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Forecasting 2020 waste arisings and treatment capacity

Analysis to inform the review of Defra financial support for the Hertfordshire County Council residual waste treatment project

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Introduction

This paper sets out analysis used to forecast levels of waste arisings and treatment capacity in England in 2020. Forecasts are used to assess the amount of biodegradable municipal waste that goes to landfill and hence whether England is expected to meet the diversion levels in 2020 that are necessary for the UK to achieve the target under the EU Landfill Directive.

The analysis provides estimates of the likelihood of meeting the Landfill Directive target. The potential impact of delivery of the Hertfordshire County Council (HCC) residual waste treatment project on the likelihood of meeting the target is also assessed.

The results of this analysis reflect updated data that has become available since the previous forecasting report of October 2013[1].

Methodology

Forecasts are made of waste arisings and treatment capacity to establish whether sufficient capacity is expected to be in place to meet the requirements of the Landfill Directive target in 2020. This requires predicting future behaviour of a number of uncertain factors, such as waste arisings, recycling rates, when infrastructure projects are likely to come online and how much waste they will divert from landfill.

There are considerable uncertainties over forecasting these factors to 2020. For example, changes in the economy, attitudes to waste, access to finance and many other issues can all potentially impact future trends. There are also limitations in some of the data available. For example, commercial and industrial waste data is not regularly available making future trends especially difficult to predict. Therefore ranges are applied to key assumptions and forecasts. A 'Monte-Carlo' modelling technique[2] is then used to bring together the uncertain factors and give an overall range of results. This is used to estimate the likelihood of having sufficient capacity to meet the 2020 target.

Whilst this methodology provides a robust approach to uncertainty, the results are dependent upon the ranges applied to the various factors within the analysis. These

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[1] See Defra (2013), "Forecasting 2020 Waste Arisings and Treatment Capacity – Analysis to Inform the Review of Defra Financial Support for the Norfolk County Council Residual Waste Treatment Project".
[2] The Monte-Carlo method is a statistical approach to modelling uncertainty.

have been based on evidence and expert judgement, but cannot be known with certainty. Furthermore, there is an unavoidable degree of model uncertainty; that is, the results depend on the type of model that is used, as well as the values of the parameters chosen within that model.

This overall approach to the modelling was developed following the commissioning of external consultants, NERA Economic Consulting, to review and refine previous models. An audit of the refined model was also undertaken by NERA for further quality assurance[3]. The refined modelling approach was subjected to internal review and sign-off from Defra's chief economist.

Waste composition

The landfill target relates to biodegradable municipal waste (BMW). Municipal waste consists of household waste plus commercial and industrial waste that is similar in nature and composition to household waste. The biodegradable proportion of this municipal waste is relevant to the landfill target.

New research finds that the proportion of residual municipal waste that is biodegradable is lower than previous estimates. This has a significant impact on the analysis because, for any given level of municipal waste to landfill, a smaller proportion is counted as relevant to the landfill target. Indeed, the new research implies that BMW to landfill in 2012 was already within the level required for the 2020 target. The analysis is conducted with previous estimates of biodegradable content for the purpose of comparison alongside the new estimates, to demonstrate the impact of this change. The new estimates of biodegradable content will be used going forward.

Results

The likelihood of meeting the Landfill Directive target is estimated by the proportion of simulations (out of a total of 10,000) that produce capacity at least equal to that required to meet the target of 10.16 million tonnes of BMW to landfill in 2020 in England.

The analysis concludes that there is a very wide range of possible net capacity positions in 2020. This includes outcomes in which capacity is more than sufficient to divert enough waste to meet the target and outcomes where capacity is insufficient to divert enough waste to meet the target.

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[3] See Appendix C.

Results using the previous assumptions on the biodegradable proportion of residual municipal waste are shown below. These results are included to allow comparison with the results using the new composition estimates. The results are dependent upon the ranges applied to the various factors within the analysis. These have been based on evidence and expert judgement, but cannot be known with certainty.

If the HCC project is assumed not to contribute any operational capacity by 2020:

- The proportion of simulations consistent with meeting or exceeding the 2020 diversion target is estimated to be approximately 97.5% using the ranges of inputs that we believe to be realistic.
- In this scenario, the average amount of BMW estimated to go to landfill is approximately 4.7 million tonnes.
- This means that the average level of diversion capacity is approximately 5.5 million tonnes, or 54%, above that required to meet the target.

If the HCC project is assumed to contribute operational capacity by 2020:

- This increases the proportion of simulations consistent with meeting or exceeding the 2020 diversion target, by approximately half a percentage point. This relatively small impact reflects that, using the ranges of inputs that we believe to be realistic, the proportion of simulations meeting the target is already high assuming no contribution from the HCC project.
- In this scenario, the average amount of BMW to landfill is approximately 4.4 million tonnes.
- This means that the average level of diversion capacity is approximately 5.7 million tonnes, or 56%, above that required to meet the target.

The results below use estimates from the new research on biodegradable content, which will be used going forward to report progress against the landfill target. As the new estimates imply that the levels of BMW to landfill in 2012 were already within the 2020 target, and further infrastructure is expected to come on line between now and 2020, we would expect a high likelihood of meeting the 2020 target. The results remain dependent upon the ranges applied to the various factors within the analysis. These have been based on evidence and expert judgement, but cannot be known with certainty.

If the HCC project is assumed not to contribute any operational capacity by 2020:

- The proportion of simulations consistent with meeting or exceeding the 2020 diversion target is estimated to be approximately 99.9% using the ranges of inputs that we believe to be realistic.
- In this scenario, the average amount of BMW estimated to go to landfill is approximately 3.5 million tonnes.

- This means that the average level of diversion capacity is approximately 6.6 million tonnes, or 65%, above that required to meet the target.

If the HCC project is assumed to contribute operational capacity by 2020:

- The proportion of simulations consistent with meeting or exceeding the 2020 diversion target remains at approximately 99.9%. This reflects that, using the ranges of inputs that we believe to be realistic, the proportion of simulations meeting the target is already very high assuming no contribution from the HCC project.
- In this scenario, the average amount of BMW estimated to go to landfill is approximately 3.4 million tonnes.
- This means that the average level of diversion capacity is approximately 6.8 million tonnes, or 67%, above that required to meet the target.

Table 1: Summary of Results

	HCC project contributes in full		HCC project does not contribute	
	Proportion meeting target	Average capacity above target (Mt)	Proportion meeting target	Average capacity above target (Mt)
Previous composition assumptions	97.9%	5.7	97.5%	5.5
New composition assumptions	99.9%	6.8	99.9%	6.6

Sensitivity testing

To the extent that the Monte-Carlo method incorporates ranges around key parameters, the analysis already takes account of variations in these parameters. However, the appropriate values to attach to model parameters cannot be known with certainty. As such there are a range of further tests that can be undertaken to test the sensitivity of the results to key inputs and assumptions.

Testing is applied to assess the sensitivity to changing key inputs and assumptions, including those that are not given ranges in the main analysis. These tests include assumptions that we believe to be relatively unlikely, in order to demonstrate the potential impact of such scenarios occurring. This testing finds that the model conclusions are robust to fairly large changes in key variables. The sensitivity tests produce proportions of simulations consistent with meeting the target ranging from approximately 92% in the lowest case assessed, to 100% in the highest case. The average amount of capacity above that required to meet the target ranges from approximately 3.3 million tonnes in the lowest case to 7.8 million tonnes in the highest case.

Independent forecasts

A number of independent forecasts of waste infrastructure requirements have also been produced. Although conclusions vary regarding infrastructure requirements in general, there appears to be a consensus of results showing sufficient capacity to meet the requirements of the 2020 landfill target[4].

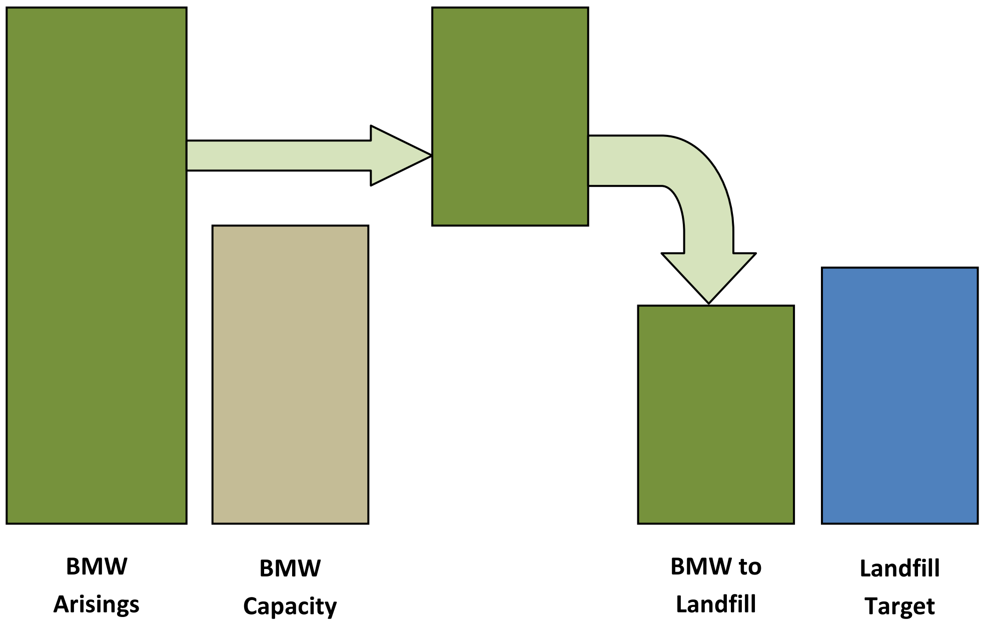
[4] See appendix B.

1 Introduction

The infrastructure capacity model forecasts waste arisings and treatment capacity in England to establish whether sufficient capacity is expected to be in place to meet the requirements of the EU Landfill Directive targets for biodegradable municipal waste[5]. The target requires that the amount of BMW sent to landfill in 2020 is reduced to 35% of 1995 levels (England's implied share of this target is to reduce BMW to landfill to 10.16 million tonnes).

