Department of Energy & Climate Change

FINAL REPORT 2013/2014

Recipient	**Department of Energy and Climate Change (DECC)**		
Title	**Review of LCP Envision Power Market (Dynamic Dispatch) Model**		
Date issued	4 December 2013	**Report No**	**1973**

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# investment decision calculations			▲	
C# model outputs				▲
Excel files				▲
Governance arrangements			▲	

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 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.

The investment decisions part of the model utilises a large amount of code that constitutes the dispatch model as it performs the same calculations under differing scenarios of new plants, plant upgrades and plant closures.

Review Objective

DECC has performed testing of the dispatch functions of the model, and to supplement this, we have undertaken a review of the investment decisions component, including the calculations in the Excel files from this component. In addition, general governance arrangements for agreeing input, performing runs and quality assurance of outputs for the model have been reviewed.

Scope

The review has included coverage of the following:

The C# Modelling suite:
The modelling suite consists of the C# component and 2 excel files. In C#, only the code files that are relevant to the investment decisions part of the model have been included in our scope of work. Other code files that are part of the dispatch model have been examined as part of this review only if they contained calls to the investment decisions code or are called by it. The version of the code files reviewed was Envision 3.3.5.0. The testing has been completed using Microsoft Visual Studio 2012 and Excel 2010 on Windows 7. Coverage has included:

1. **C# Model Inputs**
   Confirmation that the inputs relevant to the investment decisions components 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.
2. **Investment Decisions Calculations**
   Confirmation that the relevant code files perform calculations as specified in the documentation for specific components of the investment decisions model.
   - Upgrades
   - New Investment Decisions
   - Commission all new build from minimum build limits
   - Find all eligible projects to be considered
   - Determine which plant will be on the system

- Calculate SRMC of all plant
- Calculate Merit Order
- Run simulation
- Calculate utilisation and income for each eligible project
- Calculate Cash Flows and IRR for Eligible Projects
- Determine the Hurdle rate for each eligible plant
- Commission plant

3. **Model Outputs**
   Confirmation that outputs from the investment decisions calculations are correctly stored in memory and copied to the appropriate output charts and worksheets.

Excel output file:
The methodology statement paper related to the cost benefit analysis (***CBA calculation v0_2.docx***) has been reviewed and cross-referenced against the relevant sections in the model CBA results Template, namely the 'CBA' sheet. The formulae in the <CBA> sheet of the ***CBA Results template v2_62.4.xlsm*** model have been reviewed, including confirmation that the calculations are internally consistent, mathematically correct and copied down or across where expected.

Review of the governance arrangements:
Governance and control processes have been reviewed covering the arrangements in place for agreeing the input assumptions (parameters) for model runs, performing model runs (including the documentation or log of model runs) and the arrangements in place for quality assurance by management of the output results.

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 actual investment decisions specific code files and related input files, calls to the dispatch model code and the relevant investment decision outputs in the Excel 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 dispatch model. Our work has been carried out on the assumption that the core dispatch models operate as intended. We have not checked or carried out a full review of the C# code files relating to the dispatch model We

may have reviewed some code not included in the investment decisions folder if they relate to function calls to or from the investment decisions code;

- Review or comment on the appropriateness of the evaluation methodology used in the models;
- Review of any of the assumptions, judgements and commercial risks associated with the proposed investments;
- The excel models contain links to external files. We did not trace these formulae to the external sources, or confirm the validity of links and data;
- Review of sheets in the excel files that were not specifically included in scope (see appendix B to the Scoping Contract for a full list of sheets excluded from scope);
- Review of calculations in other sheets of the model (***CBA Results template v2_62.4.xlsm***) other than <CBA> sheet;

The governance review has been limited to gaining an understanding of the processes undertaken by officers involved in model runs with responsibility for confirming input parameters, running the model and quality assuring model run outputs.

Overall Assurance

Some weaknesses in the control environment

We have undertaken testing of the C# component, specific excel files and CBA worksheet of the Envision dispatch model and reviewed governance arrangements surrounding its operation. No issues were found with the investor decisions C# code that could impact on the model performance. The CBA calculations in the DDM output file worked as expected. Governance arrangements have been set up according to good practice, although improvements could be made by updating RAG risk ratings more regularly and through stricter management of access to DDM files. Six areas for improvement have been identified to address issues that were noted during the review.

The main findings from our review are:

***C# component and 2 excel files*:**
The C# code relating specifically to the investment decisions 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 appropriate and consistent input assumptions.

***<CBA> sheet in the CBA Results template v2_62.4.xlsm model*:**
No potential errors in the formulae on the CBA worksheet have been identified.

