total AD feedstock. For paper, biogas generation will depend on the type of paper in the waste stream – lignin-rich newspaper will not degrade readily, although cellulose-rich paper waste is likely to result in a reasonable quantity of biogas generation. It is not clear, however, how much of the organic waste stream is food waste – which is readily degradable to produce biogas – and how much is garden waste, which has a high lignin content and as such does not degrade readily under anaerobic conditions.

Table 4: Composition of AD Feedstock

	Tonnage to AD	Composition (%)
Paper and card	4,000	10
Plastic film	2,000	5
Combustibles	8,000	20
Non-combustibles	4,091	10
Glass	500	1
Organic waste	20,900	52
Ferrous metal	74	0
Non-ferrous metal	26	0
WEEE	409	1
TOTAL	**40,000**	**100**

2.4.2.2 Assumed Electricity Output from the AD Plant

Fichtner's Waste Flow Model states an expected annual generation figure of 7,843 MWh. This effectively assumes a net electricity-to-grid figure of 310 kWh of electricity per tonne of input degradable waste.[14] Whether this is reasonable depends in part on how much of the organic waste is food waste, and the newspaper content of the paper waste stream. As mentioned in Section 2.4.2.1, neither is clear from the composition data presented by Fichtner.

This assumption of a net 310 kWh of electricity per tonne of input degradable waste also depends upon the digester operating optimally to maximise biogas generation. As mentioned above, such smooth operation is very unlikely to be the case given the relatively large quantity of non-degradable material within the feedstock. As a result, the generation of biogas and, ultimately, the amount of energy generated and corresponding CO_2 benefit estimated by Fichtner, appears to be very optimistic.

Furthermore, there is also a lack of clarity in Fichtner's reporting of their methodology used to calculate the 310 kWh net electricity figure. The three reports do not confirm whether changes were made to the WRATE 'Allocation Rule' which calculates the figure within the WRATE model, and also do not state the assumption for the amount of electricity used by the AD plant. The latter is assumed to be zero as the electricity to grid figure is quoted as a 'net' figure, but the approach is not stated in the report.

In addition, Fichtner do not state whether they have amended in their UDP the assumption for the annual tonnage accepted by the plant. This could also affect the electricity generation calculation depending on the nature of the 'Allocation Rule' used. The standard process upon which the UDP is based calculates all impacts assuming 51,000 tonnes of waste is treated, rather than the 40,000 tonne facility proposed for the AWRP. As a result, Fichtner could be again overestimating the likely amount of electricity generation.

2.4.2.3 Assumptions Relating to Output Digestate

Fichtner assume that all the digestate produced by the AD process is sent to the onsite incinerator. As such, Fichtner has modified the standard WRATE assumptions regarding the mass of the waste streams sent to the incinerator to account for the amount of carbon degraded in the AD process. Fichtner assumes that 34% of the carbon contained within the 'miscellaneous combustible' stream has been degraded. For the reasons highlighted above, we believe this assumption to be highly questionable. As a result, we think it extremely likely that a higher tonnage than forecast would be sent to the incinerator, with a potentially higher calorific value than has been modelled by Fichtner. This would result in a reduced environmental benefit of the AWRP scheme than presented in the three reports.

[14] This is calculated assuming only the organic and paper waste fractions degrade

2.4.3 Incineration UDP

In creating their UDP for the incineration process, Fichtner have amended the following aspects of the standard process, which is based on the Chineham incinerator, operated by Veolia in Hampshire:

- Energy generation, where an electrical generation efficiency of 24% is assumed by Fichtner:
  - This is at the upper end of the range of performance for UK facilities, but is feasible given the size of the plant.
- The CO_2 emissions data (for both fossil and biogenic CO_2), which are recalculated on the basis of a revised carbon balance presented in the report:
  - This appears to be reasonable.
- Recovery of non-ferrous metals:
  - Fichtner model a recovery rate of 54% at the grate. Survey data collated from the Netherlands, however, where the focus of metal recovery is from incinerators rather than via kerbside collections, indicate that only 30% of non-ferrous metal is typically recovered and therefore we believe Fichtner has been overly-optimistic in this regard.[15]
- Energy use by the facility, equivalent to 1.45 kWh/tonne:
  - It should be noted here that this is a low value, but as the assumption relating to electricity exported to the grid is stated as a *net* figure, we believe this is potentially a reasonable estimate.

