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Forecasting 2020 Waste Arisings and Treatment Capacity

Revised February 2013 Report

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Introduction

This paper sets out the analysis used to forecast levels of waste arisings and treatment capacity in England in 2020. The forecasts are used to assess the amount of biodegradable municipal waste that goes to landfill and hence whether England is expected to meet the necessary diversion levels in 2020 for the EU Landfill Directive. The analysis provides estimates of the likelihood of meeting the Landfill Directive target and the impact from withdrawing Defra's provisional allocation of financial support for those Private Finance Initiative (PFI) projects that are yet to reach financial close.

This paper is a revised version of that published in February 2013. The original February analysis did not fully account for all of the known potential capacity expected to be delivered by 2020. This meant that the likelihood of meeting the target was underestimated. This paper outlines revised results from the amended analysis. Note that no changes are made to the underlying dataset used in the analysis. This is so that the results can be compared on the basis of the information that was available at the time that the February analysis was undertaken[1].

Methodology

The infrastructure capacity model forecasts 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.

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

[1] Note that this paper has been revised to reflect the amended results only with additional points of clarification added in footnotes where relevant. The model used for this revised analysis has been independently audited by NERA Economic Consulting. The outcome of this audit, which includes a change to one of the sensitivity tests undertaken, is outlined in Appendix D.

[2] The Monte-Carlo method is a statistical approach to modelling uncertainty. More detail is provided in Appendix C.

uncertain factors and give an overall range of results. This is used to predict 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 model. These 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 to review and refine previous models[3]. The refined modelling approach was subjected to internal review and sign-off from Defra's chief economist.

Results

Using the method discussed, the impact of withdrawing provisional allocation of financial support for those projects yet to reach financial close is assessed. 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 capacity surplus to that required to meet the target. The analysis concludes that:

- There is a very wide range of possible net capacity positions in 2020. This includes surpluses (when capacity is more than sufficient to divert enough waste to meet the target) and deficits (when capacity is insufficient to divert enough waste to meet the target).
- If financial support is given to all of the projects yet to reach financial close, there is an estimated 97% likelihood of meeting the 2020 diversion target using the ranges of inputs that we believe to be realistic. In this scenario the mean surplus capacity is approximately 2.7 million tonnes.
- If provisional financial support is withdrawn from all of the projects yet to reach financial close, there is an estimated 95% likelihood of meeting the 2020 diversion target using the ranges of inputs that we believe to be realistic. In this scenario the mean surplus capacity is approximately 2.4 million tonnes.
- Hence withdrawing provisional financial support for the projects reduces the likelihood of meeting the 2020 diversion target, by approximately 2%.

Model Testing

To the extent that the Monte-Carlo method incorporates ranges around key parameters, the modelling already takes account of variations in key parameters. However, there are a

[3] See Appendix B.

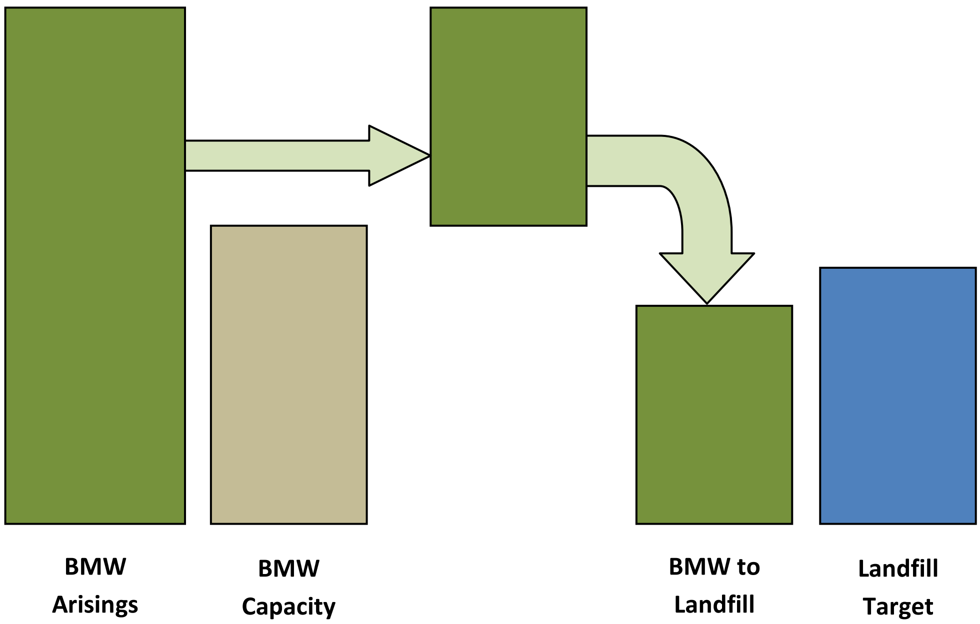
range of further tests that can be undertaken to test the sensitivity of the results to key inputs and assumptions. Tipping point analysis is used to test what level key factors, such as waste arisings, would need to be for capacity to just achieve the necessary diversion to meet the 2020 diversion target. Further testing is applied to assess the sensitivity to changing other key inputs and assumptions, including those that are not given ranges in the main analysis. This testing finds that the model conclusions are robust to fairly large changes in key variables.

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 (BMW)[4]. The target requires that the amount of BMW sent to landfill in 2020 is reduced to 35% of 1995 levels (i.e., to 10.2 million tonnes).

Figure 1 below illustrates this process: the forecast level of residual biodegradable municipal waste (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 compositions 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.

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

An approach is therefore used which provides a range of possible outcomes and a probability of meeting the 2020 target based on these results. This approach uses ranges for the various uncertain factors and applies a 'Monte-Carlo' technique[5], 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.

[5] The Monte-Carlo method is a statistical approach to modelling uncertainty. More detail is provided in Appendix C.

2 Waste Arisings Analysis

2.1 Arisings Data[6]

Household arising data is taken from the Defra 'Local Authority (LA) Collected Waste for England' statistics. Household waste levels have fallen since an assessment of the provisional financial support of PFI projects was last published at Spending Review 2010 (SR10)[7]. In 2009-10 household waste arisings were 23.7 million tonnes. The forecasts produced for SR10 predicted total household waste arisings of approximately 23.5 million tonnes in 2011-12, compared with the observed outturn of 22.9 million tonnes in that year, a 3% reduction since 2009-10 (see Appendix B, Figure B1).

Data for C&I waste arisings in England are not regularly collected. The most recent data is from the 2009 'Commercial and Industrial Waste Generation and Management Survey'. In the 2009 survey, arisings were 47.9 million tonnes. The municipal component[8] of this C&I waste is estimated to be 24.7 million tonnes. At the time of the analysis at SR10, the latest available data was from the previous survey, from 2002-03, which showed C&I waste arisings of 67.9 million tonnes. Hence, based on data that has become available since SR10, C&I waste arisings have fallen by a substantial 29% compared to the previous survey (see Appendix B, Figure B2). The 2009 survey data also shows arisings are lower than forecast at SR10. In the previous analysis the estimate for 2008-09 was approximately 56.3 million tonnes of C&I arisings in total, which constitutes approximately 27.6 million tonnes of municipal C&I waste.

Therefore, for both household and C&I waste there have been larger actual decreases in arisings than forecast at SR10.

As the Landfill Directive target relates to biodegradable municipal waste, construction and demolition arisings are out of scope of this analysis. These arisings were 77.4 million tonnes in the Defra 2010 'Construction and Demolition Waste, England' statistics.

2.2 Forecast Arisings

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

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[6] Department for Environment, Food and Rural Affairs, Waste statistics. Household statistics are from the 2011-12 statistical release. C&I statistics are from the 2009 survey.

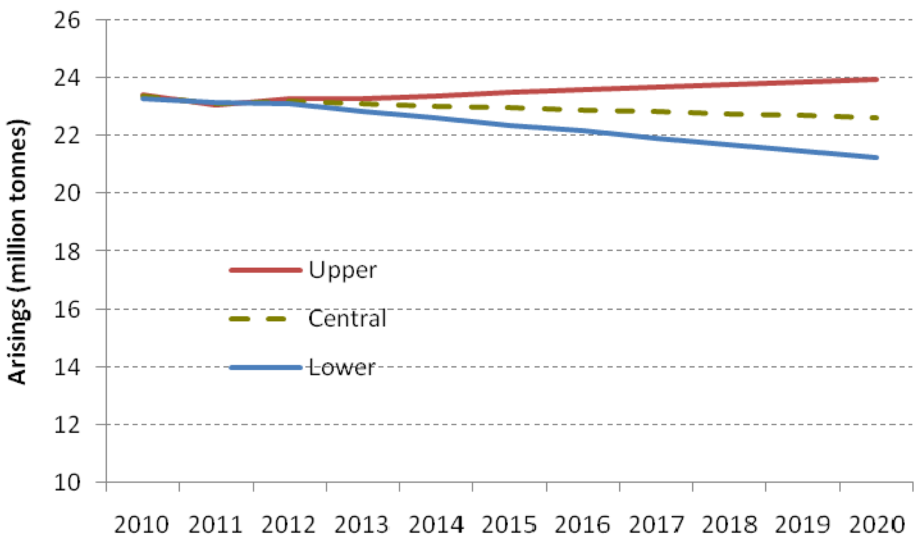
[7] Department for Environment, Food and Rural Affairs (2010), "Spending Review 2010 – Changes to Waste PFI Programme".