Governance arrangements:
General governance arrangements have been set up according to good practice expectations, although some areas for improvement have been identified, relating to:

- Maintaining an up to date training log for officers who are required to undertake model runs;
- Documentation of authorisation for changes to the Reference Case, and review and timely update of RAG ratings for Reference Case;
- Access and use of non-quality assured model.

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, which are relevant to the investment decisions components, 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. • VIU Assumptions • Merchant Assumptions • VIU Limit • New Plant • Plant Available for New Build • Maximum Build Limits • Cumulative Maximum Build Limits • Minimum Build Limits • Model Settings • Endogenous Closures. No significant issues have been identified. However, it was noted that the user guide appears to have been written using an earlier version of Envision (see finding 1). It was also noted that in some cases where the Envision model is provided with inconsistent input assumptions, the code crashes (see finding 2).
C# investment decision calculations	 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 investment decisions model: • Plant Upgrades • New Investment Decisions • Commission all new build from minimum build limits • Find all eligible projects to be considered • Determine which plant will be on the system • Calculate SRMC of all plants • Calculate Merit Order • Run simulation • Calculate utilisation and income for each eligible project • Calculate construction costs for each project • Calculate Cashflows and IRR for Eligible Projects • Determine the hurdle rate for each eligible plant • Commission plant. No significant issues have been identified but it was noted that a hard coding of the plant name ‘Cockenzie1’ may cause a small adjustment resulting in incorrect output (see finding 3). However this was included in the model by LCP for debugging purposes and they have confirmed that it does not have an impact on the results. The plant in question is closed.

Area examined:	Assurance:	Conclusion:
C# model outputs	 Strong control environment	The outputs resulting from the investment decisions calculations have been reviewed to confirm that they are correctly stored in memory and copied to the following output charts and worksheets: • Investors IRR • Investment Decisions. • Cashflow Generation • Cashflow Load Factor • Cashflow Max Capacity. No significant issues have been identified.
Excel files	 Strong control environment	The methodology statement paper related to the cost benefit analysis (***CBA calculation v0_2.docx***) has been reviewed and cross-referenced against the relevant sections in the model CBA results template, namely the 'CBA' sheet. The formulae in the <CBA> sheet of the ***CBA Results template v2_62.4.xlsm*** model have been reviewed, including confirmation that the calculations are internally consistent, mathematically correct and copied down or across where expected. No significant issues have been identified.
Governance arrangements	 Some weaknesses in control environment	Governance and control processes have been set up according to good practice expectations for agreeing the input assumptions (parameters) for model runs, performing model runs (including the documentation or log of model runs) and the arrangements in place for quality assurance by management of the output results. Areas for improvement have been identified, relating to: • Maintaining an up to date training log for officers who are required to undertake model runs (see finding 4); • Documentation of authorisation for changes to the Reference Case and review and timely update of RAG ratings for Reference Case (see finding 5); • Access and use of non-quality assured model (see finding 6).

PART 2 – DETAILED AUDIT FINDINGS

Finding 1: User Guide not updated for latest version of Envision

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

Detailed Findings

The version of the code under review was Envision 3.3.5.0. The user guide appears to have been written using an earlier version of Envision as some of the screenshots are out of date. An example is the input screen on page 8 of "Envision User Guide v1.0". This shows two spaces to enter output file details labelled "Template File" and "Output Folder". Envision 3.3.5.0 that has been reviewed includes an additional input labelled "UEM template file".

The following other minor documentation issues have been identified:

- There are some minor inconsistencies in the documentation that appear to be mistakes. The first is in "Envision User Guide V1.0", page 11. The section "Run Status Interface" should read "Once the user has entered all values into the input window".

- In the document "Envision Technical Guide v1.0", the table "Description of Variables Used in SRMC Calculation" states that the NonFuelCost is taken from the [Existing Plant] workbook. In the code, it appears that this variable is actually taken from the [Fuel Assumptions] workbook.

Proposed Action	Priority level
1. The user guide should be fully updated each time the model is significantly changed and should contain details of the version of the code that the user guide corresponds to	**Action is necessary**

Management Response

Agreed - LCP will provide an up to date user guide and technical guide for version 3.3.5.0 (and for the most recent upgrades to the model for the delivery plan analysis) and we will include updates in the specification for future upgrades.

Action owner	Action to be completed by	Progress report due by
Stuart Younger	19/12/2013	For IA use only

Finding 2: Error handling for inconsistent inputs

Key residual risks	Actual controls in place
Entering of incorrect input assumptions may cause the code to crash.	• Review of model log.