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[15] Muchova L and Rem P (2008) Wet or Dry Separation: Management of Bottom Ash in Europe, Waste Management World Magazine, 9(3)

3.0 Assumptions used in Comparative WRATE Analysis

As outlined above, the goal of this analysis is, where relevant, to set out a range of alternative assumptions to those used by Fichtner. These are used in our modelling of both the proposed AWRP and several alternative waste treatment technology configurations, which we have described in Sections 4.0 and 5.1.

Again, as per the analysis within Section 2.0, we have split the assumptions into both 'general', i.e. those which apply to all technologies, in Section 3.1, and into a range of other 'plant specific' assumptions, which we have used to remodel Fichtner's UDPs in Section 3.2.

3.1 General Assumptions

3.1.1 Waste Composition

In remodelling the performance of the AWRP alongside our additional alternative treatment technologies, to test and demonstrate the sensitivity of the results to changes in waste composition, we have used the following two compositions:

- That used in Fichtner's analysis as presented in Table 1. This data is based on municipal solid waste (MSW) composition data dating from 2005 and represents our 'central' scenario;[16] and
- A 'high recycling performance' composition that is considered to be more representative of a 'future' scenario, as is presented in Table 5.

The composition data in Table 5 has been partly derived from the national Local Authority Collection (LAC) composition dataset, but assumes that an overall recycling rate of 60% is achieved, which we believe is reasonable within the lifetime of the proposed AWRP.[17] The data combines the LAC dataset with data on the commercial and industrial (C&I) stream to achieve an overall composition for the mixed LAC, C&I and Household Waste Recovery Centre (HWRC) streams.

Our revised waste composition in Table 5 contains higher quantities of plastics, absorbent hygiene products and textiles but a lower proportion of paper than the composition modelled by Fichtner (see Section 2.3.1 above). The greater concentration of plastics occurs as increasing amounts of recyclables, such as paper, card, glass and metals are readily targeted by kerbside collections. Although we assume that plastic bottles and other rigid plastic packaging are also increasingly collected, we also assume that much of the plastic film and non-packaging streams

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[16] MSW is now broadly referred to as LAC waste, which is the term used in this report, even when referring to the older definition

[17] Composition data published in: Resource Futures (2009) Municipal Waste Composition: A Review of Municipal Waste Component Analyses, Final Report for Defra

will not be recovered for recycling. As a consequence plastic material in general becomes more concentrated in the residual stream along with combustibles, textiles and absorbent hygiene products.[18] Data in the table is consistent with that given to Eunomia by current operators of residual waste treatment plants, which have confirmed that plastics often account for more than 20% of the input stream.

Table 5: Residual Waste Composition for 60% Recycling Rate

Material	Proportion of Waste Stream
Paper and card	11.52%
Plastic film	9.68%
Dense plastic	8.14%
Textiles	4.73%
Absorbent hygiene products including nappies	7.16%
Wood	3.44%
Combustibles	7.38%
Non-combustibles	7.75%
Glass	4.67%
Organic	27.55%
Ferrous metal	5.13%
Non-ferrous metal	0.78%
Fine material <10mm	2.05%
Specific hazardous household	0.02%

[18] The contribution of plastic to the residual stream would, however, be expected to be reduced once collection schemes for plastic films are more widely introduced, which may take place in the medium term

3.1.2 Carbon Intensity of Displaced Electricity Generation

In remodelling the performance of the AWRP alongside our additional alternative treatment technologies, to test and demonstrate the sensitivity of the results to changes in the marginal form of electricity generation, we have modelled the following two scenarios:

