FINAL REPORT 2013/14			
Recipient	**Department of Energy and Climate Change (DECC)**		
Title	**Review of LCP Envision Power Market Model**		
Date issued	13 August 2014	**Report No**	

OVERALL ASSURANCE	RED	AMBER / RED	AMBER / GREEN	GREEN
Some weaknesses in control environment				

AREAS EXAMINED	ASSURANCE FOR EACH AREA EXAMINED			
	RED	AMBER/ RED	AMBER/ GREEN	GREEN
C# model inputs				
C# components				
C# model outputs				

DEFINITION OF ASSURANCE LEVELS

RED	AMBER / RED	AMBER / GREEN	GREEN
Fundamental weaknesses in control environment *Urgent actions required*	Significant weaknesses in control environment *Urgent / necessary actions required*	Some weaknesses in control environment *Necessary actions required.*	Strong control environment *No actions required*

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PART 1 – EXECUTIVE SUMMARY

Introduction

Envision is a power market dispatch model that has been built by LCP for DECC. The scope of the model is to perform two primary functions. The first (Dispatch Model) reports metrics of electricity dispatch from British (GB) power generators. The second (Investment Decisions Model) determines appropriate investment decisions in generating capacity in GB.

The model opens through a user interface that allows the user to specify the input files and parameters used for a model run, the output templates, and where to store the output from the model. The input and output files are stored as Excel spreadsheets but the core simulation component has been built using the object oriented programming language C#. The Excel files contain the model run core outputs and calculations, related to cost-benefit analysis, that are based on the model run outputs.

Review Objective

The investment decisions component of the model has been reviewed and DECC now require a review of the remainder of the code.

The objectives of the review are outlined in the Scope of Review section below

Scope

The review has included coverage of the following:

The C# Modelling suite:
The modelling suite consists of the C# component and the Excel input and output sheets. In C#, only the code files that are relevant to the components specified in the scoping contract have been included in our scope of work. Other code files have been examined as part of this review only if they contain calls to the scoped in sections of the code or are called by it (unless they have been reviewed as part of the work previously performed on investment decision which was assumed to be functioning appropriately). The version of the code files reviewed was Envision 4.0.12.35.4.The testing has been completed using Microsoft Visual Studio 2012 with .Net Framework 4.0 and Excel 2010 on Windows 7. Coverage has included:

1. **C# Model Inputs**
Confirmation that the inputs from the components as specified in the Scoping Contract are accurately read in, any transformations to the data are consistent with the algorithm set out in the documentation, and whether they are applied to the algorithm also as specified in the documentation.

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2. **C# Components**
Confirmation that the relevant code files perform calculations as specified in the documentation for the components as specified in the Scoping Contract.

3. **Model Outputs**
Confirmation that the outputs from the components as specified in the Scoping Contract resulting from the internal calculations are correctly stored in memory and copied to the deterministic or stochastic output sheets

In addition we have performed the following procedures:

- Checked the code for hard-coded values and redundant or unused code;
- Tested how the model deals with poor input data, i.e. missing values, zeroes/infinities, and examined the limits of the model, i.e. over what range of inputs does it behave; and
- Provided observations on whether the code can be made more efficient.

Approach

Procedures undertaken to test the model are summarised in Annex B. Annex C summarises results of specific tests undertaken to review the C# model under different inputs.

Exclusions

The review has been restricted to the specified code modules per the Scoping Contract and related input and output files. The following have been excluded:

- Review of the assumptions made in preparing the model (including the economic, climate and assumption files);
- Except to the extent that our scope explicitly included such tests, our work assumed that the inputs and assumptions to the model had been properly extracted from relevant underlying documentation and we did not perform any procedures to check such extraction;
- The extent and nature of issues identified relate solely to the scope of the review requested. As sensitivity analyses were not in scope, with the exception of testing input data and examining the limits of the model, the review was only a technical (arithmetical) check of the formulae and calculations in the model and not an analytical review of variances in the model. Therefore, errors that might otherwise be picked up by sensitivity analyses may not have been identified;
- Review of parts of the model relating to the investment decisions. Our work has been carried out on the assumption that the investment decisions models operate as intended. We have not checked or carried out a full review of the C# code files relating to the investment decisions model. This part of the model was also subject to review by PWC in December 2013 (Model Version 3.3.5.0). We may have reviewed some code included in the investment decisions folder if they relate to function calls to or from the specified modules of code in the scoping document;
- Review or comment on the appropriateness of the evaluation methodology used in the models; and
- Review of any of the assumptions, judgements and commercial risks associated with the proposed investments.