Detailed Findings

In some cases where the Envision model is provided with inconsistent input assumptions, the code crashes. A specific example is where values in the "minimum build limits" are greater than values in the "maximum build limits". As expected, the model is not able to handle this input. However, the issue is not immediately obvious to the user. The model attempts to run and then displays a failure error. The user can view the model log to understand that the code has crashed but the specific error message does not identify the actual error.

Proposed Action	Priority level
2. Validation on the Excel input file should be undertaken so that a user cannot mistakenly enter incorrect input. Error checking and reporting within the model should also be improved.	Action is necessary

Management Response

The QA macro in the input file is run by a DDM team member (always different to the individual who did the run) after every run. It identifies all cells that have been changed when compared to a reference file and is used to checking for errors and invalid values. However validation will be added to cells in the input file to prevent the user from inputting illegal values.

Action owner	Action to be completed by	Progress report due by
Stuart Younger	19/12/2013	For IA use only

Finding 3: Hardcoded values in the C# code

Key residual risks	Actual controls in place
• Hard coded values in the code may result in incorrect adjustments to the output.	• Code files perform calculations as specified in the documentation.

Detailed Finding

The C# code file "UnprofitablePlantDataCollection.cs" contains a method "SortAndRemoveAllButLeastProfitable" that contains an 'if' statement specifying specific treatment for a particular plant name "Cockenzie 1". This plant name is hardcoded in the C# code and adds a specific small adjustment to the variable capacityNotRemoved if the plant under consideration is "Cockenzie 1". For all other plant names, the method continues to sort the plants and remove all except the least profitable.

It is not clear if this specific treatment for this particular plant is intentional and is not mentioned in the user guide. It will have no impact on the output of the model if no plants of that name are considered. However, if a plant of that name is considered by the model, the adjustment will be made for that plant.

The specific adjustment for "Cockenzie 1" is a very small adjustment This was included for debugging purposes for a plant that is now closed, and does not have an impact on the overall output of the model, but it is best practice not to have hardcoded values in the code.

Proposed Action	Priority level
3. If behaviour for the "Cockenzie 1" plant name is unintentional, it is recommended that this type of hardcoded value is removed from the code to prevent any unexpected consequences. However, if the behaviour is intentional, it is recommended that the user guide is updated to include this adjustment so that the user is aware. If the adjustment is required under certain conditions, then this should be configured by a transparent input variable and not by a hardcoded check in the model logic.	**Action is necessary**

Management Response

This has been checked with LCP and they confirmed that it is included for testing purposes and has no impact on the outputs. LCP will remove this from latest version of the code.

Action owner	Action to be completed by	Progress report due by
Stuart Younger	19/12/2013	For IA use only

Finding 4: Governance arrangements – Guidance and initiating model runs

Key residual risks	Actual controls in place
• The lack of an up to date training log may increase the risk of untrained officers being able to initiate model runs.	• A DDM User and Technical Guide is produced and updated by LCP the software developer. • A Quality Assurance Template must be completed when any model output is quality assured. The template defines the checks and tests to be performed. • The ability to initiate a model run is restricted to those who have adequate expertise and training. • Initiation of a model run requires authorisation.

Detailed Finding

Procedural user guidance and associated reference documentation

- The DDM User and Technical Guide explains how to define parameters, perform model runs, save outputs and all other model functionalities. It is updated by LCP whenever there are major model developments and DECC receives new versions directly from LCP.
- We confirmed that the DDM User and Technical Guide and the Quality Assurance Template are available on the DDM shared drive, which is accessible by all DECC staff.

Initiating model runs

- DECC teams submit requests for modelling projects to the DDM Team. At the Quarterly Prioritisation meetings, the DDM Team reviews all bids, prioritises them, and agrees on which to accept, defer and reject. Therefore, we consider that appropriate authorisation for projects are obtained through this forum.
- We confirmed the occurrence of this prioritisation to the DDM Team resource map for the current quarter.
- Model runs can be initiated by any officer who has received training and performed an initial model run under supervision from a DDM Team member.
- For approved bids, the DDM Team consider what level of model training the bidding team has and, therefore, what level of DDM Team support will be required. DDM Team resource is then allocated to support the projects for the next quarter. If the Team or person requesting a modelling project has received no training, a DDM Team member will perform the model runs.

We noted that no log is maintained of officers who have received training.

Proposed Action	Priority level
4. The training log should be kept up to date for all officers who have received the appropriate training for undertaking model runs.	**Action is necessary**

Management Response

Agree that a training log should be created and then updated as new users are trained. The log will include some detail of their level of experience with the DDM.