- The 'central' scenario is based on the electricity mix used in Fichtner's analysis from 2020 as presented in Table 2; and
- The 'future' scenario is based on a 'grid decarbonisation pathway', modelled to achieve a target of 100 $kgCO_2/kWh$ in 2027/28, which is half-way through the contract period for the proposed AWRP.[19] This scenario is based on extrapolation between the 3rd and 4th 'carbon budget' targets recommended by the Committee on Climate Change (CCC).[20]

3.2 Assumptions used to Remodel Fichtner UDPs

As outlined in Section 2.0, due to a lack of transparency within the Fichtner Reports it has not been possible to fully understand and recreate all of the UDP assumptions Furthermore, in certain limited cases, the associated assumptions do not appear to make sense. As a result, in an effort to reproduce the UDPs created by Fichtner, we have used assumptions that we believe, based on our industry knowledge and experience, to be reasonable estimates of all given parameters.

In summary, we have taken the following approach in recreating the UDPs:

- Fichtner's assumptions and Allocation Rules have been reproduced exactly as presented in Report 1 for:
    - The level of energy generated by the incineration plant; and
    - The energy use at all three facilities (pre-treatment, AD and incineration).
- We have reduced the capture rates at the pre-treatment plant to 70% for ferrous metal and 45% of the non-ferrous metal from the LAC fraction of the waste stream;
- Fichtner's assumptions have been retained for the recovery rates for plastics and paper from the pre-treatment facility;
- Energy generation by the AD facility has been assumed to be 290 kWh per tonne of degradable waste. To account for the amount of non-degradable material in the input stream, this is a slightly lower number than that calculated in Section 2.4.2.2 as having been used by Fichtner;

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[19] As it is not possible to set exact carbon intensity levels in WRATE, this is modelled as 25% CCGT and 75% hydroelectricity

[20] See www.theccc.org.uk/carbon-budgets

- Fichtner's assumptions relating to digestate have been reproduced unchanged for the most part, with the exception of the Allocation Rule for combustibles, for which we have assumed that only 10% of the material is degraded;
- We have used an Allocation Rule for the recovery of metal from incineration processes at 60% for ferrous metal and 30% for non-ferrous metal;
- We have left the CO_2 emissions assumptions in the incinerator UDP unchanged as this was expected to result in only a minor difference to the GWP;[21]
- We have calculated the benefits of paper recovery from the pre-treatment facility assuming the recovery of card rather than paper to account for the lower quality of the material likely to be recovered via sorting from a mixed waste stream; and
- Transport impacts have been excluded from the analysis.[22]

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[21] Under the Fichtner Allocation Rule, slightly more CO_2 will be released, worsening the performance of the facility under the GWP assessment

[22] This is in contrast to the overseas transport of SRF to 'R1 designated incineration facilities' in the alternative treatment scenarios, as is discussed in Section 4.0

4.0 Additional Treatment Solutions Modelled

Results from the two solutions modelled by Fichtner (AWRP and incineration only) have been compared with two alternative approaches identified by Eunomia to treating residual waste:

- A MBT 'bio-drying' process that recovers recyclable materials via upfront mechanical separation, with the onward management of a 'Dual Fuel' stream:
    - A biomass rich stream sent to a designated R1 incineration facility located in Holland, which operates in combined heat and power (CHP) mode, which is far more efficient than all incinerators currently operating in the UK.[23] In the context of this option it should be noted that:
        - Export of SRF currently represents a real option for operators in the UK. In February 2012, the tonnage licensed for export by the Environment Agency stood at 1,921,000 tonnes, which we expect to increase over time;[24] and
        - Eunomia has recently met with two operators of incinerators in Holland, both of which are interested in relatively long contracts with local authorities in the UK. These organisations regard their spare capacity as a means to help local authorities avoid being locked into long term treatment contracts and therefore to increase related recycling targets.
    - A plastic rich stream sent to a cement kiln where it is assumed to displace the use of coal (as a primary fuel rather than as a source of electricity).[25] At present, there are five cement kilns in the UK processing SRF (Ketton, Padeswood, Tunstead Quarry, Rugby and South Ferriby), each of which are currently seeking to increase the tonnage of SRF processed.[26]
- A MBT process recovering recyclable materials via up front separation, with the resulting (largely organic) fraction undergoing a 'biostabilisation' process prior to being sent to landfill.[27]