Additionally, we have not reviewed the correctness of the stochastic evolutions (as these are not explained in detail in the user guide) or the implementation of the Random number generator.

Overall Assurance

Some weaknesses in the control environment

We have undertaken testing of the C# component, of the Envision dispatch model and reviewed governance arrangements surrounding its operation. No issues were found with the C# code that could impact on the model performance. Eleven areas for improvement have been identified to address issues that were noted during the review.

If the eleven areas for improvement are addressed as described in the Management Responses, the overall assurance and the assurance for each area examined can be considered to have changed from AMBER/GREEN to GREEN.

The main findings from our review are:

C# component
The C# component of the model has been implemented as described in the Envision technical user guide. As part of the review process, some minor issues have been found relating to the code and documentation but these do not affect the overall output of the model, where the model is used with the current input assumptions and working settings.

Potential to improve efficiency
During the review, opportunities to improve the efficiency of the model were noted, including:

- The model currently starts at 2010 (in reality 01/12/2009) and has to simulate five years of calculations before it reaches the current year; and
- The structure that holds the Largest Credible Loss Requirement by Date is rebuilt every time the simulation loop in the Unserved energy module is run even though it is static and therefore there is potential for efficiency improvement.

Review Scope and Summary of Conclusions		
Area examined:	**Assurance:**	**Conclusion:**
C# model inputs	 Some weaknesses in control environment	Testing has been undertaken of the inputs from the following, to confirm whether they are accurately read in, any transformations to the data are consistent with the algorithm set out in the documentation, and that they are applied to the algorithm also as specified in the documentation. • Inputs specified in the user interface • Climate data file • Economic data file • Technology Assumptions • Technology Efficiency Rates • Outage rates (new and existing) • Fuel Assumptions • Demand Projections • Policy Demand Reductions • Daily Load Curves • Policy Overview • Existing Policies • Strategic Reserve • Carbon Price Floor • Tax on Profit • Tax on CO2 • Tax on Fuel • Policy Billing • Capacity Mechanism • Feed in tariff (1-7) • CfD (contract for difference) (1-25) • Regulated Asset Base 1 • Capacity Payments • CO2 Limits • Reserve • Autogeneration • Interconnectors • UEM Inputs • Strike Prices • Heat revenues • CfD Network Losses Adjustment • Capacity Payment 1 • EDF Pricing Assumptions • Pricing Mark-up • Capacity Margin Derating • DSR • Inter Fixed Flow 1 • Inter Price Responsive 1 • Maximum Build Limits (changed since previous version) • Cumulative Max Build Limits (changed) • New Plant (changed) • Water • Efficiency Rates • Spark and Dark Spreads

Area examined:	Assurance:	Conclusion:
		• Intermittency • Existing Plant • Upgrades • Investment scenarios • UEM Data No significant issues have been identified. However, five minor issues were identified, which are described in detail in Finding 1. It was also noted that in some cases where the Envision model is provided with inconsistent input assumptions, the model crashes (see Finding 3).
C# components	 Some weaknesses in control environment	Testing has been undertaken to confirm whether the relevant code files perform calculations as specified in the documentation for the following components of the model when operated both in Deterministic and Stochastic modes: • Simulation Loop • Calculate Operating Capacity ➢ Application of limited running hours strategy ➢ Planned outages ➢ Unplanned outages • Calculate SRMC • Calculate Merit Order • Simulate Quarter • Calculate Demand net of interconnection, pumped storage, autogeneration and wind • Calculate required reserve • Calculate system SRMC • Calculate Price Mark-up • Calculate wholesale price • Calculate consumer price • Calculate plant income and utilisation • Calculate power plant balance sheets • Calculate policy costs ➢ Renewable obligation certificates ➢ Levy exemption certificates ➢ Potential policies ➢ Fixed feed in tariffs ➢ Premium feed in tariff ➢ Contract for difference ➢ Carbon price ➢ Carbon price floor ➢ Regulated Asset Base ➢ Capacity Payment ➢ CO2 Limits ➢ Strategic Reserve ➢ Tax on profit ➢ Tax on CO2 ➢ Tax on fuel • Capacity Mechanism ➢ Triggering the auction

