13th February 2013

IN STRICTEST CONFIDENCE

WORKSTREAM 3 - PHASE 3
TIPPING POINT ANALYSIS REPORT

Grid Scientific Limited

Grid Scientific Ltd
Carpenter House,
Broad Quay
Bath
BA1 1UD

Telephone: +44 (0) 1491 871252

Email: info@gridscientific.com

www.gridscientific.com

Table of Contents

1 DOCUMENT CONTROL 4
1.1 CONTROL INFORMATION 4
1.2 REVISION HISTORY 4
1.3 APPROVAL 4
1.4 DISTRIBUTION 4
2 PREFACE 5
2.1 PURPOSE 5
2.2 SCOPE 5
2.3 DOCUMENT CONTEXT 5
2.4 REFERENCES 5
3 EXECUTIVE SUMMARY 6
4 INTRODUCTION 8
4.1 BACKGROUND 8
4.2 SCOPE OF WORK 8
4.3 APPROACH 8
5 TIPPING POINT ANALYSIS OVERVIEW 9
5.1 GENERAL PRINCIPLES 9
5.2 STRATEGIC ANALYSIS AND INTEGRATING FRAMEWORKS 10
6 TIPPING POINTS IN THE PHASE 2 TRANSFORM MODEL 12
6.1 DEFINITIONS 12
6.2 THRESHOLDS 12
6.3 PROCESS AND USAGE 13
7 WHAT ARE THE MAIN OBJECTIVES OF TPA IN THE TRANSFORM MODEL? 15
8 TASK 3.5 (TIPPING POINT ANALYSIS) KEY FINDINGS 16
9 REQUIREMENTS 17
9.1 SUMMARY - TIPPING POINT RELATED 17
9.2 SUMMARY - NON-TIPPING POINT RELATED 18
10 PHASE 3 TPA SOLUTION 19
10.1 THRESHOLDS APPROACH 19
10.2 THRESHOLD VALUES 19
10.3 COST CURVES 23
10.4 INTEGRATING FRAMEWORKS AND TRIGGERS 25
10.5 BUSINESS ATTRIBUTES 27
10.6 TIPPING POINT REPORT 30
10.7 TPA FOR ENABLING TECHNOLOGIES 33
10.8 LEAD TIMES FOR ENABLING TECHNOLOGIES 34
10.9 SELECT ENABLING TECHNOLOGY INDEPENDENT OF SOLUTIONS 34
10.10 ENABLING TECHNOLOGY CATEGORISATION 35
10.11 NEW ENABLING TECHNOLOGY - ADVANCED CONTROL SYSTEMS 35
10.12 NEW ENABLING TECHNOLOGY - ICT FOR ENTERPRISE INTEGRATION 35
11 PROPOSED NEW PROCESS & WORKED EXAMPLE 37
11.1 PROCESS 37
11.2 WORKED EXAMPLE 38
12 FURTHER WORK 44
13 OTHER CONSIDERATIONS 46

14 APPENDIX A – ENABLING TECHNOLOGY CATEGORISATION 47
15 APPENDIX B – NEW ENABLERS 49
15.1 ADVANCED CONTROL SYSTEMS 49
15.2 ICT FOR ENTERPRISE INTEGRATION 50
16 APPENDIX C – BUSINESS ATTRIBUTES 51
16.1 BUSINESS ATTRIBUTES – SIMPLIFIED PRO-FORMA 51
16.2 BUSINESS ATTRIBUTES – SIMPLIFIED DEFAULT DATA 53
16.3 BUSINESS ATTRIBUTES – FULL 56
17 APPENDIX D – THRESHOLDS PER LICENCE AREA 58
18 APPENDIX E –LEAD TIMES FOR ENABLING TECHNOLOGIES 59
19 APPENDIX F – THRESHOLD VALUE ANALYSIS 61
19.1 £50M, £30M, £20M 61
19.2 £30M, £20M, £20M 62
19.3 £20M, £20M, £20M 62

List of Figures

FIGURE 1 - TIPPING POINT PRINCIPLES 9
FIGURE 2 - STEP CHANGE DILEMMA (JOHN SCOTT, CHILTERN POWER) 10
FIGURE 3 - INTEGRATING FRAMEWORKS (JOHN SCOTT, CHILTERN POWER) 10
FIGURE 4 - TIPPING POINT YEARS 13
FIGURE 5 - CUMULATIVE DEPLOYMENT NUMBERS 20
FIGURE 6 - TIPPING POINT YEARS 20
FIGURE 7 - COST CURVE PRO FORMA 24
FIGURE 8 - COST CURVE BEHAVIOUR – PHASE 2 24
FIGURE 9 - COST CURVE BEHAVIOUR - PROPOSED 25
FIGURE 10 - ILLUSTRATION OF AN INTEGRATING FRAMEWORK 26
FIGURE 11 - BUSINESS ATTRIBUTES – SIMPLIFIED 27
FIGURE 12 - TIPPING POINT REPORT - SUMMARY 30
FIGURE 13 - TIPPING POINT ANALYSIS - REPORT 32
FIGURE 14 - THRESHOLDS PER LICENCE AREA 58

List of Tables

TABLE 1 - ELEMENTS OF AN INTEGRATING FRAMEWORK (JOHN SCOTT, CHILTERN POWER) 11
TABLE 2 - TIPPING POINT RELATED REQUIREMENTS 18
TABLE 3 - NON TIPPING POINT SPECIFIC REQUIREMENTS 18
TABLE 4 - FURTHER WORK 45
TABLE 5 – OTHER CONSIDERATIONS 46

1 DOCUMENT CONTROL

1.1 CONTROL INFORMATION

Document Number:	GSWS3.3DOC06
Revision:	1.0
Status:	Draft
Revision Date:	13th February 2013
Filename:	GSWS3.3DOC06 - Tipping Point Analysis Report - v1.0 Issue.docx

1.2 REVISION HISTORY

0.1 Draft	12th November 2012	First version
0.2 Draft	19th November 2012	Updated after internal review
0.3 Draft	29th November 2012	Updated after internal review
0.4 Draft	30th November 2012	Updated after internal review
0.5 Draft	30th November 2012	Updated for initial distribution
0.8 Draft	14th December 2012	Final updates prior to distribution
0.9 Draft	11th February 2013	Updates to incorporate feedback
1.0 Issue	13th February 2013	Formal issue

1.3 APPROVAL

Name	Role	Approval and Date
Duncan Yellen	Project Manager	

1.4 DISTRIBUTION

Duncan Yellen	Dave Roberts	Mark Sprawson
SGF Project Team		

2 PREFACE

2.1 PURPOSE

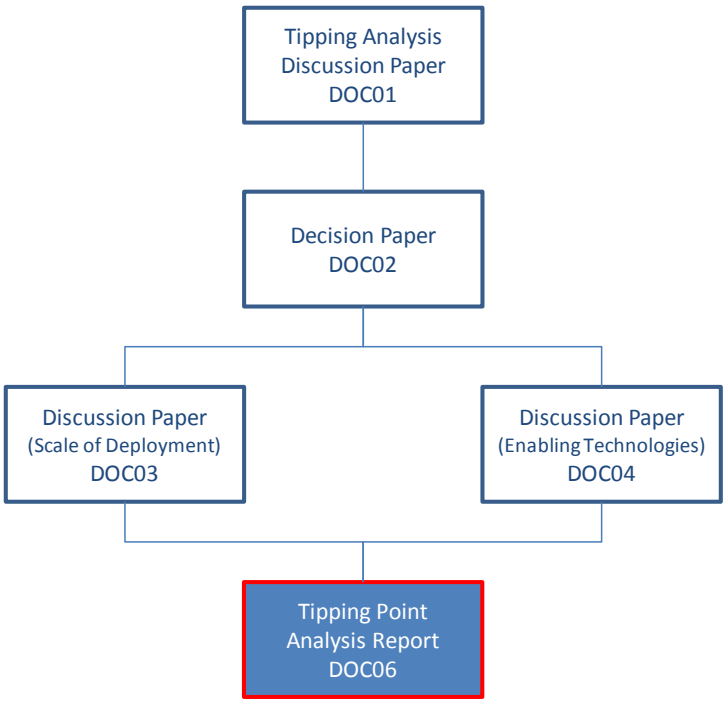
The purpose of this document is to present the results from Task 3.5 within the Smart Grid Forum Workstream 3 Phase 3 project.

2.2 SCOPE

The scope of this document is limited to the results from Task 3.5 only; all other aspects of the broader Phase 3 project are detailed in separate documents.

2.3 DOCUMENT CONTEXT

The diagram below shows the context (shaded) of this document in relation to other key existing and planned documents.



2.4 REFERENCES

[1] Workstream 3, Phase 2 Tipping Point Materials, John Scott, Chiltern Power

[2] Workstream 3, Phase 1 Report, Developing Networks for Low Carbon - The Building Blocks for Britain's Smart Grids

[3] Workstream 3, Phase 2 Report, Assessing the Impact of Low Carbon Technologies on Great Britain's Power Distribution Networks

3 EXECUTIVE SUMMARY

Tipping Point Analysis (TPA) is a technique that can be used to analyse environments with significant growth and/or change in terms of “volume”, “complexity”, “costs” etc. and to identify/forecast the point in time when it may be beneficial (or in some cases essential) to implement an alternative strategy to more effectively address the growth/change, or to avoid a major disruption to the business.

TPA was a relatively late addition to the scope of the Workstream 3 Phase 2 project and as such, the depth of analysis and the associated implementation within the Transform Model was constrained.

This report documents the work undertaken in Task 3.5 of Workstream 3 Phase 3:

- To reassess the use of TPA in the context of the Transform Model
- To ensure there is a consistent understanding of the TPA opportunity
- To identify any perceived shortfalls in the Phase 2 implementation of the Transform Model and the TPA methodology
- To define a set of requirements and options to extend and improve the implementation within the Transform Model
- To identify techniques or enhancements to support more effective use of TPA.

The Tipping Point technique used in the Phase 2 Transform Model flags the years in which certain pre-defined thresholds for each solution deployment will be crossed. These thresholds are expressed in terms of cumulative costs which are directly related to the volume of equipment or components deployed for the given solution. The current thresholds are set at the GB network level as: EHV = £50m, HV = £30m and LV = £20m. For the purpose of TPA within the Transform Model, there is assumed to be a relationship between volume/cost and business impact/complexity.

TPA is ideally an iterative process, whereby the model is run with an initial set of parameters. Tipping Point flags are raised in the years when the model predicts the Tipping Point thresholds will be breached. Users then have the opportunity to analyse the model outcomes, the associated Tipping Points and their own business strategies and then to implement changes in the model input parameters to represent the desired change required at/after the Tipping Point. The model can then be re-run to determine if the changes have achieved the desired change in outcomes at the Tipping Point – the process can be repeated if required. This process highlights the fact that the model identifies Tipping Points and supports TPA, but there is a significant component of TPA that is undertaken using an ”off-line” process.

The Phase 3 analysis of the TPA approach has highlighted that there are a wide variety of expectations from the DNO community in terms of how the technique can be used and how best it can be implemented within the Transform Model. However, there is general consensus that the main purpose of TPA within the Transform Model is to help:

> *Evaluate the many complex and varied parameters and outcomes in the model and to “flag” when business critical “Tipping Points” are predicted to occur. This will support/guide them to undertake (off-line) analysis to determine options for alternative strategies to address the behaviour after the Tipping Point and achieve improved business benefits and/or to avoid a major disruption to the business.*

The conclusion has been drawn based on feedback received, that Tipping Point identification is a useful function of the model and the Phase 2 approach to raise Tipping Point flags based on volume/cumulative investment cost is a reasonable approach in the first instance. However, adding more capability to the Tipping Point function within the model will be useful and some key requirements have been identified and documented in this report.

Many of the new requirements identified relate to the ability to apply more sophisticated behaviours within the model to represent the changes in strategy at/after the Tipping Point, for example the ability to select different or additional enabling technologies, or apply a different cost curve – the Phase 2 model simply applies a 10% cost reduction after the Tipping Point.

Another key requirement area is the ability to specify a set of *business attributes* for each solution and enabling technology. These attributes aim to provide an objective assessment of the key business impacts which may not be easily defined in pure financial terms, but which are nevertheless very important when considering the business strategy. This would include factors such as impacts on systems, processes, organisation and security for example.

With the business impact attributes defined, the model can produce a set of Tipping Point Reports, which can be used to provide guidance to the DNOs for their TPA activities and hence for investment planning.

Analysis has been undertaken of the original Tipping Point thresholds (EHV = £50M, HV = £30M, LV = £20M), using the latest available version of the Transform Model and latest available parameter and data sets including revised costs defined as part of Task 3.4. This analysis concludes that the EHV threshold in particular is too high, and as a result only 5 of the 10 selected EHV solutions tip, and even these do not tip until 2047. It is therefore proposed that all thresholds are set at £20M as the default, as this represents a significant investment regardless of voltage level, and individual solution costs are not as variable across voltage levels as originally anticipated.

The requirements and findings identified in this report have been agreed by the Workstream 3, Phase 3 participants. Enhancements to the Transform Model and the associated methodology deliver a capability that will enable the DNOs to gain “actionable insight” into factors that drive or influence their planning processes.

With completion of Task 3.5, DNOs will have available:

- A Transform Model with enhanced functionality
- Pro-formas for systematically capturing and managing data that supports TPA
- Default data that enables initial models runs to be undertaken that will deliver meaningful results; these have been developed through with various members of the Phase 3 team
- The basis for iterative application of the model to gain further understanding of the benefits that could potentially be achieved by using TPA to inform business planning.

The DNO community can execute TPA using this capability and assess and where appropriate, act upon the outcomes.

4 INTRODUCTION

4.1 BACKGROUND

Tipping Point Analysis (TPA) was a relatively late addition to the scope of the Workstream 3 Phase 2 project and as such, the depth of analysis and the associated implementation within the Transform Model was constrained.

Phase 3 provides the opportunity to reassess the use of TPA in the context of the Transform Model. Task 3.5 addresses this opportunity and aims:

- To develop a consistent understanding of the TPA technique
- To identify any perceived shortfalls in the Phase 2 implementation
- To define a set of requirements and options to extend and improve the implementation within the Transform Model
- To identify techniques or enhancements to support more effective use of TPA.

4.2 SCOPE OF WORK

The agreed objectives of Task 3.5 are summarised as:

- To review and consolidate work undertaken in Work Stream 3 Phase 2 regarding use of (TPA to assist in DNO investment planning
- To understand the DNOs' requirements for further development of their use of TPA
- To identify options for extensions or enhancements to the Transform Model that respond to agreed requirements.

4.3 APPROACH

The approach used for Task 3.5 was comprised of a number of steps:

- Detailed review of Work Stream 3 – Phase 2 tipping point analysis and implementation.
- Assessment of TPA in other sectors (e.g. telecoms).
- Preparation of initial discussion paper for review at stakeholder kick-off workshop to establish shared understanding of TPA and its use
- Agreement of the scope of TPA as it is to be used by the DNOs, specifically focused on the Scale of Deployment Case and Enabling Technologies
- Documentation of initial findings for review in Discussion Papers
- Bi-lateral telephone discussions with DNO and project team stakeholders
- Review and analysis of information and requirements collected
- Ad hoc discussions with DNO representatives
- Preparation of a report (this document) detailing: key findings; feedback on the Phase 2 TPA implementation; proposed enhancements to address gaps in the Phase 2 implementation and to respond to new requirements; assessment of requirements (priority, model impacts); identification of solutions for responding to requirements; conclusions and recommendations for further work

5 TIPPING POINT ANALYSIS OVERVIEW

5.1 GENERAL PRINCIPLES

Tipping Point Analysis (TPA) is a technique that can be used to:

- Analyse environments with significant growth and/or change in terms of "volume", "complexity", "costs" etc. and to identify/forecast the point in time when it may be beneficial to implement an alternative strategy to more effectively address the growth/change, or to avoid a major disruption to the business
- Typically the transition to new strategy will be a significant "step change" compared to the existing strategy – ideally this should be based on an *integrating framework*
- For best results, the new strategy needs to in place *at* or *before* the Tipping Point

Figure 1 below illustrates the relationship between the initial Strategy and business drivers, and the need to switch to an alternative Strategy at the Tipping Point to achieve improved business outcomes. The definition of the Tipping Point itself is based on a pre-defined set of criteria.

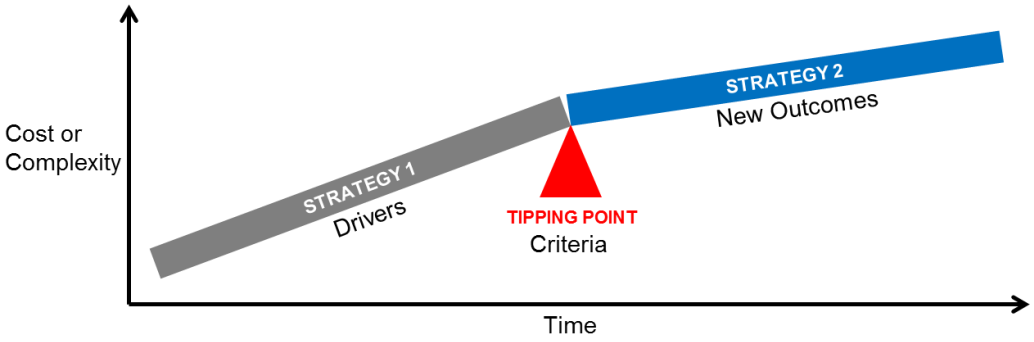


Figure 1 - Tipping Point Principles

Two key aspects of successful implementation of TPA are:

- Business benefits can be achieved by taking a more strategic view providing the opportunity to define and implement an alternative strategy potentially based on an *integrating framework* as part of the Tipping Point transition
- The need to commence the definition and implementation of the new strategy (or Integrating Framework) *in advance* of the Tipping Point to ensure that the new strategy is ready for use when the Tipping Point is reached

This approach and the use of *Integrating Frameworks* are discussed in more detail in the following sections.