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[23] In this context it should be noted that the AWRP incinerator, whilst stated by AmeyCespa to be 'CHP ready', has no identified user for its heat

[24] See http://www.letsrecycle.com/news/latest-news/energy/test

[25] This approach is similar to that used in the New Earth Solutions MBT process as it currently operates in their three UK facilities. A similar approach is also being proposed by FCC and H W Martin for an MBT plant aiming to operate in the UK within the next three years

[26] Operators of these plant are Heidelberg-Hanson, Cemex, Tarmac and Lafarge

[27] Similar to the process operated by Premier Waste and previously operated by New Earth Solutions

Assumptions used to model these two treatment solutions are presented respectively in Table 6 and Table 7. The assumptions have been developed based on data obtained from plant operators, which has been cross referenced with published information on facility performance.[28]

The results from modelling these UDPs are presented in Section 5.0, in which we have also presented results for the landfilling of all residual waste, therefore reproducing the baseline 'do nothing' solution modelled within the Fichtner Reports.

[28] Muchova L and Rem P (2008) Wet or Dry Separation: Management of Bottom Ash in Europe, Waste Management World Magazine, 9(3); European Commission (2006) Reference Document on Best Available Techniques for the Waste Treatment Industries, August 2006; University of Leeds (2010) New Technologies Demonstrator Programme – Research, Monitoring and Evaluation of the Premier Waste Tower Composting System in Thornley, County Durham, Report for Defra; University of Southampton (2010) New Technologies Demonstrator Programme – Research, Monitoring and Evaluation of the Merseyside WDA/Orchid Environmental Ltd MHT plant in Huyton, Merseyside, Report for Defra

Table 6: Assumptions Used to Model the MBT: 'Dual Fuel' Solution

Parameter	Assumption
Recovery of recyclable materials from sorting process	
Dense plastics	30%
Ferrous metal	70%
Non-ferrous metal	45%
Overall mass balance (central case)[1]	
Recyclable materials	4%
SRF to R1 facility (stabilised)	55%
Cement kiln stream (un-stabilised)	10%
Process loss (moisture and volatile solids)	18%
Stabilised waste to landfill	13%
Electricity used in sorting process	25 kWh / tonne
Cement kiln stream[2]	
Fossil carbon content of fuel stream (dry basis)	22%
CV of fuel stream	17.5 MJ / kg
SRF utilisation efficiency at cement kiln	90%
Coal emissions offset	0.368 kg CO_2 / kWh
Assumed energy content of coal	26 MJ / kg
Energy generation – R1 incineration facility[3]	
Electricity (gross)	18%
Net heat utilisation	25%
Recyclate recovered from R1 incineration facility	
Ferrous metal	60%
Non-ferrous metal	30%
Transport assumptions[4]	
Distance over land to port for export	300 km
Sea freight distance	350 km
Distance to cement kiln in UK	160km

Notes:

1. The sorting and composting processes were modelled using two UDPs developed from WRATE standard processes 21227 (autoclave) and 11316 (VKW composting), with mass balance and electricity consumption modified to reflect the assumptions indicated above. All contracted waste is assumed to go through the sorting process.
2. The performance of the cement kiln is based on a UDP developed from WRATE standard process 21274 (SRF combustion at cement kiln). Offset emissions were modified to reflect the assumptions indicated above (SRF is assumed to displace an equivalent amount of energy from coal taking into account the above CV and RDF utilisation efficiency).
3. The standard flexible WRATE Energy from Waste process 21849 was used to model the R1 incineration process. Energy generation performance is in line with the anticipated performance of the AVR Rotterdam plant in 2015.
4. Modelled using standard processes 21291 (ship) and 12026 (road)

Table 7: Assumptions Used to Model the MBT: Biostabilisation Solution

Parameter	Assumption
Recovery of recyclable materials from sorting process	
Dense plastics	30%
Ferrous metal	70%
Non-ferrous metal	45%
Overall mass balance (central case)[1]	
Recyclable materials	4%
Process loss (moisture and volatile solids)	34%
Stabilised waste to landfill	62%
Electricity used in MBT process	28 kWh / tonne

Notes:

1. Stabilisation process modelled using a UDP developed from standard process 12086 (composting from stabilite generic process), with mass balance and electricity use modified as above. All contracted waste is assumed to go through the sorting process.