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

Household waste arisings are forecast based on trends in quarterly data using a SARIMA economic forecasting approach[9,10]. This approach provides an upper and lower forecast based on two alternative specifications of the SARIMA model. The average of these two forecasts is used as the central prediction, which shows household waste arisings falling gradually to reach 22.6 million tonnes in 2020.

Alternative approaches for forecasting household waste arisings were also considered; for example, models based on changes in the underlying drivers of waste, such as economic activity and waste intensity. Such alternative approaches were found to produce implausible results for household arisings with high forecast error. Therefore, the SARIMA model provides the most statistically robust forecast of future levels of household waste arisings.

Figure 2: Household Waste Arising Forecasts



The SARIMA approach is not possible with C&I waste arisings because regular data is not available. It is therefore necessary to forecast these waste streams based on linked parameters. C&I waste is projected forward in line with economic growth in the commercial and industrial sectors, measured by gross value added (GVA)[11]. Efficiency savings in

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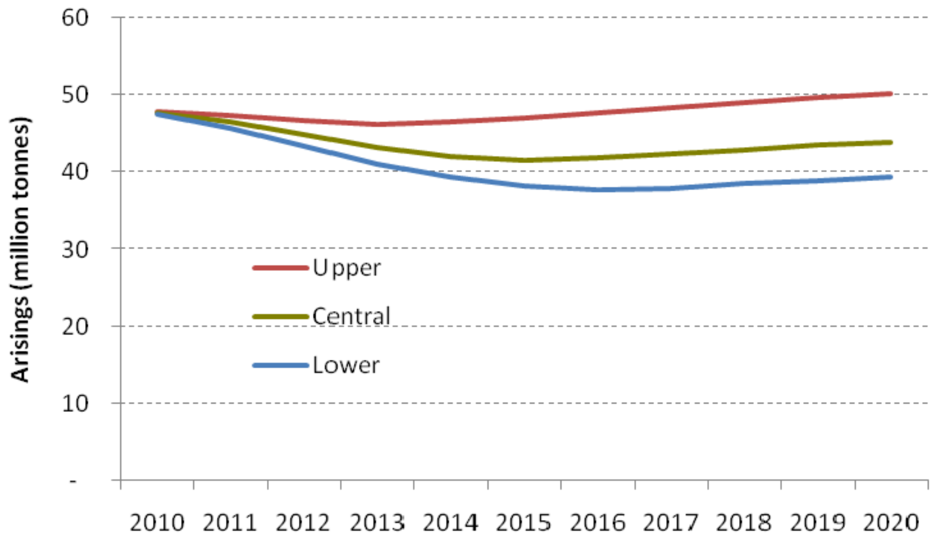
[9] Seasonal Auto-Regressive Integrated Moving Average. This type of economic model uses patterns in past data to forecast forward. See further discussion in Appendix B.

[10] An additional quarter of data has become available since this analysis was undertaken. The additional data, for quarter 1 2012-13, shows a fall in household waste arisings compared to the same quarter in 2011-12. This is consistent with the forecast range used in the analysis. See: Department for Environment, Food and Rural Affairs, “Local Authority collected waste for England – quarterly statistics”.

[11] 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 December 2012 “Economic and Fiscal Outlook” report.

waste have led to a fall in C&I waste per unit of economic output in recent years. However, the level of these efficiency savings going forward is uncertain, and upper, lower and central forecasts for C&I waste arisings are produced to account for this uncertainty. The central forecast estimates C&I waste arisings in 2020 will be 43.9 million tonnes. This is lower than their 2009 levels.

Figure 3: Commercial & Industrial Waste Arising Forecasts



A further adjustment is made to allow for the possibility that waste arising patterns could potentially change from those observed in the data. For example, a pronounced economic recovery could cause waste arisings to increase unexpectedly, potentially up to or beyond levels seen before the recession started in 2008-09. Therefore, the possibility of an upward ‘shock’ to household and C&I waste arising trends is explored 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 (see Appendix B). A 20% upward ‘shock’ is used in the model, occurring with a probability of 20% between now and 2020. The impact of altering this assumption is tested as part of the sensitivity analysis in Section 6.

2.3 Recycling

Household recycling has increased in recent years to reach a rate of 43% in 2011-12 (see Appendix B, Figure B3)[12]. This upward trend is expected to continue going forward as the UK progresses towards the Waste Framework Directive recycling target. Household recycling is projected to reach 51% in 2020, slightly exceeding the 50% target of the Waste Framework Directive. This is based on a continuation of factors such as behavioural changes that have led to increases in recycling. Whilst there has been a clear

[12] Department for Environment, Food and Rural Affairs, Local Authority Collected Waste statistics, 2011-12.

upward trend in recycling rates, with a rise of twelve percentage points over the past five years, the fairly rapid changes mean that there is some uncertainty around the level of recycling expected to be reached in 2020. A range of five percentage points either side of 51% is used to reflect uncertainty in the projected recycling rate[13].

The last data point for C&I recycling is from the 2009 survey, showing a rate of 52%[14]. This is an increase of ten percentage points compared to the 42% reported in the 2003 survey (see Appendix B, Figure B4). C&I recycling is assumed to increase by a further ten percentage points to reach 62% in 2020, reflecting factors such as landfill tax which are expected to continue to reinforce existing recycling trends going forward. However, the projected recycling rate remains uncertain for the reasons described above, and the lack of regular data means there is more uncertainty in projecting the C&I recycling rate compared to the household recycling rate. A range of eight percentage points either side of 62% is used.

2.4 Composition

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

The biodegradable content of municipal waste has a central assumption of 68%. A range is used around this estimate in 2020, of 55% to 75%. This broad range reflects that the biodegradable content may vary over time and that a shortage of data makes predicting these changes to 2020 especially uncertain. The range is not symmetric as there is some suggestion from ongoing compositional research that biodegradable content is more likely to be lower than 68% in some cases.

All household waste is assumed to be municipal. The municipal content of C&I waste is estimated using data from the 2009 survey as 84% for commercial waste and 19% for industrial waste. For the 2020 municipal content of C&I waste, a range of 79% to 89% is used for commercial waste and 15% to 23% is used for industrial waste. The lack of regular data means the municipal content of C&I waste in 2020 is uncertain. It is assumed that the municipal content is equally likely to be anywhere within these ranges.

2.5 Correlations Between Inputs

There are certain inputs which are likely to be correlated. 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

[13] An additional quarter of data has become available since this analysis was undertaken. The additional data, for quarter 1 2012-13, shows an increase in household recycling compared to the same quarter in 2011-12. This is consistent with the forecast range used in the analysis. See: Department for Environment, Food and Rural Affairs, "Local Authority collected waste for England – quarterly statistics".

[14] Department for Environment, Food and Rural Affairs, Commercial and Industrial Waste statistics, 2009 Survey.

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 positive correlation. This is because they will tend to move in the same direction, because of shared drivers such as economic growth and levels of consumption.
- The household recycling rate and the C&I recycling rate are also given a positive correlation. This is because they will also tend to move in the same direction due to shared drivers such as awareness of waste issues and cost of virgin materials.

Relatively small positive correlations with a coefficient of 0.25 are applied to these inputs. This is consistent with past data and our understanding of the drivers of these inputs. The correlations in both cases are relatively low because of factors specific to household waste or C&I waste. 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.

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 1 below.

