



Audit of WIDP Monte Carlo Model

Prepared for Defra

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1. Scope of Model Audit

NERA has been commissioned to audit two versions of Defra's Waste Infrastructure Delivery Programme (WIDP) Monte Carlo simulation model, which is an updated version of the model provided by NERA in November 2012. The aim of this model is to assess whether England is likely to achieve the necessary waste diversion as part of the UK targets under the 2020 Landfill Directive. The model uses a Monte Carlo simulation approach to assess the likelihood of meeting the target, taking as given a range of data inputs and assumptions including the statistical distribution of key determinants of waste arisings and the provision and performance of diversion capacity.

Our review focuses on the structure and implementation of the model within Microsoft Excel and the "@Risk" add-in. Hence, as well as checking for spreadsheet errors, etc, our review considers whether Defra's current model achieves the aims set out in the report on the original model provided by NERA, entitled "Stochastic Modelling of Landfill Directive Targets" (dated 20 December 2012). On this occasion, our review does not assess whether the data inputs and statistical distributions Defra has used are appropriate.

Defra has asked that we audit two versions of its model, entitled "WIDP MC Forecast v6 AMENDED" and "WIDP MC Forecast v9 050713".¹ The results from our audit of these models are presented in the tables below. The tables list the issues we identified, the effect of the issues on the model's results (if any), and where appropriate, suggests amendments to the model. As the tables below show, because the models are two versions of the same file, our comments on the two models are similar.

Following submission of these comments to Defra, we subsequently checked whether our recommended changes to the model had been implemented. The final column of the audit tables shows the findings from this final check. Note, we did not re-check the rest of the model at this stage; we only confirmed whether our recommended changes had been implemented as we intended.

¹ Received by NERA from Defra by email on 5 July 2013.

2. Model Audit Results

Table 1
Audit of Model “WIDP MC Forecast v6 AMENDED”

Worksheet	Affected Cells	Description of Issue	Suggested Change	Effect of Change (if any)	Changes implemented by DEFRA?
Outputs	F14	<p>The volume of waste diverted from landfill (implied by the EA landfill returns data) is multiplied by a “Programme Contingency” when the model performs the “Method 2” calculations. It is not clear why this adjustment is necessary, as the volume of diversion should already account for the effects of outages and any other derates to capacity.</p> <p>In general, contingencies (such as those applied in the original model we audited in 2012) should not be necessary within this stochastic framework.</p>	<p>We suggest removing the multiplication by cell E46 from the Inputs sheet from this calculation.</p> <p>However, we understand from Defra that the purpose of this adjustment is also to reflect uncertainty about the capability of the existing capacity/availability of diversion projects. Hence, we recommend adding a new variable on the Inputs sheet to reflect this uncertainty, but with a mean value of 100%, as there is no basis on which to think the sample year diversion volumes are higher or lower than average for given capacity.</p>	<p>The effect of this change would be to slightly increase the probability of meeting the target under Method 2. No effect on Method 1 results.</p>	Change implemented
Inputs	J9, J10, L9, L10	Cells contain links but are shaded yellow, which is the colour of input cells.	Change cell colour to green, in line with the model convention.	No effect.	Change implemented