5.2 STRATEGIC ANALYSIS AND INTEGRATING FRAMEWORKS

When a "Tipping Point" has been identified or predicted, the opportunity exists to analyse the strategies and solutions in place *before* and *after* the Tipping Point. This strategic analysis will establish if there is alternative strategy or solution which can be applied after the Tipping Point that will provide significant benefit compared to continued deployment of the existing solution.

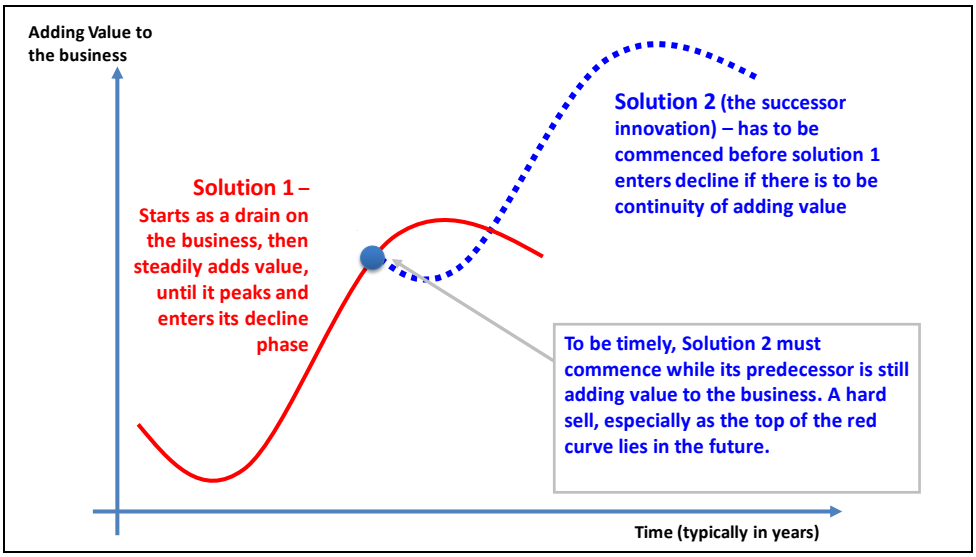


Figure 2 - Step Change Dilemma (John Scott, Chiltern Power)

One challenge for this analysis is identifying the appropriate timing to commence the work on the new strategy/solution, as it may not be easy to predict the "top of the curve" for the existing solution; this is the "Step Change Dilemma" as depicted in Figure 2 above.

The concept of "*Integrating Frameworks*" has been identified as one option to define and implement a significant change in strategy. An Integrating Framework can provide a range of benefits and is not restricted to "technology" solutions only. For example, the new strategy could include a change to strategic procurement policies; new or enhanced inter-company commercial relationships or a radical change in the operating model of the operator.

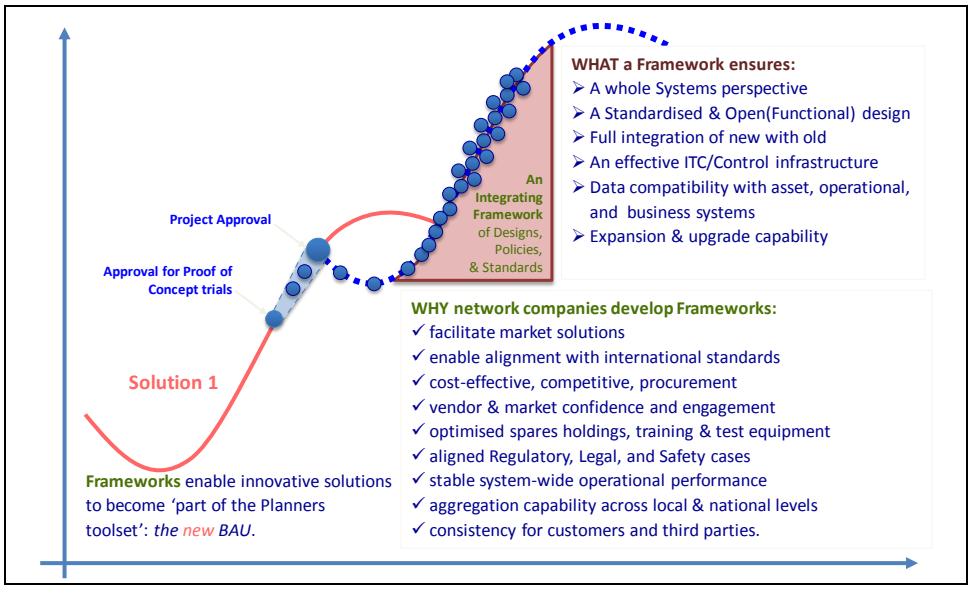


Figure 3 - Integrating Frameworks (John Scott, Chiltern Power)

The key elements of an *integrating framework* include:

A standardised functional specification	for the product/system, described in the form of an Open Functional Specification; standardisation is an enabler for market solutions and may be implemented at a national, multi-company, or single company level;
Change control mechanisms	to manage the risks/benefits associated with likely further development and gaining the benefits of on-going research;
A procurement strategy	that enables multi-vendor sourcing, addresses Licences and IP, and is risk-managed by means of independent Testing & Certification;
External alignment with wider standards	including European/International standards and codes; this is an enabler for open sourcing and attracts much greater vendor interest than 'company specials' or 'country specials';
Company integration across business processes	including operational, communication and data aspects, to align with the network company's corporate IT strategy and asset management and business systems, ensuring seamless information access and efficient integration of centralised and distributed systems in the medium and longer term; innovation knowledge capture is part of the thinking here;
Platform for new business	for network companies this is under-pinned by the above aspects: such as development of Demand Response services, DSO roles, effective strategies for managing flexibility and risk, provision of consistent interfaces for customers, and a coherent response to Ofgem's requirements for innovation in RIIO business plans.

Table 1 - Elements of an Integrating Framework (John Scott, Chiltern Power)

The set of parameters and criteria required to predict the "top of the curve" and identify the Tipping Point at which the integrating framework should be applied can be varied and complex.

Using a model such as the Transform Model is a useful technique to help predict the timing of a potential Tipping Point if a reasonable and deterministic set of criteria can be defined and agreed which the model is able to consistently evaluate.

The approach used in the Phase 2 Transform model for predicting Tipping Points is discussed in the following sections.

6 TIPPING POINTS IN THE PHASE 2 TRANSFORM MODEL

6.1 DEFINITIONS

It is important to understand the difference within the Phase 2 model between a ***solution*** and an ***enabling technology***:

- A ***solution*** directly provides benefit in the form of increased headroom and may be dependent on one or more enabling technologies
- An ***enabling technology*** facilitates one or more solutions, but does not directly release headroom

To date TPA has been applied to solutions and not to enabling technologies as these are defined in the Phase 2 model.

A ***Tipping Point*** is defined in the Phase 2 model to occur when a pre-determined number of devices have been deployed or a cumulative investment cost reached for a particular solution. This pre-determined ***threshold*** is expressed in terms of the number of devices likely to result in a significant network impact or with regard to the total financial materiality of the deployed solutions. With respect to enabling technologies, there will be a ***trigger*** which is the point in time when the enabling technology needs to begin deployment to support the relevant solution.

6.2 THRESHOLDS

The Tipping Point approach used in the Phase 2 model flags the years in which certain pre-defined thresholds for each solution deployment will be crossed. These thresholds are expressed in terms of cumulative costs which are directly related to the volume of equipment or components deployed for the given solution. The current thresholds are set at the GB network level as, EHV = £50m, HV = £30m and LV = £20m.

Note: The original Phase 2 Tipping Point threshold values were set without the benefit of being able to analyse actual model outputs with validated parameters and solution costs. The voltage level threshold for EHV was set on the assumption that EHV solutions are generally more expensive than HV solutions – in reality the per solution costs for EHV solutions which are selected within the Transform Model are very similar to HV solutions with a couple of exceptions such as Embedded DC and D_FACTS/STATCOM

This approach does not address all the potential complexities that exist in real-life associated with when a given solution reaches a "critical mass" and therefore some strategic change may be required or beneficial. However, it is reasonable to assume that there is typically a strong relationship between the number of deployments of a given solution and the associated "complexity" that this gives rise to, and therefore for the purposes of high-level modelling, this approach may be sufficient provide a reasonable indication or approximation of the Tipping Point for planning and analysis purposes.

Figure 4 below shows an example of how the years are flagged in the Phase 2 model for a subset of the solutions. In this case the model predicts that the £30M cumulative investment Tipping Point threshold for solution "*RTTR for HV Overhead Lines* " will be crossed in 2029.

– EHV - £50m
– HV - £30m
– LV - £20m

	Network Name	Year Reached
1	Active Network Management - Dynamic Network Reconfiguration - HV	2017
2	Distribution Flexible AC Transmission Systems (D-FACTS) - HV	2020
3	Permanent Meshing of Networks - LV Urban	2023
4	Permanent Meshing of Networks - LV Sub-Urban	2023
5	DSR - DNO to residential	2024
6	Permanent Meshing of Networks - HV	2024
7	Fault Current Limiters_HV reactors - mid circuit	2026
8	Local smart EV charging infrastructure_Intelligent control devices	2026
9	Temporary Meshing (soft open point) - HV	2026
10	RTTR for HV Overhead Lines	2029
11	RTTR for HV/LV transformers	2029
12	D-FACTS - HV connected STATCOM	2030

Figure 4 - Tipping Point Years

It should be noted that the model allows for the thresholds to be expressed as the number of instances of a solution deployed, but this capability has not been used in the work undertaken to date. Clearly there is a direct relationship between cumulative and instances deployed driven by unit cost.

6.3 PROCESS AND USAGE

When the model has identified the predicted Tipping Point years, the user has the opportunity to analyse the strategies and options to determine a course of action to implement the required change of strategy at the Tipping Point and hence achieve an improved outcome and benefits beyond the Tipping Point. The process can be summarised as:

Step 1 **Set initial Tipping Point thresholds & run model**

Model identifies and selects which solutions are required and when
Model identifies when (if) TP's crossed for each solution

Step 2 **User review of Tipping Point flags and (off-line) analysis of business strategy to address post TP requirements**

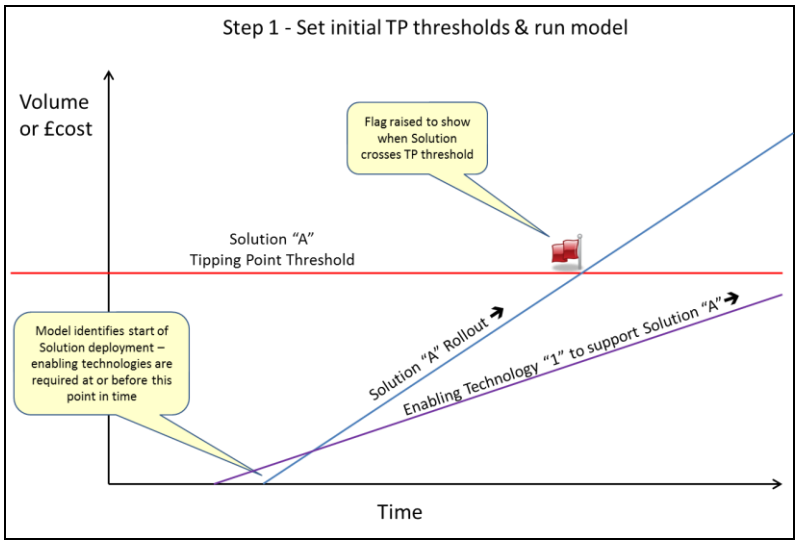
Step 3 **Implement changes to input data within Transform model (eg vary cost parameters for economies of scale after Tipping Point) and re-run model**

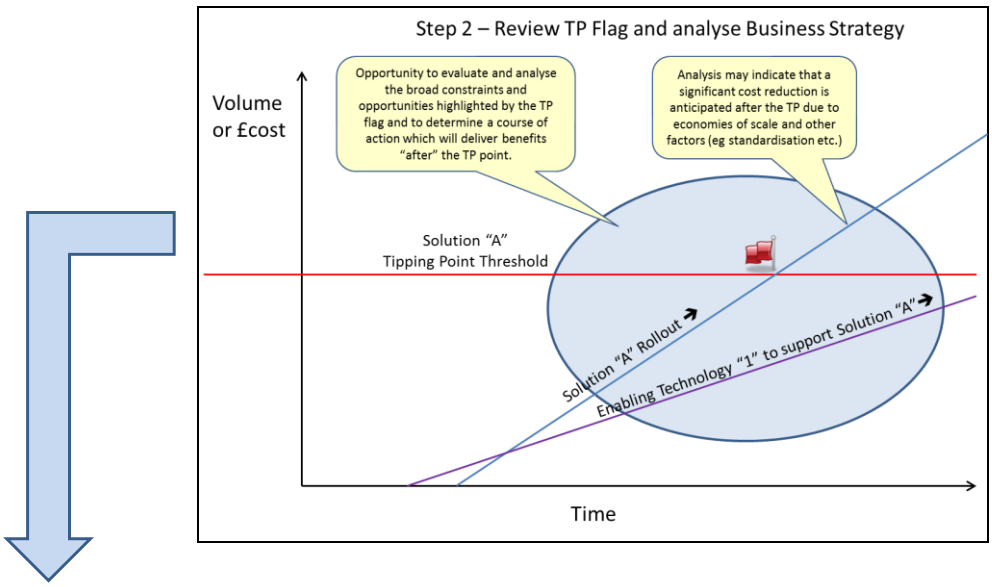
Model identifies and selects which solutions are required and when
Post TP outcomes will be different based on changes to parameters

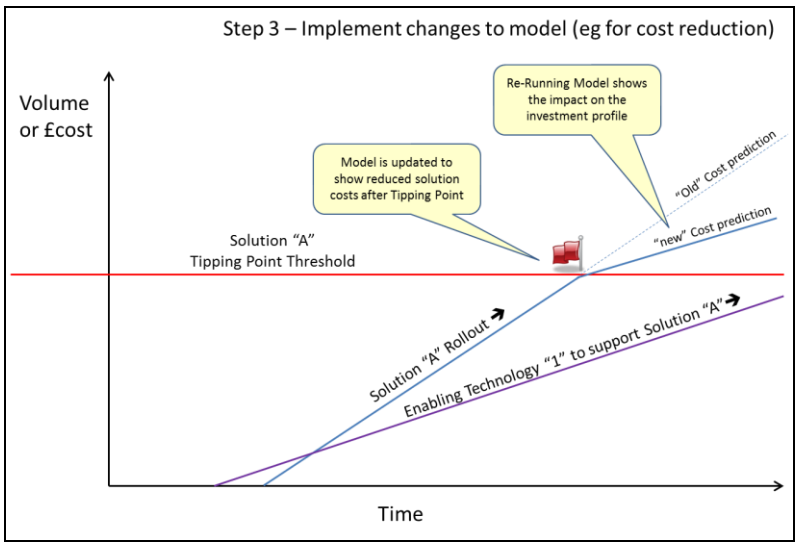
Step 4 **Analyse new outcomes**

Step 5 **Repeat steps 1-4 to assess sensitivities if required**

The diagrams overleaf illustrate the application of these steps in more detail.


Step 1 - Set initial TP thresholds & run model
Volume or £cost
Flag raised to show when Solution crosses TP threshold
Solution "A" Tipping Point Threshold
Model identifies start of Solution deployment – enabling technologies are required at or before this point in time
Solution "A" Rollout
Enabling Technology "1" to support Solution "A"
Time


Step 2 – Review TP Flag and analyse Business Strategy
Volume or £cost
Opportunity to evaluate and analyse the broad constraints and opportunities highlighted by the TP flag and to determine a course of action which will deliver benefits "after" the TP point.
Analysis may indicate that a significant cost reduction is anticipated after the TP due to economies of scale and other factors (eg standardisation etc.)
Solution "A" Tipping Point Threshold
Solution "A" Rollout
Enabling Technology "1" to support Solution "A"
Time


Step 3 – Implement changes to model (eg for cost reduction)
Volume or £cost
Re-Running Model shows the impact on the investment profile
Model is updated to show reduced solution costs after Tipping Point
"Old" Cost prediction
"new" Cost prediction
Solution "A" Tipping Point Threshold
Solution "A" Rollout
Enabling Technology "1" to support Solution "A"
Time

7 WHAT ARE THE MAIN OBJECTIVES OF TPA IN THE TRANSFORM MODEL?

Meetings and discussions to date have identified that there are differing viewpoints regarding the implementation and principal objectives of TPA in the context of the Transform Model and how it can best be used to support the needs of the DNOs with respect to their investment planning and associated price control submissions.