Table 1: Summary of Waste Inputs[15]

Waste arisings pre-shock	Distribution	Central	Minimum	Maximum	Forecast Rationale
Household waste	Triangular	22.6	20.3	24.9	SARIMA econometric model
C&I waste (municipal component)	Triangular	23.1	20.7	26.4	Sector growth forecasts and efficiency assumptions
Upward 'shocks' to arisings	**Probability**	**Magnitude**			
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**	**Minimum**	**Maximum**	
Household waste	Triangular	51%	46%	56%	Continuation of upward trend in line with target
C&I waste	Triangular	62%	54%	70%	Continuation of upward trend
BMW content					
BMW content of MSW	Triangular	68%	55%	75%	Wide range due to data limitations
MSW content					
MSW % of industrial waste	Uniform	19%	15%	23%	Estimate from C&I survey 2009
MSW % of commercial waste	Uniform	84%	79%	89%	Estimate from C&I survey 2009

[15] A triangular distribution places the greatest probability of occurrence on the central value and least probability on the limits of the range. A uniform distribution places equal probability of occurrence on all values within the range.

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. Adjustments are made within the model to allow for the various stages of development that projects have reached and for differences between types of technologies[16].

3.1 Project Risks

Assessments of project risks are needed because of uncertainties in the development of large-scale infrastructure projects. The likelihood of projects progressing depends 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 of each project based on a number of criteria associated with effective project management and of specific local factors likely to present a barrier to delivery of that project.

A RAG assessment is made for each criterion and used to generate a single overall RAG for each project. A percentage is attached to each overall RAG. 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 established after consultation with experienced project managers within the team and with stakeholders. The delivery adjustment rates for each RAG status and project type are outlined in Table 2.

Table 2: Delivery Adjustment Rates[17]

	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

[16] Project data taken from the assumed position of projects in the WIDP database up to 31st December 2012.

[17] 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.

Those projects given a 'red' RAG assessment are judged to be unlikely to become operational by 2020 for project specific reasons – note that this does not preclude their delivery sometime after 2020.

Of the three projects yet to reach financial close, two have a RAG rating of 'amber red' at the time of this analysis and one has a RAG rating of 'red'. The North Yorkshire and York project is the one to have been assessed as 'red'. The principal reason is that the securing of a satisfactory planning permission[18] is likely to be problematic given the controversial nature of the development. Recent experience of such projects would suggest that securing planning may take three to four years. The time to financially close the project and the subsequent build period pushes the delivery period to around 2020. Given this uncertainty, the project has been deemed unlikely to go live by 2020[19].

3.2 Project Risks With Provisional Financial Support Withdrawn

A decision to withdraw provisional financial support from the projects that are yet to reach financial close would significantly reduce the likelihood of them going ahead. Whether or not these projects do go ahead will depend on various factors, such as the particular decisions of local authorities (LAs). However, for the purposes of modelling an assumption must be made regarding the likelihood of each project reaching completion by 2020. For the purposes of this exercise, it is assumed that if provisional financial support is withdrawn, the projects will not become operational by 2020.

The impact on affordability where PFI credits are withdrawn is substantial. The PFI grant typically covers around 30% of the charges payable under the PFI contract. If the credits are withdrawn, this creates an affordability gap which LAs would need to consider. Long-term contracts with creditworthy providers of waste are needed to attract finance into the sector. Without these, the promoters of such schemes would be unlikely to attract bank finance. Even with corporate-financed projects, long-term public sector contracts appear to be a pre-cursor to investment. This reduces the likelihood of projects proceeding without central government support, particularly in the current economic climate.

In the longer term, there is uncertainty about the relative costs of landfill and diversion. For example, due to large economies of scale, the cost of energy from waste (EfW) capacity is dependent on the capacity of the plant. In other words, for a given plant, a larger capacity tends to be more cost effective. However, planning constraints tend to reduce the size of plant built, which can in turn significantly raise the average gate fee. In addition, spare capacity in EfW plants in Northern Europe may tempt some LAs to exploit the relatively low gate fees there through short- to medium-term contracts rather than enter into longer-term contracts for investment in new capacity in the UK.

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[18] Satisfactory planning is achieved when the time period for a legal challenge has expired.
[19] Assessments based on the assumed position of projects in the WIDP database up to 31st December 2012.

Withdrawing provisional financial support from projects following Spending Review 2010 resulted in three of the seven projects proceeding. Of these, one has reached financial close, one is at Preferred Bidder stage and the third is proceeding with procurement. However, none are yet guaranteed to deliver operational capacity in 2020. Whilst circumstances can vary for different projects, this suggests that the assumption that none of the projects yet to reach financial close would come on line by 2020 if provisional financial support is withdrawn is a cautious one.

3.3 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. In this case, 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, to reflect unforeseen events.

3.4 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. 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 completely efficient.
- 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 in these rates (See Table 3 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 than actual levels as well as lower.

3.5 Summary Of Capacity Inputs

Table 3 summarises the capacity inputs used in the analysis.

Table 3: Summary of Capacity Inputs[20]

Utilisation Rates	Distribution	Central	Minimum	Maximum
BMBT Utilisation	Triangular	80%	75%	100%
EfW Utilisation	Triangular	100%	90%	105%
LFMBT Utilisation	Triangular	80%	75%	100%
MT Utilisation	Triangular	80%	75%	100%
Diversion Efficiency				
BMBT Efficiency	Triangular	85%	70%	90%
EfW Efficiency	n/a	100%	100%	100%
LFMBT Efficiency	Triangular	77%	50%	90%
MT Efficiency	n/a	0%	0%	0%
Tonnes to EfW				
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%

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

[20] BMBT= bio-treatment mechanical biological treatment; EfW = energy from waste; LFMBT = Landfill mechanical biological treatment; MT = mechanical treatment.

4 Results

Using the methodology and parameters discussed in previous sections, estimates are made of whether there will be sufficient capacity to provide the necessary diversion from landfill in 2020. A net ‘surplus’ occurs when capacity is more than sufficient to divert enough waste to meet the target. A net ‘deficit’ occurs when capacity is insufficient to divert enough waste to meet the target.

The surplus or deficit is reported in terms of the capacity required to treat only the biodegradable component of waste. In other words, a surplus of 1 million tonnes (Mt) implies that England will landfill 1Mt less of biodegradable municipal waste than the allowable 10.2Mt (as implied by the Landfill Directive target). However, since biodegradable waste is generally mixed in with residual waste (and is treated in this way), the surplus of necessary capacity for residual waste as a whole will be greater than 1Mt.

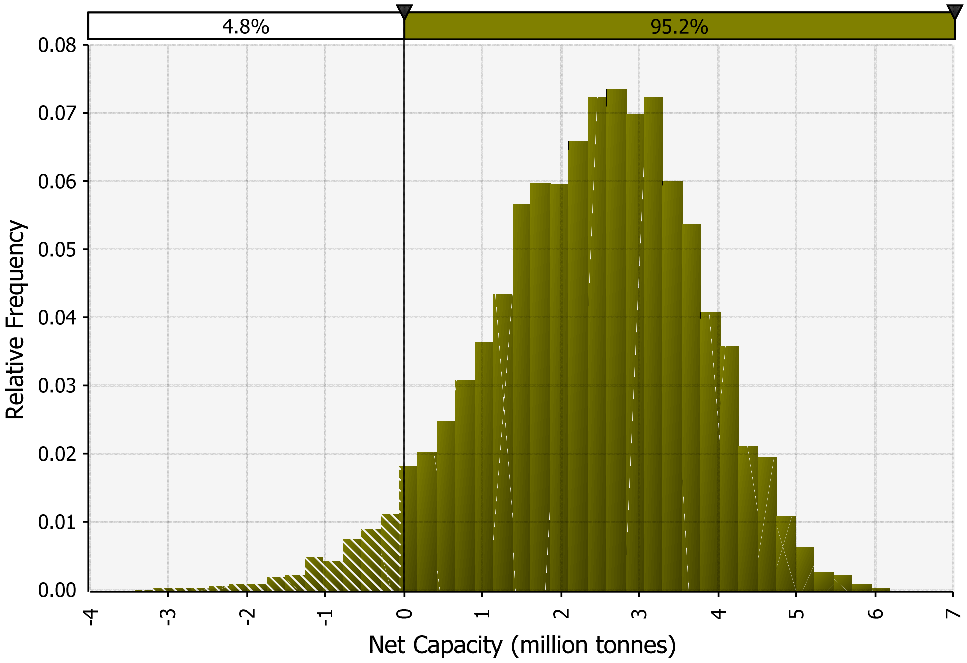
The Monte-Carlo analysis produces a wide range of outcomes including both surpluses and deficits. From this range, a probability of meeting the target is estimated. Withdrawing provisional financial support from the PFI pipeline projects yet to reach financial close shifts the range of outcomes so that the average surplus is lower. This is because capacity in 2020 will be lower without these projects. The probability of meeting the target is therefore reduced if provisional support is withdrawn for these projects (and hence they are assumed not to go ahead).