Area examined:	Assurance:	Conclusion:
		➢ Plant eligibility ➢ Interaction with new build ➢ Plant bids ➢ Clearing the auction • Output quarterly values • Create Summary Demand Profiles • Update Interconnector and Pumped Storage Summary Profiles • Update Plant Specific Data • State Transition of Plant No significant issues have been identified. However a number of non-critical issues have been identified, which are described in detail in Finding 2. Opportunities to improve the efficiency of the model were noted, including: • the model currently starts at 2010 (in reality 01/12/2009) and has to simulate five years of calculations before it reaches the current year (see Finding 3)**.** • the structure that holds the Largest Credible Loss Requirement by Date is rebuilt every time the simulation loop in the Unserved energy module is run even though it is static and therefore could be a potential area of inefficiency (see Finding 4).
C# model outputs	 Some weaknesses in control environment	The following outputs resulting from the Model internal calculations have been reviewed to confirm that they are correctly stored in memory and copied to their respective deterministic output sheets: • Operating Capacity • Installed Capacity • Generation • Prices • IRRs • Spreads • Fuel • Demand • Fuel Prices – worksheet not generated in deterministic output as it would be repeating model inputs • Carbon price– worksheet not generated in deterministic output as it would be repeating model inputs • Portfolio Data – Portfolios are not used in the current set-up • Reserve payments • CapacityMechanism • CMBids • CO2 • Prices • DeratedCapacities • DemandExtreme

Area examined:	Assurance:	Conclusion:
		• CASHFLOW Capacity • CASHFLOW CM Payments • PolicyCosts • Load Curve - duration and demand curve construction explanation is not currently included in the user guide. • Wholesale curve • SystemSRMC Curve • IntraDayGeneration • Upgrade report • CASHFLOW Max capacity • CASHFLOW LoadFactor • CASHFLOW SRMC • CASHFLOW strike price • CASHFLOW generation • CASHFLOW income • CASHFLOW profit • CASHFLOW Spread • CASHFLOW IRRs • CASHFLOW CM Penalty • CM Penalties • MarginalEmissions curve • Marginal emission factors • CapacityMechanism • CM payments • CMcapacityProcured • RenewableSplitGeneration • SC – Generation • SC – Construction • SC – Capacity Mechanism – worksheet not generated in deterministic output • SC – Ancillery Payments - explanation on metric's calculation is not currently in the user guide. • SC – Financing Cost • EEU • LOLE • EFC Data • SC – Ancillary Payments • System cost (broken down into SC – Generation, SC – Construction, SC - Cap Mech, SC – Ancillary, SC - Financing Cost) • Retail prices • LOLE data • PolicyCostsByTech • SC – Cap Mech • SC – Ancillary • Investor Decisions • Costs The following outputs resulting from the Model internal calculations have been reviewed to confirm that they are correctly stored in memory and copied to their respective stochastic output sheets

Area examined:	Assurance:	Conclusion:
		• Generation • Generation Mix • Operating capacity • Unserved Energy • Installed Capacity • Capacity in development • Capacity margin - explanation on metric's calculation is not currently in the user guide. • Short run marginal costs - explanation on metric's calculation is not currently in the user guide. • Demand • Peak Prices • Off-peak prices • Policy • Fuel consumed • Load factors- explanation on metric's calculation is not currently in the user guide. • Emissions • Fuel prices • Carbon prices • New Build Capacity • Mothballed Capacity • Derated Capacity – Note that only the Central Derated capacity is displayed • Decommissioned Capacity No significant issues have been identified. There are very immaterial rounding errors. Additionally, for best practice purposes, the model should not allow a stochastic run unless the correct stochastic output template is inserted. A potential issue could arise where a tab exists in the template output for outputs not outputted by the model as highlighted above which would cause data in the worksheet not to be updated and thus mistakenly taken for model output (see Finding 1).