At one end of the spectrum there is the view that the Phase 2 implementation within the model whilst relatively simple and restricted in terms of what it can do, is probably sufficient for immediate needs and the addition of more functions, capabilities and flexibility is unlikely to improve the quality or accuracy of the outcomes.

At the other end of the spectrum is the view that without the addition of more functions, capabilities and flexibility, the Phase 2 implementation does not exploit the full opportunities that TPA can potentially offer.

However, notwithstanding the range of views regarding the detailed capabilities, there is a degree of consistency in terms of the principal objectives that the DNOs have identified. Fundamentally what they want TPA to do is:

> *Evaluate the many complex and varied parameters and outcomes in the model and to "flag" when business critical "Tipping Points" are predicted to occur, to enable them to undertake (off-line) analysis to determine options for alternative strategies to address the behaviour after the Tipping Point and achieve improved business benefits and/or to avoid a major disruption to the business.*

The role of TPA is of particular interest in the context of developing understanding of when investment before need is required and in what timescale.

In terms of the Transform Model itself, this could be expressed as:

1. Basic ability to set criteria against solutions (and enabling technologies) which allow the model to evaluate when some sort of "threshold" is reached, and to flag the point in time when this threshold (Tipping Point) is predicted to occur
    - Ideally the threshold should take into account multiple factors such as "*deployment volume*"; "*cumulative cost*"; "*rate/density of deployments*"; "*complexity of solution*"; "*business/operational impact*"
2. Ability to modify various input parameters to the model to represent changes in strategy both before and after the predicted Tipping Point, in order to vary (and hopefully improve) the outcomes of the model
    - Ideally the set of parameters which can be changed should include "*cost curves*"; "*solution and enabling technology selections after the Tipping Point*"

The remaining sections of this document describe the specific findings, derived requirements and options/recommendations to develop the TPA capabilities within the Transform Model based on the meetings, conference-calls and analysis to date.

8 TASK 3.5 (TIPPING POINT ANALYSIS) KEY FINDINGS

The conclusion has been drawn based on feedback received that Tipping Point identification is a useful function of the model and the current approach to raise Tipping Point flags based on volume/cumulative investment cost is a reasonable approach in the first instance. Adding more capability to the Tipping Point function within the model will be useful and some key requirements have been identified, but there is general acknowledgement that:

- Adding more capability and flexibility will necessarily involve more effort and analysis from the DNO users in order to usefully populate any new parameters or flexibility points
- The model is already complex with many moving parts and it may be more critical to focus on the core components of the model in the first instance to ensure that the outcomes are aligned with DNO requirements and expectations – this is perceived as higher priority than further development of the Tipping Point capability

Analysis and associated meetings and bi-lateral conference calls have yielded a number of key feedback responses from the participating DNO stakeholders. It is worth noting that some of the comments are related to the Transform Model and its usage in general terms and are not all related directly to the "Tipping Point" aspect of the model.

- Effective use of the model depends on an understanding of the purpose it is intended to serve. The TPA capability of the model is intended to identify the point at which the deployment of a particular solution reaches a threshold hence flagging the need to undertake off-line analysis and decision making. The model itself does not perform this analysis off-line.
- The Phase 2 model implements the Scale of Deployment case; it does not address more complex cases where there are different drivers or criteria for tipping points.
- The Phase 2 model implements the Economies of Scale response following a Tipping Point; it does not address situations where the change after the Tipping Point is manifested in other benefits or actions. The Phase 2 model does not implement Integrating Frameworks as a specific entity. Implementation of more complex responses or Integrating Frameworks may require substantial extension of the model or could possibly be achieved through implementation of external applications. However, initial benefits can be realised by informing the DNO analysis and planning processes by interpretation and presentation of information that is available.
- The Phase 2 implementation of cost curves does not enable cost behaviour to be modelled to a level which reflects actual or expected behaviour in all cases.
- There would be benefit in allowing the relationship between solutions and enabling technologies which are currently fixed, to be more flexible. However the need to maintain balance between the complexity of this increased flexibility and the usefulness and purpose of the model is acknowledged.
- The generic GB Tipping Point financial thresholds set at £50M, £30M and £20M for EHV, HV and LV respectively need to be validated using the revised and updated model parameters defined by Phase 3, specifically Task 3.4.
- Interest in the outcomes of TPA extend beyond the DNOs to include others in the Smart Grid Forum community, including equipment manufacturers for example.

9 REQUIREMENTS

The tables in sections 9.1 and 9.2 below summarise the key requirements agreed for enhancement and extensions to the Transform Model and for TPA in Phase 3.

9.1 SUMMARY - TIPPING POINT RELATED

Link to Detailed Description	Description
Section 10.1	**Thresholds:** Ability to define and apply thresholds on an individual solution basis; this capability to be provided to the DNO for use at run time of the model
Section 10.3	**Cost Curves:** Availability of a more sophisticated cost curve implementation (e.g. switch from one cost curve to another) to support more complex cost behaviour before and after the Tipping Point: costs may decrease, they may increase, they may decrease following a temporary increase, cost changes may be delayed due to external effects, there may be market behaviours outside the UK that have an impact, etc.
Section 10.4	**Support for Integrating Frameworks**: Ability to define and implement a different strategy and/or different enabling technologies after the Tipping Point; this would address circumstances in addition to the economies of scale case such as business decisions regarding strategic technology choices (e.g. move to a distributed architecture for control instead of a centralised one), need to deploy applications to automate processes (e.g. analysis of monitoring or smart meter data), response to risks of solutions ceasing to function properly (e.g. timely response to customer connection requests)
Section 10.4	**Triggers for Integrating Frameworks:** Ability to specify the point at which investment in an Integrating Framework should begin in order that necessary preparations are in place at the point when the Integrating Framework is required to be available.
Section 10.7	**TPA for Enabling Technologies:** Ability to set Tipping Point thresholds for individual enabling technologies; Tipping Point threshold approach to be the same as that used for solutions, namely based on volume deployed or cumulative cost. This may not be applicable to all enabling technologies recognising that some are “strategic decision” based (e.g. Smart Meter infrastructure, design tools etc.); ideally need ability to “tag” enabling technologies as “deployment based” or “strategic decision”, together with other useful information or attributes (see Knowledge Base requirement). It should also be noted that whilst TPA will be relevant for enabling technologies in both incremental and top-down investment scenarios, the Transform Model will identify explicit Tipping Points for enabling technologies in the incremental case only.
Section 10.5	**Business Attribute Analysis:** Business Attributes seek to inform the analysis and planning processes undertaken to determine the most advantageous strategy to follow after the Tipping Point. They support developing an holistic view of technical, operations and business

	aspects directly and indirectly arising from a potential change of strategy implemented at a Tipping Point. Business Attribute analysis forms a basis for defining and implementing an Integrating Framework.
Section 0	**Tipping Point Report:** The Tipping Report summarises key outputs from TPA and presents this information in a readily accessible form. The report seeks to inform the process of investment, both in terms of which investments should be made and in what timescale. The report identifies Tipping Point years as well as associated trigger years for solutions. In addition the effort required in the investment before need period (if any) is noted.

Table 2 - Tipping Point Related Requirements

9.2 SUMMARY - NON-TIPPING POINT RELATED

Link to Detailed Description	Description
Section 10.8	**Lead Times for Enabling Technologies**: Ability to specify the point at which investment in an enabling technology should begin in order that it would be available at the point where deployment of the associated solution begins; this would indicate the period of time that investment is required "ahead of need", recognising that some technologies may take considerable effort/time to deploy before they are ready for use; it may be easiest to group the enabling technologies (e.g. <1 yr; 1-3 yrs; 3-5 yrs) as opposed to having a specific lead time defined for each.
Section 10.9	**Select Enabling Technology for Deployment, Independent of Solutions:** In the Phase 2 Transform Model enabling technologies are only selected for deployment when one or more solutions which depend on them are selected. However, some enabling technologies have a more "strategic" aspect, and may be chosen for deployment independent of solutions even though they may not directly release headroom (eg advanced control centre, design tools etc.).
Section 10.10	**Enabling Technology Categorisation:** Ability to identify and tag enabling technologies to classify them as "volume based" or "strategic decision". This would provide useful information to support the Tipping Point analysis for a given solution and its associated enabling technologies.
Section 10.11	**New Enabling Technology - Advanced Control Systems:** Existing control centre tools, applications and operational processes will not be sufficient to effectively manage the increasingly complex and varied technologies and solutions and more advanced capabilities and tools/processes will be required.
Section 10.12	**New Enabling Technology - ICT for Enterprise Integration:** Expansion of the tools and applications used within the control centre and more widely in the enterprise will increase the need for inter-operation and integration between the various applications in order to share data (e.g. network configuration and connectivity) and ensure consistency and alignment between them.

Table 3 - Non Tipping Point Specific Requirements

10 PHASE 3 TPA SOLUTION

The Phase 3 TPA solution to address the requirements defined above introduces a number of new tools and techniques, such as Business Attributes and variable Cost Curves. The method used to capture the data associated with these new components is based on a set of structured spreadsheets which is in keeping with the approach used for other key data sets and parameters within the model.

These new Tipping Point tools and spreadsheets will become part of the full set of Transform Model tools and will be subject to the agreed Governance and Change Control processes.

This report shows examples of the various tools and spreadsheets, but the reader is directed to EA Technology for access to the latest available set at any given time.

10.1 THRESHOLDS APPROACH

Ability to define and apply thresholds on an individual solution basis:

- **Phase 2 Implementation:**
  - Cumulative spend for each solution ***at the GB level***
  - Original thresholds categorised by network type:
    - EHV £50 million
    - HV £30 million
    - LV £20 million
  - Same thresholds applied to all solutions
- **Phase 3 implementation**:
  - Ability to set threshold for each solution
  - Thresholds to be set "***per licence area***" with the threshold based on pro-rata number of customers for the given licence area
  - Validate and review threshold values
- **Benefit:**
  - Improve alignment with actual or expected behaviour
  - Supportive of more granular sensitivity analysis

10.2 THRESHOLD VALUES

The Phase 3 project includes some significant changes to a number of the main parameters within the Transform Model based on feedback and input from the DNOs. Phase 3, Task 3.4 has also identified cost adjustments for a number of enablers; a revised matrix of solutions vs enablers and a different approach for allocating opex costs and optimism bias.

The effect of the above activities has changed the selection profile (when and how often they are selected) for several solutions and enablers and has significantly affected (increased) the overall investment costs.

Based on the above changes, analysis was undertaken to review the outputs from the Transform Model based on the latest available dataset (parameters and revised solution/enabler costs) and to validate the Phase 2 default voltage level thresholds (£50M, £30M and £20M) and where appropriate to highlight any anomalies and propose recommendations

The Transform Model was run using the latest available parameter set and adjusted solution/enabler costs as of January 2013, using the Incremental (Smart) case. A spreadsheet was created showing the selection profile for all solutions and enablers with the total number of cumulative deployments shown for each year (Figure 5).

	DSR - DNO to residential	Temporary Meshing - HV	RTTR for HV U/G Cables
2012	0	0	0
2013	0	0	0
2014	0	0	0
2015	0	0	0
2016	0	0	0
2017	0	0	0
2018	0	0	0
2019	0	0	0
2020	0	34	0
2021	738	34	0
2022	3542	164	0
2023	6460	164	0
2024	8302	463	0
2025	18667	550	0
2026	23168	565	734
2027	25972	1437	734
2028	32066	1437	734
2029	52594	1437	749
2030	62959	2450	1274

Figure 5 - Cumulative Deployment Numbers

Each selected solution was annotated with voltage level and per deployment costs. Cells were highlighted to show Tipping Point year based on current thresholds and calculating cumulative number of deployments x per deployment Totex cost (Figure 6).

	LV	HV	HV	EHV	HV	HV	HV	EHV	LV	HV	EHV	EHV	EHV	EHV
Capex	£1,000	£20,000	£24,900	£500,000	£10,000	£100,000	£6,640	£49,800	£2,000	£100,000	£40,000	£13,280	£3,000	£30,000
Totex	£1,452	£27,106	£24,900	£642,124	£81,062	£101,421	£6,640	£49,800	£2,711	£102,842	£47,106	£13,280	£3,000	£32,842
	DSR - DNO to	Temporary M	RTTR for HV U	Embedded D	Generator Pr	Permaner	RTTR for H	RTTR for E	EAVC - LV	Distributio	Active Ne	RTTR for E	RTTR for E	Permaner
2012	0	0	0	0	0	0	0	0	34	0	0	0	0	0
2013	0	0	0	0	0	0	0	0	34	0	0	0	0	0
2014	0	0	0	0	0	0	0	0	68	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	68	0	0	0	0	0
2016	0	0	0	0	0	0	0	0	169	0	0	0	0	0
2017	0	0	0	0	0	0	0	0	169	0	0	0	0	0
2018	0	0	0	0	0	0	0	0	169	0	0	0	0	0
2019	0	0	0	3	0	34	0	4	169	0	4	4	0	0
2020	0	34	0	3	0	34	878	4	169	0	8	8	0	0
2021	738	34	0	5	0	34	895	4	1013	0	20	20	0	0
2022	3542	164	0	14	101	51	1013	24	1013	0	20	41	17	0
2023	6460	164	0	14	101	103	1065	38	2025	0	34	41	17	0
2024	8302	463	0	14	270	103	1234	139	2025	0	42	154	17	4
2025	18667	550	0	18	270	103	1267	207	3124	0	110	154	17	19
2026	23168	565	734	22	975	103	1267	218	3124	0	110	166	17	23
2027	25972	1437	734	22	975	103	2686	218	3968	28	110	267	45	49
2028	32066	1437	734	47	993	150	2715	243	3968	45	197	293	92	49
2029	52594	1437	749	47	1765	150	2715	246	4721	97	201	293	864	113
2030	62959	2450	1274	47	2461	228	2802	250	6071	97	206	456	1638	113
2031	70073	2450	1274	47	2461	228	2802	250	6071	97	218	456	1638	113
2032	87850	2450	1274	47	2506	228	2802	258	6071	97	319	456	1683	188
2033	97045	2450	1274	47	2551	228	2802	258	6071	97	400	456	1683	188
2034	159688	4143	1274	47	3492	659	2830	270	6071	112	408	467	1824	188
2035	170053	4143	1289	47	4877	1590	4428	270	6105	1041	484	475	2668	281

Figure 6 - Tipping Point Years

The above analysis highlighted a number of key points for solutions:

- 29 solutions selected for deployment
  - 1 solution deployed immediately in ED1

  - 12 solutions selected in second-half ED1
  - 6 solutions selected in ED2
  - Remaining solutions selected beyond ED2
- No solutions tip within ED1 period
- 3 solutions tip within ED2
- Bulk of tipping points are clustered in the 2034 – 2040 period
- The pattern for HV and LV solutions is such that most of them tip within the first 6 years where there is incremental deployment
- 5 solutions do not tip (all EHV)
- Of the remaining EHV solutions, they all tip beyond 2040, mostly around 2045-2047

The analysis also highlighted key points for enablers:

- 23 enablers selected for deployment:
  - 5 selected immediately in ED1
  - 15 selected in second-half ED1
  - All remaining enablers selected in ED2
- 1 enabler tips in ED1
- 8 enablers tip in ED2
- 10 enablers tip beyond ED2 (bulk around 2040)
- 3 enablers not allocated against voltage level (design tools, COMMS)

Note 1: Analysis was conducted using interim model outputs generated in January 2013. The method for calculating for costs (cumulative deployment x Totex) is simplistic compared to actual model – for example it does not take into account "cost curves".

Note 2: The voltage level threshold for EHV was originally set on the assumption that EHV solutions are generally more expensive than HV solutions – in reality the per solution costs for EHV solutions which are selected within the Transform Model are very similar to HV solutions with a couple of high cost exceptions (eg Embedded DC, D_FACTS).