4.1 Provisional Financial Support Withdrawn For All Three Projects

With the provisional allocation of financial support withdrawn for the three projects, the likelihood of meeting the target is estimated to be 95%. The possible net capacity position has a wide range including both surpluses and deficits. While the level of net capacity is uncertain, mean surplus capacity in 2020 is estimated to be 2.4 million tonnes.

This 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, 95% are above zero, representing a surplus. The Y-axis in Figures 4 and 5 can be interpreted as the percentage likelihood (0.01 = 1%) of a specific net capacity value (X-axis) occurring.

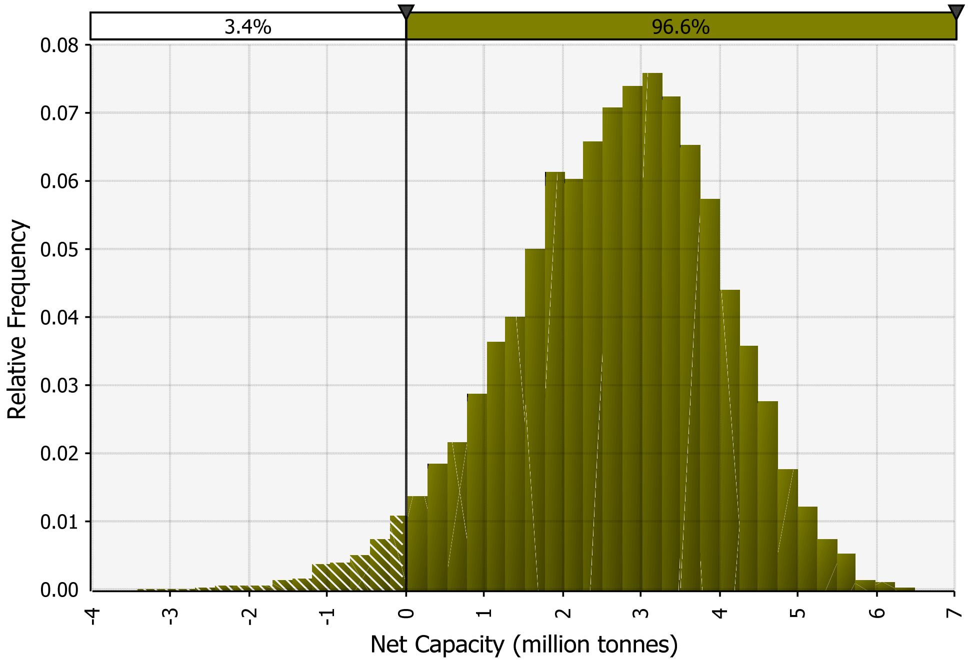
Figure 4: Range of Net Capacity Results With Provisional Financial Support Withdrawn



4.2 Financial Support Provided For All Three Projects

With all three of the projects receiving financial support, the likelihood of meeting the target is estimated to be 97%. Providing financial support to the projects increases the likelihood of meeting the target by approximately 2%. Once again, a wide range of net capacity positions are possible. While the level of net capacity is uncertain, mean surplus capacity in 2020 is estimated to be 2.7 million tonnes. This estimate is approximately 0.3 million tonnes higher than the scenario discussed in Section 4.1 because of the average additional capacity provided by the three projects.

Figure 5: Range of Net Capacity Results With Financial Support Provided



4.3 Provisional Financial Support Withdrawn For Some But Not All Of The Projects

If the provisional allocation of financial support were withdrawn from some, but not all, of the projects yet to reach financial close, the results would be between those outlined above. The estimated likelihood of reaching the target would be more than 95% but less than 97%. The estimated net capacity would have a wide range, with mean surplus capacity in 2020 estimated to be more than 2.4 million tonnes but less than 2.7 million tonnes.

4.4 Summary Of Results

The results are summarised in Table 4 below. Withdrawing provisional support reduces the likelihood of meeting the target by approximately 2%. The estimated net capacity has a wide range with and without the projects, with the mean surplus capacity in 2020 reduced by an estimated 0.3 million tonnes of biodegradable waste if provisional support is withdrawn.

Table 4: Summary of Results

Option	Likelihood of Meeting Target	Average Surplus (Mt)
provisional support withdrawn	95.2%	2.4
support given	96.6%	2.7

5 Tipping Points

This section identifies values of key inputs such that there is just sufficient capacity to meet the Landfill Directive target.

The tipping point analysis is applied to the inputs to which the results are most sensitive. These are identified as: household arisings, C&I arisings, household recycling rate, C&I recycling rate, biodegradable component of municipal solid waste, and EfW utilisation. Each of these inputs is tested individually to establish the value for which the forecast capacity is just sufficient to achieve the necessary diversion to meet the Landfill Directive target in 2020. Levels beyond the critical values would imply that capacity is forecast to be below the level necessary to meet the target. Table 5 summarises these critical values for all of the inputs mentioned above.

Table 5: Summary of Tipping Point Analysis

Input	Central value (in 2020)	Forecast range	Critical value	% Distance from limit of range
Household arisings pre-shock	22.6 Mt	20.3-24.9 Mt	30.1Mt	21%
C&I arisings pre-shock (municipal component)	23.1 Mt	20.7-26.4 Mt	32.9Mt	25%
Household recycling rate	51%	46-56%	35%	24%
C&I recycling rate	62%	54-70%	47%	13%
Biodegradable content of municipal solid waste	68%	55-75%	87%	16%
EfW utilisation	100%	90-105%	49%	46%

The critical value for household waste arisings (30.1 million tonnes) is 21% outside the forecast range, and a level higher than has been observed in the data. The critical value for the municipal component of C&I arisings (32.9 million tonnes) is 25% outside the forecast range. This level of arisings is similar to 2002-03, when municipal C&I arisings were approximately 33.5 million tonnes. Appendix B1 contains details of historic data for comparison.

The analysis suggests a return to these levels by 2020 is unlikely. Not only are these levels beyond the upper range of forecast arisings (household and C&I), they are also beyond the range of outcomes following a 20% upward 'shock'. For example, it requires arisings to reach the maximum point in the forecast range and to also experience a higher upward shock beyond that already high level.

The critical values for household and C&I recycling rates are also significantly outside the ranges used. Both require a fall in rates to levels that last occurred several years ago, when in reality increasing recycling rates are expected going forward (See Appendix B, Figures B3 and B4).

The critical values for the biodegradable content of municipal waste and EfW utilisation are also significantly outside the probable range.

However, it is important to note that these results are based on testing inputs individually. There are potential combinations of values for these inputs (within the assumed ranges) that can result in forecast capacity that is just sufficient to meet the target. For example, the combination of inputs in Table 6 results in such an outcome (with other assumptions unchanged).

Table 6: Example Inputs To Reach Tipping Point When Varied Simultaneously

Input	Value
Household arisings	24.0 Mt
C&I arisings (municipal component)	25.5 Mt
Household recycling rate	47%
C&I recycling rate	55%

Whilst possible (based on the ranges used in the analysis), such an outcome relies on several inputs collectively reaching levels that are relatively unlikely individually, and hence even more unlikely together. Indeed, as outlined in Section 4, there is estimated to be approximately a 3% or 5% likelihood of a deficit net capacity in the main analysis – depending on whether the projects yet to reach financial close are given provisional financial support or not, respectively.

6 Sensitivity Analysis

In order to test the robustness of the results obtained, a number of tests of sensitivity have been conducted. In various ways, these assess the extent to which the output of the model changes when the inputs, or modelling methods, vary from the assumptions used in the analysis. The sensitivity testing particularly focuses on those 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 arising shocks.
4. Sensitivity to project level risk adjustments.
5. Sensitivity to the assumptions used for projects yet to reach financial close.
6. Sensitivity to the programme level risk adjustment.

6.1 Alternative Modelling Approach

An alternative method to forecasting net capacity in 2020 was considered. The standard approach to modelling has been 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. By contrast, the alternative methodology takes as a starting point the latest available data for the level of 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 surplus or deficit in capacity.

If the projects yet to reach financial close are provided with financial support, the standard and alternative methodologies return likelihoods of meeting the 2020 diversion target of 97% and 93%, respectively. Hence the alternative approach suggests a lower likelihood of meeting the target. The alternative approach is also slightly more sensitive to the exclusion of the three projects. Withdrawing provisional financial support reduces the likelihood of meeting the target to 95% under the standard method and to 90% under the alternative method.

Table 7: Sensitivity to Alternative Modelling Approach

Likelihood of meeting target	support given	provisional support withdrawn
Standard	96.6%	95.2%
Alternative	92.7%	89.6%

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. For this reason, the standard approach is preferred. The alternative approach nonetheless provides a useful comparison.