Inputs	C46 & E46	Typo in the spelling the word "contingency"	Replace word 'Contringency in cell C46 and 'Continengency' in cell E46	No effect.	Change implemented
Inputs	E14 and E15	The colour coding is not consistent with the convention used in the model.	Format E14 and E15 in green	No effect.	Change implemented
Diversion Efficiency	F21, F22, F24, F32, F33	Cells have no dependents. If you were to change the assumptions in these cells, you should make sure you change the structure of the calculations at the same time.	You could potentially insert a check to ensure that cells F21:F24 and cells F32:F35 sum to 100%.	No effect.	Change implemented
Diversion Efficiency	F23, F34	Typo: 'residues to landrill'	Change to 'Residues to landfill'	No effect.	Change implemented
Delivery Adjustment	Column L	The formula which calculates DAR is different for the subset of projects featured in the 'Project Controls' table. While these manual adjustments seem to be working as intended, the way in which they have been implemented is prone to future errors when updating the database of projects.	We would suggest adding a column indicating whether each project belongs to the subset of projects that has its own DAR. You could then add an "IF" statement to say if the project does have its own DAR then the model should pick up DARs from a different table than if it does not.	No effect.	Change not implemented, as this is a potential improvement to be made during future model development.
Sum Capacity	Array J8 to J18	We have given some further consideration to the aggregation of new capacity that is used for Method 2. Because capacity will tend to come online gradually over time, the volume of waste diverted from landfill in a given year will represent the average volume of capacity installed during that year, and not the	To illustrate the effect of adopting a less conservative approach to estimating the amount of diversion capacity currently online, we suggest adding half of the capacity added in the sample year to the volume of waste diverted.	Making this change would increase slightly the probability of meeting the target under Method 2. No effect on Method 1 results.	Change implemented

		capacity available at the end of the year. Therefore, by adding the volume of waste diverted in the sample year (as a proxy for average capacity) to new capacity delivered after the end of the year, the volume of capacity installed by 2020 is probably slightly understated.	Hence, for example, the formula in cell J8 would become: =SUM(F9:F18)+F8/2		
Forecasts	Rows 58:87 Columns L:Q	Although we see no problem with the calculations, the structure of this sheet could be improved.	One way to improve the structure, rather than adding new forecasts to the bottom of the worksheet and referencing them in the Inputs sheet, might be to (1) move the tables current in rows 38 and below to a new worksheet, and (2) link the data currently in E9:E19 to the data currently in O40:O50. Also, if moving the data in rows 38 and below to a new sheet, it would probably make sense to move the tables in cells L7:Q34 to the same new worksheet.	No effect.	Change not implemented, as this is a potential improvement to be made during future model development.
Forecasts	E10, E11 E9	Wrong colour code	These cells are calculations, fill in blue	No effect	Change implemented

Outturn	H22,H23 I22, I23	There are potentially circular formulae in these cells. We would recommend changing the structure of the formulae to ensure the model remains robust.	We recommend copying cells H23:I23 (including the formulae) and pasting them in H22:I22.	This does not affect the analysis at the moment, as Method 2 uses 2011 as the base year for the calculations.	Change implemented
Outturn	G8 – G18	The residual BMW is calculated as BMW Content x Waste x Recycling Rate, which is incorrect.	Change to BMW Content x Waste x (1 – Recycling Rate) . Note, the recycling rate (in H22:I32 on the Outturn sheet) appears in the formulae in this array four times. For example, for cell G8 the corrected formula should be: $=IF(F8=0,0,(IF(Inputs!$F$74=1,(1-H22)*Forecasts!E9,Forecasts!E24*(1-H22))+IF(Inputs!F75=1,(1-I22)*Forecasts!F9,(1-I22)*Forecasts!F24))*Inputs!E24)$	The effect of this change is to reduce slightly the probability of meeting the target under Method 2, and to bring the results of Methods 1 and 2 more closely into line. However, the effect is small because the recycling rate is close to 50%.	Change implemented
Outturn	G7, C20	Typos	Change G7 for 'Residual BMW (mt)' and C20 for 'Recycling Rates'	No effect	Change implemented

Outturn	G22	Defra has advised us that a change in the assumed recycling rate is required.	Use the recycling rate from the 2009 C&I survey of 52%.	This makes no difference to any of the results used, but is amended for completeness.	Change implemented
Forecasts	E9-11	Defra has advised us that these input assumptions should be based on the household waste arisings data shown below on the same worksheet.	Change of cell references is required.	No effect	Change implemented
Outturn	F8- F9	Defra has advised us that the inputs in these cells should change, and has provided the data.	Change in input assumptions required.	Reduces slightly the likelihood of meeting the target under method 2.	Change implemented

Table 2
Audit of Model “WIDP MC Forecast v9 050713”