PART 2 – DETAILED AUDIT FINDINGS

Finding 1: Issues identified for C# Model Inputs and outputs

Key residual risks	Actual controls in place
• If the user guide does not provide accurate and up to date procedure notes for inputs, the model may not be operated properly and consistently.	• A user guide exists, which describes inputs to the model, and is available to users.

Detailed Findings

Testing has been undertaken of the inputs to confirm whether they are accurately read in, any transformations to the data are consistent with the algorithm set out in the documentation, and that they are applied to the algorithm also as specified in the documentation. No significant issues have been identified. However, six minor issues have been identified as follows:

1) The inputs are scaled to :
    a. £ Millions for any financial assumption
    b. Tonnes for emissions
    c. MW for capacities and generation
    d. Fuel specific units for units of fuel used

    It should be noted that in many cases the outputs do not include Units for example the SRMC Cashflow is in £m but this is not stated anywhere in the output sheet **(see recommendation #1)**.
2) A group of inputs including Efficiency, Fixed and Variable costs and Daily load curves have a small unique error introduced for each plant, for which, upon enquiring with LCP, it was confirmed that this is to ensure uniqueness of calculation outputs. The errors will not materially affect the results as they are in the order of 10^{-14}.
3) Duplication of certain inputs exist in the input file for example Plant Variable Costs and No Load Costs exist both in Existing Plant worksheet and the Technology Assumptions worksheets. Both are read correctly into the code however only the Technology Assumptions inputs are used in the calculation **(see recommendation #2).**
4) The input reader works consistently as long as the excel cells names are kept unchanged. Any change in the cell names would cause anomalies in the reading of the data. The names of the cells are hardcoded in their respective reader classes and are not centrally kept making editing in the code segmented and difficult.

    LCP's response was that when developing the read-in they determined that this is one of the rare situations when locating the name ranges in a central location would actually be detrimental to maintainability. The current approach keeps the name range definitions within the object responsible for reading that area, for example the module responsible for the capacity mechanism contains all of the named range definitions for the corresponding worksheet. The way the named ranges are defined mean that all read-ins are defined only once and no named range reference is duplicated. Introducing a central list of named ranges would and an unnecessary additional layer of naming.
5) We have noted that the demand file is read and stored in a data structure up to 24/04/2011 The last 6 days' worth of data are discarded as they do not form a complete week.
6) A separate point to note on inputs is that the carbon medium point is in many cases higher than the carbon high point in the input file (this does not affect the input reading but does affect the output). The carbon high and low points are only used when running the model in stochastic mode.
7) Some inputs in the user guide are explained to be read from the wrong worksheet **(see recommendation #3).**
8) A potential issue could arise where a tab exists in the template output for outputs not

outputted by the model which would cause data in the worksheet not to be updated and thus mistakenly taken for model output **(see recommendation #4).**

Proposed Action	Priority level
1) The scaling factors for all inputs scaled, units for the key variables and output unit should be included in the user guide as well as the output spreadsheet.	Action is necessary
2) All duplication instances should be investigated and removed to ensure consistency and robustness.	Action is necessary
3) The User Guide should be updated to ensure it is consistent with the current version of the model. For example listing the correct source for all inputs.	Action is necessary
4) Controls should be put in place to ensure template output spreadsheets only contain tabs that are outputted by the model. .	Action is necessary

Management Response

1) We have asked LCP to add units and scaling factors to the user guide. A list of all output sheets produced by Envision will be added to the output template along with units used in each.

2) We will remove instances of unused inputs or add comments to indicate that they are unused where appropriate, checking with LCP that we have made the correct changes. The example of Plant Variable Costs and No Load Costs was tested and the code actually does use both sets of costs, one for existing/pipeline plants, and one for plants built endogenously by the model, so both will be kept in the input file.

3) We will review the user guide and ask LCP to change incorrect references to the input file.

4) We will list all output sheets produced by Envision (see response to recommendation 1). Other sheets have been added by DECC, for example some sheets are copied from the input file when the model is run, and some sheets are added to interpret or analyse the raw outputs, or to present them in summary tables and charts. These will be labelled appropriately.

Action owner	Action to be completed by	Progress report due by
Stuart Younger	30/09/2014	For IA use only

Finding 2: Issues identified for C# Model Calculations

Key residual risks	Actual controls in place
• If the user guide does not provide accurate and up to date descriptions for calculations, the model may not be operated properly and consistently.	A user guide exists, which describes calculations undertaken by the model, and is available to users.