6.2 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 be positively correlated (correlation coefficient of 0.25).
- Household recycling rate and the C&I recycling rate are also are assumed to be positively correlated (correlation coefficient of 0.25).

Alternative correlation assumptions were tested. This included 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 (e.g. economic growth) 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 probability of meeting the target. A positive correlation for (3) and (4) causes an increase in the probability of meeting the target and a negative correlation reduces the probability. A positive correlation for (5) and (6) causes an increase in the probability of meeting the target. Table 8 outlines possible high and low cases for the likelihood of meeting the target, based on varying the correlation inputs. Table 9 shows the probability of 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 LA 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	0.25
Between Different Projects	0.00	0.00	0.25

Table 9: Sensitivity to Correlation Inputs

Likelihood of meeting target	support given	provisional support withdrawn
Main Analysis	96.6%	95.2%
Low Case	96.0%	94.4%
High Case	97.4%	96.3%

Correlations in the low case slightly decrease the probability of meeting the 2020 target compared to the main analysis and correlations in the high case slightly increase the probability of meeting the 2020 target. The impact of withdrawing provisional financial support for the projects yet to reach financial close also changes only slightly with the different correlation assumptions. This suggests the analysis is not especially sensitive to even large deviations in these correlations.

6.3 Arisings Shocks

As discussed in Section 2.1, the possibility of upward ‘shocks’ to forecast 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. The sensitivity of the results to this shock assumption is tested by varying the probability of the shock from 10% to 30%. Table 10 shows the model results under three cases: 20% (as in the main analysis), 10% and 30%.

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

Table 10: Sensitivity to Shocks

Likelihood of meeting target	support given	provisional support withdrawn
Main Analysis (20%)	96.6%	95.2%
10% probability of shock	98.3%	97.6%
30% probability of shock	94.4%	92.5%

6.4 Project Level Risk

The probability of an individual project delivering capacity is determined by its RAG status. To test the sensitivity of the output to these probabilities, two scenarios were considered: a Low Case in which each RAG status probability was reduced by 10 percentage points (but going no lower than 0% and excluding those plants that are already operational or cancelled); and a High Case in which each RAG status probability was increased by 10 percentage points (but going no higher than 100% and excluding those plants that are already operational or cancelled). Table 13 shows the probability of meeting the target under the main analysis, and the Low and High cases.

Table 11: Delivery Adjustment Rates - Low Case

Delivery Adjustment Rates low case	PFI	PPP	Merchant	Project Status
B	100%	100%	100%	Fully operational
G	80%	80%	80%	Commissioning
AG	70%	70%	70%	Financial close, with planning
A	60%	60%	30%	Financial close, no planning
AR	50%	50%	10%	In procurement, no planning
R	10%	10%	0%	Unlikely to go live by 2020
n/a	0%	0%	0%	Cancelled Project

Table 12: Delivery Adjustment Rates - High Case

Delivery Adjustment Rates high case	PFI	PPP	Merchant	Project Status
B	100%	100%	100%	Fully operational
G	100%	100%	100%	Commissioning
AG	90%	90%	90%	Financial close, with planning
A	80%	80%	50%	Financial close, no planning
AR	70%	70%	30%	In procurement, no planning
R	30%	30%	13%	Unlikely to go live by 2020
n/a	0%	0%	0%	Cancelled Project

Table 13: Sensitivity to Delivery Adjustment Rates

Likelihood of meeting target	support given	provisional support withdrawn
Main Analysis	96.6%	95.2%
Low Case	92.4%	90.6%
High Case	99.3%	98.7%

Whilst the estimated likelihood of meeting the target remains relatively high in all cases, the model demonstrates some sensitivity to the assumed rate of delivery. The rates used are based on WIDP's expertise in the sector and were supported in the independent review of the model (see Appendix B)[21].

6.5 Assumptions For Projects Yet to Reach Financial Close

The three projects yet to reach financial close were also tested separately to determine the impact of their assumed delivery rates on the results. Under the main analysis, the probability that the projects occur with financial support is determined by their RAG statuses. If provisional financial support is withdrawn, this is reduced to 0% (i.e., it is assumed that the projects would not go ahead without financial support). Testing the sensitivity to these assumptions, if the projects are assumed to be delivered with 100% probability when receiving financial support, the likelihood of meeting the target is estimated to be 98% (see Table 14). Comparing this to the likelihood of meeting the target with provisional financial support withdrawn, 95%, the maximum impact that withdrawing provisional support could have is reducing the likelihood by approximately 3% (assuming other model parameters are unchanged from the main analysis).

Table 14: Sensitivity To Delivery Adjustment Rates For Projects Yet To Reach Financial Close

Likelihood of meeting target	support given	provisional support withdrawn
Main Analysis	96.6%	95.2%
High Impact Case	97.8%	95.2%

6.6 Programme Level Risk

The sensitivity of the results to the programme level risk parameter is tested by performing Monte-Carlo 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. Reducing the programme level risk parameter has a relatively large effect on the probability of meeting the 2020 target compared to other sensitivity tests. However, the difference between the probabilities with and without provisional financial support remains similar in each case. The inclusion of a programme level risk adjustment in the main analysis already reflects a cautious approach.

[21] NERA Economic Consulting (2012), "Review of Methodology for Forecasting Waste Infrastructure Requirements".

Table 15: Sensitivity to Programme Level Risk

Likelihood of meeting target	support given	provisional support withdrawn
Main Analysis	96.6%	95.2%
Low Case (80%)	89.2%	86.3%
High Case (100%)	98.0%	97.1%

6.7 Summary of Sensitivity Analysis

Results from the sensitivity analysis are summarised in Table 16 below. Overall, the model conclusions are robust to the use of an alternative method and to fairly large changes in key variables.

Table 16: Summary of Sensitivity Analysis[22]

Sensitivity Test	support given	provisional support withdrawn
Main Analysis	96.6%	95.2%
Alternative forecasting approach		
Alternative Method	92.7%	89.6%
Correlations		
Low Case	96.0%	94.4%
High Case	97.4%	96.3%
Shocks		
10% probability of shock	98.3%	97.6%
30% probability of shock	94.4%	92.5%
Project level risk adjustments		
Low Case	92.4%	90.6%
High Case	99.3%	98.7%
DARs for projects yet to close		
High Impact Case	97.8%	95.2%
Programme level risk adjustment		
Low Case	89.2%	86.3%
High Case	98.0%	97.1%

[22] DAR = Delivery Adjustment Rate (see Tables 11 and 12).

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Appendix A – Detailed Forecast Results

This appendix provides further detail of the results obtained under the main analysis.

Table A1 provides forecast outputs in 2020 if the provisional allocation of financial support is withdrawn for the three projects yet to reach financial close. The mean value for the outputs are given as well as the 90th percentile value (for which only 10% of model iterations will be higher) and the 10th percentile value (for which only 10% of model iterations will be lower). The estimated likelihood of meeting the Landfill Directive target is 95% under this scenario (see Section 4).

It should be noted that 'Diversion Capacity' in the Tables below refers to the proportion of capacity that treats biodegradable residual waste (since this is the relevant measure for the 2020 Landfill Directive target). That is, this figure is lower than the nominal capacity available for residual waste as a whole (see Section 4).

Table A1: Output Details With Provisional Financial Support Withdrawn

Mt	Mean	90th Percentile	10th Percentile
Waste Arising	47.9	52.4	44.1
Waste Recycled	27.2	30.1	24.6
Residual Waste	20.7	23.1	18.6
Residual BMW	13.7	15.6	11.9
Diversion Capacity (for BMW)	5.9	6.6	5.1
BMW to Landfill (Target = 10.2)	7.8	9.5	6.1
Surplus capacity	2.4	4.0	0.6

Table A2 provides forecast outputs in 2020 if financial support is provided for the three projects yet to reach financial close. This impacts on the infrastructure side and so only the last three rows differ from Table A1. The estimated likelihood of meeting the Landfill Directive target is 97% under this scenario (see Section 4).

Table A2: Output Details With Financial Support Provided

Mt	Mean	90th Percentile	10th Percentile
Waste Arising	47.9	52.4	44.1
Waste Recycled	27.2	30.1	24.6
Residual Waste	20.7	23.1	18.6
Residual BMW	13.7	15.6	11.9
Diversion Capacity (for BMW)	6.1	7.0	5.4
BMW to Landfill (Target = 10.2)	7.5	9.3	5.8
Surplus capacity	2.7	4.3	0.9

Figure A1 illustrates the mean results in Tables A1 and A2. This Figure shows the total municipal arisings and how much of that is recycled, compared to the residual treatment capacity available. The blue section indicates the increase in residual treatment capacity that is expected to come on line on average if financial support is provided to all three projects. This measure of treatment capacity is the *total* rather than the proportion that is devoted to biodegradable waste only, as is reported elsewhere in this paper.