Figure 1 below illustrates this process: the forecast level of residual BMW in 2020 is compared to the forecast level of residual BMW capacity in 2020; the difference between these two quantities is then compared to the Landfill Directive target.

Figure 1: Illustration of Model Process



The analysis requires forecasting future outcomes which are subject to considerable uncertainties. Future waste levels, recycling rates and infrastructure levels cannot be known for certain. There are limitations in some of the data available, such as a lack of regular data for commercial and industrial waste (C&I). Forecasting future trends is especially uncertain at the present time because it is difficult to distinguish between recessionary effects, long-run trends and policy impacts in past data. There is also inherent uncertainty in the timing and delivery of large scale infrastructure projects such as those for waste, especially following a recession.

An approach is therefore used which provides a range of possible outcomes and a likelihood of meeting the 2020 target based on these results. This approach uses

[5] See European Council (1999), Council Directive 1999/31/EC.

ranges for the various uncertain factors and applies a 'Monte-Carlo' technique[6], which runs thousands of simulations of possible outcomes to establish the possible range of outcomes from varying the uncertain factors or inputs. The ranges to apply to the inputs have been based on evidence and expert judgement, with relatively broad ranges used for more uncertain inputs.

The result is a fuller understanding of the possible impacts of uncertainty and the likelihood of meeting the 2020 target based on the parameters used in the analysis.

2 Waste arisings analysis

2.1 Arisings data[7]

Municipal waste consists of household waste plus commercial and industrial waste that is similar in nature and composition to household waste. The biodegradable proportion of this municipal waste is relevant to the landfill target.

Household waste arisings peaked in 2002-03 and have since been falling or flat over the past decade. The latest complete year of data, 2012-13, shows household arisings of 22.6 million tonnes; 12.6% lower than in 2002-03. Data for the first six months of 2013-14 shows a fall of around 1% compared to the same period in the previous year[8,9].

Regular data on commercial and industrial (C&I) waste is more difficult to obtain. The last national survey was undertaken in 2009, in which arisings were estimated to be 47.9 million tonnes. However, new estimates based on combining a number of data sources, such as the EA data interrogator, provide information up to 2012[10]. This approach yields estimated C&I arisings of 43.8 million tonnes in 2012 and appears to show a steady increase in the latest years of data.

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[6] The Monte-Carlo method is a statistical approach to modelling uncertainty.

[7] Department for Environment, Food and Rural Affairs, Waste Statistics.

[8] Note that the percentage quoted for 2013-14 relates to 'waste from households'. This measure is slightly different to 'household waste' which also includes waste from streams such as street bins and street cleaning. 'Household waste' is the measure used elsewhere in this analysis, reflecting that the landfill target relates to all biodegradable municipal waste as opposed to purely waste from households.

[9] An additional quarter of data has become available since this analysis was undertaken, for October to December 2013. Taken together with the previous data for 2013-14, this appears broadly in line with the forecast ranges described in section 2.2.1 below.

[10] Jacobs (2014), "New methodology to estimate waste generation by the commercial and industrial sector in England"

Only the municipal component[11] of C&I waste is relevant to the landfill target. Using the latest estimates for C&I waste in 2012, approximately 44% of C&I waste is estimated as municipal, equating to 19.1 million tonnes in total.

2.2 Forecast arisings

Future levels of waste arisings are uncertain and therefore a range of forecasts are used.

2.2.1 Household arisings forecast

Household waste arisings are forecast based on trends in quarterly data using a SARIMA forecasting approach[12]. This approach has the advantage of using a trend based technique specified to fit the past data as closely as possible. However, it does not explicitly distinguish the underlying drivers of arisings, such as changes in the wider economy or in attitudes to waste. Alternative approaches that control for such factors have also been considered previously. These methods proved to be less reliable for the purpose of this analysis because the precise influences of the various drivers of household waste arisings could not be reliably determined with the approaches identified. The SARIMA approach is therefore preferred as the more statistically robust approach for this analysis[13].

The SARIMA approach incorporates a range of outcomes for household arisings, including the possibilities that arisings could increase or fall. The central forecast is for household arisings to fall steadily to reach approximately 20 million tonnes per year by 2020. This is consistent with a continuation of trends observed over the past decade of data. However, a wide range of possible outcomes around this central estimate is included to reflect the uncertainties around the forecast. This range is generated using the regression outputs from the SARIMA approach. The tenth percentile, towards the lower end of the range, is 13.6 million tonnes; and the 90th percentile, towards the upper end of the range, is 26.5 million tonnes, as shown in figure 2 below. Values closest to the central estimate are given the highest probability of occurring in the analysis, with those towards the edges of the range relatively unlikely to occur.

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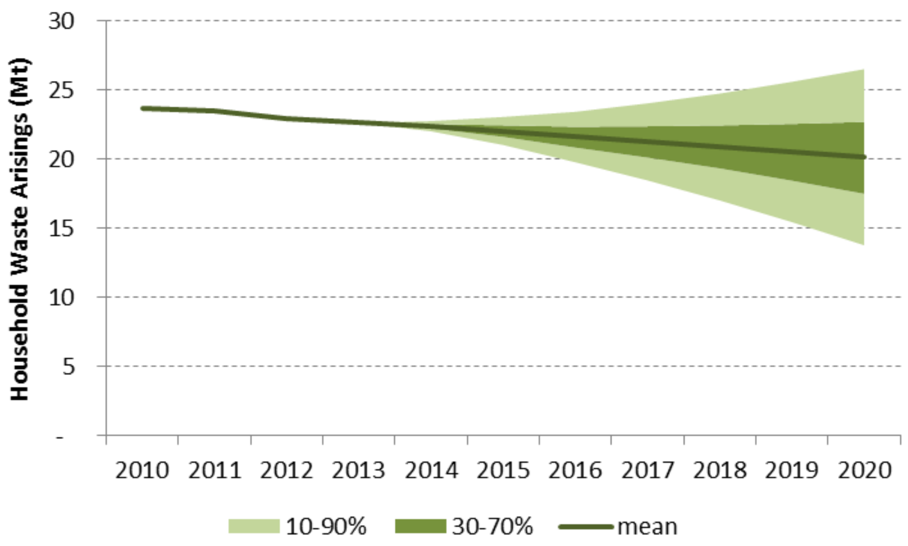
[11] The municipal component of C&I waste is defined as that which is similar in nature and composition to household waste.

[12] Seasonal Auto-Regressive Integrated Moving Average. This type of approach uses changes in past data to forecast forward.

[13] The SARIMA approach was found to be the most suitable following an independent review of forecasting methodologies. See: NERA Economic Consulting (2012), “Review of Methodology for Forecasting Waste Infrastructure Requirements”.

The central estimate for household arisings is lower than the previous forecast published in October 2013, reflecting that arisings have fallen further in the data that has since become available. However, a wider range of possible outcomes is incorporated in the current analysis, including the possibility of increasing arisings[14].

Figure 2: Household Arisings Forecast



2.2.2 Commercial and industrial arisings forecast

C&I waste is projected forward in line with economic growth in the commercial and industrial sectors, measured by gross value added (GVA)[15]. This technique is used because waste in these sectors is likely to be more directly linked to economic output and because a lack of regular data means statistical forecast techniques are not possible.

However, it is likely that the level of waste for a given level of GVA will fall over time as businesses make efficiency savings. It is assumed that these efficiency savings take a long-term trend of 1% per year. This is consistent with evidence regarding the long-run rate of efficiency savings in other sectors such as energy efficiency in

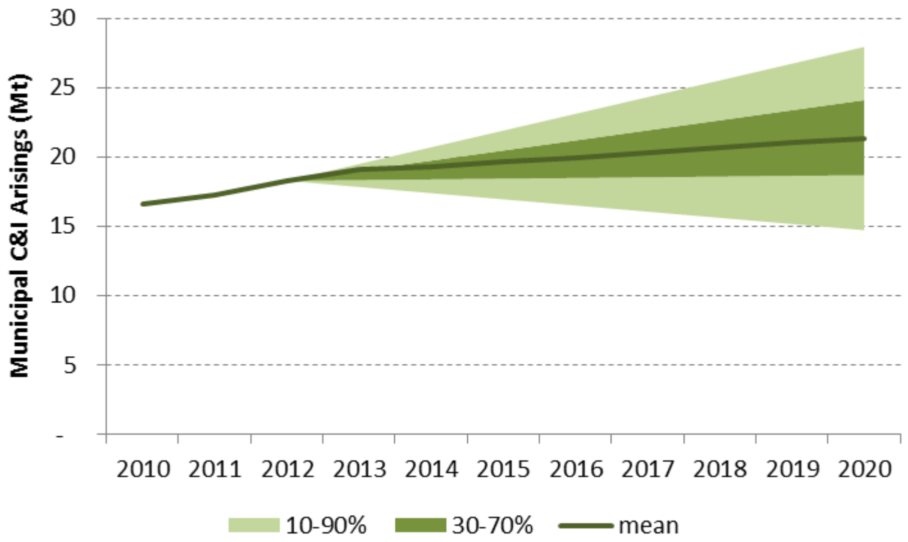
[14] The previous forecast used two alternative specifications of the SARIMA approach to provide a range of possible outcomes. In the present analysis, one specification of the SARIMA approach was found to perform best under a series of statistical tests. The possibility of alternative outcomes is incorporated by estimating a probability distribution using the SARIMA regression outputs and a 'bootstrapping' statistical technique. This allows for a wider range of outcomes overall, including the possibility of higher or lower levels of arisings than included in the previous analysis.

[15] Gross Value Added measures the total economic outputs of a sector net of the economic inputs it uses. This is similar to Gross Domestic Product (GDP) but can be used to measure growth in individual sectors rather than the economy as a whole. The GVA forecasts used are produced by Oxford Economics, with an adjustment made to ensure consistency with Office of Budget Responsibility GDP forecasts from the March 2014 "Economic and Fiscal Outlook".