Worksheet	Affected Cells	Description of Issue	Suggested Change	Effect of Change (if any)	Changes implemented by DEFRA?
Inputs	C46 & E46	Typo in the spelling the word “contingency”	Replace word ‘Contringency in cell C46 and ‘Continengency’ in cell E46	No effect	Change implemented
Sum Capacity	Array J8 to J18	<p>We have given some further consideration to the aggregation of new capacity that is used for Method 2.</p> <p>Because capacity will tend to come online gradually over time, the volume of waste diverted from landfill in a given year will represent the average volume of capacity installed during that year, and not the capacity available at the end of the year. Therefore, by adding the volume of waste diverted in the sample year (as a proxy for average capacity) to new capacity delivered after the end of the year, the volume of capacity installed by 2020 is probably slightly understated.</p>	<p>To illustrate the effect of adopting a less conservative approach to estimating the amount of diversion capacity currently online, we suggest adding half of the capacity added in the sample year to the volume of waste diverted. Hence, for example, the formula in cell J8 would become:</p> $=SUM(F9:F18)+F8/2$	Making this change would increase slightly the probability of meeting the target under Method 2. No effect on Method 1 results.	Change implemented
Outputs	F14	The volume of waste diverted from landfill (implied by the EA landfill returns data) is multiplied by a “Programme Contingency” when the model performs the “Method 2” calculations. It is not clear why this adjustment is necessary, as the volume of diversion should already account for the	<p>We suggest removing the multiplication by cell E46 from the Inputs sheet from this calculation.</p> <p>However, we understand from Defra that the purpose</p>	The effect of this change would be to slightly increase the probability of meeting the target under Method 2. No effect	Change implemented

		<p>effects of outages and any other derates to capacity.</p> <p>In general, contingencies (such as those applied in the original model we audited in 2012) should not be necessary within this stochastic framework.</p>	<p>of this adjustment is also to reflect uncertainty about the capability of the existing capacity/availability of diversion projects. Hence, we recommend adding a new variable on the Inputs sheet to reflect this uncertainty, but with a mean value of 100%, as there is no basis on which to think the sample year diversion volumes are higher or lower than average for given capacity.</p>	<p>on Method 1 results.</p>	
Inputs	E14 and E15	The colour coding is not consistent with the convention used in the model.	Format E14 and E15 in green	No effect.	Change implemented
Correlations	F8 to GV206	The re-ordering of projects as compared to the version we provided has caused the data on the Projects worksheet to go out of line with the correlation matrix.	<p>It may be desirable to fix this issue to make the model more robust to future changes.</p> <p>In general, after adding a new project to the project list, or re-ordering the project list, the correlation matrix needs to be re-created:</p> <ol style="list-style-type: none"> 1. First, click in cell E7 of the 'Correlation' sheet, where the current correlation matrix is located 2. Click on the Define Correlations button in the 	<p>This does not affect the analysis, because it assumes no correlation between the delivery of projects.</p> <p>Also, as long as all projects have the same correlation coefficients, this mistake will not matter to the analysis.</p>	Change implemented