5.0 Presentation of Results

5.1 Summary of Scenarios and Treatment Solutions

In our comparative analysis we have modelled both 'future' and 'central' scenarios. The future scenario presents what we believe are more accurate results (compared with our central scenario, which is based on Fichtner's approach). These scenarios are summarised in Table 8 alongside each of the treatment solutions which have been modelled under both scenarios. The outcomes of this modelling are presented in Section 5.2 for the central scenario and in Section 5.4 for the future scenario. In Section 5.3, we have also compared the results of modelling our central scenario against the results presented in the Fichtner Reports.

Table 8: Treatment Solutions and Scenarios Modelled in Comparative Analysis

Parameter	Name	Description
Scenarios	'Central'	Fichtner's waste composition with the 2020 grid mix as detailed in Section 2.3.2
	'Future'	Composition for 60% recycling with the 'decarbonisation pathway' detailed in Section 3.1.2
Treatment Solutions	Incin / AD (AWRP)	Based on Fitchner's UDPs for the solution using AD and Incin with modified assumptions as detailed in Section 3.2
	Incin only	Based on Fichtner's UDPs for the solution using AD and Incin with modified assumptions as detailed in Section 3.2
	MBT 'Dual Fuel'	SRF to both overseas R1 incinerator and cement kiln; recovery of recyclable materials and a stabilised stream to landfill
	MBT 'Biostabilisation'	Recovery of recyclable materials with stabilised output to landfill
	Direct to Landfill	All waste sent directly to landfill (as in baseline scenario in Fichtner Reports)

5.2 Results from Modelling the Central Scenario

Table 9 presents results from modelling each of the treatment solutions under the central scenario, and shows the annual climate change impact expressed in GWP units. Impacts are presented according to the process stages defined in WRATE. This aggregates all direct emissions to air from the treatment process along with transport impacts to form a 'direct process burdens' category. The breakdown also identifies separately benefits from energy generation and recycling.

Under the central scenario, the best performing solution is the MBT 'Dual Fuel' solution. This generates less energy than either of the 'Incin / AD' or 'Incin only' (AWRP) solutions because only 55% of the input waste is sent for energy generation. The benefit attributed to energy generation, however, is significant by virtue of both fuel streams being sent to relatively high efficiency generation processes. The GWP benefit attributed to the cement kiln stream is particularly significant as this material is assumed to avoid the direct use of coal (as a primary fuel rather than as a source of electricity), which has relatively high carbon content. The MBT 'Dual Fuel' solution also recovers more material for recycling, as the total contracted waste passes through the sorting process. Direct process burdens are lower for this option, as some of the combustible material containing fossil carbon is landfilled (post-stabilisation) in addition to a greater proportion of the plastic being recycled.

The two scenarios based on those modelled by Fichtner ('Incin/AD', i.e. AWRP and 'Incin only') both perform at a similar level below the MBT 'Dual Fuel' solution, whilst the MBT 'biostabilisation' solution performs relatively poorly by virtue of its relatively low energy generation. Sending material directly to landfill is by far the worst performing option.