Action owner	Action to be completed by	Progress report due by
Stuart Younger	19/12/2013	For IA use only

Finding 5: Governance arrangements – defining input parameters

Key residual risks	Actual controls in place
• Without evidence of good practice for reference case parameters, it is not possible to demonstrate that input to the model is the most up to date and appropriate.	• Access to input parameters is restricted to those trained and authorised to define and amend them. • Changes to baseline parameters require authorisation from the appropriate designated senior officers. • Input parameters, and any changes to them, are logged. • The quality and robustness of parameter limitations and caveats are reviewed and documented.

Detailed Finding

Reference Case parameters

- These are the baseline parameters which govern every model run. The DDM Team is responsible for updating the Reference Case and obtaining the required authorisations.
- The parameters of the Reference Case are regularly updated to incorporate new market intelligence, cost forecasts or Government policy. Any change requires authorisation. Each type of parameter has named officers or bodies who are required to authorise any change:
    - Any changes to technology assumptions require sign off from the head of the relevant Technology Office;
    - Changes to assumptions for generation costs and technical data, maximum build limits, existing and pipeline plant and plant retirements require authorisation from the Levelised Cost Board; and
    - Any other types of assumption change can be authorised by the named Grade 5 Analysts.
- These authorisation requirements are defined by a document held by the DDM Team, of which we were provided a copy. Whilst testing did not identify instances where authorisation was not obtained, there was a lack of formal documentation of the authorisation. For example, authorisation may have been confirmed at a meeting but the meeting was not minuted, or authorisation was provided orally but not confirmed by an email (recommendation 5a).
- The Reference Case input parameters and sources are recorded in the DDM input file. The Reference Case DDM input file includes a version control table. This records all changes made to the parameters, the analyst who made the change and the name of the updated input file version. At the time of the audit (September 2013), the version control log for June was reviewed, which corresponded to the version of the model under review. We understand that this has been updated in all subsequent versions of the input file since June..
- The Reference Case input file contains an Assumption Log page that lists all input assumptions. It sets out the limitations and caveats around the data and assigns a RAG rating. We noted that the RAG ratings had not been reviewed since November 2012 (recommendation 5b).

Individual model run parameters

- Each model run performs sensitivity analysis versus the Reference Case by making adjustments to the Reference Case parameters. The specific parameters for an

individual model run are defined by the person performing the model run. In accordance with the established procedure, the specific parameters set for each model run do not require authorisation each time. The focus of authorisation and review is on the outputs of the model run.

Proposed Action	Priority level
5. Reference case parameters should be improved as follows: a. The authorisations for agreed changes to the reference case should be documented formally, for example, in the minutes to meetings and/or confirmed in email. The record for all authorisations should be maintained. b. The RAG risk ratings for the assumptions used in the reference case should be reviewed and updated in a timely manner	**Action is necessary**

Management Response
a. Updates to the reference case assumptions for the delivery plan analysis have been signed off by the DECC Levelised Costs Board, chaired by the Chief Economist. We plan to continue this formal process for future updates, and the role of the current board will be further developed. b. We will produce RAG ratings for the updated reference case for the final delivery plan analysis and update that document as assumptions change for future reference cases.

Action owner	Action to be completed by	Progress report due by
a. Jenna O'Byrne b. Birgit Wosnitza	a. Ongoing b. 31/01/2013	For IA use only

Finding 6: Governance arrangements – model runs and output

Key residual risks	Actual controls in place
• Unrestricted access to the DDM shared drive could result in unauthorised staff picking up and using outputs from model runs on the DDM shared drive that have not been quality assured and are not intended for use in developing policy work.	• Model runs are only performed by those with adequate expertise and training. • Details of model runs are logged. • The inputs and outputs of all model runs are securely stored and retained. • Model outputs are quality assured by officers with an appropriate level of expertise and understanding of the model, who are not the same officers who performed the model run. • Outputs are subject to appropriate and sufficient tests and checks to obtain quality assurance. • Distribution of model outputs is controlled and access to them is restricted to appropriate personnel.

Detailed Finding

Performing model runs

- Model runs are performed by DDM Team members or officers who have received training. The runs are performed on fixed modelling computers which record the user and time of the run. Details of the person running the model and the time stamp are also recorded in the Quality Assurance Template.
- The run output and input files are automatically saved to the modelling computer in a user-determined target folder. The final runs within the target folder are then copied over to the DDM shared drive using USB drives.