Figure A2 illustrates the mean level of biodegradable residual waste expected to go to landfill, compared to the total allowable level implied by the 2020 Landfill Directive target. The blue section indicates the increase in biodegradable municipal waste (BMW) to landfill that is expected to occur on average if provisional financial support is withdrawn from all three projects.

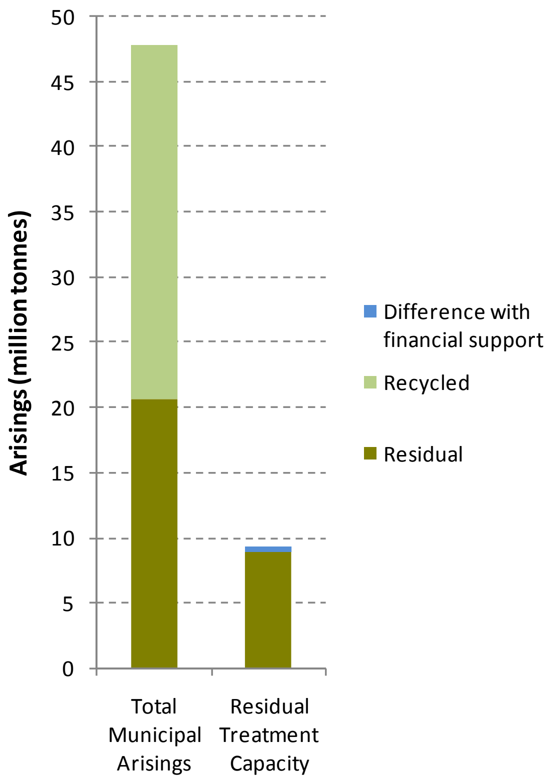

Figure A1: Mean Total Municipal Arisings and Residual Treatment Capacity

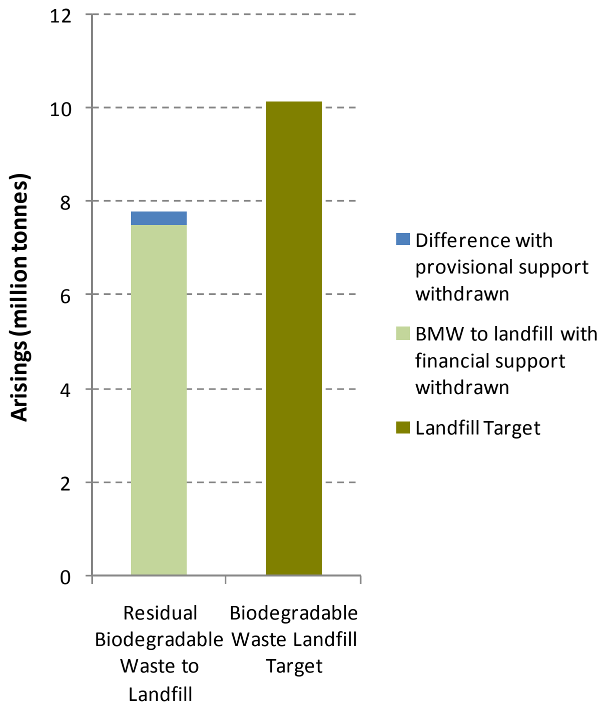

Figure A2: Mean Residual Biodegradable Waste to Landfill and Landfill Directive Target

Appendix B – Changes Since Spending Review 2010

An assessment of financial support for waste infrastructure projects through the PFI programme was last published at the 2010 Spending Review (SR10)[23]. The forecast net capacity at SR10 was a surplus of 1.5 million tonnes with 32 projects receiving provisional financial support. Using the same methodology, but with updated data, gives a higher expected surplus of 2.7 million tonnes. This is similar to the results with the refined methodology outlined in this paper. With the refined methodology, an average surplus of 2.4 million tonnes (with 29 projects receiving financial support) or 2.7 million tonnes (with 32 projects receiving financial support) is forecast.

The remainder of this appendix outlines key changes in data and information since SR10, and changes in the approach used in light of this new information and as a result of an independent methodology review undertaken by NERA Economic Consulting[24].

B1 Changes In Waste Arisings And Capacity Data

B1.1 Waste Data[25, 26]

Waste arising levels have fallen since SR10. In 2009-10 household waste arisings were 23.7 million tonnes and were predicted to fall to 23.5 million tonnes in 2011-12. In 2011-12 the actual level of arisings was 22.9 million tonnes (a 3% fall from 2009-10). C&I arisings data that has become available since SR10 shows a fall from 67.9 million tonnes (in the 2002-03 survey) to 47.9 million tonnes (in the 2009 survey that has since become available). This is a fall of 29%. Modelling at SR10 predicted total C&I arisings of approximately 56.3 million tonnes in 2008-09 which constitutes approximately 27.6 million tonnes of municipal C&I waste. Estimates from the 2009 C&I survey suggest that municipal C&I arisings were around 24.7 million tonnes in that year.

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[23] Department for Environment, Food and Rural Affairs (2010), “Spending Review 2010 – Changes to Waste PFI Programme”.

[24] NERA Economic Consulting (2012), “Review of Methodology for Forecasting Waste Infrastructure Requirements”.

[25] Department for Environment, Food and Rural Affairs (2010), “Spending Review 2010 – Changes to Waste PFI Programme.

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

Figure B1: Household Waste Arisings Data

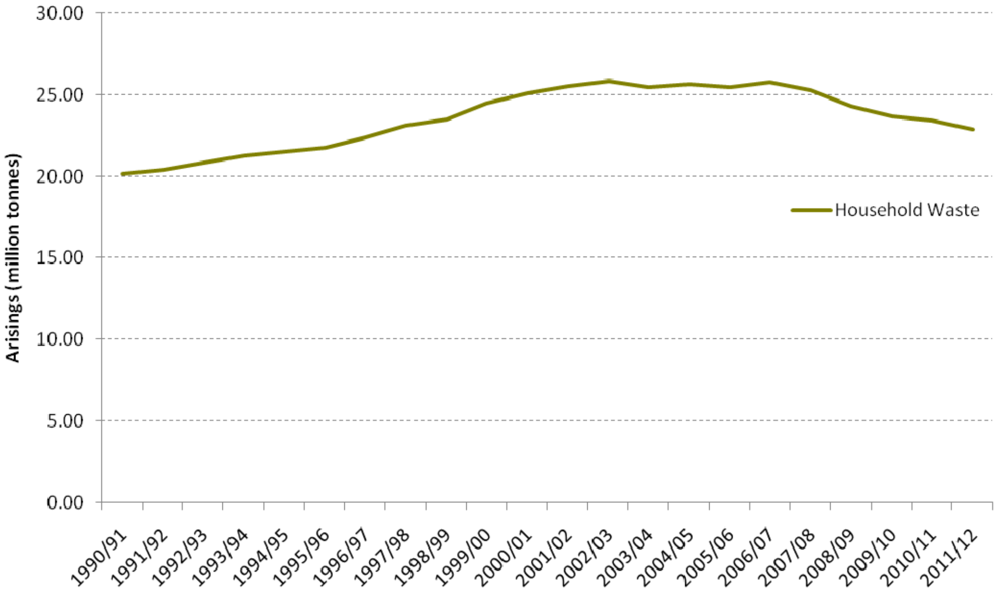


Figure B2: Commercial and Industrial Waste Arisings Data

Recycling rates have increased since SR10. This further reduces the amount of waste going to facilities lower down the waste hierarchy. The household recycling rate has increased from 39.7% in 2009-10 to 43.0% in 2011-12. The C&I recycling rate has increased from 42% in the 2002-03 survey used at SR10, to 52% in the latest data that has since become available from the 2009 survey.