OECD Europe[16] and global resource efficiency[17]. The central estimate is for steady increases in C&I arisings, to reach 48.9 million tonnes per year by 2020.

As noted in section 2.1, only the municipal component of C&I waste is relevant to the landfill target. The central estimate for municipal C&I waste is 21.4 million tonnes per year by 2020. A probability distribution is fitted around these forecasts to allow for a wide range of possible outcomes. The tenth percentile, towards the lower end of the range, is 14.7 million tonnes and the 90th percentile, towards the upper end of the range, is 27.9 million tonnes, as shown in figure 3 below. Values closest to the central estimate are given the highest probability of occurring in the analysis, with those towards the edges of the range relatively unlikely to occur.

Figure 3: Municipal Commercial & Industrial Arisings Forecast



The central forecast for total C&I waste arisings is higher than previously forecast in October 2013. This reflects the use of new arisings estimates for 2012 and that economic growth forecasts have increased. However, the estimate for the proportion of C&I waste that is municipal is lower when using the new C&I data. The net effect is that the estimate of municipal C&I arisings, of 21.4 million tonnes per year by 2020, is lower than the previous estimate of 22.9 million tonnes. However, a wider range of possible outcomes is incorporated in this analysis compared to the previous forecast in October 2013[18].

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[16] International Energy Agency (2008), "Worldwide Trends in Energy Use and Efficiency".

[17] See for example: OECD, "Resource Productivity in the G8 and the OECD"; and Krausmann, F. et al (2009), "Growth in global materials use, GDP and population during the 20th century".

[18] The previous forecast used alternative assumption on the levels of efficiency savings in waste per unit of GVA to generate a range of possible outcomes. The present analysis uses a probability distribution which allows for a wider range of outcomes. As there is insufficient past data to estimate a

2.2.3 Shocks to waste arisings

A further adjustment is made to allow for the possibility that household or C&I waste arisings patterns could potentially change from those observed in the past data. For example, a more pronounced than expected economic recovery could potentially cause waste arisings to increase compared to past trends. To reflect such an eventuality, the possibility of an upward 'shock' to household or C&I waste arisings trends is included in the analysis. The size of this shock is based on a reversal of the downward shift in waste patterns that occurred after 2002-03. A 20% upward shock is used, occurring with a probability of 20% between now and 2020. Therefore, when the upward shock occurs in the analysis, it shifts the distribution of waste arisings forecasts shown in figures 2 and 3 upwards by 20%.

2.3 Recycling

Household recycling rates have increased from 14.5% in 2002-03 to 43.2% in 2012-13[19]. However, the rate of increase has slowed in recent years. For the purpose of this analysis, a central assumption is taken that household recycling reaches 50% by 2020, in line with the Waste Framework Directive target. A range of alternative rates is included to reflect uncertainty in future recycling levels. A ten percentage point range is used, from 45% to 55%.

The C&I recycling rate was 52% in the 2009 survey, an increase of ten percentage points compared to the 42% reported in the 2003 survey[20]. C&I recycling is assumed to increase by a further ten percentage points to reach 62% in 2020, reflecting a continuation of factors which are expected to continue to reinforce existing recycling trends going forward. However, the projected recycling rate is uncertain, and the lack of regular data means there is more uncertainty in projecting the C&I recycling rate compared to the household recycling rate[21]. A range of eight percentage points either side of 62% is used.

The recycling rate ranges are the same as used in the previous analysis in October 2013.

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probability distribution statistically for C&I arisings, the distribution estimated for household arisings is applied to municipal C&I arisings.

[19] Department for Environment, Food and Rural Affairs, "Statics on waste managed by Local authorities in England in 2012/13"

[20] Department for Environment, Food and Rural Affairs, Commercial and Industrial waste generation and management statistics

[21] A robust estimate of C&I recycling is not currently available from the new C&I data estimates. This is because the ability to calculate a C&I recycling rate from the waste returns information is limited by the datasets used in the methodology. See Jacobs (2014) for further details.

2.4 Composition

The Landfill Directive targets relate to the biodegradable content of municipal waste.

All household waste is assumed to be municipal. The municipal content of C&I waste in 2012 is estimated to be approximately 44%. A range of five percentage points either side of this is assumed for the 2020 composition of C&I waste. It is assumed that the municipal proportion is equally likely to lie anywhere within this range, reflecting that a degree of volatility is possible over time. The range used is lower than in the previous analysis in October 2013 because the municipal proportion of C&I waste in the new data for 2012 is lower than that in the previous 2009 survey (44% as opposed to 52%, respectively). The width of the range is the same as used previously.

Once the total level of municipal waste is determined, it is necessary to estimate the proportion that is biodegradable and therefore relevant to the landfill target if it goes to landfill.

The majority of municipal waste to landfill, over 90%, is from two types of mixed waste streams: waste from mechanical treatments and mixed municipal waste[22]. Recent research into the composition of these waste streams estimates their biodegradable content as approximately 46% and 56%, respectively[23]. These estimates will be used for reporting progress against the landfill target going forward. Taken together, and combined with the comparatively small tonnage of more specific municipal waste types, this research implies that approximately 50% of municipal waste to landfill is currently biodegradable. For forecasting purposes, the biodegradable proportion assumed for 2020 is given a central value of 50% with a relatively narrow range of three percentage points either side of this estimate. This range is used to reflect the possibility that there could be a degree of fluctuation in the relative tonnages of the different waste codes described above over time. The same range is applied to municipal waste going to residual treatments or disposal[24].

These assumptions for biodegradable content are lower than the assumptions used in the previous forecasts in October 2013, in which a central estimate of 68% was used with a range of 55% to 75% to reflect uncertainty. The 68% estimate was

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[22] European Waste Catalogue codes 19.12.12 and 20.03.01 respectively

[23] Resource Futures, "Biodegradability of municipal solid waste" (report WR1003)

[24] In practise, it is possible the biodegradable content of waste to residual treatments could potentially be higher than waste to landfill, depending on the level of pre-treatment or sorting. A higher biodegradable content of waste going to residual treatments would imply that these facilities divert more BMW from landfill for a given tonne of waste processed. Therefore, applying the same range of composition assumptions for residual treatments as for landfill is a relatively cautious approach in terms of assessing progress against the landfill target.

based on a study undertaken in 2002[25]. The lower percentage in the new research is likely to be partially driven by a divergence in the composition of waste arisings and residual waste, reflecting the changes in collection regimes and increases in recycling rates that have occurred over the past decade. Indeed, research on changes in biodegradable content over time shows that controlling for these types of changes yields results that are consistent with a fall in the biodegradable percentage compared to the previous 68% estimate[26].

The new composition estimate has a significant impact on the analysis because, for any given level of municipal waste to landfill, a smaller proportion is counted as relevant to the landfill target. This does not change the total amount of waste going to treatment or disposal, but it nonetheless affects progress against the landfill target. Indeed, the new research implies that levels of BMW to landfill in 2012 were already within the level required for the 2020 target[27]. Whilst the new estimates will be used for the purposes of reporting progress against the landfill target going forward, both the new percentage and the previous range of assumptions are included in this analysis to allow comparison.

2.5 Correlations between inputs

There are certain inputs which are likely to be correlated. This requires controlling for in the Monte-Carlo analysis to reflect that the ranges used in the analysis may therefore be linked to one another. A correlation between two inputs implies that a high or low value of one is likely to be associated with a high or low value of another. If two variables are positively correlated they tend to move in the same direction; if they are negatively correlated they tend to move in opposite directions.

There are two correlations that are used in the analysis:

- Household and C&I arisings are assumed to have a modest positive correlation
- The household recycling rate and the C&I recycling rate are also given a modest positive correlation.

In each case the correlation coefficient used is 0.25. The correlations are applied because there may be some common drivers between each pair of inputs and there is some evidence of correlation in the past. However, the correlations in both cases are relatively low because factors specific to household waste or C&I waste mean

[25] Parfitt J. (2002) "Analysis of household waste composition and factors driving household waste increases".
[26] Resource Future, "Analysis of biodegradability of residual waste based on subtraction of diverted materials" (report 2327)
[27] Statistics on levels of BMW to landfill were published in September 2014. See: Department for Environment, Food and Rural Affairs, UK Statistics on Waste.

they will not move perfectly together. For example, changes in technologies used by businesses may affect C&I waste but not household waste.

The correlations are given fixed values rather than ranges in the analysis. This avoids introducing excessive complexity that would make assessing the fundamental waste variables, such as arisings, more difficult. However, alternative correlation assumptions are included in the sensitivity analysis in section 5.2.

2.6 Summary of waste inputs

As outlined above, forecasts are produced of various factors that affect the amount of biodegradable municipal waste. The forecasts of these factors are given ranges in the analysis to reflect the uncertainties in future trends. These inputs are summarised in table 2 below.

Table 2: Summary of Waste Inputs

Waste arisings pre-shock (Mt)	Distribution	Central	Standard deviation		Forecast Rationale
Household waste	Normal	20.0	5.0		SARIMA econometric model
C&I waste (municipal component)	Normal	21.4	5.0		Sector growth forecasts
Upward 'shocks' to arisings	**Probability**	**Size**			
Household waste	20%	20%			Past occurrences of shocks to arisings
C&I waste	20%	20%			Past occurrences of shocks to arisings
Recycling rates	**Distribution**	**Central**	**Min**	**Max**	
Household waste	Triangular	50%	45%	55%	Household recycling target
C&I waste	Triangular	62%	54%	70%	Continuation of upward trend
BMW content					
Previous BMW content of MSW	Triangular	68%	55%	75%	Wide range due to data limitations
New BMW content of MSW	Triangular	50%	47%	53%	Compositional research
MSW content					
MSW content of C&I waste	Uniform	44%	39%	49%	Modest fluctuations over time

3 Capacity analysis

Various types of infrastructure are capable of diverting biodegradable municipal waste from landfill. A database of infrastructure projects is used to forecast the total operational capacity by 2020[28]. The current project database contains details on about 100 residual waste facilities that are either operational, in construction, or in various stages of development. Since the previous analysis in October 2013 a number of projects have progressed in the development chain, from procurement through to operational start and so on.