- This is largely due to the fact that conventional EHV solutions (eg power transformers) are capital-intensive items of plant.
- However, when considering innovative solutions such as RTTR or ANM, the technology and deployment cost of EHV solutions is very similar to that for HV solutions – if anything, because EHV solutions are generally deployed in smaller numbers, the cumulative costs are typically lower than HV and LV solutions

Conclusions:

- The general approach of using generic thresholds based on financial materiality works consistently although there are a few individual solution anomalies
- The majority of solutions tip within the first 6 years where there is incremental deployment – however, as the cumulative deployment numbers are high especially for some LV solutions, this may need to be adjusted on a per solution basis
- Analysis indicates that the generic voltage based threshold (£50M) for EHV is too high:
  - Only 5 out of 10 EHV solutions tip, and of the 5 that do, they do not tip until around 2047
  - There are also specific anomalies for individual EHV solution tipping points :
    - EHV Embedded DC has a non uniform deployment profile - gradual deployment initially, then no deployment for 12 years, and then more than doubles in 2040, at which point it tips
    - RTTR for EHV Underground Cables and Active Network Management are both deployed gradually over a 30 year period from 2019, but they do not tip until 2047
    - In both above cases, it seems more likely that the tipping point should occur earlier in the lifecycle – lowering the EHV threshold would achieve this
- The variations in deployment profiles for the individual solutions and the affect this has on the tipping points, together with the assessment of the anomalies, indicates that defining thresholds on a per solution basis is likely to yield more realistic outcomes

Recommendations:

- Revise (lower) the generic voltage based threshold for EHV solutions (Appendix F provides additional analysis to support this recommendation)
- Alternatively, set *all thresholds* to £20M, as this represents a significant investment regardless of voltage level, and individual solution costs are not as variable across voltage levels as originally anticipated
- Variant option - set to be same as HV solutions (£30M)
- Re-run model and associated threshold analysis for a small number of licence areas and confirm that the analysis yields similar outcomes in terms of deployment profiles, tipping point years and potential per solution anomalies
- For the anomalous cases, set thresholds on a per solution basis using the threshold analysis as one factor to help inform choice of threshold
- Set default per solution, per licence area thresholds based on pro-rata number of customers in the licence area compared to GB total customers
- Include Tipping Point “Deployment Profiles” spreadsheet as part of the standard model outputs to assist with threshold analysis – Figure 6 above provides an example of how this can be implemented, showing the cumulative profile of solution deployments before and after the Tipping Point; note this format is particularly helpful when interpreting results after running the Transform model.

Note: APPENDIX F shows a more detailed view of the threshold analysis that leads to the above recommendation to set all thresholds to a default of £20M regardless of voltage level and then to individually adjust those solutions (primarily EHV) whose deployment profiles still do not tip within a reasonable period of the initial solution deployment.

10.3 COST CURVES

More sophisticated cost curve implementation to support more complex cost behaviour after the Tipping Point

- **Phase 2 Implementation:**
  - Pre-Tipping Point
    - Each solution and enabling technology is assigned one of 5 cost curves:
      - 1: Rising 120% of original cost after 30 years
      - 2: Flat 100% of original cost after 30 years
      - 3: Shallow Decreasing 75% of original cost after 30 years
      - 4: Medium Decreasing 50% of original cost after 30 years
      - 5: High Decreasing 20% of original cost after 30 years
  - Post-Tipping Point
    - Same cost curve applied
    - A multiplier of 0.9 is applied to the cost curve for the solution
  - The Post-Tipping Point response is applied to all solutions and all enabling technologies
  - This implementation is illustrated in Figure 8 below
  - This approach was taken in the Phase 2 work to illustrate the Tipping Point concept
- **Phase 3 Implementation:**
  - Possible to assign each solution and enabling technology a Pre-Tipping Point cost curve and a Post-Tipping Point cost behaviour
  - Pre-Tipping Point
    - Each solution and enabling technology is assigned one of the existing 5 cost curves:
  - Post-Tipping Point
    - The solution/enabling technology can move to a new cost curve (selected from the existing 5 options)
    - The solution/enabling technology will follow this new cost curve for a period of time "x"
    - The solution/enabling technology can move to a new cost curve (selected from the existing 5 options)
    - Multipliers can be applied to the cost curves at any time, but most likely at the change points between cost curves
    - Solution and enabling technology cost behaviours are treated independently
    - This implementation is illustrated in Figure 9 below
    - This information would be documented for each solution and enabling technology in a form such as that provided in Figure 7 below:

Solution Overview	**Representative Solution:**	Temporary Meshing (soft open point)		
	Variant Solution:	EHV - maximising latent capacity		
	Description:	"Temporary meshing" refers to running the network solid, utilising latent capacity, and relying on the use of automation to restore the network following a fault		
Cost Curve	**Variable**	**Setting**	**Notes**	**Comments**
	1st curve		one from set of 5	
	a		multiplier for increase or decrease	
	2nd curve		one from set of 5	
	x (years)		time after tipping point for second chnage in cost behaviour	
	b		multiplier for increase or decrease	
	3rd curve		one from set of 5	

Figure 7 - Cost Curve Pro Forma

- **Benefit:**
  - Can model more complex behaviours or impacts
  - Improve alignment with actual or expected behaviour
- **Default**

  In the first instance the parameters that define this new behaviour are set t to reflect the current cost curve behaviour; that is, the same curve is used for the duration of the model period, and if a multiplier is applied it is applied as is the case today, namely to all solutions and enabling technologies. More sophisticated behaviours can be introduced when modelling results have been obtained.

  A Cost Curve spreadsheet has been developed to manage the applied settings and is included in the additional set of Tipping Point tools that form an integral part of the Transform Model – please refer to EA Technology for the latest available version of the Cost Curve spreadsheet tool.

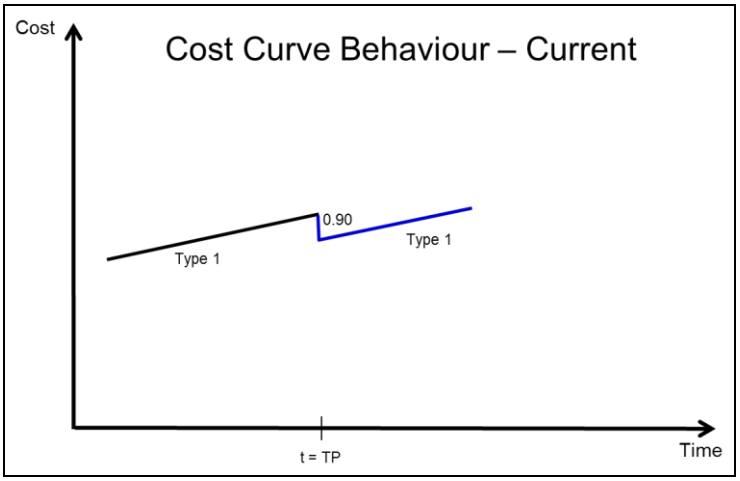


Figure 8 - Cost Curve behaviour – Phase 2

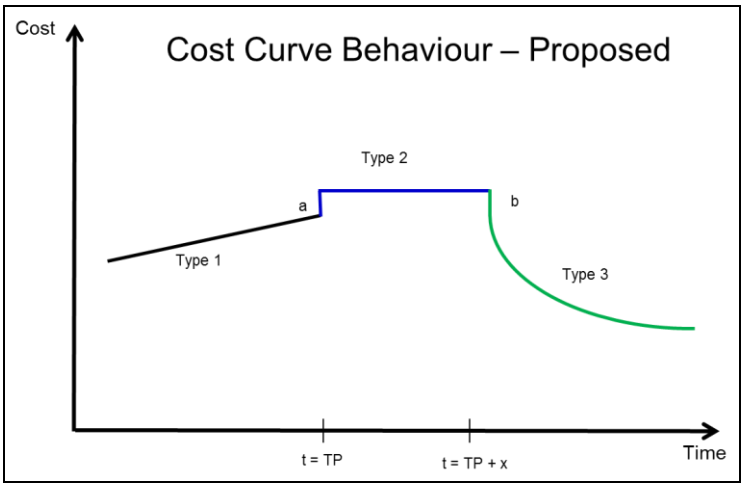


Figure 9 - Cost Curve Behaviour - Proposed

10.4 INTEGRATING FRAMEWORKS AND TRIGGERS

Integrating Frameworks: Ability to define and implement a different strategy and/or different enabling technologies after the Tipping Point

Triggers for Integrating Frameworks: Ability to specify the point at which investment in an Integrating Framework should begin in order that necessary preparations are in place at the point when the Integrating Framework is to be available.

- **Phase 2 Implementation:**
  - Not implemented in the Phase 2 model
  - Limited interpretation through modelling an outcome, today the "Economies of Scale" case
- **Phase 3 Implementation:**
  - Integrating Frameworks seek to enable change or provide insight into impact in circumstances such as:
    - Business decisions regarding strategic technology choices (e.g. move to a distributed architecture for control instead of a centralised one)
    - Need to deploy applications to automate processes (e.g. analysis of monitoring or smart meter data)
    - Response to risks of solutions ceasing to function properly (e.g. timely response to customer connection requests) etc.
  - A representation of an Integrating Framework as provided in Phase 3 is illustrated in Figure 10. The framework comprises:
    - The change of enabling technologies for a particular solution that may be beneficial after the Tipping Point
    - The introduction of new enabling technologies
    - The delivery of a Tipping Point Report which informs the broader analysis and planning activity that will support identifying options for strategy change.

- The Tipping Point Report depends on completion of Business Attributes analysis for each solution.
- Business Attributes and the Tipping Point Report are considered in Section 10.5 and Section 0 respectively.

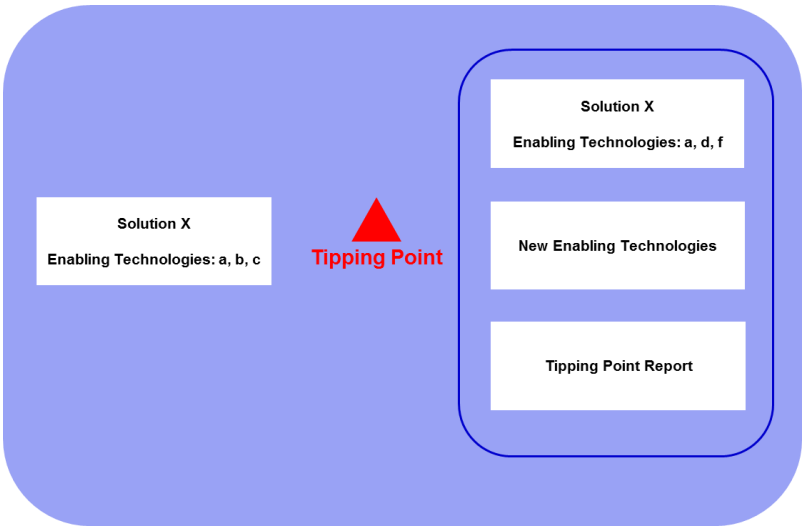


Figure 10 - Illustration of an Integrating Framework

- **Benefits:**
  - More realistic approach to model behaviour changes at/after a Tipping Point compared to current simple price change multiplier

10.5 BUSINESS ATTRIBUTES

Business Attributes are defined for each solution and enabling technology. They provide a set of considerations that extend beyond technology to include operations, business, customer and commercial matters. These are captured in a form as provided in Figure 9.

Solution Overview	**Representative Solution:**	Temporary Meshing (soft open point)
	Variant Solution:	EHV - maximising latent capacity
	Description:	"Temporary meshing" refers to running the network solid, utilising latent capacity, and relying on the use of automation to restore the network following a fault

BUSINESS ATTRBUTES	Impact Alert (1,2,3,4,5)	Trigger Time (months)	Trigger Effort (people months)	Example Considerations	Comments
architecture				the solution architecture may no longer be appropriate, a change might be suggested, for example distributed/central; open/proprietary	
data				volume; source; sharing; consolidation; processing, reporting; storage, transport	
communications				architecture: point-to-point; routed; technology; new or upgrade; performance, reliability, security; protocols	
security				architecture; data; communications; applications; physical; assurance; compliance	
deployment				planning, build, commissioning, test, introduction into service	
operations systems/applications				capability; users, user interface, IT infrastructure; systems management; open interfaces; roadmap; standards; systems integration; data; communications; functionality; evolution; control centre upgrade	
operations processes				change; alignment - business, systems, tools; new; manual; automation; integration	
people and organisation				structure; skills; training; management	
enterprise integration				strategy; organisation; processes; systems; open interfaces: availability; roadmap; standards; systems integration; data; communications; functionality; evolution	
customer relationship/engagement				direct/indirect; increased number of transactions; increased complexity of transactions; dependency; negotiation; perception; interest commercial frameworks; new contract types; regulatory; innovation	
procurement				frameworks; open/closed; discount structures; strategic partnerships; support and maintenance; regulatory; innovation	
migration				network; operations systems/applications; data; customers; operations; organisation	
standards				international; national; imposed; best practice	
corporate business model				consolidation; regulation; in source, outsource	
SOLUTION	0				

Summary				
Impact Index	0			
Trigger Time	0	months		
Trigger Effort	0	person month	0.0	person years

Figure 11 - Business Attributes – Simplified

Each attribute is assigned an Impact Alert which seeks to indicate the impact of issues such as Complexity (business, operations, technical), Disruption, Enterprise Criticality, Reusability (DNO, many DNOs, GB, international, global), Risk and Benefit.

It should consider the role of all relevant stakeholders in the business and externally (if appropriate)

Impact should be considered across the lifecycle – from design through implementation and introduction into service.

The Impact Alert indicates the impact arising from the Tipping Point and includes the effects associated with the trigger period (in advance of the Tipping Point)

The possible Impact Alert values are:

- **5: Very High** - the solution will have impact that will require substantial intervention, including management intervention
- **4: High** - the solution will have impact that will require significant intervention, including management intervention
- **3: Medium** - the solution will have impact that can be readily managed
- **2: Low** - the solution will have some impact on the business
- **1: Very Low** - the solution will have limited impact on the business

The Impact Alerts are used to generate an Impact Index for the overall solution impact.

Each Business Attribute has associated with it two other values:

- A Trigger Time which indicates the amount of time in advance of the Tipping Point (for that solution) work which addresses the particular attribute should begin
- A Trigger Effort which indicates the amount of effort that will be required to be expended over the trigger period.

The Trigger Time for the overall solution is taken as the longest trigger period for the solution.

The overall Trigger Effort for the solution is the total of that associated with each attribute.

The Business Attributes referenced in Figure 11 - Business Attributes – Simplified are referred to as the simplified version. This relies on a single Impact Alert. A more complex version has been considered as shown in Appendix C. It is proposed that use of Business Attributes – Full is a future activity which requires the experience of using the simplified version and the opportunity to learn from exercising the Tipping Point capabilities of the model.

- **Phase 2 Implementation:**
  - Not implemented
- **Phase 3 Implementation:**
  - A Business Attribute analysis is undertaken for each solution which captures information that describes the impact associated with the Tipping Point for the solution and hence the implications for a change in strategy. As noted above, the impact is ranked as an Impact Alert for each of several key considerations associated with the change. The highest Impact Alert score is then as taken as the impact of the overall solution.
  - The impact analysis should take into account the expected impact associated with any investment required before need. The start point for any such investment is the trigger point. The analysis includes an estimate of the length of the trigger period associated with each of the business attributes and in addition, an estimate of the level of effort that would be required to undertake the work needed during the trigger period.
  - These factors are then used by Tipping Point Reports to inform the analysis and planning that would be undertaken to determine the most beneficial course of action beyond a Tipping Point.
- **Benefits:**
  - Explicit insight into the broad set of issues associated with a solution and the changes in strategy that may be implemented at Tipping Point.
  - A mechanism for understanding certain trade-offs that can be made

- More information is gained that is supportive of investment planning.

- **Default Data:**

  Initial default population of the Business Attributes is provided for initial use in the TPA process. This should be reviewed and updated or refined as experience is gained in use of the Phase 3 model.

  A Business Attributes spreadsheet has been developed to manage the applied settings and is included in the additional set of Tipping Point tools that form an integral part of the Transform Model.

  A summary and a few examples have been included in Appendix C - please refer to EA Technology for the latest available version of the full Business Attributes spreadsheet tool.

10.6 TIPPING POINT REPORT

The Tipping Point Report comprises a set of summaries for each of the RIIO periods and a set of more detailed reports which provide supporting detail.

The report structures are shown as "blank" reports in Figure 12 and Figure 13 below – a full worked example in section 11 illustrates how the reports may be used in practice.

TIPPING POINT REPORT SUMMARY ED1		Year							
		2015	2016	2017	2018	2019	2020	2021	2022
Tipping Points									

TIPPING POINT REPORT SUMMARY ED2		Year							
		2023	2024	2025	2026	2027	2028	2029	2030
Tipping Points									

TIPPING POINT REPORT SUMMARY ED3		Year							
		2031	2032	2033	2034	2035	2036	2037	2038
Tipping Points									

TIPPING POINT REPORT SUMMARY ED4		Year							
		2039	2040	2041	2042	2043	2044	2045	2046
Tipping Points									

TIPPING POINT REPORT SUMMARY ED5		Year							
		2047	2048	2049	2050				
Tipping Points									

Figure 12 - Tipping Point Report - Summary

TIPPING POINT REPORT - ANALYSIS				
BY TIPPING POINT YEAR				
Tipping Point Year	Solution	Impact Index	Trigger Period Effort (person months)	Trigger Year

TIPPING POINT REPORT - ANALYSIS				
BY SOLUTION				
Solution	Impact Index	Trigger Period Effort (person months)	Tipping Point Year	Trigger Year

TIPPING POINT REPORT - ANALYSIS BY TRIGGER YEAR				
Trigger Year	Solution	Impact Index	Trigger Period Effort (person months)	Tipping Point Year

Figure 13 - Tipping Point Analysis - Report

The entries are colour coded to indicate the Impact Index level:

	Very High Impact
	High Impact
	Medium Impact
	Low Impact
	Very Low Impact

The Tipping Point – Summary report shows for each year the solutions that reach their Tipping Point in a particular year. These are categorised according to their anticipated potential impact using the Impact Index that is determined using the Business Attributes data.

The report also shows for each solution when the trigger point occurs.