Detailed Findings

Testing has been undertaken to confirm whether the relevant code files perform calculations as specified in the documentation when operated both in Deterministic and Stochastic modes.

No significant issues have been identified. However a number of non-critical issues have been identified, which are described below:

1) Parts of the CHP module have been switched-on, however we have not found any change in calculation that is caused by this part of the code. There are implementations of CHP module operational throughout the code which perform calculations but do not affect the outcomes of any of the above calculations. However, they do consume computational time.

2) There are some hardcoded parts of the code but these mainly relate to global constants, for example the Unserved Energy Deratings **(see recommendation #5)**.

   Of importance is a hardcoded procedure in the ModelEngine Class which removes the error handling if the user is “jrp” or “twp”. It has been confirmed with LCP that this will be removed in future releases and that if one of DECC’s users has the same username they would experience no change in the results produced by the model.

3) Feed in Tariffs - Modelled based on Output

   a. If it is a fixed feed- in Tariff then the cost is calculated as Tariff * plant Generation - plant IncomeFromOutput. This is not consistent with the User Guide. Per the user guide this should be Tariff * plant Generation;
   b. If it is a Premium fuel Based tariff then Tariff * plant Generation - plant IncomeFromOutput + plant FuelCosts which is consistent with User Guide
   The current settings in the input spreadsheet all point to the fuel based tariff and therefore the current results are not affected by this inconsistency.

It has been confirmed with LCP that this is a user guide inconsistency not a model one and the user guide will be revised.

4) Feed in Tariffs - Modelled based on Capacity. This is not used in the model currently as settings are set to output but it stills suffers from the same inconsistency.

   a. If it is a fixed feed- in Tariff then the cost is calculated as Tariff * plant Capacity- plant IncomeFromOutput <- Not Consistent with the User Guide. Per the user guide this should be Tariff * plant Capacity

It has been confirmed with LCP that this is a user guide inconsistency not a model one and the user guide will be revised.

5) CFD Cost Calculation

a. If the ReferenceIndex is Spreadbased then the cost is calculated as: Cost = [plant Generation * CFD strikePrice - plant IncomeFromOutput + plant FuelCosts] *(1 - Network Losses) * Percentage Eligible and this is not consistent with the User Guide
b. For description on inputs purposes if the _upsideOption is ON then the cost is MAX of (Cost, 0)

It has been confirmed with LCP that this is a user guide inconsistency not a model one and the user guide will be revised.

6) CFD SRMC Adjustment

a. If the ReferencePrice is year ahead or season ahead: = (CFD referencePrice - CFDstrikePrices)* Percentage Eligible. This is not consistent with the user guide as the sign is reversed and also multiplied with the proportionOfCapacityEligibleForSupport
b. If the ReferencePrice is DayAhead = - CDF strikePrice. This is not explained in the user guide and should be added in subsequent versions.

It has been confirmed with LCP that this is a user guide inconsistency not a model one and the user guide will be revised.

7) The regulated Asset base cost of policy is not implemented. As discussed with DECC, this was intentional and the code gives an exception **(see recommendation #6).**

It has been confirmed with LCP that a regulated asset base is not currently planned within government policy it is not clear how it would, in theory, interact with the other areas of EMR, such as the Capacity Mechanism and CfDs. This code throws an error as a precaution.

8) Tax on Fuel Cost is calculated as -Fuel1Used*TaxRates - Fuel2Used * TaxRates which results in opposite sign from the user guide.

It has been confirmed with LCP that this is a user guide inconsistency not a model one and the user guide will be revised.

9) In the ROC Policy the Adjustment to SRMC sign is inverted from the formula shown in the user guide.

It has been confirmed with LCP that this is a user guide inconsistency not a model one and the user guide will be revised.

10) In the LEC Policy the Adjustment to SRMC sign is inverted from the formula shown in the user guide.

It has been confirmed with LCP that this is a user guide inconsistency not a model one and the user guide will be revised.