Table 9: Results from Central Scenario – WRATE Process Stages

Treatment Solution	Global Warming Potential, tonnes CO_2 equivalent[4]					
	Direct process burdens[1]	Energy input	Energy output	Operational product output[2]	Other impacts[3]	TOTAL
Incin / AD (AWRP)	116,041	10,867	-138,490	-21,558	9,725	-23,416
Incin only	120,068	1,189	-137,684	-14,447	7,765	-23,108
MBT 'Dual Fuel'	96,828	5,815	-100,156	-36,290	-281	-34,083
MBT 'Biostabilisation'	59,431	5,558	-16,729	-28,118	1,146	21,287
Direct to Landfill	102,497	241	-30,819	n/a	579	72,498

Notes:

1. Direct process burdens include all direct emissions from the treatment process along with transport impacts (this is only included for the MBT Dual Fuel solution)
2. Operational product output largely relates to the benefit associated with the recovery of materials for recycling
3. Other impacts include construction and maintenance burdens and decommissioning impacts
4. Negative numbers indicate net savings i.e. an environmentally "better" performance

WRATE also allows for the viewing of results by a separate categorisation which identifies the contribution to the total results of the landfill and transportation elements. This data is presented in Table 10, which combines both the energy-related benefits with the treatment-related process emissions in the 'Treatment and

Recovery' category. The data in Table 10 demonstrates that although transportation and landfill impacts make a reasonable contribution to the total impact of the MBT 'Dual Fuel' solution, these are far outweighed by the recycling and energy generation (treatment and recovery) benefits.

Table 10: Results from Central Scenario – WRATE Categories

Treatment Solution	Global Warming Potential, tonnes CO_2 equivalent[1]				
	Transport[2]	Recycling	Treatment and Recovery	Landfill	TOTAL
Incin / AD (AWRP)	n/a	-20,238	-3,372	194	-23,416
Incin only	n/a	-13,315	-9,838	44	-23,108
MBT 'Dual Fuel'	12,715	-31,783	-24,729	9,713	-34,083
MBT 'Biostabilisation'	n/a	-25,873	7,744	39,416	21,287
Landfill	n/a	n/a	n/a	72,498	72,498

Notes:

1. Negative numbers indicate net savings i.e. an environmentally "better" performance
2. Transport impacts are included only for the MBT 'Dual Fuel' solution as all other transport impacts are assumed to be very similar for all solutions

5.3 Comparison with Results presented by Fichtner

The results presented in Section 5.2 suggest that the AWRP (Incin / AD) solution will perform less well than is claimed in the three Reports submitted by AmeyCespa. The associated emissions are predicted by Fichtner to be around -60,000 tCO_2eq. This is significantly higher than the circa -23,000 tCO_2eq modelled under our central scenario shown in Table 9.

Confidence in our analysis is provided by the results published in Report 1, which show baseline results for sending residual waste directly to landfill of 70,100 tCO_2e, which is similar to those presented for landfill in this study (given the exclusion of the transport impacts). This suggests that there is no significant difference in the assumed biogenic carbon composition made in each study.

Fichtner's Report 1 provides (in Figure 8) a breakdown of the results for the 'Incin / AD' (AWRP) solution. This suggests a treatment impact (for the AD and incineration facilities combined) of approximately -30,000 tCO_2e, which includes a contribution from materials recycling of around -38,000tCO_2e. This is significantly better than the performance of the same solution modelled within our own analysis.

Fichtner's Report 2 includes a scenario where all contracted waste is sent directly to the incineration plant, and for which a 2020 marginal grid mix (including 33% coal, which, as mentioned above, is contrary to DECC guidance) is assumed to be displaced by electricity generation by the AWRP. This scenario results in a GWP of -41,802 tCO_2e. We have sought to replicate the UDP assumptions used by Fichtner , but our analysis results in a GWP of only -28,808 tCO_2e for this scenario. As above, we cannot explain this discrepancy without access to the UDP file developed by Fitchner. This does not necessarily mean that Fichtner has made an error, but they certainly have not been transparent in their assumptions, which is unhelpful in this type of analysis.

We recognise that the results in the Fichtner Reports 1 and 2 include transport impacts which are not included in our models. Furthermore, our models do not incorporate Fichtner's revisions to the carbon balance of the incineration plant. The inclusion of both these amendments, however, would worsen the performance within our recreated models, thereby widening the discrepancy between the two sets of analyses.

5.4 Analysis of Future Scenario

Table 11 presents the results from the future scenario for the treatment solutions previously described in Section 5.1. This presents what we believe are more accurate results (than under the central scenario, which is based on Fichtners approach) for the different treatment solutions examined for this study.