The more detailed Tipping Point – Analysis Reports provide information regarding solutions and enabling technologies that have reached their Tipping Point or trigger point. These are indexed by Tipping Point year, by solution and by trigger point year.

The reports are used to provide information regarding the time at which effort should be expended and investment made in advance of need to enable changes to be made at or beyond the Tipping Point.

- **Phase 2 Implementation:**
  - Not implemented
- **Phase 3 Implementation:**
  - A run of the Transform Model will identify the Tipping Points arising from the data and parameters that it has been provided.

  - The impact of these Tipping Points is determined using the Impact Index from the Business Attributes for the respective solutions.
  - The Trigger Year for each solution is determined by calculation using the Tipping Point year identified by the model and the Trigger Time for the solution as provided in the associated Business Attribute data.
  - The Trigger Effort for each solution is determined from the Business Attribute data for the respective solutions.
  - This information is reported in the Tipping Point Reports – Analysis and hence in the Tipping Report – Summary.
  - The user is likely to begin further analysis and planning using the Summary report. This will give an immediate indication regarding which years will require effort (and hence cost) to be expended to be in a position to implement beneficial strategy changes at the Tipping Point.

- **Benefits:**
  - Supportive of more detailed planning, particularly for the investment in advance of need case.

10.7 TPA FOR ENABLING TECHNOLOGIES

DNO feedback identified the need to set Tipping Point thresholds for individual enabling technologies, using a similar approach to that used for solutions, namely based on volume deployed or cumulative cost.

The reason for applying Tipping Point flags to some enabling technologies is that enablers can be used to support multiple solutions and the volumes and costs associated with enabling technologies can be high. It may therefore be very useful to identify when certain enablers reach a pre-defined Tipping Point threshold to alert the DNO that large volumes are being deployed and to provide the opportunity for some analysis to be undertaken and potentially to make changes to the Transform Model (e.g. to apply an “economies of scale” multiplier to the enabler costs curve in recognition of the volumes being deployed).

This may not be applicable to all enabling technologies recognising that some are “strategic decision” based (e.g. Smart Meter infrastructure, design tools etc.) rather than “volume of deployment”.

- **Phase 2 Implementation:**
  - Not implemented; Tipping Point thresholds apply to solutions only
- **Phase 3 Implementation:**
  - Ability to set Tipping Point thresholds for individual enabling technologies, using the same Tipping Point threshold approach as that used for solutions, namely based on volume deployed or cumulative cost.
- **Benefits:**
  - Recognises that enablers can be material to the investment strategy in terms of volumes and costs in their own right and economies of scale could be used to vary the cost curve if volumes are high enough

10.8 Lead Times for Enabling Technologies

The Phase 2 model allows enabling technologies to be associated with specific solutions, but assumes that for incremental investments they are deployed as needed with the solutions, and for top-down investments they are deployed at the start of the relevant period. In reality, it is likely that some enabling technologies will require a certain amount of time from initial investment to the point at which they are ready for use, and therefore they need to be deployed in advance of the initial deployment of the solution. The degree to which a particular enabling technology will need to be deployed in advance will vary from technology to technology.

- **Phase 2 Implementation:**
  - Enabling technologies deployed at the same time as dependant solutions for incremental investments and at the start of the period for top-down investments
- **Phase 3 Implementation:**
  - Ability to specify the point at which investment in an enabling technology should begin in order that it would be available at the point where deployment of the associated solution begins; this would indicate the period of time that investment is required "ahead of need"; recognising that some technologies may take considerable effort/time to deploy before they are ready for use, it may be easiest to group the enabling technologies (e.g. <1 yr; 1-3 yrs; 3-5 yrs) as opposed to having a specific lead time defined for each.
  - The lead times for enabling technologies is provided in Appendix E
- **Benefits:**
  - Allows for cases where enabling technologies potentially have a long lead time required from initial investment to "ready for service" which is not accounted for in the Phase 2 model
  - This could help identify cases where investment in a particular enabler is required in ED1, even though the corresponding solution is not required until ED2
  - Similarly, this could delay investment in the top down case for enablers which are not required until near the end of the period (based on the timing of the dependant solutions)

10.9 Select Enabling Technology Independent of Solutions

In the Phase 2 Transform Model enabling technologies are only selected for deployment when one or more solutions which depend on them is/are selected. However, some enabling technologies have a more "strategic" aspect, and may be required independent of solutions even though they may not directly release headroom (e.g. advanced control centre, design tools, new ICT enablers etc.).

- **Phase 2 Implementation:**
  - Enabling technologies only selected when a dependant solution is selected
- **Phase 3 Implementation:**
  - Ability to select an enabling technology independently of any particular solution
  - Need to define and agree the criteria that can be used to enable the model to select the enabling technology (solutions are selected based on ability to address specific constraints and compared based on merit criteria)
- **Benefits:**
  - Provides the flexibility for DNOs to identify "strategic enablers" even if they don't directly release headroom (e.g. new design tools etc.)

10.10 Enabling Technology Categorisation

The ability to identify and tag enabling technologies to classify them as "volume based" or "strategic decision" provides useful information to support TPA for a given solution and its associated enabling technologies.

- **Phase 2 Implementation:**
  - Not implemented
- **Phase 3 Implementation:**
  - New attribute for an enabling technology which allows it to be tagged as "volume based" or "strategic"
  - The categorisation is provided in Appendix A.
- **Benefits:**
  - Provides a useful indicator to assist in planning for deployment of enablers which could be deployed independent of solutions

10.11 New Enabling Technology - Advanced Control Systems

Existing control centre tools, applications and operational processes will not be sufficient to effectively manage the increasingly complex and varied technologies and solutions and a more advanced set of capabilities and tools/processes will be required.

- **Phase 2 Implementation:**
  - Not implemented
- **Phase 3 Implementation:**
  - New enabler – see Appendix B for details
- **Benefits:**
  - The ability for network operations to effectively manage the evolving and rapidly changing network and associated new technologies will be become increasingly difficult without the deployment of a more sophisticated control systems infrastructure and could reach breaking point where the network simply cannot be managed within the required service levels

10.12 New Enabling Technology - ICT for Enterprise Integration

The expansion of the tools and applications used within the control centre will increase the need for inter-operation and integration between the various applications in order to share data (eg network configuration and connectivity) and ensure consistency and alignment between the systems

- **Phase 2 Implementation:**
  - Not implemented
- **Phase 3 Implementation:**
  - New enabler – see Appendix B for details
- **Benefits:**
  - The current silo-ed systems environments are comprised of a small number of core applications (e.g. GIS, SCADA, etc.); are often based on hard-coded proprietary models with very little integration or data sharing between systems, and multiple manual processes to try and ensure a degree of alignment between the systems – this approach

will not scale to address the complexity and diversity of systems in the future and a more holistic approach to systems integration will become critical.

11 PROPOSED NEW PROCESS & WORKED EXAMPLE

The following sections outline a proposed new process for undertaking TPA assuming the Phase 3 solution as described in Section 10.ction 11.2 provides a worked example.

11.1 PROCESS

The main process steps are:

1. Run model with base parameters
2. Complete Business Attributes for selected solutions/enabling technologies
3. Re-run model and review Tipping Point Summary Report to identify priority Tipping Points
4. Review detailed Tipping Point Reports to assess trigger points and key impacts
5. Undertake detailed TPA on selected solutions using Business Attributes worksheets as a guide to key business impact areas
6. Define strategy and change behaviour options (Integrating Framework) and determine changes to model data to represent them (e.g. cost curve changes; additional/different enabling technology changes etc.)
7. Implement changes in model
8. Re-run model and assess outcomes to determine if changes have achieved desired benefits

Section 0 below shows the above process using a worked example based partially on information from the Phase 2 report (e.g. selected solutions and Topping Points) together with example data added for demonstration purposes (e.g. Business Attributes for DSR solution).

11.2 WORKED EXAMPLE

The following section provides a worked example which demonstrates how the new Tipping Point tools are used in the context of the Transform Model.

Note: the example used is for "demonstration purposes only" and uses indicative data to highlight the key points of the Tipping Point tools. Please refer to the latest official documentation and toolset from EA Technology for actual data sets.

11.2.1 RUN MODEL WITH BASE PARAMETERS

Using the Phase 2 report as the baseline, the solution selected by the model are identified, including **DSR – DNO to residential** – this solution is used for the worked example:

Table 8.5 Breakdown of solution selection from the model for the Smart Top-Down investment strategy (Scenario 1)

Solution	2020	2030	2040	2050
Active Network Management - Dynamic Network Reconfiguration	13%	2%	2%	2%
D-FACTS	13%	6%	10%	11%
DSR	0%	3%	5%	8%
EAVC	0%	0%	0%	1%
Fault Current Li...rs	0%	1%	0%	1%
Local smart EV ...	0%	2%	11%	14%
Permanent Me...	1%	35%	25%	23%
RTTR	1%	6%	6%	6%
Switched capac...	0%	0%	0%	0%
Temporary Meshing	0%	1%	1%	1%
Split Feeder	0%	12%	8%	5%
New Transformer	2%	21%	18%	14%
Minor Works	3%	5%	7%	12%
Comms & Control Platforms between variant solutions	1%	0%	0%	0%
Network Measurement Devices	39%	4%	3%	2%
DCC to DNO communications and platforms	17%	2%	1%	1%
Phase imbalance measurement	5%	1%	0%	0%
Protection and remote control	4%	0%	0%	0%
Cumulative (undiscounted) Investment (£)	£787m	£7,602m	£14,918m	£23,865m

Model shows DSR solutions selected

The standard Tipping Point report from Phase 2 shows which years the selected solutions are predicted to cross the pre-determined thresholds for cumulative investment – this shows 2024 for the DSR to residential example:

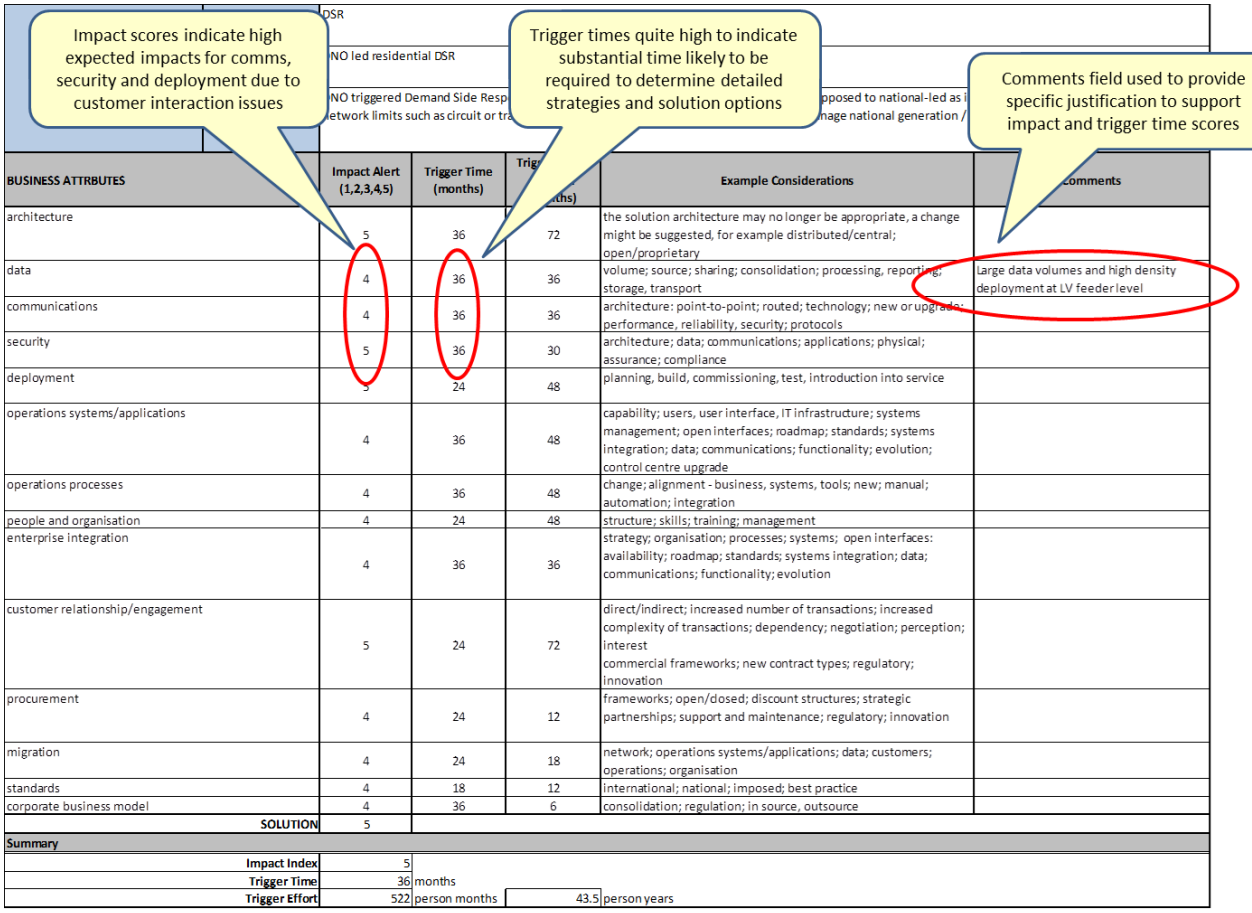
Table 8.7 Tipping Point Results for both smart investment strategies based on the default data assumptions

	Network Name	Year Reached
1	Active Network Management - Dynamic Network Reconfiguration - HV	2017
2	Distribution Flexible AC Transmission Systems (D-FACTS) - HV	2020
3	Permanent Meshing of Networks - LV Urban	2023
4	Permanent Meshing of Networks - LV Sub-Urban	2023
5	DSR - DNO to residential	2024
6	Permanent Meshing of Networks - HV	2024
7	Fault Current Limiters_HV reactors - circuit	2026
8	Local smart EV charging infrastructure_In control de	2026
9	Temporary Meshing (soft open point	2026
10	RTTR for HV Overhead Lines	2029
11	RTTR for HV/LV transformers	2029
12	D-FACTS - HV connected STATCOM	2030
13	RTTR for HV Underground Cables	2036
14	RTTR for EHV/HV transformers	2037
15	EAVC - LV PoC voltage regulators	2038
16	D-FACTS - LV connected STATCOM	2039
17	Distribution Flexible AC Transmission Systems (D-FACTS) - EHV	2039
18	Active Network Management - Dynamic Network Reconfiguration - EHV	2042
19	Temporary Meshing (soft open point) - LV	2042
20	D-FACTS - EHV connected STATCOM	2045
21	RTTR for EHV Overhead Lines	2049
22	RTTR for EHV Underground Cables	2050

Tipping Point report shows that DSR for residential TP threshold s predicted to occur in 2024

11.2.2 Complete Business Attributes for Selected Solutions

Having identified selected solutions and associated Tipping Points, the Business Attributes information needs to be completed for each selected solution and the model re-run. The worked example shown below indicates that DSR for residential is potentially a very high impact solution due to complexities relating to comms, data and commercial (ie contracts) challenges.



DSR

NO led residential DSR

NO triggered Demand Side Resp… opposed to national-led as i…
etwork limits such as circuit or tra… nage national generation /…

BUSINESS ATTRBUTES	Impact Alert (1,2,3,4,5)	Trigger Time (months)	Trig… …ths)	Example Considerations	…omments
architecture	5	36	72	the solution architecture may no longer be appropriate, a change might be suggested, for example distributed/central; open/proprietary	
data	4	36	36	volume; source; sharing; consolidation; processing, reporting; storage, transport	Large data volumes and high density deployment at LV feeder level
communications	4	36	36	architecture: point-to-point; routed; technology; new or upgrade; performance, reliability, security; protocols	
security	5	36	30	architecture; data; communications; applications; physical; assurance; compliance	
deployment	5	24	48	planning, build, commissioning, test, introduction into service	
operations systems/applications	4	36	48	capability; users, user interface, IT infrastructure; systems management; open interfaces; roadmap; standards; systems integration; data; communications; functionality; evolution; control centre upgrade	
operations processes	4	36	48	change; alignment - business, systems, tools; new; manual; automation; integration	
people and organisation	4	24	48	structure; skills; training; management	
enterprise integration	4	36	36	strategy; organisation; processes; systems; open interfaces: availability; roadmap; standards; systems integration; data; communications; functionality; evolution	
customer relationship/engagement	5	24	72	direct/indirect; increased number of transactions; increased complexity of transactions; dependency; negotiation; perception; interest commercial frameworks; new contract types; regulatory; innovation	
procurement	4	24	12	frameworks; open/closed; discount structures; strategic partnerships; support and maintenance; regulatory; innovation	
migration	4	24	18	network; operations systems/applications; data; customers; operations; organisation	
standards	4	18	12	international; national; imposed; best practice	
corporate business model	4	36	6	consolidation; regulation; in source, outsource	
SOLUTION	5				
Summary					
Impact Index	5				
Trigger Time	36	months			
Trigger Effort	522	person months	43.5	person years	

11.2.3 Re-run Model and Review Tipping "New" Point Summary Report

The new Tipping Point Summary report highlights the year in which the solutions tip, and also highlight the anticipated impact based on the Impact index from the associated Business Attributes information, together with the trigger point year in which planning and design activities need to commence (again based on Business Attributes) in order to achieve the desired (or required) change at the Tipping Point.