11) The UEM PDF generation is explained theoretically but inputs and iteration methods used to estimate the PDFs and calculating resultant outputs are not explained clearly in the UEM technical guide. An explanation of the workings has been provided to DECC to ensure that this is working as they intended. (See findings below)

12) The code has some over complication that leads to rounding errors and to degradation in model performance. As an example:

Per the definition, Initial outage probability = mean outage / (mean outage + mean running)
This translates to the following (All variables are from the input spreadsheet):
= Expected outage in days /[expected outage in days+ (expected outage in days * Average Availability)/(1-Average Availability)]
Which can be simplified as = 1-Average Availability
The above calculations introduce some very small rounding errors which are immaterial.

13) The model calculates an SRMC Heat and SRMC Power but these are not defined anywhere in the Technical user guide. These are used in the upgrades made for the CHP project, and we have confirmed that LCP will be including an explanation in the latest technical user guide.

14) The Largest plant capacity in the powerplant structure is based on the largest non-intermittent plant and not the largest plant. Therefore, the plants not taken into consideration when calculating the largest capacity are the ones that have FuelWater and are flagged as both must run and intermittent. The largest plant capacity is used in System Supply Curve and in calculating the Required reserve.
Confirmed with LCP that the largest plant definition will no-longer be used in modelling as it was decided a fixed amount was a more useful input.

15) When calculating the Plant Profit before tax the model adds CapacityMechanismPayments and subtracts CapacityMechanismPenalties which are not included in the formula in the user guide.

Proposed Action	Priority level
5) Hardcoded parts of the code should be centrally kept in a global data structure which can easily be tracked and changed.	Action is necessary
6) The user guide should be updated to reflect the model for the non-implementation of a regulated asset base cost of policy.	Action is necessary
7) For best practice purposes the model should not allow a stochastic run unless the correct stochastic template is inserted.	Action is necessary

Management Response

5) We have asked LCP to consider changing the way that hardcoded values are defined so that they are more easily traceable. In the case of the unserved energy deratings, LCP confirmed that the functionality is no longer used so can be removed.

6) We have asked LCP to update the user guide to explain that the RAB policy has not been implemented in the DDM.

7) We have asked LCP to insert a check at the start of a stochastic run, which will only allow the run to continue if a valid output template is inserted in the user interface.

Action owner	Action to be completed by	Progress report due by
Stuart Younger	30/09/2014	For IA use only

Finding 3: Inefficiencies

Key residual risks	Actual controls in place
• Entering of incorrect input assumptions may cause the code to crash. • Unnecessary calculations may reduce the efficiency of the model.	• Code files perform calculations as specified in the documentation.

Detailed Finding

It was noted that in some cases where the Envision model is provided with inconsistent input assumptions, the model crashes. **(see recommendation #9).**

It was also noted that the model currently starts at 2010 (in reality 01/12/2009) and thus has to simulate 5 years before it reaches the current year **(see recommendation #8).**

Proposed Action	Priority level
8) Unless results for the five years from 1/12/2009 are required for back-testing, the start date should be changed to improve the model's efficiency.	Action is necessary
9) Input validation and error handling should be improved to return an error message which clearly indicates the source of the problem.	Action is necessary

Management Response

8) Recent upgrades to the DDM have greatly improved its run time, so small improvements to efficiency are less important than they were in earlier versions. The projections can be extended beyond the current 40 years if required. Running the model from 2010 provides also more ready potential for backcasting. We propose that the model continues to run from 2010.

9) We will improve cell validation in the input file to reduce the risk of errors in the assumptions. The QA procedure that is followed when the model is run, is designed to locate changes in the input file and check that they are valid. The model also has a function that can be selected to check named ranges in the input file before it is read in. For errors that cause the model to crash while running the simulation, a model log file is produced with details of the error.

Action owner	Action to be completed by	Progress report due by
Stuart Younger	30/09/2014	For IA use only

Finding 4: Unserved Energy Module

Key residual risks	Actual controls in place
The user guide is not descriptive enough. The risk of the model not performing the exact operations that DECC desires or miscommunication about certain inputs is heightened.	• Enhancement of User Guide • Reasonableness review of the results.

Detailed Finding

Description of the Unserved Energy Module including initialisation of demand file, the conventional capacity distribution function, intermittent (wind) capacity distribution functions the demand distribution function and the EEU (Expected Energy Unserved) and LOLE (Loss of Load Expectation).