Adjustments are made within the analysis to allow for the various stages of development that projects have reached and for differences between types of technologies.

3.1 Project level risks

A forecast is generated using data on both operational infrastructure projects and those under development. Project risk adjustments are applied to control for uncertainty over when projects are likely to come on line and how much waste they will divert from landfill.

Project risks depend upon many factors. For example, whether projects are at the commissioning stage, have achieved financial close, have planning permission and so on may all affect the likelihood of their coming on line by 2020. A 'Red-Amber-Green' (RAG) risk assessment is made for each project based on the stage of development reached, alongside any factors specific to an individual project that may affect the likelihood of delivery by 2020. In some cases a project may be assigned a lower assessment compared to that usually assigned for its stage of development because of project specific risks, in order to take a cautious approach to the analysis. Note that this does not preclude their delivery sometime after 2020. This system of risk adjustments provides a relatively cautious approach to forecasting infrastructure capacity.

A percentage is attached to each RAG rating. This delivery adjustment rate is used in the analysis to assess the likelihood of projects coming on line by 2020. The RAG assessments and percentages are based on the experience of Defra's Waste Infrastructure Delivery Programme (WIDP) and were also found to be consistent with infrastructure delivery in other comparable sectors[29]. The general approach to delivery adjustment rates for each RAG status and project type is outlined in table 3.

[28] Project data for this analysis is taken from the assumed position of projects in the WIDP database up to 29th May 2014.

[29] See NERA (2012)

Table 3: Delivery Adjustment Rates[30]

	PFI	PPP	Merchant	Project Status
B	100%	100%	100%	Fully operational
G	90%	90%	90%	Commissioning
AG	80%	80%	80%	Financial close, with planning
A	70%	70%	40%	Financial close, no planning
AR	60%	60%	20%	In procurement, no planning
R	20%	20%	3%	Unlikely to go live by 2020
n/a	0%	0%	0%	Cancelled Project

3.2 Programme level risk

In addition to the project level risk adjustments, a programme level risk factor is also used. This adjustment is made to account for the possibility of unforeseen events that could reduce the amount of capacity delivered across all projects. The rationale is therefore similar to the upward 'shocks' that are modelled for waste arisings; both can be thought of as a contingency against unknown and unpredicted events. The adjustment is applied to reflect any such risks to operational projects, or to those in development, and allows for the possibility that risks could potentially be correlated across projects. The programme risk factor reduces total capacity, to between 90% and 100% of the capacity that is assumed to be delivered by the model. The adjustment is assumed to be equally likely to take any level within this range.

3.3 Technology specific input adjustments

There are three types of technology specific input adjustments that are used in the analysis:

- Utilisation rates – this accounts for the possibility that projects deliver less than their headline capacity when operational. For example, where permitted throughput of waste feedstock is reported rather than actual throughput (since the latter can be significantly less than the former).
- Diversion efficiency – this describes the proportion of biodegradable waste going to a facility that is diverted from going to landfill. This is generally less than 100% (except in the case of EfW) because some residue waste still goes to landfill and/or the biodegradable reduction is not complete.

[30] PFI = Private Finance Initiative; PPP = Public Private Partnership; Merchant refers to facilities that are financed without a long-term government anchor contract for municipal waste in place.

- Tonnes to EfW – this describes the proportion of waste derived from mechanical biological treatment processing (fuel fraction) that is passed on to an EfW facility.

Ranges are generally applied to these inputs to reflect uncertainty (see table 4 below).

Ranges are not uniformly applied to all project types because of the nature of the technologies in question. For example, for EfW projects, all biodegradable waste is diverted from landfill (diversion efficiency of 100%) and all the waste goes to EfW (tonnes to EfW of 100%). Mechanical treatment projects are given a diversion efficiency of 0% because, unless accompanied by a secondary treatment, these types of plants do not tend to divert waste from landfill. Tonnes to EfW are assumed to be 0% for landfill mechanical biological treatment projects because these types of plants send waste to landfill rather than EfW.

The utilisation rate is assumed to be higher for EfW compared to other technologies, centred at 100%. This is because the information used is already based on actual throughput levels. For this reason a smaller range is used, with the possibility that throughput could be higher or lower than previous levels.

3.4 National approach

The analysis is undertaken at the national level for England in order to monitor progress against national targets. A market clearing assumption is used such that, subject to the various adjustments described above, it is assumed that the available capacity will be utilised to divert waste otherwise going to landfill.

The implication of this market clearing assumption is that if, for example, an operational facility could not obtain sufficient waste feedstock from a local authority to operate profitability, it may attract waste from a neighbouring authority or from C&I streams. In practise there may be costs that limit waste movements to some extent. However, there are several examples of feedstock moving between regions, demonstrating that this can be a cost effective option and that the market clearing assumption appears reasonable in the current market. Indeed, the bulk of residual waste treatment facilities are energy from waste facilities and to date these almost always operate at the designated full (operational) capacity. The effect of relaxing the market clearing assumption is assessed in the sensitivity analysis in section 5.7.

3.5 Exports

The likely levels of waste requiring treatment or disposal domestically will be affected by exports of refuse derived fuels (RDF) to abroad. Whilst exports have historically been very low, levels have increased in recent years to reach approximately 1 million tonnes of RDF exported in 2012 and this upward trend appears to have continued in 2013[31].

The future availability of these export routes will depend upon changes in the waste market across Europe, which is very difficult to forecast reliably. It is assumed that exports per year by 2020 are equally likely to take any value in the range of 0 to 2 million tonnes. This is a relatively cautious approach given the significant increases in recent export data.

3.6 Summary of capacity inputs

Table 4: Summary of Capacity Inputs[32]

Utilisation Rates	Distribution	Central	Minimum	Maximum
BMBT	Triangular	80%	75%	100%
EfW	Triangular	100%	90%	105%
LFMBT	Triangular	80%	75%	100%
MT	Triangular	80%	75%	100%
Diversion Efficiency				
BMBT	Triangular	85%	70%	90%
EfW	n/a	100%	100%	100%
LFMBT	Triangular	77%	50%	90%
MT	n/a	0%	0%	0%
Tonnes to EfW		Central	Minimum	Maximum
BMBT to EfW	Triangular	50%	40%	60%
EfW to EfW	n/a	100%	100%	100%
LFMBT to EfW	n/a	0%	0%	0%
MT to EfW	Triangular	85%	70%	90%
Programme level risk				
% of capacity online	Uniform	95%	90%	100%
Exports (Mt)				
MSW exported abroad	Uniform	1	0	2

[31] Environment Agency data. The figure quoted is exports from England and Wales.
[32] BMBT= bio-treatment mechanical biological treatment; EfW = energy from waste; LFMBT = Landfill mechanical biological treatment; MT = mechanical treatment.

Delivery Adjustment Rates	PFI	PPP	Merchant	Project Status
B	100%	100%	100%	Fully operational
G	90%	90%	90%	Commissioning
AG	80%	80%	80%	Financial close, with planning
A	70%	70%	40%	Financial close, no planning
AR	60%	60%	20%	In procurement, no planning
R	20%	20%	3%	Unlikely to go live by 2020
n/a	0%	0%	0%	Cancelled Project

4 Results

Using the method and parameters outlined, the likelihood of meeting the Landfill Directive target in 2020 is determined by the proportion of simulations (out of a total of 10,000) that produce treatment capacity above that required to meet the target.

There is a very wide range of possible net capacity positions in 2020. This includes positions where capacity is more than sufficient to divert enough waste to meet the target; and positions where capacity is insufficient to divert enough waste to meet the target.

The analysis is run either assuming the HCC project definitely does not contribute any operational capacity by 2020, or assuming that the HCC project definitely does contribute capacity by 2020. This allows comparison of the maximum potential impact of the HCC project on the likelihood of meeting the target (with other input assumptions unchanged).

The analysis is conducted twice to demonstrate the impact of the change in the assumptions used on the proportion of municipal waste that is biodegradable[33]. The results are dependent upon the ranges applied to the various factors within the analysis. These have been based on evidence and expert judgement, but cannot be known with certainty.

4.1 Results using previous composition assumptions

The analysis is first conducted using the previous assumptions on waste composition, with a range around a central assumption of 68%.

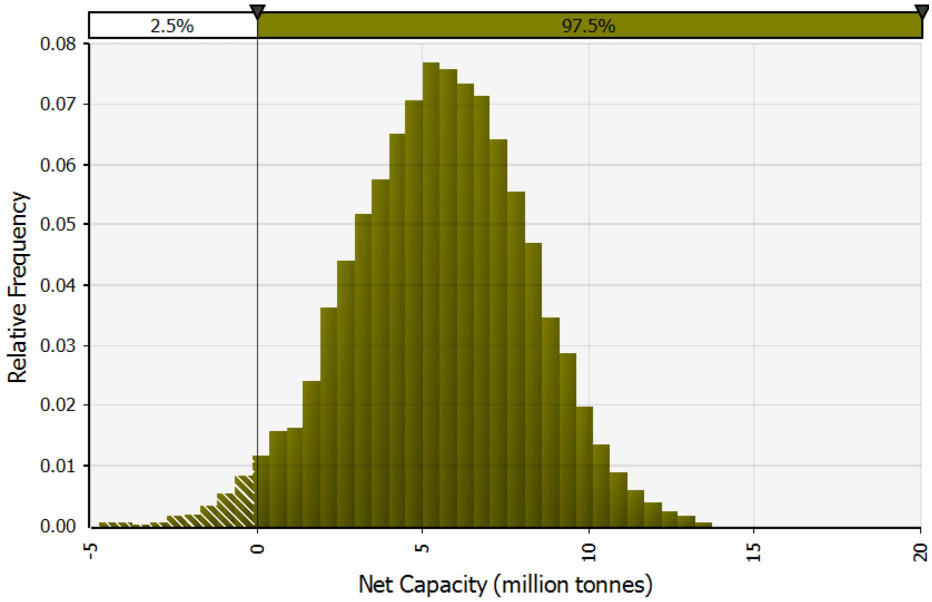
If the HCC project is assumed not to contribute any operational capacity by 2020, the proportion of simulations consistent with meeting or exceeding the 2020 diversion target is estimated to be approximately 97.5% using the ranges of inputs that we believe to be realistic. In this scenario, the average amount of BMW estimated to go to landfill is approximately 4.7 million tonnes. This means that the average level of diversion capacity is approximately 5.5 million tonnes, or 54%, above that required to meet the target.