For the worked example of DSR for residential, this highlights the Tipping Point in 2024, and the Trigger to commence the planning and design in 2022 (the data for other solutions is indicative only.)

TIPPING POINT REPORT SUMMARY ED1		Year							
		2015	2016	2017	2018	2019	2020	2021	2022
Tipping Points	Active Network Mgt (HV)	Trigger		TP					
	D-FACTS (HV)			Trigger			TP		
	Meshing - LV Urban								Trigger
	Meshing - LV Sub-Urban							Trigger	
	DSR - DNO to residential								Trigger

TIPPING POINT REPORT SUMMARY ED2		Year							
		2023	2024	2025	2026	2027	2028	2029	2030
Tipping Points	Meshing - LV Urban	TP							
	Meshing - LV Sub-Urban	TP							
	DSR - DNO to residential		TP						
	Meshing - HV		TP						
	Fault Current Limiters (HV)				TP				

11.2.4 Review Detailed Tipping Point Reports

The summary report above identifies the Tipping Point year and associated trigger year, and indicates the high-level Impact Index. The detailed Tipping Point reports provide additional information primarily for report purposes (e.g. estimated effort):

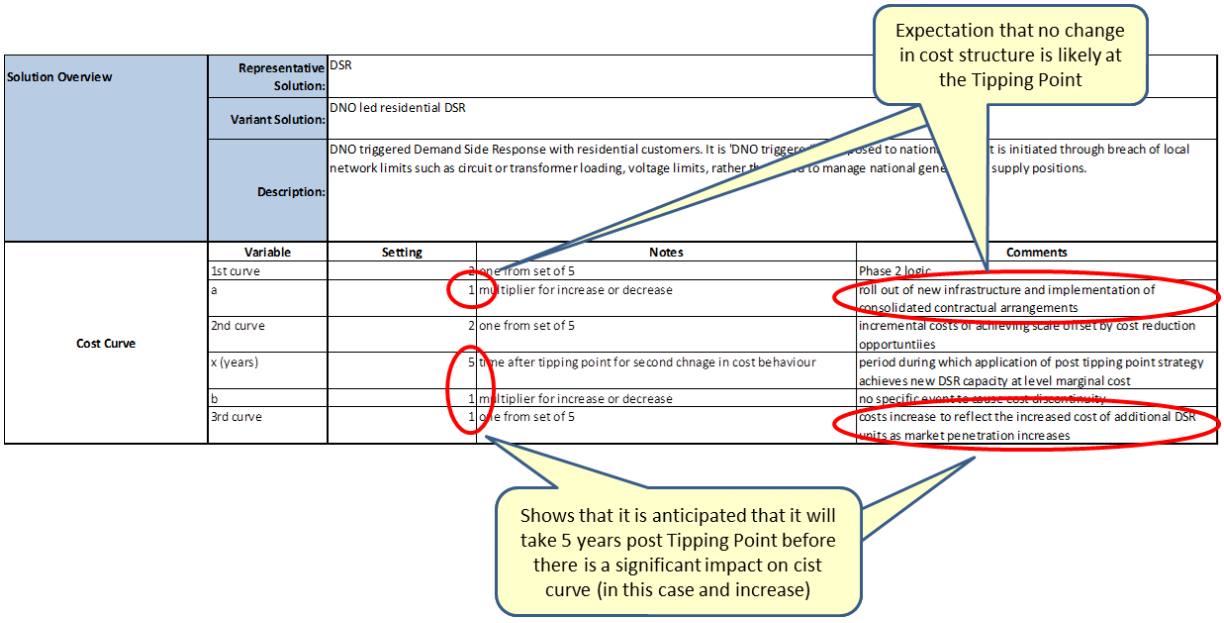
TIPPING POINT REPORT - ANALYSIS BY TIPPING POINT YEAR				
Tipping Point Year	Solution	Impact Index	Trigger Period Effort (person months)	Trigger Year
2017	Active Network Mgt (HV)	5	250	2015
2020	D-FACTS (HV)	4	170	2017
2023	Meshing - LV Urban	4	100	2022
2023	Meshing - LV Sub-Urban	4	120	2021
2024	DSR - DNO to residential	5	308	2022
2024	Meshing - HV	2	75	2023
2026	Fault Current Limiters (HV)	1	50	2025

11.2.5 DETAILED TPA AND STRATEGY CHANGE DEFINITION

This stage is done largely independent of the Transform Model, but uses the high level information in the Business Attributes matrix to guide the analysis in terms of most likely high-impact areas.

The analysis needs to consider all aspects of the solution and associated Tipping Point to determine what change is desired to occur at the Tipping Point and how this can be represented within the model (e.g. change in cost curve, addition or change of enabling technologies etc.).

One manifestation of the strategy change could be the application of a new cost curve behaviour in the model. The example below shows a cost curve change 5 years after the Tipping Point:

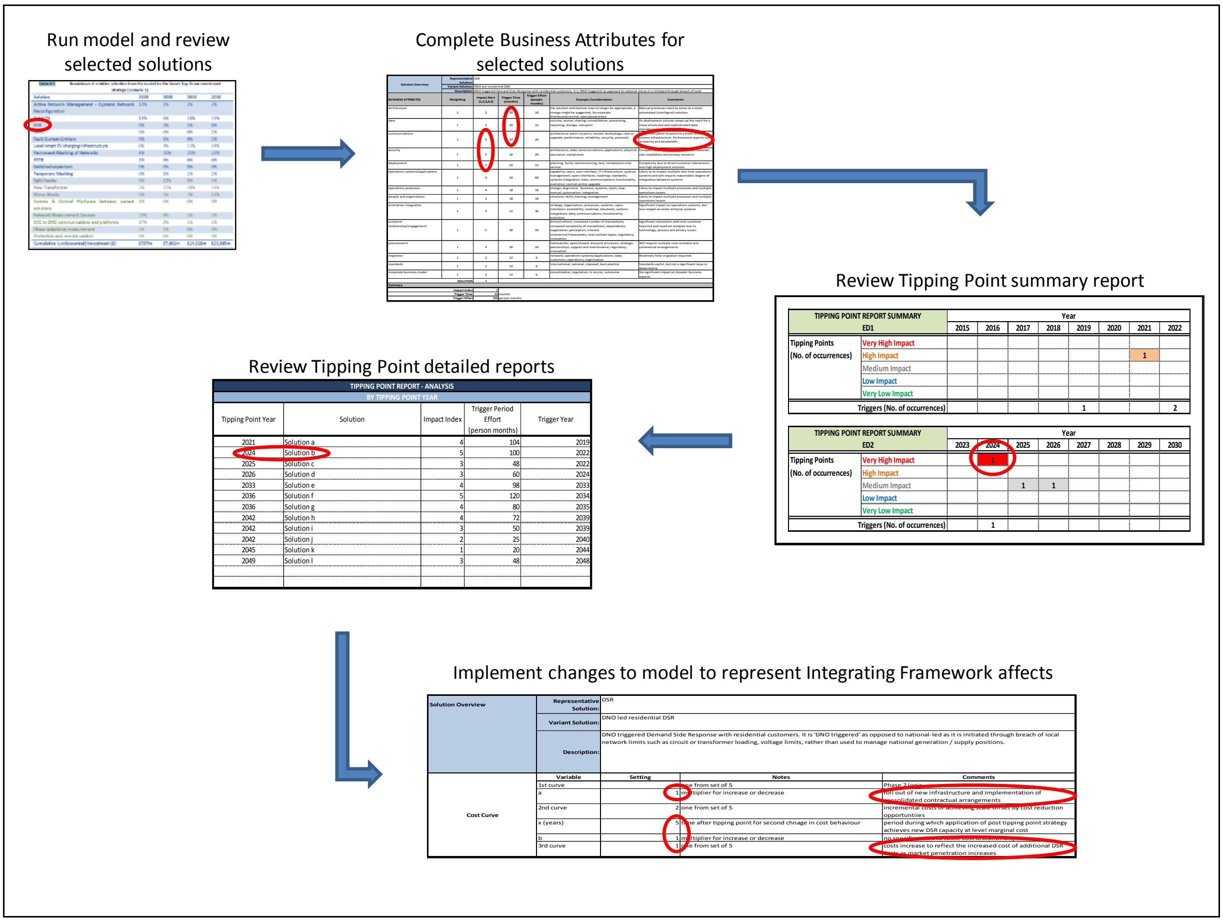


Solution Overview	**Representative Solution:**	DSR		
	Variant Solution:	DNO led residential DSR		
	Description:	DNO triggered Demand Side Response with residential customers. It is 'DNO triggered' as opposed to national... t is initiated through breach of local network limits such as circuit or transformer loading, voltage limits, rather than used to manage national gene... supply positions.		
Cost Curve	**Variable**	**Setting**	**Notes**	**Comments**
	1st curve	2	one from set of 5	Phase 2 logic
	a	1	multiplier for increase or decrease	roll out of new infrastructure and implementation of consolidated contractual arrangements
	2nd curve	2	one from set of 5	incremental costs of achieving scale offset by cost reduction opportuntiies
	x (years)	5	time after tipping point for second chnage in cost behaviour	period during which application of post tipping point strategy achieves new DSR capacity at level marginal cost
	b	1	multiplier for increase or decrease	no specific event to cause cost discontinuity
	3rd curve	1	one from set of 5	costs increase to reflect the increased cost of additional DSR units as market penetration increases

The model is then updated to reflect the identified changes andcan be re-run to assess if the changes have achieved the desired affects identified as part of the strategic analysis.

11.2.6 PROCESS SUMMARY

The diagram below summarise the flows between the various input and report sheets.



12 FURTHER WORK

This section outlines some candidate areas for further study and analysis which fall outside the current scope of the Task 3.5 Tipping Point analysis project, but could prove very beneficial to the users of the Transform Model as practical experience of its usage develops.

Ref	Title	Description
FW-01	Specification of cost behaviour	More complex cost behaviour is accommodated in the Phase 3 Transform Model. In the first instance the parameters that define this new behaviour are set t to reflect the current cost curve behaviour; that is, the same curve is used for the duration of the model period, and if a multiplier is applied it is applied as is the case today, namely to all solutions and enabling technologies. More sophisticated behaviours can be introduced when modelling results have been obtained.
FW-02	Sensitivity analysis	An important consideration in interpreting the meaning and value of identified Tipping Points is understanding their sensitivity to changes in key variables that drive them. Cases that might warrant sensitivity analysis based investigation include: • The behaviour against DECC scenarios – indicative of the impact of the uptake of different LCTs • The change in Tipping Point thresholds • Application of different cost behaviour after a Tipping Point • Selection of different enabling technologies after a Tipping Point
FW-03	Business Attributes – Simplified	Default population of the Business Attributes is provided for initial use in the TPA process. This should be reviewed and updated or refined as experience is gained in use of the Phase 3 model.
FW-04	Other Tipping Point Drivers	As experience is gained with TPA it could be beneficial to consider other Tipping Point drivers and critera such as the rate of solution deployment for example.
FW-05	Logical Grouping of Solutions	There may be benefit in grouping solutions in a logical way that reflects expected implementation approaches. For example, storage solutions may be viewed as a group as a way to inform decision making at the individual solution level.
FW-06	Logical Grouping of	There may be benefit in grouping solutions in a logical way that reflects expected implementation approaches.

	Enabling Technologies	For example, communications solutions may be viewed as a group as a way to inform decision making at the individual solution level.
FW-07	Interactions Between Solutions	There may be correlations between the Tipping Points of solutions that reveal interesting information useful to the planning process.
FW-08	Enhanced Reporting	As experience with using the model grows, it is likely that requirements for new reports or report enhancements will be identified in order to align with current and evolving planning processes.
FW-09	Tipping Point Visualisation Report	The Phase 2 implementation of Tipping Points generated a relatively simple report identifying which year a solution is predicted to tip. However, the TP threshold analysis undertaken as part of Phase 3 and outlined in section 10.2 shows that a more visually rich data presentation, showing the profile of solution deployments before and after the Tipping Point, is particularly helpful and can inform the innovation strategy and investment cases for individual solutions.
FW-10	Business Attributes – Full	Review and development of the full business attributes set is required. This should reflect results obtained from using the Transform Model and experience in using the simplified business attributes set.
FW-11	Inclusion of unique identifiers for each solution and enabling technology	Availability of unique identifiers for each solution and enabling technology would facilitate association of solutions with their enabling technologies and Tipping Points with their triggers,

Table 4 - Further Work

13 OTHER CONSIDERATIONS

This section outlines a number points for users of the Transform Model to consider when undertaking their detailed (off-line) Tipping Point analysis activities. These points relate to areas which cannot be directly incorporated into the model due to their subjective and variable nature, but may be important in individual specific cases.

Ref	Description
LP-01	A solution could potentially have multiple Tipping Points depending on what aspect of the solution is under consideration. For example, if considering EV charging from a "demand management" perspective, it may be that 5,000 charging points could be a critical threshold. However, if considered from a "billing and settlements" perspective, it may be that 10,000 charging points can be accommodated before a Tipping Point is reached.
LP-02	It is likely that some economies of scale (i.e. price variations) will occur due to global influences rather than just those arising in GB. For example, storage costs are more likely to be driven by non-GB take-up rates than GB only take-up. As a result the opportunity for a price decrease may not align with the Tipping Point threshold defined by the model. It is not clear how this can be fully accommodated; some aspects may be addressed to some approximation through the proposed ability to change cost behaviour at Tipping Points.
LP-03	In the Phase 2 Transform Model the Transform Model works at the GB level. In Phase 3 the model will be updated to operate at the licence area level. However a DNO may own more than one licence area. Some investment decisions will be made at the DNO level. It is not obvious how licence area data can easily be aggregated to give a DNO view.

Table 5 – Other Considerations

14 APPENDIX A – ENABLING TECHNOLOGY CATEGORISATION

The table below considers which of the existing and proposed new enablers may benefit from or be appropriate TPA using the existing techniques based around a "threshold" such as numbers of devices deployed or cumulative investment costs.

NOTE: *the fact that an enabler is identified below as "No" does not mean that TP analysis would not be beneficial, it simply means that the current criteria as used in the existing model (e.g. when number of deployed devices hits a pre-defined threshold), is unlikely to be the best method, and the decision to invest in and deploy these enablers is more likely to be based on strategic analysis including a wide variety of criteria/parameters, which may or may not be incorporated directly into the model.*

Enabler	TPA?	Comments
Advanced control systems	No	The need to design and deploy advanced control system infrastructure is based on a variety of factors including rate of change and complexity of network solutions, variety of new technologies and ability for existing systems to handle new technologies.
Communications to and from devices	Yes	
Design tools	No	The need for more sophisticated Design Tools is based on a variety of factors including rate of change and complexity of network solutions, variety of new technologies and ability for existing tools to handle new technologies.
DSR - Products to remotely control loads at consumer premises	Yes	
DSR - Products to remotely control EV charging	Yes	
EHV Circuit Monitoring	Yes	
HV Circuit Monitoring (along feeder)	Yes	
HV Circuit Monitoring (along feeder) w/ State Estimation	Yes	
HV/LV Tx Monitoring	Yes	
Link boxes fitted with remote control	Yes	
LV Circuit Monitoring (along feeder)	Yes	
LV Circuit monitoring (along feeder) w/ state estimation	Yes	
LV feeder monitoring at distribution substation	Yes	
LV feeder monitoring at distribution substation w/ state estimation	Yes	
RMUs Fitted with Actuators	Yes	

Communications to DSR aggregator	Yes	
Dynamic Network Protection, 11kV	Yes	
Weather monitoring	Yes	
Monitoring waveform quality (EHV/HV Tx)	Yes	
Monitoring waveform quality (HV/LV Tx)	Yes	
Monitoring waveform quality (HV feeder)	Yes	
Monitoring waveform quality (LV Feeder)	Yes	
Smart Metering infrastructure - DCC to DNO 1 way	No	The need to deploy Smart Metering infrastructure will be driven by many technical, commercial, operational and policy factors.
Smart Metering infrastructure -DNO to DCC 2 way A+D	No	The need to deploy Smart Metering infrastructure will be driven by many technical, commercial, operational and policy factors.
Smart Metering infrastructure -DNO to DCC 2 way control	No	The need to deploy Smart Metering infrastructure will be driven by many technical, commercial, operational and policy factors.
Phase imbalance - LV dist s/s	Yes	
Phase imbalance - LV circuit	Yes	
Phase imbalance -smart meter phase identification	Yes	
Phase imbalance - LV connect customer, 3 phase	Yes	
Phase imbalance -HV circuit	Yes	
NEW: IT for operations systems and advanced control centres	No	The need for more sophisticated ICT infrastructure and advanced control systems will be based on many factors relating to the rate of deployment of new technologies and the variety and complexity of such solutions.
NEW: IT for enterprise integration (inside the enterprise and with external parties).	No	The need for an enterprise integration capability will be driven by the proliferation of new systems and the need exchange structured information between internal and external systems.