Our future scenario accords a lower benefit to the generation of electricity at waste treatment facilities, and also assumes that the residual waste composition contains more fossil carbon (particularly plastics). It is important to note that under this scenario, both the 'Incin / AD' (AWRP) and the 'Incin only' solutions perform worse than either landfill or the MBT 'biostabilisation' solution. The latter performs well by virtue of the lower quantity of direct emissions to air than under the central scenario.

Under this scenario, the MBT 'Dual Fuel' solution considerably outperforms the others, as the climate change benefit associated with energy generation at the cement kiln is not affected by grid decarbonisation, and the R1 incinerator also generates heat as well as electricity.

Table 11: Results from the Eunomia Future Scenario – WRATE Process Stages

	Global Warming Potential tonnes CO_2 equivalent[4]					
	Direct process burdens[1]	Energy input	Energy output	Operational product output[2]	Other impacts[3]	TOTAL
Incin / AD (AWRP)	130,200	9,014	-21,938	-32,766	8,908	93,418
Incin only	132,459	1,050	-22,239	-23,690	7,285	94,865
MBT 'Dual Fuel'	71,299	5,337	-39,795	-52,447	-8,460	-24,066
MBT 'Biostabilisation'	41,803	5,133	-1,961	-42,731	1,282	3,526
Landfill	88,624	241	-4,518	0	579	84,926

Notes:

1. Direct process burdens include all direct emissions from the treatment process along with transport impacts (this is only included for the MBT Dual Fuel scenario)
2. Operational product output largely relates to the benefit associated with the recovery of materials for recycling
3. Other impacts include construction and maintenance burdens and decommissioning impacts
4. Negative numbers indicate net savings: a better environmental performance

6.0 Summary of Key Findings

The key findings from our analysis can be summarised as follows:

- In their three reports, Fichtner do not provide full information relating to many of their model assumptions. These omissions make it difficult to directly replicate (and hence verify) their analyses. Greater transparency would enable the performance of the proposed AWRP to be verified by stakeholders within the consenting process;
- The assumed waste composition used within the Fichtner analysis, which is based on data from 2006/7, is not representative of LAC residual waste today. More importantly, it even less accurate with regard to a representation of the waste composition to be treated throughout the duration of the contract. This is because recycling rates have risen significantly since 2006/7 and are expected to increase further over time, thus altering the concentrations of different materials within the residual waste stream;
- Fichtner's assumptions relating to the recovery of metals (particularly non-ferrous metals) from both the sorting and incineration processes are somewhat optimistic, as is the level of assumed energy recovery via AD;
- Although outside of the scope of this study, use of such a highly contaminated feedstock in a digester, as planned at the AWRP, is likely to result in adverse operational issues;
- The results presented in Fichtner's Report 1 are not likely to be representative of the performance of the AWRP over time by virtue of the anticipated decarbonisation of the electricity grid. This is demonstrated within the scenarios presented in Fichtner's own WRATE Report 3;
- Under our 'future' scenario, we have modelled the AWRP using a probable future electricity grid mix and a more likely residual waste composition, assuming a higher overall level of recycling, Under this approach, the AWRP solution performs worse than landfill (the 'do nothing' option) in terms of GWP;
- Again, under our 'future' scenario, we have also compared the AWRP solution with two other established forms of residual waste treatment; a mechanical biological treatment (MBT) 'Dual Fuel' solution and a MBT 'biostabilisation' solution. The outcome of this modelling shows that the AWRP solution performs significantly worse than each of these MBT solutions in terms of GWP;
- The analysis presented in this report, therefore, shows that potential alternative options for waste disposal would offer more beneficial long-term climate change benefits compared to the AWRP scheme. It also shows that the AD / incineration approach proposed for the AWRP does not perform discernibly better than an 'incineration only' solution; and
- Finally, it is important to acknowledge Fichtner does not claim that any of the three published WRATE reports represents a full options appraisal. This suggests that these reports should not therefore be presented as evidence

within the consenting process that the proposed AWRP is an environmentally sound solution.