Firstly the required reserve for the year is retrieved by finding the Largest Credible Loss Requirement (per the Reserve input tab) for the year that is currently being modelled. The structure that holds the Largest Credible Loss Requirement by Date is rebuilt every time this is run even though it is static and therefore efficiency improvements are possible.

The model then iterates through the list of all plants to create a list of all operating intermittent plants (this includes solar and wind plants). The Assumed interconnector flow is then retrieved from the Assumed interconnector flow field for the relevant year from the UEM inputs.
The Peak Demand Level for the current simulation year for the current simulation demand values (either based on inputs or simulated depending on Stochastic or Deterministic) is used as the base and then the Autogeneration for the year as obtained from the user inputs in the autogeneration tab is subtracted from it to arrive at net peak demand.

The model then creates a list of all conventional plants (existing, pipeline and built by model) except intermittent plants, plants with Average availability of 0 or plants with Expected outage 0. This data structure includes each plants outage settings e.g. Average availability, initial outage probability, plant capacity and also calculates

DurationDistribution= recovery rate / PeriodsPerDay;

RunningDistribution= failureRatePerDay / PeriodsPerDay;

There are three scenarios that are considered. A +3000 MW shift, a 0 shift and a -3000MW shift.

A PDF structure is initialised by the model and then iteratively adds the capacity of each plant by:

For each conventional plant, the model does the following:

- If the step size is 25MW for example (per the UI setting) and the plant under consideration has a capacity of 53MW then
- 53/25 = 2 (always rounded to the nearest integer with the midpoint being allocated to the largest)

The new PDF is now 2 lengths bigger to show that the cumulative capacity including the new plant including the 50extra MW.

The process of creating the PDF is by multiplying the existing PDF number with (1-

Probability) the pre-existing vector position and any new positions by probability of availability.

The demand data is obtained from the UEM demand file. The UEM demand file is bucketed in weeks per season with granular data for each half hour of each of those weeks.

The data is stored after it has been scaled by its corresponding ACS value.

Each of the weeks in the winter season are then retrieved and scaled back to demand by multiplying by the peak demand value of the current simulation year.

The values for each half hour after scaling are then passed on to the PDF creation function.

The PDF creation function counts the amount of occurrences at each demand level and then divides by the total number to create a PDF of demand.

The demand distribution is then shifted for interconnection flow. This is done by changing the starting point of the PDF to take account of the interconnector flow. Then the demand distribution is also shifted for the reserve allowance in the same manner as the interconnector flow. Please note that only the minimum index number is shifted and not the maximum as it is updated automatically.

The average intermittency stream is then obtained by iterating through each wind plant and adding its capacity to the relevant wind stream. This would create two capacities: one for default onshore and one for default offshore. Then the Wind load factor data from the wind input file are obtained for the winter season.

The model then multiplies the appropriate load factor for each half hour with the capacity for off shore or onshore to get the two wind capacity files. The same methodology as the demand PDF creator is used to then create the wind capacity PDF.

The addition and subtraction of the PDFs is then performed by convolution.

EEU is then calculated as the mean of negative values in the resulting net pdf * days * 24 hrs. This is done with Shift 0 , shift 3000 and -3000 MW. LOLE is calculated as the probability of negative values in the resulting net pdf * days * 24 hrs also for the same scenarios.

Proposed Action	Priority level
10) LCP should expand the user guide to explain in more detail inputs, outputs and calculation workings	Action is necessary
11) DECC should confirm that the description above is as expected.	Action is necessary

Management Response

10) We have asked LCP to expand the technical guide to provide a fuller description of the UEM.

11) We have confirmed with LCP that the above description is correct for the specific setup of the model that was provided to PWC, for step size 25, running with 2 wind streams and with a shift in peak demand of +/-3000MW.

Action owner	Action to be completed by	Progress report due by
Stuart Younger	30/09/2014	

ANNEX A

DEFINITIONS

ASSURANCE LEVELS

Fundamental weaknesses in control environment

There are fundamental weaknesses in the risk and control environment that pose a very high residual risk to effective and efficient delivery unless urgent corrective action is taken.

Significant weaknesses in control environment

There are significant weaknesses in the risk and control environment that pose a high residual risk to effective and efficient delivery unless corrective action is taken.