This result is demonstrated in figure 4 below. The net capacities towards the centre of the distribution are most likely to occur, while those outcomes at either end are relatively unlikely but possible. Of all predicted outcomes, approximately 97.5% are above zero, representing more than enough capacity to meet the target. The vertical-

[33] See appendix A for further detailed forecast results.

axis can be interpreted as the percentage likelihood (0.01 = 1%) of a specific net capacity value (horizontal-axis) occurring.

Figure 4: Range of Net Capacity Results Using Previous Composition Assumptions and Assuming No Contribution from HCC Project



If the HCC project is assumed to contribute operational capacity by 2020, this increases the proportion of simulations consistent with meeting or exceeding the 2020 diversion target, by approximately half a percentage point. This relatively small impact reflects that the proportion of simulations meeting the target is already high assuming no contribution from the HCC project. In this scenario, the average amount of BMW to landfill is approximately 4.4 million tonnes. This means that the average level of diversion capacity is approximately 5.7 million tonnes, or 56%, above that required to meet the target.

Table 5: Summary of Results Using Previous Composition Assumptions

Scenario	Proportion Meeting Target	Average Capacity Above Target (Mt)
No contribution from HCC project	97.5%	5.5
Full contribution from HCC project	97.9%	5.7

The results show a higher proportion of simulations meeting the 2020 target than the previous analysis published in October 2013, when the estimate was 95%. This is driven by a combination of factors including progress in infrastructure projects since the previous forecast and increases in exports of waste. The changes to waste arisings forecasts reduce the average level of arisings and therefore increase the average capacity above that required to meet the target. However, the wider ranges applied to waste arisings largely offsets the effect on the proportion of simulations meeting the target because the analysis also includes more simulations with higher levels of waste arisings than previously.

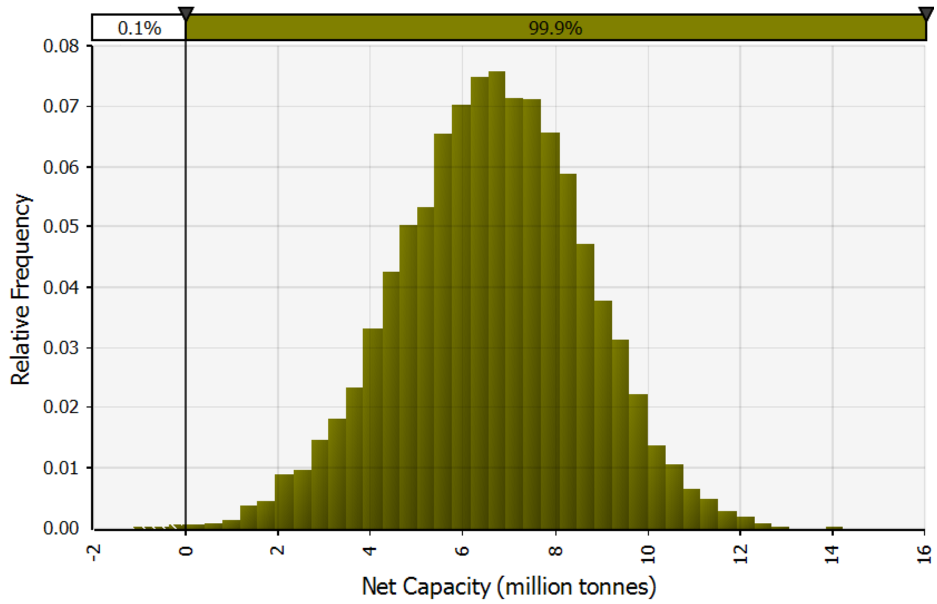
4.2 Results using new composition assumptions

The analysis is conducted a second time using the new assumptions on waste composition, with a range around a central assumption of 50% to reflect the new research discussed in section 2.4, which will be used for reporting against the landfill targets going forward.

As expected, it can be seen that incorporating the new estimate of the biodegradable proportion of municipal waste increases the proportion of simulations meeting the 2020 target.

If the HCC project is assumed not to contribute any operational capacity by 2020, the proportion of simulations consistent with meeting or exceeding the 2020 target is estimated to be approximately 99.9% using the ranges of inputs that we believe to be realistic. In this scenario, the average amount of BMW estimated to go to landfill is approximately 3.5 million tonnes. This means that the average level of diversion capacity is approximately 6.6 million tonnes, or 65%, above that required to meet the target.

Figure 5: Range of Net Capacity Results Using New Composition Assumptions and Assuming No Contribution from HCC Project



If the HCC project is assumed to contribute operational capacity by 2020, the proportion of simulations consistent with meeting or exceeding the 2020 diversion target remains at approximately 99.9%. This reflects that the proportion of simulations meeting the target is already very high assuming no contribution from the HCC project. In this scenario, the average amount of BMW estimated to go to landfill is approximately 3.4 million tonnes. This means that the average level of diversion capacity is approximately 6.8 million tonnes, or 67%, above that required to meet the target.

Table 6: Summary of Results Using New Composition Assumptions

Scenario	Proportion Meeting Target	Average Capacity Above Target (Mt)
No contribution from HCC project	99.9%	6.6
Full contribution from HCC project	99.9%	6.8

5 Sensitivity analysis

Whilst the Monte-Carlo analysis already incorporates uncertainty by applying ranges to key parameters, further testing is undertaken to outline the sensitivity of the results to alternative assumptions or approaches.

In various ways, these sensitivity tests assess the extent to which the results change when the inputs, or forecasting methods, vary from the assumptions used in the main analysis. The sensitivity testing also includes inputs that are given a single value rather than ranges in the analysis. The following inputs and sensitivities are tested:

1. Sensitivity to an alternative forecasting approach.
2. Sensitivity to correlations.
3. Sensitivity to waste arisings.
4. Sensitivity to recycling rates.
5. Sensitivity to project level risk adjustments.
6. Sensitivity to the programme level risk adjustment.
7. Sensitivity to regional capacity constraints.
8. Sensitivity to exports.

5.1 Alternative forecasting approach

An alternative method to forecasting net capacity in 2020 was considered. The approach in the main analysis is to forecast the level of waste arisings in 2020 and the level of available capacity in 2020. The two are then compared to derive an expected net capacity and the level of waste to landfill. By contrast, the alternative methodology takes as a starting point the latest available data on waste sent to landfill. It then adds on the expected change in arisings based on the household and C&I projections and subtracts the expected change in diversion capacity. This is carried forward to 2020 to estimate an alternative expected capacity position.

The alternative forecasting approach yields a slightly lower proportion of simulations meeting the target, as detailed in table 7. The average level of capacity above that required to meet the target is also slightly lower under the alternative method.

Table 7: Sensitivity to Alternative Modelling Approach

	HCC project contributes in full		HCC project does not contribute	
	Proportion meeting target	Average capacity above target (Mt)	Proportion meeting target	Average capacity above target (Mt)
Results using previous composition assumptions				
Main Analysis	97.9%	5.7	97.5%	5.5
Alternative Method	95.5%	4.6	94.7%	4.3
Results using new composition assumptions				
Main Analysis	99.9%	6.8	99.9%	6.6
Alternative Method	99.8%	5.8	99.7%	5.7

Whilst the alternative approach has the advantage of making use of the latest landfill returns data, the use of one year of data will not capture annual fluctuations. Hence the alternative approach places reliance on information from one year of data which may not be representative of future years. In addition, landfill returns data will typically reflect the average capacity over the course of a year, rather than the total capacity available at the end of that year. Hence additional infrastructure that becomes operational over the course of a year may not be fully reflected. In this respect the alternative method is likely to slightly underestimate operational capacity. For these reasons, the standard approach is preferred. The alternative approach nonetheless provides a useful comparison and a check against the latest waste to landfill data[34].

5.2 Input correlations

The correlations between inputs are difficult to know with certainty; hence, the sensitivity of the results to these assumptions is tested. There are two correlations that are used in the main analysis:

- Household and C&I arisings are assumed to have a modest positive correlation.
- The household recycling rate and the C&I recycling rate are also given a modest positive correlation.

[34] Further discussion of the relative merits of the standard and alternative approaches is outlined in the methodology review undertaken by NERA Economic Consulting. See NERA (2012).

Alternative correlation assumptions are tested. This includes both alternative values for the two correlations already described and the addition of other possible correlations.

It is possible that household arisings could be correlated with the household recycling rate, as they may have common drivers. Similarly, it is possible that C&I arisings could be correlated with the C&I recycling rate. For example, policy initiatives may simultaneously cause waste arisings to fall while causing recycling to increase. On the other hand, it does not seem clear that an increase in waste arisings should necessarily be associated with a fall in the recycling rate, since recycling capacity is flexible (at least within reasonable variations). No correlation has been assumed, but this assumption is tested for sensitivity.

There may also be a correlation between arisings and project delivery if, for example, increases in waste arisings are associated with an increased likelihood of infrastructure coming on line. This suggests a possible positive correlation. However, it would likely take a significant and sustained change in arisings for a correlation to occur, with large time lags for capacity to respond (due to long lead-in times). Therefore, whilst a correlation could be possible in the long-term, this is unlikely over the time period under consideration (i.e., to 2020). No correlation has been assumed, but this assumption is tested for sensitivity.