			<p>@Risk ribbon. This opens the correlation matrix environment</p> <p>3. Click on the button 'Delete Matrix' to delete the old correlation matrix</p> <p>4. Then define the new correlation matrix:</p> <p>a. Re-click on the Define Correlations button in the @Risk ribbon.</p> <p>b. Enter the matrix name (eg 'corr') in the first line 'Matrix Name'</p> <p>c. Specify the location of the matrix with the Location button (eg E7 of the Correlations sheet)</p> <p>d. Define the correlated inputs by clicking the button Add Inputs and add first the cells E9:E10 of the Input sheet, then cells E21:E22 of the Input sheet and then the cells P23 to P217 of the Project sheet which includes the new project list</p> <p>e. Then click OK, and edit the yellow cells of the matrix with the correlation coefficient (eg type = C8 in</p>		
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			<p>cell F9 so that the correlation between LA arising and C&I arising is equal to the value specified in cell C8, as in the v9 of the model)</p> <p>The new correlation matrix consistent with the new project list is now created.</p>		
Delivery Adjustment	Column L	<p>The formula which calculates DAR is different for the subset of projects featured in the 'Project Controls' table. While these manual adjustments seem to be working as intended, the way in which they have been implemented is prone to future errors when updating the database of projects.</p>	<p>We would suggest adding a column indicating whether each project belongs to the subset of projects that has its own DAR. You could then add an "IF" statement to say if the project does have its own DAR then the model should pick up DARs from a different table than if it does not.</p>	No effect.	<p>Change not implemented, as this is a potential improvement to be made during future model development.</p>
Diversion Efficiency	F21, F22, F24, F32, F33	<p>Cells have no dependents. If you were to change the assumptions in these cells, you should make sure you change the structure of the calculations at the same time.</p>	<p>You could potentially insert a check to ensure that cells F21:F24 and cells F32:F35 sum to 100%.</p>	No effect.	Change implemented
Forecasts	<p>Rows 58:87</p> <p>Columns L:Q</p>	<p>Although we see no problem with the calculations, the structure of this sheet could be improved.</p>	<p>One way to improve the structure, rather than adding new forecasts to the bottom of the worksheet and referencing them in the Inputs sheet, might be to (1) move the tables current in rows 38 and below to a new</p>	No effect.	<p>Change not implemented, as this is a potential improvement to be made during future model development.</p>

			<p>worksheet, and (2) link the data currently in E9:E19 to the data currently in O40:O50.</p> <p>Also, if moving the data in rows 38 and below to a new sheet, it would probably make sense to move the tables in cells L7:Q34 to the same new worksheet.</p>		
Inputs	J9, J10, L9, L10	Cells contain links but are shaded yellow, which is the colour of input cells.	Change cell colour to green, in line with the model convention.	No effect.	Change implemented
Forecasts	E10, E11 E9	Wrong colour code	These cells are calculations, fill in blue	No effect	Change implemented
Outturn	G7, C20	Typos	Change G7 for 'Residual BMW (mt)' and C20 for 'Recycling Rates'	No effect	Change implemented
Outturn	H22,H23 I22, I23	There are potentially circular formulae in these cells. We would recommend changing the structure of the formulae to ensure the model remains robust.	We recommend copying cells H23:I23 (including the formulae) and pasting them in H22:I22.	This does not affect the analysis at the moment, as Method 2 uses 2011 as the base year for the calculations.	Change implemented
Outturn	G8 – G18	The residual BMW is calculated as BMW Content x Waste x Recycling Rate, which is incorrect.	Change to BMW Content x Waste x (1 – Recycling Rate) . Note, the recycling rate (in H22:I32 on the Outturn sheet) appears in the formulae in this array four times. For example, for cell	The effect of this change is to reduce slightly the probability of meeting the target under Method 2, and to bring the results of Methods 1 and 2	Change implemented

			<p>G8 the corrected formula should be:</p> $=IF(F8=0,0,(IF(Inputs!\$F\$74=1,(1-H22)*Forecasts!E9,Forecasts!E24*(1-H22))+IF(Inputs!\$F\$75=1,(1-I22)*Forecasts!F9,(1-I22)*Forecasts!F24))*Inputs!\$E\$24)$	<p>more closely into line. However, the effect is small because the recycling rate is close to 50%.</p>	
Outturn	G22	Defra has advised us that a change in the assumed recycling rate is required.	Use the recycling rate from the 2009 C&I survey of 52%.	This makes no difference to any of the results used, but is amended for completeness.	Change implemented
Outturn	F8- F9	Defra has advised us that the inputs in these cells should change, and has provided the data.	Change in input assumptions required.	Reduces slightly the likelihood of meeting the target under method 2.	Change implemented
Forecasts	E40-E53	Defra has advised us that the data inputs in these cells should change, and has provided the new data. This affects the assumptions for 2011-12	Change in input assumptions required.	Reduces slightly the likelihood of meeting the target under method 2.	Change implemented

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