Quality assurance over model runs

- Model outputs can only be taken forward for use in developing policy work, or as the basis for further work, once they have been satisfactorily quality assured.
- Quality assurance of model outputs is performed by DDM Team members. The guidance states that where the model run is performed by a DDM Team member, it needs to be quality assured by a different team member.
- A Quality Assurance template must be completed, which requires the reviewer to:
    - Describe outputs and conclude on whether they are expected (sense check) versus the Reference Case.
    - Query and check any variances from the Reference Case that appear counterintuitive.
    - Review the interdependencies between outputs and check that they are logical and consistent with expectations.
    - Compare inputs to the approved Reference Case parameters to ensure that the approved parameters have been used.
    - Run a QA macro in the input file which identifies all changes to cells when compared to the reference input file.
    - Consider the cost benefit analysis (CBA) results, relative to the Reference Case CBA.

- Cross reference the CBA results against the individual outputs for logic and consistency.

- Only the outputs from a select number of model runs are taken forward to inform future policy. The outputs from these model runs are quality assured in accordance with the required criteria outlined above. However, we noted that the outputs from all model runs are copied to the DDM shared drive. As a result, some model outputs which have not been quality assured are held on the DDM shared drive.
- The DDM shared drive can be accessed by all DECC staff as it is not restricted.

Proposed Action	Priority level
6. Model outputs placed on the shared drive should be labelled clearly to identify which ones have been quality assured and are for use in informing policy work. Consideration should be given to removing the outputs from model runs that are not intended for use in policy work.	**Action is necessary**

Management Response
Agree that model output files should be clearly labelled as either quality assured or not and ones used to inform policy work should be clearly identified. Runs not used as final versions for policy scenarios are valuable as a record of the iterations that were considered so should be kept unless they contain errors. The current reference case should be clearly identifiable via a shortcut in a high level folder. Access to DDM inputs and outputs will be restricted to the DDM team and individuals who are trained to use the DDM

Action owner	Action to be completed by	Progress report due by
Stuart Younger	19/12/2013	For IA use only

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.
2. Unique formula review: Objectives: • Confirm or not that the in-scope formulae, algorithms and calculations are internally consistent and arithmetically accurate. • Confirm or not that the model has been constructed appropriately so as to materially achieve the objectives.	• Perform a manual inspection of model formulae and linkages, using Excel trace functions to trace forward from inputs to outputs. Unless you provide supporting documentation we will use row and column narratives to indicate the purpose of calculations and units of measure • Use spreadsheet analysis software utilities to identify: o inconsistencies in formulae replication o hidden assumptions which are embedded in formulae o unused inputs o cells with error conditions. • Report any exceptions.
3. Review by comparison *(this procedure is applied either during the second iteration – once the model was corrected or changed or when there are similarities between different sheets in one model or between two models and then only changes need to be reviewed)* Objectives: • Confirm or not that the in scope formulae, data and structure of the model have / have not changed as expected. • Confirm that no other changes other than those required were implemented.	• Use specialist software to compare the two versions of the model to establish differences in structure, data and formulae. • Perform a manual inspection of exceptions on model formulae, data and structural changes • Report potentially incorrect or unexpected changes.

ANNEX C DETAILED TESTING

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

Description of Test	**Test Results**
Set all hurdle rates on VIU assumptions sheet to 0. All other inputs as per dummy input file	Output as expected
Set all hurdle rates on VIU assumptions sheet to 0. All other inputs as per standard June input file	Output as expected
Set all hurdle rates on Merchant assumptions sheet to 0. All other inputs as per dummy input file	Output as expected
Set all hurdle rates on Merchant assumptions sheet to 0. All other inputs as per June input file	Output as expected
Set all hurdle rates on VIU assumptions to 100000. All other assumptions as per dummy input file	Output as expected
Set all hurdle rates on VIU assumptions to 100000. All other assumptions as per June input file	Output as expected
Set all minimum plant numbers to 100 but all other inputs as per dummy input file so build limit is 1 for only 1 plant in year 10	Index out of range exception
Set all minimum plant numbers all set to 1 but all other inputs as per dummy input file so build limit is 1 for only 1 plant in year 10	Key not found exception
Minimum plant set to 1 for 1 plant that is different to the one where build limit is 1 (i.e. min plant 1 but build limit for that technology is 0). All other inputs as per dummy input file	Code crashes
Min plant set to 1 where build limit is also 1. All other inputs as per dummy input file	Output as expected
Maximum build limits set to 0 for all plants. All other inputs as per dummy input file.	Output as expected
Maximum build limits set to 0 for all plants. All other inputs as per June input file.	Output as expected
Cumulative maximum build limits set to 0 for all plants. All inputs as per dummy input file.	Output as expected
Cumulative maximum build limits set to 0 for all plants. All other inputs as per June reference file.	Output as expected