Some weaknesses in control environment

The risk and control environment is generally sound. There are some weaknesses that should be addressed to reduce residual risk to delivery and/or improve efficiency/ effectiveness.

Strong control environment

A strong risk and control environment is in place with low residual risk to effective and efficient delivery.

AGREED ACTION PRIORITY LEVELS

"Urgent action is required" to address a serious weakness in control. IA will seek an implementation report within 1 month, and follow up within 3-6 months of final report to confirm the effectiveness of management's response.

"Action is necessary" within the agreed timeframe to address a significant weakness in control. IA will follow up to confirm the effectiveness of management's response within 3-6 months of final report.

ANNEX B

Review Procedures

The following table sets out the procedures used for testing the Envision Model:

Tasks & Objectives	Procedures
1. Review model specification document Objectives: • Confirm or not that the model meets the objectives set out in the model specification (or similar) document	• Review the model specification document or any other document describing the purpose of the model or some or all calculations contained in it, their expected functionality and outputs. • Report any exceptions and discrepancies between the model documentation and the model.

ANNEX C DETAILED TESTING

The following table summarises results of specific tests undertaken to review the model under different inputs.

As a general remark the validation of inputs performed by the model includes old excel fields not currently used and does not validate some of the newly added fields.

Description of Test	**Test Results**
Set a sample of Strike Prices to zero in sheet 'CFD Strike Prices – Control'. All other inputs are per the standard input file.	Output as expected
Set a sample of Strike Prices to negative in sheet 'CFD Strike Prices – Control'. All other inputs are per the standard input file.	Unlike ROC and LECs below this is not caught by validation – Output is significantly smaller and in some cases negative as expected.
Set a sample of values to zero in Existing Policies, ROC and LECs matrices.	Output as expected
Set a sample of values to negative in Existing Policies, ROC and LECs matrices	This is caught by the validation of the input files but simulation continues as normal and output is as expected with ROCs and LEC Policy cost considerably lower than the benchmark run.
Set Capacity Required in Strategic Reserve to 10^6 and 10^9	Not caught by validation, No change in output – as expected as this is used as a last resort.
Capacity mechanism: deratings negative or greater than 100%,	This is caught by validation but when the model is run it produces an index was out of range and Key Not Found exceptions
Extreme values for Auction delivery year horizon, New plant inclusion horizon, New plant contract duration	This is not caught by validation and Auction horizon gives an Index was out of range exception. The other 2 parameters produce and output as expected.
Demand Projections: test very high values of demand in some years, and negatives.	For very high values in demand a 'System.OutOfMemoryException' was thrown. This is an example of inadequate error handling which should be improved in future releases of the model. For small negative before 2015 then the model completes the run and the output is negative as expected For negative values after 2015 an Index was out of range exception is thrown stating that the index must be non-negative and less than the size of the collection. Confirmed with LCP that for the high demand

Description of Test	Test Results
	case the “System.OutOfMemoryException” is the correct error to be thrown. It is likely to be the result of building a huge number of plants which requires data to be held exceeding the available working memory of the machine. They believe that because this error is fatal to the application there is little value in intercepting this error message and they are not aware of this issue occurring with normal data, which is also supported by our testing. For the negative demand case it is caused by difficulties post 2015 in determining how to define the security standard for a system with negative demand. LCP will make sure going forward that negative values of demand are not permitted.
Daily Load Curves (new): Test out negative/zero/extremely high percentages of peak demand and zero frequencies, plus impact of frequencies not adding up to 365.	Frequencies not adding to 365 model runs as normal – output is changed as expected High percentages Arithmetic operation resulted in an overflow. Negative and 0 values runs as expected
Reserve: VoLL zero or negative	VoLL 0 – output as expected VoLL Negative – output as expected Note: output is unchanged as this changes the wholesale price on the event that there is unserved energy
Autogeneration: very large totals, e.g. higher than peak demand, negatives	Very large totals yield an Index was out of range error. Small negative values simulation completes as expected.
Interconnectors: extreme values of load factors, outside -100% to 100% range	This is disallowed to take any value outside the range in the input spreadsheet
Efficiency rates: Illegal values, e.g. negative or >100%	This is disallowed to take any value outside the range in the input spreadsheet