Finally, there may be a correlation between the delivery of individual projects; for example, if some common factor simultaneously increases the probability of delivery for multiple projects. This suggests a possible positive correlation. The assumption is that there is unlikely to be a significant correlation between individual projects since the key factors determining delivery (securing financial assistance, obtaining a contract, etc.) are determined largely by factors specific to each project. Furthermore, competition between projects might offset any positive correlation impacts. No correlation has been assumed, but this assumption is tested for sensitivity.

Therefore, there are six possible correlations that are tested: (1) household and C&I arisings; (2) household and C&I recycling rates; (3) household arisings and household recycling rates; (4) C&I arisings and C&I recycling rates; (5) arisings and project delivery; and (6) between individual projects.

An increase in correlations (1) and (2) causes a decrease in the proportion of simulations meeting the target. A positive correlation for (3) and (4) causes an increase in the proportion of simulations meeting the target and a negative correlation reduces the proportion. A positive correlation for (5) and (6) causes an increase in the proportion of simulations meeting the target. Table 8 outlines possible high and low cases, based on varying the correlation inputs. Table 9 shows the proportion of simulations meeting the target under these scenarios, compared to the main analysis.

Table 8: Correlations Input Cases

Correlations	Main Analysis	Low Case	High Case
Household Arisings and C&I Arisings	0.25	0.50	0.00
Household Recycling and C&I Recycling	0.25	0.50	0.00
Household Arising and Recycling	0.00	-0.25	0.25
C&I Arising and C&I Recycling	0.00	-0.25	0.25
Arisings and Project Delivery	0.00	0.00	0.20
Between Different Projects	0.00	0.00	0.20

Table 9: Sensitivity to Correlation Inputs

	HCC project contributes in full		HCC project does not contribute	
	Proportion meeting target	Average capacity above target (Mt)	Proportion meeting target	Average capacity above target (Mt)
Results using previous composition assumptions				
Main Analysis	97.9%	5.7	97.5%	5.5
Low Case	97.4%	5.7	96.9%	5.4
High Case	98.9%	5.8	98.7%	5.5
Results using new composition assumptions				
Main Analysis	99.9%	6.8	99.9%	6.6
Low Case	99.9%	6.8	99.9%	6.6
High Case	100.0%	6.8	100.0%	6.6

Using the previous composition assumptions, correlations in the low case slightly decrease the proportion of simulations meeting the 2020 target compared to the main analysis and correlations in the high case slightly increase the proportion of simulations meeting the 2020 target. However, overall the results show little sensitivity to changes in the correlation inputs, especially when the new composition assumptions are used. This suggests the analysis is not especially sensitive to even large deviations in these correlations.

5.3 Waste arisings

Two sensitivity tests are applied for waste arisings:

1. Sensitivity to higher waste arisings.
2. Sensitivity to upwards shocks to waste arisings.

In order to test the sensitivity of the results, higher arisings levels are entered as fixed values rather than the ranges of the values used in the main analysis. The results are estimated when it is assumed that household arisings reach the 90th percentile of the assumed range (26.5 Mt) with certainty. The possibility of 'upward shocks' to this level is also included. Therefore household arisings reach a high level (26.5 Mt or higher) with 100% probability rather than the range of possible outcomes that is assumed in the main analysis. The same test is conducted for municipal C&I arisings (using the 90th percentile of the range from the main analysis of 27.9 Mt).

Table 10 shows the results of these tests in comparison to the range used in the main analysis. The results show a degree of sensitivity; however, the possibility of such an outcome is already included within the ranges used in the main analysis, albeit at a lower probability.

Table 10: Sensitivity to Higher Arisings

	HCC project contributes in full		HCC project does not contribute	
	Proportion meeting target	Average capacity above target (Mt)	Proportion meeting target	Average capacity above target (Mt)
Results using previous composition assumptions				
Main Analysis	97.9%	5.7	97.5%	5.5
Higher household arisings	96.4%	3.6	95.4%	3.3
Higher C&I arisings	96.4%	4.0	95.7%	3.8
Results using new composition assumptions				
Main Analysis	99.9%	6.8	99.9%	6.6
Higher household arisings	99.9%	5.1	99.9%	5.0
Higher C&I arisings	99.9%	5.5	99.9%	5.3

In addition to the waste arisings forecast ranges, the possibility of upward 'shocks' to waste arisings are included in the analysis. The main analysis includes a 20% chance of a 20% increase to both household and C&I arisings in 2020. This size of shock is based on a reversal of the observed fall in arisings after 2002-03[35]. The sensitivity of the results to this shock assumption is tested by varying the probability of the shock from 10% to 30%. Table 11 shows the results under three cases: 20% (as in the main analysis), 10% and 30%.

[35] Department for Environment, Food and Rural Affairs, Waste statistics.

The results show a degree of sensitivity to this input parameter. However, the analysis already takes a conservative approach by assuming an asymmetric (i.e., only upward) shock.

Table 11: Sensitivity to Shocks to Waste Arisings

	HCC project contributes in full		HCC project does not contribute	
	Proportion meeting target	Average capacity above target (Mt)	Proportion meeting target	Average capacity above target (Mt)
Results using previous composition assumptions				
Main Analysis	97.9%	5.7	97.5%	5.5
10% probability of shock	98.6%	6.0	98.3%	5.7
30% probability of shock	97.3%	5.5	96.8%	5.3
Results using new composition assumptions				
Main Analysis	99.9%	6.8	99.9%	6.6
10% probability of shock	100.0%	7.0	100.0%	6.8
30% probability of shock	99.9%	6.6	99.9%	6.4

5.4 Recycling rates

Recycling rates have increased historically and further increases are assumed in the main analysis. The central assumptions are a household recycling rate of 50% and a C&I recycling rate of 62% in 2020. Relatively broad ranges are applied around these rates to incorporate uncertainty. However, the sensitivity of the results to lower than expected recycling rates is tested.

In order to test the sensitivity, the results are estimated when it is assumed that there is no progress in recycling rates. Hence the household recycling rate remains unchanged from the last observed annual data (43.2% in 2012-13). The same test is conducted for the C&I recycling rate (for which the latest observed data is 52% in 2009).

Table 12 shows the results of these tests in comparison to the ranges used in the main analysis. The results show a degree of sensitivity to these changes, particularly to the C&I recycling rate. However, these scenarios are considered relatively extreme cases since the long term trend for recycling has been upwards. This is especially true in the test for the C&I recycling rate given the rate used is from 2009 and significant progress has been observed in other recycling rates since then.

Table 12: Sensitivity to No Progress in Recycling Rates

	HCC project contributes in full		HCC project does not contribute	
	Proportion meeting target	Average capacity above target (Mt)	Proportion meeting target	Average capacity above target (Mt)
Results using previous composition assumptions				
Main Analysis	97.9%	5.7	97.5%	5.5
Household recycling rate of 43.2%	95.0%	4.8	94.3%	4.6
C&I recycling rate of 52%	93.0%	4.3	91.8%	4.1
Results using new composition assumptions				
Main Analysis	99.9%	6.8	99.9%	6.6
Household recycling rate of 43.2%	99.6%	6.1	99.5%	5.9
C&I recycling rate of 52%	99.4%	5.7	99.3%	5.5

5.5 Project level risk

The probability of an individual project delivering capacity is determined by its 'Red-Amber-Green' (RAG) status as described in section 3.1. To test the sensitivity to lower levels of infrastructure compared to the main results, the analysis is conducted only counting capacity from those projects that have achieved a blue or green rating. These project are either fully operational or are in construction/commissioning. All other projects are then assigned 0% probability of delivery capacity by 2020 to test the impact of a using a very conservative infrastructure forecast.

The results demonstrate some sensitivity to this test, but remain relatively high even with these extremely cautious assumptions for infrastructure capacity.

Table 13: Delivery Adjustment Rates – Project Level Risk Test

Delivery Adjustment Rates				
low case	PFI	PPP	Merchant	Project Status
B	100%	100%	100%	Fully operational
G	90%	90%	90%	Commissioning
AG	0%	0%	0%	Financial close, with planning
A	0%	0%	0%	Financial close, no planning
AR	0%	0%	0%	In procurement, no planning
R	0%	0%	0%	Unlikely to go live by 2020
n/a	0%	0%	0%	Cancelled Project

Table 14: Sensitivity to Project Level Risk

	HCC project contributes in full		HCC project does not contribute	
	Proportion meeting target	Average capacity above target (Mt)	Proportion meeting target	Average capacity above target (Mt)
Results using previous composition assumptions				
Main Analysis	97.9%	5.7	97.5%	5.5
Low Case	95.7%	4.8	95.0%	4.6
Results using new composition assumptions				
Main Analysis	99.9%	6.8	99.9%	6.6
Low Case	99.8%	6.1	99.8%	5.9

5.6 Programme level risk

The sensitivity of the results to the programme level risk parameter is tested by performing analysis with this parameter set to fixed values (rather than the range of 90% to 100% used in the main analysis). The parameter is set to a fixed value of 100% (meaning no programme level risk adjustment) and set to a fixed value of 80% (meaning a higher risk adjustment). Table 15 below summarises the results from this test.

The results show a degree of sensitivity to this test. However, the inclusion of a programme level risk adjustment in the main analysis already reflects a cautious approach.

Table 15: Sensitivity to Programme Level Risk

	HCC project contributes in full		HCC project does not contribute	
	Proportion meeting target	Average capacity above target (Mt)	Proportion meeting target	Average capacity above target (Mt)
Results using previous composition assumptions				
Main Analysis	97.9%	5.7	97.5%	5.5
Low Case (80%)	95.1%	4.6	94.3%	4.4
High Case (100%)	98.5%	6.1	98.2%	5.9
Results using new composition assumptions				
Main Analysis	99.9%	6.8	99.9%	6.6
Low Case (80%)	99.7%	5.9	99.7%	5.8
High Case	100.0%	7.1	99.9%	6.9

(100%)

5.7 Regional capacity constraints

The main analysis employs a market clearing assumption such that if spare capacity were to arise in one area, it is assumed that waste feedstock would be sought out from an alternative source to utilise the spare capacity.