Figure B3: Household Recycling Rate

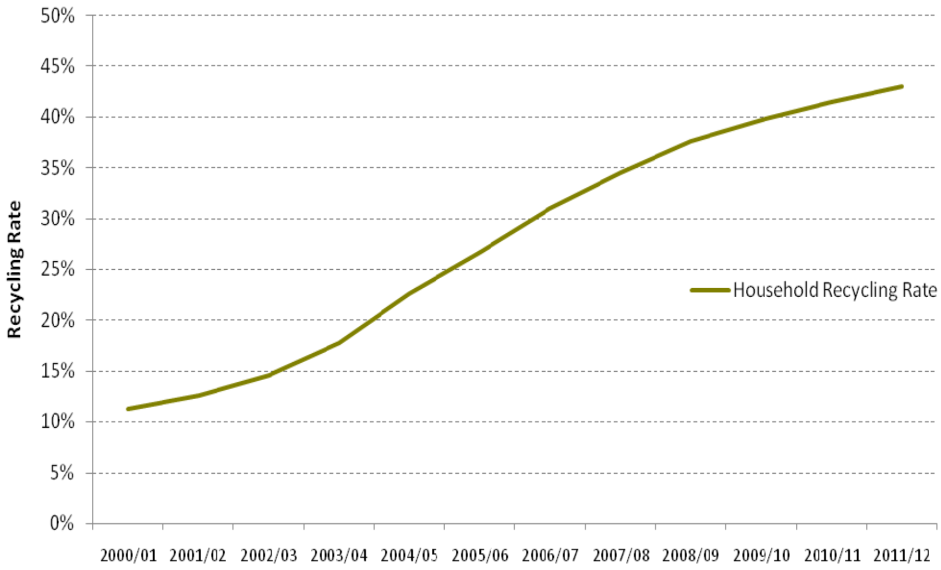
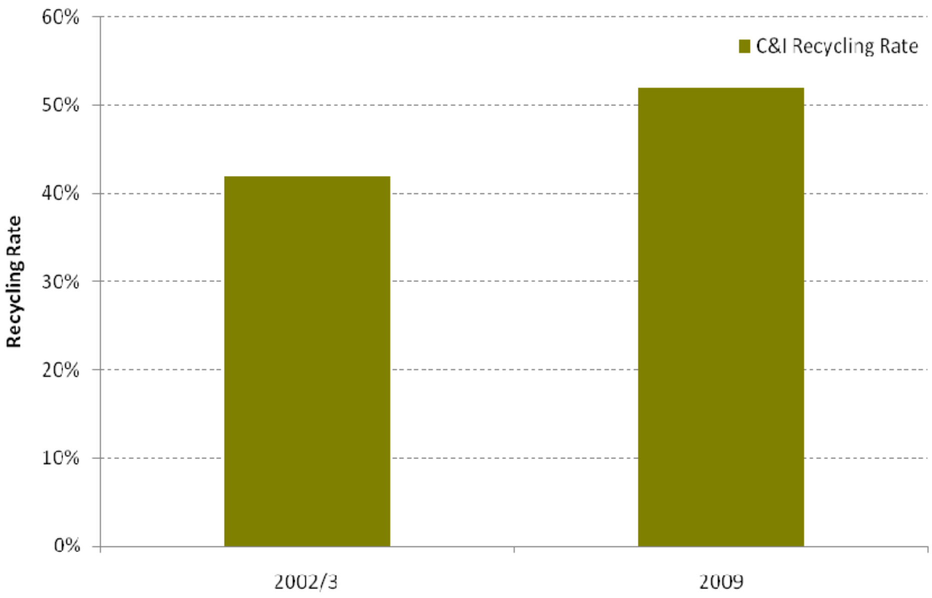


Figure B4: Commercial and Industrial Recycling Rate



B1.2 Infrastructure Data

Since March 2010[27], approximately 3.10 million tonnes of residual waste treatment capacity has gained planning permission, 2.58 million tonnes of capacity has reached financial close, and 3.09 million tonnes of capacity has begun construction. Over the same

[27] In comparison to the assumed position of projects in the WIDP database up to 31st December 2012

period, approximately 1.75 million tonnes of additional residual waste treatment capacity has become operational, a 38% increase[28].

B2 Changes in Methodology

Defra commissioned NERA Economic Consulting to provide an independent review of forecasting methodologies and an audit of the model. The key recommendations implemented as a result of the methodology review are outlined below.

B2.1 Approach to Uncertainty

The key overarching recommendation from NERA was to refine how uncertainty is incorporated within the analysis by moving to the Monte-Carlo approach described in Appendix C. Defra commissioned NERA to build Monte-Carlo functionality into the infrastructure capacity forecasting model which has been used for this analysis.

B2.2 Household Waste Arisings

NERA assessed the forecasting models previously considered by Defra: the ARIMA model[29] and the Input-Output model[30]. On the basis of NERA's recommendations and further testing by Defra, a new SARIMA[31] approach has been adopted for forecasting household waste arisings. This approach is similar to the previous ARIMA model, but uses quarterly rather than annual data.

The ARIMA model uses trends in annual arisings data to forecast into the future. NERA found that apparent structural breaks in the annual data used for this approach meant this is probably not the optimal model specification when latest available data is included. For example, household waste had risen for many years until 2002-03, but then arisings flattened and declined in subsequent years (see Figure B1 above). This change in underlying patterns in the data can potentially reduce the reliability of the ARIMA approach.

NERA recommended an alternative SARIMA model. This uses quarterly data since 2006 which overcomes the difficulty of the apparent structural break after 2002-03. This approach also has the advantage of allowing forecasts to be monitored and updated more regularly.

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[28] It should be noted that these categories are not mutually exclusive since, for example, a facility may have both received planning permission and begun construction since March 2010.

[29] Auto-Regressive Integrated Moving Average. This type of economic model uses patterns in past data to forecast forward.

[30] This type of economic model uses estimates of how waste is affected by inputs, such as consumer spending, to provide outputs of future waste arisings.

[31] Seasonal Auto-Regressive Integrated Moving Average. This type of economic model uses patterns in seasonal past data to forecast forward.

A limitation of the SARIMA model is that since the data starts in 2006, a relatively high proportion is from the period since the recession began. Hence some of this data may not represent typical patterns in waste arisings. To test this limitation, Defra interpolated the data back to 2003, the year after the structural break, using the annual dataset and the seasonality observed in the quarterly data. Reproducing the SARIMA model with this extended dataset produced results very close to those using data from 2006 onwards. This suggests that the SARIMA model is well fitted to waste arising patterns over the last decade as a whole.

NERA estimated three specifications of the SARIMA model using the quarterly data since 2006. These provide three possible forecasts of household waste arisings. The higher two of these forecasts have been adopted because the lowest forecast did not perform as well in model testing. The two SARIMA forecasts adopted are used to provide the ranges for household arisings in the Monte-Carlo analysis (see Section 2, Figure 2)[32].

NERA also assessed the alternative Input-Output forecast model. Their analysis found that this alternative model may have certain advantages because it makes use of estimated relationships of the drivers of waste. NERA observed that the forecasts from this model have become inaccurate in recent years and recommended updating the macroeconomic data in the model as a possible remedy. However, after investigating this recommendation, the model was still found to produce implausible results with high forecast error. This is likely to be caused by changes in the relationships between the input parameters and waste since this model was produced. Therefore the Input-Output model is not used in Defra's current forecasts.

The SARIMA forecast approach that has been adopted produces lower forecasts for household waste than the ARIMA approach and the alternative Input-Output model. This is consistent with the falling levels of household waste that have continued since SR10. However, the possibility of higher levels of household waste are captured through the use of an upward shock in waste arisings in the Monte-Carlo analysis. The forecasts from both the ARIMA model and the Input-Output model are within the range of household waste arisings used in the analysis with the upward shock included.

B2.3 Commercial & Industrial Waste Arisings

As part of their review of the forecast methodology NERA recommended changes to the way in which C&I arisings are forecast.

Whereas previous methodologies had linked waste arisings to forecasts of employment, NERA recommended Gross Value Added (GVA) as a more appropriate driver for waste

[32] For the minimum level of arisings, the 2020 arisings from the lower forecast is used minus one standard deviation. For the maximum level of arisings, the 2020 arisings from the upper forecast is used plus one standard deviation. Note that this is the range prior to the use of upward shocks. Once upward shocks are included, the maximum level of arisings becomes higher.

arisings. GVA is considered a more complete measure of economic production than employment and is therefore expected to capture changes in waste production more completely.

NERA also recommended that efficiency improvements in the level of waste generated for a given level of GVA should be applied. They recommended applying efficiency savings at the aggregate commercial and industrial levels (rather than sub-sectors) as the most reliable approach. NERA recommended that the rate of efficiency savings should decline from the observed historical (2003 to 2009) rate going forwards. This is because the greatest efficiency gains tend to be made first, with subsequent gains tending to become increasingly difficult. However, NERA did not make specific recommendations on the appropriate rates to use.