15 APPENDIX B – NEW ENABLERS

15.1 ADVANCED CONTROL SYSTEMS

Solution Overview:	Representative Solution:	Advanced Control Systems			
	Variant Solution:				
	Description:	Existing control centre tools, applications and operational processes will not be sufficient to effectively manage the increasingly complex and varied technologies and solutions and a more advanced set of capabilities and tools/processes will be required.			
		EHV	**HV**	**LV**	**Comments**
Headroom Release (%)	Thermal Cable:	0%	0%	0%	Enablers are installed to facilitate solutions, which in turn release headroom. Enablers themselves release no headroom.
	Thermal Transformer:	0%	0%	0%	
	Voltage Head:	0%	0%	0%	
	Voltage Leg:	0%	0%	0%	
	Power Quality:	0%	0%	0%	
	Fault Level:	0%	0%	0%	
Cost (£)	Capital:	£20M - £50M			Costs will include hardware, software and deployment/consultancy services
	Operational Expenditure:	20%			Annual support and maintenance charges
	NPV of OPEX:				
	Cost Curve Type:	2			Unlikey to be any volume based discount structure for such tools
	Life Expectancy of Solution:	10 - 15 yrs			Assumes there will be a frequent (eg every 2-3 years) software upgrade process for new features and functions, until a replacement solution is required.
Merit Order	Totex(£):				Calculated from above
	Disruption Factor (1-5)				The installation of enablers is a very low disruption activity and does not adversely affect the public or other stakeholders
	Disruption Cost (£):				Figure based on Disruption Factor (taken from Table 13.7 in the WS3 Report)
	Flexibility (1-5):				It is envisaged that the enablers are fixed once installed
	Cross Networks Benefits Factor:				Enablers do not directly result in additional benefits to other voltage levels
Other Benefits	Impact on Fixed Losses (%):				Enablers do not affect the fixed losses within the network
	Impact on Variable Losses (%):				Enablers do not affect the variable losses within the network
	Impact on Quality of Supply (%):				Enablers facilitate solutions which may improve the quality of supply, but they do not, in themselves, have an effect
	Year solution becomes available:				
	Year data (on solution) is available				
	Source of data:				
Smart Solution Relevance (WS3 Phase 1)	Smart Solution Set:				
	Focus:				
	Subset:				

15.2 ICT FOR ENTERPRISE INTEGRATION

Solution Overview:	Representative Solution:	ICT for Enterprise Integration			
	Variant Solution:				
	Description:	The expansion of the tools and applications used within the control centre will increase the need for inter-operation and integration between the various applications in order to share data (eg network configuration and connectivity) and ensure consistency and alignment between the systems.			
		EHV	**HV**	**LV**	**Comments**
Headroom Release (%)	Thermal Cable:	0%	0%	0%	Enablers are installed to facilitate solutions, which in turn release headroom. Enablers themselves release no headroom.
	Thermal Transformer:	0%	0%	0%	
	Voltage Head:	0%	0%	0%	
	Voltage Leg:	0%	0%	0%	
	Power Quality:	0%	0%	0%	
	Fault Level:	0%	0%	0%	
Cost (£)	Capital:	£7M - £18M			Costs will hardware, software and deployment/consultancy services
	Operational Expenditure:	20%			Annual support and maintenance charges
	NPV of OPEX:				
	Cost Curve Type:	2			Unlikey to be any volume based discont structure for such tools
	Life Expectancy of Solution:	10 - 15 yrs			Assumes there will be a frequent (eg every 2-3 years) software upgrade process for new features and functions, until a replacement solution is required.
Merit Order	Totex(£):				Calculated from above
	Disruption Factor (1-5)				The installation of enablers is a very low disruption activity and does not adversely affect the public or other stakeholders
	Disruption Cost (£):				Figure based on Disruption Factor (taken from Table 13.7 in the WS3 Report)
	Flexibility (1-5):				It is envisaged that the enablers are fixed once installed
	Cross Networks Benefits Factor:				Enablers do not directly result in additional benefits to other voltage levels
Other Benefits	Impact on Fixed Losses (%):				Enablers do not affect the fixed losses within the network
	Impact on Variable Losses (%):				Enablers do not affect the variable losses within the network
	Impact on Quality of Supply (%):				Enablers facilitate solutions which may improve the quality
	Year solution becomes available:				
	Year data (on solution) is available				
	Source of data:				
Smart Solution Relevance (WS3 Phase 1)	Smart Solution Set:				
	Focus:				
	Subset:				

16 APPENDIX C – BUSINESS ATTRIBUTES

16.1 BUSINESS ATTRIBUTES – SIMPLIFIED PRO-FORMA

Solution Overview	Representative Solution:	Temporary Meshing (soft open point)
	Variant Solution:	EHV - maximising latent capacity
	Description:	"Temporary meshing" refers to running the network solid, utilising latent capacity, and relying on the use of automation to restore the network following a fault

BUSINESS ATTRBUTES	Impact Alert (1,2,3,4,5)	Trigger Time (months)	Trigger Effort (people months)	Example Considerations	Comments
architecture				the solution architecture may no longer be appropriate, a change might be suggested, for example distributed/central; open/proprietary	
data				volume; source; sharing; consolidation; processing, reporting; storage, transport	
communications				architecture: point-to-point; routed; technology; new or upgrade; performance, reliability, security; protocols	
security				architecture; data; communications; applications; physical; assurance; compliance	
deployment				planning, build, commissioning, test, introduction into service	
operations systems/applications				capability; users, user interface, IT infrastructure; systems management; open interfaces; roadmap; standards; systems integration; data; communications; functionality; evolution; control centre upgrade	
operations processes				change; alignment - business, systems, tools; new; manual; automation; integration	
people and organisation				structure; skills; training; management	
enterprise integration				strategy; organisation; processes; systems; open interfaces: availability; roadmap; standards; systems integration; data; communications; functionality; evolution	
customer relationship/engagement				direct/indirect; increased number of transactions; increased complexity of transactions; dependency; negotiation; perception; interest commercial frameworks; new contract types; regulatory; innovation	
procurement				frameworks; open/closed; discount structures; strategic partnerships; support and maintenance; regulatory; innovation	
migration				network; operations systems/applications; data; customers; operations; organisation	
standards				international; national; imposed; best practice	
corporate business model				consolidation; regulation; in source, outsource	
SOLUTION	0				

Summary				
Impact Index	0			
Trigger Time	0	months		
Trigger Effort	0	person month	0.0	person years

KEY:

Impact Alert addresses the impact of issues including COMPLEXITY (BUSINESS, OPERATIONS, TECHNICAL), DISRUPTION, ENTERPRISE CRITICALITY, REUSEABILITY, RISK AND BENEFIT and should consider the role of all relevant stakeholders in the business and externally (where appropriate).

The Impact Alert indicates the impact arising from the Tipping Point and includes the effects associated with the trigger period (in advance of the Tipping Point)

Impact should be considered across the lifecycle - from design through implementation and introduction into service.

Impact Alert:
5: Very High - the solution will have impact that will require substantial intervention, including management intervention
4: High - the solution will have impact that will require significant intervention, including management intervention
3: Medium: the solution will have impact that can be readily managed
2: Low: - the solution will have some impact on the business
1: Very Low - the solution will have limited impact on the business

Trigger Time: number of months in advance of Tipping Point that preparatory work should begin
Effort: Estimate of the amount of effort needed to undertake the preparatory work expressed in person months

Additional Information

Complexity (Business, Operations, Technical):
Very High - substantial complexity involved; innovative concepts; many integrations; very large scale
High - significant complexity involved; new concepts, many interactions, large scale
Medium: some complexity but within the scope of current DNO capability
Low: - straightforward; DNO is familiar with all concepts and has some relevant experience
Very Low - simple; DNO is very familiar with all concepts and has extensive, relevant experience

Disruption:
Very High - completely new solution at the technology, process and business level; substantial changes; affects the DNO broadly
High - substantial changes to existing solutions and additional new capabilities; affects many aspects of the DNO significant complexity involved; new concepts, many interactions, large scale
Medium: new concepts and solutions; moderate level of change; relatively contained scale
Low: - few changes which are largely incremental; limited in scale; can be accommodating through normal evolution processes
Very Low - addressed through normal upgrade and maintenance processes; effective; minor enhancements

Criticality (Enterprise):
Very High - essential to introduce new capability or to maintain operations
High - needed to introduce new capability or to assure effective operations; short term work around might be available
Medium - required to achieve effective and efficient operations; might be addressed through workaround
Low - helpful but not necessary
Very Low - potentially beneficial; can be available at some point in the future

Reusability:
Very High - global applicability
High - international applicability
Medium - applicable to GB
Low -applicable for multiple DNOs
Very Low - limited to DNO

Risk:
Very High - substantial risks complexity involved; innovative concepts; many integrations; very large scale
High - significant element of risk; risk management in place
Medium -some risks identified; likelihood and mitigations well understood and prepared
Low - limited risks which are well understood; unlikely to occur and mitigations exist straightforward factor with which the DNO is familiar and which involves few changes
Very Low - few risks and those identified are highly unlikely and mitigations exist

Benefit:
Very High - substantial benefits for business and operations
High - significant benefits for business or operations
Medium: some benefits for business or operations
Low: - little benefit for business or operations
Very Low - negligible benefit

16.2 BUSINESS ATTRIBUTES – SIMPLIFIED DEFAULT DATA

Initial default population of the Business Attributes is provided for initial use in the TPA process. This should be reviewed and updated or refined as experience is gained in use of the Phase 3 model. A Business Attributes spreadsheet has been developed to manage the applied settings and is included in the additional set of Tipping Point tools that form an integral part of the Transform Model.

The worked example in section 11.2 shows how the Business Attributes component can be used.

In total there are 96 solutions/enablers, and therefore on a summary and a few examples have been included here in this report - please refer to EA Technology for the latest available version of the full Business Attributes spreadsheet tool.

Business Attributes Summary:

Reference (Work Sheet)	Solution	Variant	Impact Index	Trigger Time (months)	Trigger Effort (person years)
BA - ANM - EHV	Active Network Management - Dynamic Netv	EHV	4	24	15.8
BA - ANM - HV	Active Network Management - Dynamic Netv	HV	4	24	15.8
BA - ANM - LV	Active Network Management - Dynamic Netv	LV	4	24	15.8
BA - DFACTS - Statcom EHV	Distribution Flexible AC Transmission Systen	EHV connected STATCOM	2	18	3.5
BA - DFACTS - Statcom HV	Distribution Flexible AC Transmission Systen	HV connected STATCOM	2	18	3.5
BA - DFACTS - Statcom LV	Distribution Flexible AC Transmission Systen	LV connected STATCOM	2	18	4.0
BA - DFACTS - EHV	Distribution Flexible AC Transmission Systen	D-FACTS@ EHV	2	18	3.5
BA - DFACTS - HV	Distribution Flexible AC Transmission Systen	D-FACTS@ HV	2	18	3.5
BA - DFACTS - LV	Distribution Flexible AC Transmission Systen	D-FACTS@ LV	2	18	4.0
BA - DSR - Central	DSR	DNO to Central business District DSR	5	30	19.9
BA - DSR - Resident	DSR	DNO led residential DSR	5	36	43.5
BA - DSR - Agg EHV	DSR	DNO to aggregetor led commercial DSR (EHV customer)	5	24	8.7
BA - DSR - Agg HV	DSR	DNO to aggregetor led commercial DSR (HV customer)	5	24	8.7
BA - DSR - EHV	DSR	DNO to commercial DSR (direct with EHV customers)	5	30	13.3
BA - DSR - HV	DSR	DNO to commercial DSR (direct with HV customers)	5	36	43.5
BA - EES - HV central	Electrical Energy Storage	EES - HV Central Business District (commercial building le	5	24	10.7
BA - EES - EHV large	Electrical Energy Storage	EHV connected EES - large	4	24	8.5
BA - EES - EHV medium	Electrical Energy Storage	EHV connected EES - medium	4	24	8.5
BA - EES - EHV small	Electrical Energy Storage	EHV connected EES - small	4	24	8.5

Example 1 – Business Attribute sheet for – Active network Management (EHV)

Solution Overview		
	Representative Solution:	Active Network Management - Dynamic Network Reconfiguration
	Variant Solution:	EHV
	Description:	The pro-active movement of EHV network split (or open) points to align with the null loading points within the network in real-time.

BUSINESS ATTRBUTES	Impact Alert (1,2,3,4,5)	Trigger Time (months)	Trigger Effort (people months)	Example Considerations	Comments
architecture	4	24	30	the solution architecture may no longer be appropriate, a change might be suggested, for example distributed/central; open/proprietary	Key component of the end-to-end operations systems environment
data	4	18	30	volume; source; sharing; consolidation; processing, reporting; storage, transport	Potential to generate substantial data, useful for real-time analysis and historical trending
communications	4	18	30	architecture: point-to-point; routed; technology; new or upgrade; performance, reliability, security; protocols	
security	3	18	18	architecture; data; communications; applications; physical; assurance; compliance	Some concern but no more than most other solutions
deployment	3	12	12	planning, build, commissioning, test, introduction into service	Nothing major associated with the Tipping Point
operations systems/applications	4	12	12	capability; users, user interface, IT infrastructure; systems management; open interfaces; roadmap; standards; systems integration; data; communications; functionality; evolution; control centre upgrade	
operations processes	3	12	12	change; alignment - business, systems, tools; new; manual; automation; integration	Nothing major associated with the Tipping Point
people and organisation	3	12	12	structure; skills; training; management	Nothing major associated with the Tipping Point
enterprise integration	4	18	12	strategy; organisation; processes; systems; open interfaces: availability; roadmap; standards; systems integration; data; communications; functionality; evolution	Solution will benefit from broader integration with other operational and business systems
customer relationship/engagement	3	12	9	direct/indirect; increased number of transactions; increased complexity of transactions; dependency; negotiation; perception; interest commercial frameworks; new contract types; regulatory; innovation	Limited direct customer facing aspects
procurement	2	12	4	frameworks; open/closed; discount structures; strategic partnerships; support and maintenance; regulatory; innovation	
migration	2	6	3	network; operations systems/applications; data; customers; operations; organisation	
standards	2	12	3	international; national; imposed; best practice	
corporate business model	1	12	3	consolidation; regulation; in source, outsource	
SOLUTION	4				

Summary				
Impact Index	4			
Trigger Time	24	months		
Trigger Effort	190	person months	15.8	person years

Example 1 – Business Attribute sheet for – DSR Aggregator (HV)

Solution Overview		
	Representative Solution:	DSR
	Variant Solution:	DNO to aggregetor led commercial DSR (HV customer)
	Description:	Demand Side Response contract between a DNO and an Aggregator (who in turn contracts with a number of HV connected customers) to resolve HV network

BUSINESS ATTRBUTES	Impact Alert (1,2,3,4,5)	Trigger Time (months)	Trigger Effort (people months)	Example Considerations	Comments
architecture	3	18	6	the solution architecture may no longer be appropriate, a change might be suggested, for example distributed/central; open/proprietary	
data	3	18	3	volume; source; sharing; consolidation; processing, reporting; storage, transport	
communications	2	18	3	architecture: point-to-point; routed; technology; new or upgrade; performance, reliability, security; protocols	
security	5	18	6	architecture; data; communications; applications; physical; assurance; compliance	
deployment	2	9	3	planning, build, commissioning, test, introduction into service	
operations systems/applications	3	18	12	capability; users, user interface, IT infrastructure; systems management; open interfaces; roadmap; standards; systems integration; data; communications; functionality; evolution; control centre upgrade	
operations processes	3	18	9	change; alignment - business, systems, tools; new; manual; automation; integration	
people and organisation	3	18	12	structure; skills; training; management	
enterprise integration	2	18	12	strategy; organisation; processes; systems; open interfaces: availability; roadmap; standards; systems integration; data; communications; functionality; evolution	
customer relationship/engagement	4	24	18	direct/indirect; increased number of transactions; increased complexity of transactions; dependency; negotiation; perception; interest commercial frameworks; new contract types; regulatory; innovation	
procurement	4	24	12	frameworks; open/closed; discount structures; strategic partnerships; support and maintenance; regulatory; innovation	
migration	2	6	2	network; operations systems/applications; data; customers; operations; organisation	
standards	4	18	6	international; national; imposed; best practice	
corporate business model	2	0	0	consolidation; regulation; in source, outsource	
SOLUTION	5				

Summary				
Impact Index	5			
Trigger Time	24	months		
Trigger Effort	104	person months	8.7	person years

16.3 BUSINESS ATTRIBUTES – FULL

BUSINESS ATTRIBUTES

Business Attributes seek to inform the analysis and planning processes undertaken to determine the most advantageous strategy to follow after the tipping point.
They support developing an holistic view of technical, operations and business aspects directly and indirectly arising from a potential change of strategy.
They seek to highlight areas that should be considered as the DNO looks forward from the tipping point.