To test the sensitivity of the analysis to this assumption, the utilisation rates of infrastructure facilities are adjusted downward by ten percentage points compared to the central assumptions in the main analysis. This reflects a scenario under which waste feedstock is less able to move between regions and this results in available capacity being underused.

Table 16: Utilisation Rates in Regional Capacity Constraints Test

Utilisation Rates	
BMBT Utilisation	70%
EfW Utilisation	90%
LFMBT Utilisation	70%
MT Utilisation	70%

Table 17: Sensitivity to Regional Capacity Constraints

	HCC project contributes in full		HCC project does not contribute	
	Proportion meeting target	Average capacity above target (Mt)	Proportion meeting target	Average capacity above target (Mt)
Results using previous composition assumptions				
Main Analysis	97.9%	5.7	97.5%	5.5
Lower Utilisation	96.6%	5.1	95.9%	4.8
Results using new composition assumptions				
Main Analysis	99.9%	6.8	99.9%	6.6
Lower Utilisation	99.8%	6.3	99.8%	6.1

Whilst the main analysis includes the possibility of lower than average utilisation levels within the ranges of assumptions used, the sensitivity test undertaken shows the results are not especially sensitive to lower utilisation assumptions which could be implied by regional capacity constraints.

5.8 Exports

Table 18: Sensitivity to Exports

	HCC project contributes in full		HCC project does not contribute	
	Proportion meeting target	Average capacity above target (Mt)	Proportion meeting target	Average capacity above target (Mt)
Results using previous composition assumptions				
Main Analysis	97.9%	5.7	97.5%	5.5
No exports	96.7%	5.1	96.1%	4.8
Exports of 3 Mt	99.3%	7.0	99.2%	6.8
Results using new composition assumptions				
Main Analysis	99.9%	6.8	99.9%	6.6
No exports	99.9%	6.3	99.8%	6.1
Exports of 3 Mt	100.0%	7.8	100.0%	7.6

The main analysis assumes that exports of refuse derived fuel (RDF) range between 0 and 2 million tonnes per year by 2020.

Given significant increases in exports of RDF in recent years, the sensitivity to this assumption is tested. The possibility of exports increasing to a fixed value of 3 million tonnes is tested. The possibility of exports reducing to negligible levels is also explored.

The results demonstrate some sensitivity to this test, but remain relatively high in all cases.

5.9 Summary of sensitivity analysis

Results from the sensitivity analysis are summarised in table 19 below. The testing finds that the results are robust to fairly large changes in key variables. The sensitivity tests produce proportions of simulations consistent with meeting the target ranging from approximately 92% in the lowest case assessed, to 100% in the highest case. The average amount of capacity above that required to meet the target ranges from approximately 3.3 million tonnes in the lowest case to 7.8 million tonnes in the highest case. The results with the new composition assumptions demonstrate relatively little sensitivity as a result of the proportion of simulations meeting the target being higher in this case.

Table 19: Summary of Sensitivity Analysis

Results using previous composition assumptions		HCC project contributes in full: Proportion meeting target	HCC project contributes in full: Average capacity above target (Mt)	HCC project does not contribute: Proportion meeting target	HCC project does not contribute: Average capacity above target (Mt)
Main Analysis		97.9%	5.7	97.5%	5.5
Alternative forecasting approach					
	Alternative Method	95.5%	4.6	94.7%	4.3
Correlations					
	Low Case	97.4%	5.7	96.9%	5.4
	High Case	98.9%	5.8	98.7%	5.5
Higher waste arisings					
	Higher household arisings	96.4%	3.6	95.4%	3.3
	Higher C&I arisings	96.4%	4.0	95.7%	3.8
Shocks to waste arisings					
	10% probability of shock	98.6%	6.0	98.3%	5.7
	30% probability of shock	97.3%	5.5	96.8%	5.3
Recycling Rates					
	Household recycling 43.2%	95.0%	4.8	94.3%	4.6
	C&I recycling 52%	93.0%	4.3	91.8%	4.1
Project level risk adjustments					
	Low Case	95.7%	4.8	95.0%	4.6
Programme level risk adjustment					
	Low Case	95.1%	4.6	94.3%	4.4
	High Case	98.5%	6.1	98.2%	5.9
Regional Capacity Constraints					
	Low Case	96.6%	5.1	95.9%	4.8
Exports					
	Low Case	96.7%	5.1	96.1%	4.8
	High Case	99.3%	7.0	99.2%	6.8

Results using new composition assumptions	HCC project contributes in full		HCC project does not contribute	
	Proportion meeting target	Average capacity above target (Mt)	Proportion meeting target	Average capacity above target (Mt)
Main Analysis	99.9%	6.8	99.9%	6.6
Alternative forecasting approach				
Alternative Method	99.8%	5.8	99.7%	5.7
Correlations				
Low Case	99.9%	6.8	99.9%	6.6
High Case	100.0%	6.8	100.0%	6.6
Higher waste arisings				
Higher household arisings	99.9%	5.1	99.9%	5.0
Higher C&I arisings	99.9%	5.5	99.9%	5.3
Shocks to waste arisings				
10% probability of shock	100.0%	7.0	100.0%	6.8
30% probability of shock	99.9%	6.6	99.9%	6.4
Recycling Rates				
Household recycling 43.2%	99.6%	6.1	99.5%	5.9
C&I recycling 52%	99.4%	5.7	99.3%	5.5
Project level risk adjustments				
Low Case	99.8%	6.1	99.8%	5.9
Programme level risk adjustment				
Low Case	99.7%	5.9	99.7%	5.8
High Case	100.0%	7.1	99.9%	6.9
Regional Capacity Constraints				
Low Case	99.8%	6.3	99.8%	6.1
Exports				
Low Case	99.9%	6.3	99.8%	6.1
High Case	100.0%	7.8	100.0%	7.6

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Appendix A: Detailed forecast results

Table A1: Detailed Forecast Results[36]

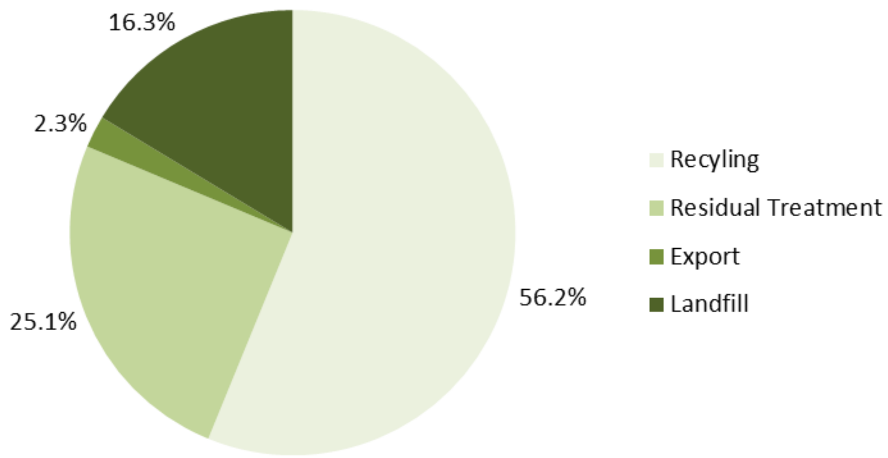
Using previous composition assumptions (Mt)	Mean	90th Percentile	10th Percentile
Assuming no contribution from HCC project			
Waste Arising MSW	43.1	54.3	32.1
Waste Recycled MSW	24.2	30.7	18.0
Residual MSW	18.9	24.0	13.9
Residual BMW	12.5	16.0	9.1
Diversion Capacity for BMW	7.1	8.0	6.3
Export of BMW	0.7	1.2	0.1
BMW to Landfill (Target = 10.2)	4.7	8.1	1.3
Capacity above target	5.5	8.9	2.0
Assuming full contribution from HCC project			
Waste Arising MSW	43.1	54.3	32.1
Waste Recycled MSW	24.2	30.7	18.0
Residual MSW	18.9	24.0	13.9
Residual BMW	12.5	16.0	9.1
Diversion Capacity for BMW	7.4	8.2	6.5
Export of BMW	0.7	1.2	0.1
BMW to Landfill (Target = 10.2)	4.4	7.9	1.0
Capacity above target	5.7	9.1	2.3
Using new composition assumptions (Mt)	Mean	90th Percentile	10th Percentile
Assuming no contribution from HCC project			
Waste Arising MSW	43.1	54.3	32.1
Waste Recycled MSW	24.2	30.7	18.0
Residual MSW	18.9	24.0	13.9
Residual BMW	9.4	12.0	6.9
Diversion Capacity for BMW	5.4	5.9	4.9
Export of BMW	0.5	0.9	0.1
BMW to Landfill (Target = 10.2)	3.5	6.1	1.0
Capacity above target	6.6	9.2	4.0
Assuming full contribution from HCC project			
Waste Arising MSW	43.1	54.3	32.1
Waste Recycled MSW	24.2	30.7	18.0
Residual MSW	18.9	24.0	13.9
Residual BMW	9.4	12.0	6.9
Diversion Capacity for BMW	5.6	6.1	5.1
Export of BMW	0.5	0.9	0.1
BMW to Landfill (Target = 10.2)	3.4	6.0	0.8
Capacity above target	6.8	9.4	4.2

[36] Figures may not sum due to rounding and asymmetry in some of the probabilistic distributions.

Table A1 above outlines detailed forecast outputs. The mean results represent the central outcome, the 10th percentiles are towards the lower end of the results ranges, and the 90th percentiles are towards the upper end of the results ranges.

Figure A1 below demonstrates the distribution of total municipal waste under the average forecast results for 2020. This includes household waste plus commercial and industrial waste that is similar in nature and composition to household waste. The figure includes all municipal waste, rather than the biodegradable proportion which is the main focus elsewhere in the analysis. The figure is shown assuming no contribution from the HCC project. Assuming a full contribution would reduce the proportion to landfill by approximately one percentage point.