The key piece of evidence regarding the appropriate level of efficiency savings to assume in the forecast is the observed efficiencies over the period 2003 to 2009[33]. Over this period an average annual fall of 5.5% of waste per unit of GVA was observed. The landfill tax escalator is likely to be a key driver of these efficiency savings. For this reason, a rate of annual efficiency savings of 4% is assumed while the landfill tax escalator continues[34]. This rate is comparable though slightly lower than those observed over 2003 to 2009. The rate then converges to a lower long-run trend of 1% thereafter. This is consistent with evidence regarding the long-run rate of efficiency savings in other sectors such as energy efficiency in OECD Europe[35] and global resource efficiency[36]. The assumptions used are consistent with NERA's recommendation to incorporate that the rate of efficiency savings may fall in future. Alternative levels of efficiency savings are used to produce the high and low case C&I forecasts (see Section 2, Figure 3).

B2.4 Capacity Risks

Forecast capacity takes into account both project and programme level delivery risks to capacity. The project level risks assign a probability of projects occurring by 2020 based on RAG ratings. The RAG ratings take into account factors such as the stage of development of a project. In addition, the programme level risk adjustment reduces capacity by a certain amount on the basis that there could be unforeseen factors that reduce overall capacity.

This treatment of project and programme level risk is slightly different to the approach used at SR10. In 2010, two stages of RAG ratings were applied: one for individual projects and one for groups of projects. The adjustments made to groups of projects reflected their

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[33] Department for Environment, Food and Rural Affairs, Commercial and Industrial Waste statistics.

[34] HM Revenue and Customs (2012), Notice LFT1: "A general guide to landfill tax".

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

[36] 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".

procurement stage and project type such as PFI, PPP or merchant. In particular, an adjustment rate was used for those projects yet to reach financial close at the time. This adjustment assumed that 55% of the capacity otherwise predicted from these projects would be delivered by 2020 if receiving financial support. The reason for the additional adjustments was that there could be risks affecting projects nationally, including factors such as planning policy, attitudes to waste treatment facilities, or the possibility that actual throughput could be lower than headline capacity.

The adjustments to groups of projects are no longer applied as these risk factors are now sufficiently captured elsewhere in the model. Planning risks are captured in the project level delivery adjustment rates which have been refined to further distinguish between the different stages of project development. The possibility that throughput may be lower than headline capacity is captured in the utilisation rates, with the possibility that this may vary over time captured through the use of ranges. The risk of nationwide factors, such as a change in attitudes to waste treatment facilities, is captured in the programme level risk adjustment. Taken together, the overall adjustments to capacity from all of the risks applied are broadly similar in the current analysis to that used at SR10.

The treatment of merchant facilities is similar in approach to SR10. However, the RAG ratings and associated likelihood of projects coming on line have been revised such that very little capacity is expected to become operational from these types of projects by 2020. This reflects the fact that, whilst there are a number of potential merchant projects, very few merchant projects have come on line in the past[37].

In the independent review of the infrastructure forecasting methodology, NERA assessed the project delivery adjustment rates by considering evidence from infrastructure in the electricity generation sector. This analysis supported the approach used, as the rates were found to be generally consistent with those observed with electricity generation infrastructure.

NERA also observed that the delivery adjustment rates take downside risk into account but not upside risk. That is, the possibility that more infrastructure than expected could come on line is not taken into account. We have decided not to take upside risk into account because our understanding of the sector is that it is relatively unlikely that unforeseen capacity will come on line by 2020 given the particularly long lead in times to develop waste infrastructure projects. This is a relatively cautious approach.

[37] A merchant plant is defined as any project that has been financed and built without the benefit of a pre-existing (at financial close) long term (>10 years) public sector contract.

B2.5 Likelihood Of Projects Proceeding If Provisional Financial Support Is Withdrawn

In the analysis at SR10, it was assumed that if projects yet to reach financial close had provisional financial support withdrawn, they were unlikely to become operational by 2020. To reflect this, a delivery adjustment rate of 5% was used, meaning 5% of the capacity was assumed to come on line by 2020. This was deemed the appropriate rate to use on average for the eighteen projects in SR10.

In this analysis it is assumed that if provisional financial support is withdrawn from the three projects yet to reach financial close, then they will not become operational by 2020 (a delivery adjustment rate of 0%). This is a more cautious approach and reflects the reasons outlined in Section 3.2. The analysis was also run with a 5% delivery adjustment rate to test the sensitivity to this assumption compared to the 0% adjustment rate used in the main analysis. It was found to have only a very marginal impact on the results (a change of approximately 0.2% on the estimated likelihood of meeting the target).

Appendix C – Technical Summary of Monte-Carlo Method

C1 Monte-Carlo Method

Monte-Carlo analysis is a mathematical method used to combine a number of key uncertainties into a single encompassing measure of uncertainty. It allows the user to view all possible values of that output and the relative likelihood of those values occurring. The method involves the following general process:

1. Each parameter which is both an input to the modelling process and subject to uncertainty in some way is replaced with a random variable. The user must specify the range of possible values for each uncertain variable and the relative likelihood of those values. Essentially, the user manually defines the probability distribution of each variable. This probability distribution can take various forms (for example, normal distribution, triangular distribution, uniform distribution) depending on prior expectations regarding its behaviour.

2. A computerised process then undertakes a number of 'iterations' in which a value is drawn at random from the probability distributions of each random variable and combined to produce a value for the output variable. Thousands of such iterations are performed to provide a picture of the full range of possible values for the output variable. The range and relative likelihood of the output values generated creates a probability distribution for the output variable (much like those defined by the user for input variables). This probability distribution allows the user to view the range of all possible outcomes and how likely each of those is relative to others.

This iteration process in this analysis is carried out in Microsoft Excel using a piece of Monte-Carlo simulation software, @RISK.

C2 Advantages

- *Interpretation:*

  The Monte-Carlo output provides a mathematical and visual representation of possible outcomes (see Figures 4 and 5 in Section 4). This provides a systematic and formalised approach to uncertainty as a whole and a richer understanding of the likelihood of a range of forecast outcomes. The probability of reaching any given outcome can be derived or a confidence interval can be established for a given level of confidence.

- *Correlations:*

With inputs defined as random variables it is possible to specify a degree of correlation between certain variables in order to reflect cases in which two random variables tend to consistently move either in the same or opposite directions. This makes the modelling more accurate by incorporating a greater level of realistic detail.

- *Sensitivity Analysis:*

  The Monte-Carlo method allows a range of tests to be applied to investigate the effect on the output variable of an individual input as it varies across different values. This provides improved understanding of the sensitivity of the results to key inputs and therefore of the robustness of the conclusions of the analysis.

C3 Limitations

- *Defining Input Distributions:*

  While the Monte-Carlo method provides an accurate and objective picture of overall uncertainty given the inputs, it relies on the accuracy of the probability distributions attributed to input variables. If the probability distribution of an input variable were inaccurately specified this would adversely affect the accuracy of the overall Monte-Carlo output. Sections 5 and 6 describe the testing used to mitigate this risk.

Appendix D – Revisions to Previous Analysis

This appendix outlines revisions made to the analysis originally published in February 2013 in order to fully account for all of the known potential capacity expected to be delivered by 2020. The likelihood of meeting the target was underestimated in the original February 2013 analysis for this reason. In light of this, an external audit of the forecasting model was commissioned with NERA Economic Consulting to further ensure it is fully robust.

This audit identified no further issues that affect the method used in the main analysis. The conclusions of the audit are outlined in turn below.

- *Main analysis:*

  The analysis had been appropriately amended and there were no further issues that affect the method used in the main analysis.

- *Alternative method:*

  The auditing process highlighted improvements that could be made to the alternative forecasting method which is used as a sensitivity test (see Section 6.1 above). These changes only affect this sensitivity test, not the standard forecasting method of the main analysis. Implementing these changes reduces the estimated likelihood of meeting the target under the alternative method test.

- *Model appearance:*

  The auditing process highlighted improvements to the appearance of the model that do not have any impact on any of the results. These include changes to headings, possible formatting improvements and possible alternative formulas that could be considered to improve the efficiency of data updates in future. The majority of these improvements have been implemented and others will be considered for future model development.

Table D1 summarises the effect of the model amendments outlined above. The revision to the main analysis increases the estimated likelihood of meeting the target, by approximately two percentage points. The improvements to the alternative method sensitivity test reduce the estimated likelihood of meeting the target under this test. The results of this test are now lower than under the main analysis. Whilst the alternative approach provides a useful comparison to the main analysis, it 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.

Table D1: Effect of Model Revisions

Likelihood of meeting target	support given	provisional support withdrawn
Original February 2013 Report		
Main Analysis	95.0%	93.2%
Alternative Method Sensitivity Test	99.4%	99.0%
Revised February 2013 Report		
Main Analysis	96.6%	95.2%
Alternative Method Sensitivity Test	92.7%	89.6%