Figure A1: Summary of Average Results for Total Municipal Waste



Appendix B: Summary of independent forecasts

This appendix provides a brief summary of a number of independent forecasts assessing future waste levels or infrastructure requirements. The scope and results of the forecasts vary, reflecting the inherent uncertainties in any forecast analysis. Conclusions vary on infrastructure requirements in general, with some analyses highlighting demand for additional capacity, whereas one analysis forecasts potential overcapacity. Nonetheless, there appears to be a consensus of results showing sufficient capacity to meet the requirements of the 2020 landfill diversion target.

Ricardo-AEA report for Chartered Institute of Wastes Management (2013) – commercial and industrial waste in the UK and Republic of Ireland

The report for the Chartered Institute of Wastes Management (CIWM) focuses primarily on commercial and industrial waste but also includes an analysis of waste infrastructure requirements more broadly.

The report forecasts the following changes for 2020 for those waste streams that include municipal waste:

- C&I waste arisings in England increase gradually to a level of 48.3 million tonnes in 2020. However, C&I arisings for the UK as a whole fall slightly to 57.9 million tonnes in 2020.
- Forecasts of Local Authority municipal waste show a slight fall to 29.8 million tonnes for the UK in 2020. This forecast is based on Defra's household waste projections at the time of the CIWM report.

The CIWM report forecasts future levels of infrastructure capacity by using data on existing projects and assigning percentages to the probability of new projects reaching completion based on their stages of development. The report concludes that there is likely to be a gap between available capacity and waste potentially requiring treatment in the UK in 2020. It is found that this gap is likely to be more than 5 million tonnes per year and could be up to 15 million tonnes. However, this result is nonetheless consistent with meeting the 2020 landfill target because the analysis assumes an ambition that levels of waste diverted from landfill go beyond the 2020 target. Indeed, the report notes that “*If landfilling is maintained at the EU target level, there will be no capacity shortfall*”[37].

Market & Customer Insight (2013) – The UK waste management market development

The Market & Customer Insight (MCi) report includes forecasts of waste arisings in the UK up to 2017 but does not forecast infrastructure capacity requirements. Household waste arisings are forecast to fall from 27.7 million tonnes in 2013 to 26.6 million tonnes in 2017. Commercial waste arisings are forecast to fall from 26.6 million tonnes in 2013 to 24.5 in 2017. Industrial waste arisings are forecast to increase from 30.6 million tonnes in 2013 to 33.7 in 2017. Taken together, this yields a relatively flat trajectory for total municipal waste arisings.

Although the MCi report does not forecast capacity requirements, the total waste arisings profiles are broadly similar to our central estimates and therefore appear consistent with meeting the 2020 landfill target when compared to our infrastructure capacity forecast.

SITA (2014) – Mind the Gap – UK residual waste infrastructure requirements 2015 to 2025

SITA forecast UK arisings and treatment capacity for local authority municipal waste and C&I waste. The waste arisings forecasts for 2020 are as follows:

- Local authority waste is forecast to increase gradually to around 30 million tonnes per year in 2020.
- C&I arisings are also forecast to increase, reaching around 60 million tonnes per year in 2020.

SITA forecast that UK residual waste treatment infrastructure will reach a capacity of 20 million tonnes in 2020. They conclude that this means a ‘capacity gap’ of 11.7 million tonnes between available capacity and levels of residual waste potentially requiring treatment that would otherwise be likely to go to landfill.

Although SITA forecast a capacity gap in residual waste treatment more broadly, their results nonetheless appear consistent with meeting the requirements of the 2020 landfill target. If the 11.7 million tonnes of residual municipal waste[38] identified as a capacity gap were all to go to landfill, this is within the 2020 target for the UK of

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[37] Ricardo-AEA & CIWM (2013), “Commercial and industrial waste in the UK and Republic of Ireland”, pp 42.
[38] Local authority municipal waste and similar commercial and industrial waste

12.5 million tonnes of biodegradable municipal waste. It is also likely that not all of the 11.7 million tonnes of residual waste would be biodegradable. Applying our assumptions on waste composition from the new research described in section 2.4 would suggest around half of this waste would be non-biodegradable and therefore not relevant to the landfill target.

Imperial College London (2014) – Waste infrastructure requirement for England

The Imperial College London (ICL) report, commissioned by Veolia, does not forecast future capacity requirements but provides a critique of Defra's forecasting approach as set out in our previous reports[39]. The ICL report considers:

- "*The composition of different waste streams rather than aggregating them*
- *The regional significance of facilities (rather than taking an aggregate of all facilities across the UK)*
- *The technologies necessary to deliver the necessary infrastructure*"[40].

The ICL report argues that applying Defra's general approach to data from 2009-10 underestimates infrastructure requirements, because the result they find is inconsistent with the levels of waste to landfill in the data. However, our analysis shows that our approach fits past data well. For example, the 'alternative forecasting approach' sensitivity test in section 5.1 provides results when the starting point of the analysis is the level of waste to landfill in the latest data. This sensitivity test has similar results to the main analysis, showing our approach performs well against the data.

Our approach takes into account the composition of residual waste and relevant infrastructure technologies with the approaches set out in sections 2.4 and 3 respectively. A national approach is preferred for the purposes of our analysis for the reasons outlined in section 3.5. The sensitivity tests in section 5.7 demonstrate our results are not especially sensitive to a scenario under which waste feedstock is assumed to be less able to move between regions.

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[39] See Department for Environment, Food and Rural Affairs (2013), "Forecasting 2020 waste arisings and treatment capacity – revised February 2013 report"

[40] ICL (2014), "Waste infrastructure requirements for England", pp9.

Eunomia (May 2014) – Residual waste infrastructure review – issue 6

Eunomia's review provides an assessment of UK residual treatment capacity requirements. Household, commercial and industrial waste streams are analysed. These waste streams follow the following profiles in the analysis:

- Household arisings are unchanged in 2013-14, then increase by 0.5% per year thereafter.
- Commercial waste arisings increase by 0.5% per year from the baseline year used of 2009.
- Industrial waste arisings fall by 1% per year.

Alongside the arisings profiles, forecasts of the relevant treatment capacity are made by assessing the probability of potential facilities reaching financial close. Eunomia find that, counting projects already either operational or under construction, the UK has around 19.3 million tonnes of residual waste treatment capacity. This level of capacity is found to be 9.1 million tonnes less than current levels of residual waste arisings.

Under Eunomia's central scenario, there is potential overcapacity (i.e. more infrastructure than available residual waste) in 2017-18 of 1.2 million tonnes, which increases to 11.6 million tonnes in 2020-21. However, the analysis notes that very high levels of overcapacity are unlikely to materialise in practise. This is because, where merchant capacity is already under construction in a given area, it may become less likely that further capacity will continue to be developed. As Eunomia's report forecasts potential overcapacity, the results appear consistent with at least meeting the requirements of the 2020 landfill target.

Green Investment Bank (2014) – The UK residual waste market

The Green Investment Bank (GIB) report forecasts UK waste infrastructure capacity needs to 2020, with a particular focus on assessing the potential for further investment in merchant facilities for C&I waste.

Waste arisings are assessed for local authority collected waste, municipal C&I waste, and other C&I waste deemed suitable for residual waste treatment. Two scenarios for total suitable waste arisings in 2020 are outlined:

- In the 'low availability scenario' arisings increase gradually to reach 66.4 million tonnes in 2020. In this scenario there is an estimated 22.4 million tonnes of residual waste in 2020.

- In the ‘high availability scenario’ arisings increase more rapidly to reach 73.3 million tonnes in 2020. In this scenario there is an estimated 26.5 million tonnes of residual waste in 2020.

GIB forecast 0.7 million tonnes of pre-treatment capacity (from facilities such as mechanical biological treatment) and 11.9 million tonnes of energy from waste capacity. This capacity includes operational projects, those under construction and a risk adjusted contribution from additional PPP projects. GIB concludes that there will be a ‘capacity gap’ of 4.0 to 7.7 million tonnes of residual waste that could be treated by additional merchant energy from waste facilities in 2020.

Although GIB forecast a capacity gap in residual waste treatment more broadly, their results nonetheless appear consistent with meeting the requirements of the 2020 landfill target. GIB assumes 5% of waste goes to landfill, 3.3 to 3.7 million tonnes. If the upper estimate of 7.7 million tonnes of residual waste identified as a capacity gap is assumed to also go to landfill, this implies up to 11.4 million tonnes of waste to landfill. This is within the 2020 target for the UK of 12.5 million tonnes of biodegradable municipal waste. It is also likely that not all of the 11.4 million tonnes of residual waste would be biodegradable. Applying our assumptions on waste composition from the new research described in section 2.4, and taking into account that the GIB estimates include some non-municipal waste, suggests that more than half of the potential waste to landfill in the GIB report is not relevant to the landfill target.

Appendix C: Model audit

NERA Economic Consulting were commissioned to undertake an independent audit of the model used for the analysis to further ensure its robustness. The audit provided a detailed cell-by-cell check of the model to identify any areas where amendments were recommended.

The model audit made one substantive recommendation, which relates to a refinement of the approach used to assign ranges around the waste arisings forecasts. The refinement affects only the ranges used, not the central waste arisings inputs.

For household waste arisings, the previous forecast approach used two alternative specifications of the SARIMA approach to provide a range of possible outcomes. In the present analysis, one specification of the SARIMA approach was found to perform best under a series of statistical tests. The audit recommended that the possibility of alternative outcomes is incorporated by estimating a probability distribution using the SARIMA regression outputs and a ‘bootstrapping’ statistical technique. This allows for a wider range of outcomes overall, including the possibility of higher or lower levels of arisings than included in the previous analysis.

A similar recommendation was made for C&I waste arisings. The previous forecast approach used alternative assumption on the levels of efficiency savings in waste per unit of GVA to generate a range of possible outcomes. The audit recommended the use of a probability distribution which allows for a wider range of outcomes. As there is insufficient past data to estimate a probability distribution statistically for C&I arisings, the distribution estimated for household arisings is applied to municipal C&I arisings.

These recommendations were implemented for the present analysis, as outlined in section 2.2 above. The refined method represents a slightly more conservative approach overall as it allows for a wider possible range of waste arisings levels.