Solution Overview	Representative Solution:										
	Variant Solution:										
BUSINESS ATTRIBUTES	**Weighting**	**Complexity (1,2,3,4,5)**	**Disruption (1,2,3,4,5)**	**Criticality (1,2,3,4,5)**	**Reusability (1,2,3,4,5)**	**Risk (1,2,3,4,5)**	**Benefit (1,2,3,4,5)**	**Trigger Time (months)**	**Trigger Effort (people months)**	**Example Considerations**	**Comments**
architecture	1									the solution architecture may no longer be appropriate, a change might be suggested, for exampl edistributed/central; open/proprietary	
data	1									volume; source; sharing; consolidation; processing, reporting; storage, transport	
communications	1									architecture: point-to-point; routed; technology; new or upgrade; performance, reliablity, security; protocols	
security	1									architecture; data; communications; applications; physical; assurance; compliance	
deployment	1									planning, build, commissioning, test, introduction into service	
operations systems/applications	1									capability; users, user interface, IT infrastructure; systems management; open interfaces; roadmap; standards; systems integration; data; communications; functionality; evolution; contol centre upgrade	
operations processes	1									change; alignment - business, systems, tools; new; manual; automation; integration	
people and organisation	1									structure; skills; training; management	
enterprise integration	1									strategy; organisation; processes; systems; open interfaces: availability; roadmap; standards; systems integration; data; communications; functionality; evolution	
customer relationship/engagement	1									direct/indirect; increased number of transactions; increased complexity of transactions; dependency; negotiation; perception; interest commerical frameworks; new contract types; regulatory; innovation	
procurement	1									frameworks;open/closed; discount structures; strategic partnerships; support and maintenance; regulatory; innovation	
migration	1									network; operations systems/applications; data; customers; operations; organisation	
standards	1									international; national; imposed; best practice	
corporate business model	1									consolidation; regulation; insource, outsource	
	SOLUTION	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000				

Summary		
Impact Index	0.0000	
Trigger Time	0	months
Trigger Effort	0	people months

KEY:

Complexity:
5: Very High - substantial complexity involved; innovative concepts; many integrations; very large scale
4: High - significant complexity involved; new concepts, many interactions, large scale
3: Medium: some complexity but within the scope of current DNO capability
2: Low: - straightforward; DNO is familiar with all concepts and has some relevant experience
1: Very Low - simple; DNO is very familiar with all concepts and has extenvive, relevant experience

Disruption:
5: Very High - completely new solution at the technology, process and business level; substabntial changes; affects the DNO broadly
4: High - substantial changes to existing solutions and additional new caapabilities; affects many aspects of teh DNOsignificant complexity involved; new concepts, many interactions, large scale
3: Medium: new concepts and solutions; moderate level of chnage; relatoively contained scale
2: Low: - few changes which are largely incremntal; limited in scale; can be accommodating through normal evolution processesges
1: Very Low - addressed through nornal upgrade and maintenance processes; effective; minor enhancements

Criticality:
5: Very High - essential to introduce new capability or to maintin operations
4: High - needed to introduce new capability or to assure effective operations; short term work around might be available
3: Medium - required to achieve effective and efficent operations; might be addressed through workaround
2: Low - helpful but not necessary
1: Very Low - potentiually benefical; can be available at some point in the future

Reusability:
5: Very High - global applicability
4: High - international applicability
3: Medium - applicable to GB
2: Low: -applicable for multiple DNOs
1: Very Low - limited to DNO

Risk:
5: Very High - substantial riskscomplexity involved; innovative concepts; many intergrations; very large scale
4: High - significant element of risk; risk management in place
3: Medium -some risks identified; likelihood and militigations well understood and prepared
2: Low - limited risks which are well understood; unlikely to occur and miligations exista straightforward factor with which the DNO is familiar and which involves few changes
1: Very Low - few risks and those identified are highly unlikely and mitigations exist

Benefit:
5: Very High - substantial benefits for buinsess and operations
4: High - significant benefits for business or operations
3: Medium: some benefits for business or operations
2: Low: - little benefit for business or operations
1: Very Low - negligible benefit

Trigger Time: number of months in advance of Tipping Point that prepartory work should begin
Effort: Estimate of the amount of effort needed to undertake the preparatory

Weightings are all set to 1 initially; the role of weightings is to be the subject of further review and analysis based upon results generated by the model.

Impact should be considered across the lifecycle - from design through implementation and introduction into service.

17 APPENDIX D – THRESHOLDS PER LICENCE AREA

Current thresholds are set at the GB level within the model. In order for TP flags to be raised on a "per licence area" basis the thresholds need to be adjusted to represent the appropriate numbers.

The proposed approach is to use the number of customers per licence area to determine the proportion of the GB level threshold to set for the particular licence area.

Error! Reference source not found. below shows a summary. It can be seen that UK Power etworks EPN licence area has 3.5M customers, which represents a threshold £6.053M for EHV as a proportion of the £50M GB level total.

So for this particular licence area, the TP flag would be raised when the cumulative total investment in EHV solutions reaches £6.053M.

Thresholds			CUSTOMERS		
			Threshold Base (£M)		
			EHV	HV	LV
			50	30	20
DNO	Licence Area	Domestic Customers*	Threshold (£M)		
			EHV	HV	LV
Electricity North West	ENW	2,357,463	4.068	2.441	1.627
Northern Power Grid	NPG - 15	1,572,232	2.713	1.628	1.085
	NPG - 23	2,254,618	3.891	2.335	1.556
UK Power Networks	EPN	3,507,431	6.053	3.632	2.421
	LPN	2,241,478	3.868	2.321	1.547
	SPN	2,242,957	3.871	2.322	1.548
Western Power Distribution	West Midlands	2,441,615	4.214	2.528	1.685
	WPD - Wales	1,094,220	1.888	1.133	0.755
	WPD - South West	1,532,913	2.645	1.587	1.058
	WPD - EMEB	2,597,659	4.483	2.690	1.793
Scottish Power	SPD	1,483,801	2.561	1.536	1.024
	SPM	1,991,924	3.438	2.063	1.375
SSE	SHEPD	734,947	1.268	0.761	0.507
	SEPD	2,919,504	5.038	3.023	2.015
		28,972,762			

Figure 14 - Thresholds per Licence Area

18 APPENDIX E –LEAD TIMES FOR ENABLING TECHNOLOGIES

Enabler	TPA?	Comments	Lead-Time	Lead-Time Justification
Advanced control systems	No	The need to design and deploy advanced control system infrastructure is based on a variety of factors including rate of change and complexity of network solutions, variety of new technologies and ability for existing systems to handle new technologies.	1 - 3 yrs	Needs a certain amount of "volume deployed" before it can achieve objectives
Communications to and from devices	Yes		1 - 3 yrs	Needs a certain amount of "volume deployed" before it can achieve objectives
Design tools	No	The need for more sophisticated Design Tools is based on a variety of factors including rate of change and complexity of network solutions, variety of new technologies and ability for existing tools to handle new technologies.	< 1 yr	Design Tools relatively stand-alone (albeit dependant on data from other systems).
DSR - Products to remotely control loads at consumer premises	Yes		1 - 3 yrs	Needs a certain amount of "volume deployed" before it can achieve objectives
DSR - Products to remotely control EV charging	Yes		1 - 3 yrs	Needs a certain amount of "volume deployed" before it can achieve objectives
EHV Circuit Monitoring	Yes		3 - 5 yrs	Unlikely to routinely visit EHV/HV sites, therefore long-time for very costly to deplpy in sufficient volumes
HV Circuit Monitoring (along feeder)	Yes		3 - 5 yrs	Unlikely to routinely visit EHV/HV sites, therefore long-time for very costly to deplpy in sufficient volumes
HV Circuit Monitoring (along feeder) w/ State Estimation	Yes		3 - 5 yrs	Unlikely to routinely visit EHV/HV sites, therefore long-time for very costly to deplpy in sufficient volumes
HV/LV Tx Monitoring	Yes		1 - 3 yrs	Needs a certain amount of "volume deployed" before it can achieve objectives
Link boxes fitted with remote control	Yes		1 - 3 yrs	Needs a certain amount of "volume deployed" before it can achieve objectives
LV Circuit Monitoring (along feeder)	Yes		1 - 3 yrs	Needs a certain amount of "volume deployed" before it can achieve objectives
LV Circuit monitoring (along feeder) w/ state estimation	Yes		1 - 3 yrs	Needs a certain amount of "volume deployed" before it can achieve objectives
LV feeder monitoring at distribution substation	Yes		1 - 3 yrs	Needs a certain amount of "volume deployed" before it can achieve objectives
LV feeder monitoring at distribution substation w/ state estimation	Yes		1 - 3 yrs	Needs a certain amount of "volume deployed" before it can achieve objectives
RMUs Fitted with Actuators	Yes		3 - 5 yrs	Need substantial volume at 11kv level to achieve objectives
Communications to DSR aggregator	Yes		< 1 yr	One-off comms infrastructure
Dynamic Network Protection, 11kV	Yes		3 - 5 yrs	Need substantial volume at 11kv level to achieve objectives
Weather monitoring	Yes		< 1 yr	Useful on a per feeder basis?
Monitoring waveform quality (EHV/HV Tx)	Yes		1 - 3 yrs	Needs a certain amount of "volume deployed" before it can achieve objectives
Monitoring waveform quality (HV/LV Tx)	Yes		1 -3 yrs	Needs a certain amount of "volume deployed" before it can achieve objectives
Monitoring waveform quality (HV feeder)	Yes		1 - 3 yrs	Needs a certain amount of "volume deployed" before it can achieve objectives
Monitoring waveform quality (LV Feeder)	Yes		1 - 3 yrs	Needs a certain amount of "volume deployed" before it can achieve objectives
Smart Metering infrastructure - DCC to DNO 1 way	No	The need to deploy Smart Metering infrastructure will be driven by many technical, commercial, operational and policy factors.	< 1 yr	One-off comms infrastructure
Smart Metering infrastructure -DNO to DCC 2 way A+D	No	The need to deploy Smart Metering infrastructure will be driven by many technical, commercial, operational and policy factors.	< 1 yr	One-off comms infrastructure

Enabler	TPA?	Comments	Lead-Time	Lead-Time Justification
Smart Metering infrastructure -DNO to DCC 2 way control	No	The need to deploy Smart Metering infrastructure will be driven by many technical, commercial, operational and policy factors.	< 1 yr	One-off comms infrastructure
Phase imbalance - LV dist s/s	Yes		1 -3 yrs	
Phase imbalance - LV circuit	Yes		1 - 3 yrs	
Phase imbalance -smart meter phase identification	Yes		1 - 3 yrs	
Phase imbalance - LV connect customer, 3 phase	Yes		1 - 3 yrs	
Phase imbalance -HV circuit	Yes		1 - 3 yrs	
NEW: IT for operations systems and advanced control centres	No	The need for more sophisticated ICT infrastructure and advanced control systems will be based on many factors relating to the rate of deployment of new technologies and the variety and complexity of such solutions.	1 - 3 yrs	Relatively complex ICT solution
NEW: IT for enterprise integration (inside the enterprise and with external parties).	No	The need for an enterprise integration capability will be driven by the proliferation of new systems and the need exchange structured information between internal and external systems.	1 - 3 yrs	Relatively complex ICT solution
NEW: Data management for network connectivity and real-time data (sensor measurements, smart meter data etc.)	No	The need for a structured data management capability will be driven by many factors including volumes, throughput and velocity, retention and security requirements etc.	3 - 5 yrs	Very complex ICT solution

19 APPENDIX F – THRESHOLD VALUE ANALYSIS

The following charts show the effect of changing the threshold values, with the following variations:

- £50M, £30M, £20M (as defined at Phase 2)
- £30M, £30M, £20M (reduce EHV threshold to same as HV)
- £20M, £20M, £20M (set all thresholds to £20M)

These variations show that by lowering the EHV threshold to £30M, the distribution of tipping points for EHV solution becomes more consistent, but there are still many which do not tip, or tip many years after initial deployment

If the thresholds for all solutions are set to £20M in recognition that the variations in investments costs per solution are not as high as originally anticipated, and that £20M represents a significant investment regardless of voltage level, then a reasonably consistent Tipping Point profile is achieved.

However, there are still several anomalies for EHV solutions, and this strengthens the case "per solution" thresholds are needed for some solutions – further calibration (reduction) of the generic threshold level would be inappropriate and would lead to different anomalies with those solutions which do already tip at a timely stage of deployment (ie they would now tip too soon)

19.1 £50M, £30M, £20M

	LV	HV	HV	EHV	HV	HV	HV	EHV	LV	HV	EHV	EHV	EHV	EHV	HV	HV	EHV	HV	EHV	LV	LV
Capex	£1,000	£20,000	£24,900	£500,000	£10,000	£100,000	£6,640	£49,800	£2,000	£100,000	£40,000	£13,280	£3,000	£30,000	£150,000	£50,000	£15,000	£20,000	£20,000	£20,000	£15,000
Totex	£1,452	£27,106	£24,900	£642,124	£81,062	£101,421	£6,640	£49,800	£2,711	£102,842	£47,106	£13,280	£3,000	£32,842	£152,842	£51,421	£60,151	£20,000	£27,106	£16,212	£18,553
	DSR - DNO	Temporary	RTTR for H	Embedded	Generator	Permanen	RTTR for H	RTTR for EI	EAVC - LV I	Distributio	Active Net	RTTR for EI	RTTR for EI	Permanen	D-FACTS -	Fault Curre	Generator	EAVC - HV	Temporary	Generator	Local smar
2012	0	0	0	0	0	0	0	0	34	0	0	0	0	0	0	0	0	0	0	0	0
2013	0	0	0	0	0	0	0								0	0	0	0	0	0	0
2014	0	0	0	0	0	0	0								0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0								0	0	0	0	0	0	0
2016	0	0	0	0	0	0	0								0	0	0	0	0	0	0
2017	0	0	0	0	0	0	0								0	0	0	0	0	0	0
2018	0	0	0	0	0	0	0								0	0	0	0	0	0	0
2019	0	0	0	3	0	34	0								0	0	0	0	3	0	0
2020	0	34	0	3	0	34	878								0	0	0	0	3	0	0
2021	738	34	0	5	0	34	895								0	0	0	0	5	0	0
2022	3542	164	0	14	101	51	1013								0	0	0	29	14	0	0
2023	6460	164	0	14	101	103	1065	38	2025	0	4	41	17	0	0	0	14	29	14	0	0
2024	8302	463	0	14	270	103	1234	139	2025	0	4	154	17	4	0	0	14	58	14	0	0
2025	18667	550	0	18	270	103	1267	207	3124	0	110	154	17	19	0	0	14	58	14	0	0
2026	23168	565	734	22	975	103	1267	218	3124	0	110	154	17	23	0	0	16	58	14	0	0
2027	25972	1437	734	22	975	103	2686	218	3968	28	110	257	45	49	0	28	16	58	14	0	0
2028	32066	1437	734	47	993	150	2715	243	3968	45	197	293	92	49	17	28	16	58	14	0	0
2029	52594	1437	749	47	1765	150	2715	249	4721	67	201	293	264	113	17	28	23	58	14	0	0
2030	62959	2450	1274	47	2461	228	2802	250	6071	97	206	456	1638	113	17	28	23	58	14	0	0
2031	70073	2450	1274	47	2461	228	2802	250	6071	97	218	456	1638	113	17	28	26	144	14	0	0
2032	87850	2450	1274	47	2506	228	2802	258	6071	97	319	456	1673	188	17	28	93	144	14	747	747
2033	97045	2450	1274	47	2551	228	2802	258	6071	97	400	456	1683	188	17	28	93	144	27	1361	1361
2034	159688	4143	1274	47	3492	659	2830	270	6071	112	408	467	1824	188	69	734	120	144	27	3203	3203
2035	170053	4143	1289	47	4877	1590	4428	270	6105	1041	484	475	2668	281	69	1665	120	864	27	8514	8514
2036	186313	4143	1306	47	4877	1590	4876	282	6105	1041	484	488	2668	285	69	1665	123	864	27	12252	12252
2037	204211	4533	1402	47	5096	1590	4980	345	6705	1041	585	618	3150	285	114	1665	123	864	27	12999	13936
2038	210230	4533	1927	47	5621	2602	5032	426	6825	1041	653	854	3150	285	114	1665	212	864	27	13613	13936
2039	339508	5238	1927	47	5805	2602	5032	527	7669	1887	677	881	3150	285	142	1665	352	864	27	15454	13936
2040	368288	5238	1927	115	7189	2602	5065	608	8681	2412	681	986	4612	285	667	1665	356	864	27	20766	13936
2041	381447	5238	1927	115	7672	2602	5167	608	8783	2412	719	990	5890	660	667	1665	356	864	27	24503	13936
2042	434538	5238	1927	115	7842	2602	6586	608	8811	2532	820	1100	7608	660	667	1665	356	864	27	25251	13936
2043	443657	5958	1927	115	7842	2602	6615	689	8811	2532	901	1100	8133	660	667	1665	446	864	27	25864	13936
2044	547394	5958	1943	115	7891	2743	6783	692	8980	2532	951	1125	8200	660	682	1806	489	893	27	27706	13936
2045	574583	5992	1943	115	8366	3175	7301	825	11194	2548	960	1247	8659	660	682	1806	489	2243	95	33017	13936
2046	585257	5992	1992	115	8825	3175	7301	825	11194	2979	960	1247	8659	660	1113	1806	489	2243	97	36755	13936
2047	679715	6093	2021	135	10187	3204	8021	1035	11194	3000	1142	1451	10250	757	1113	1806	602	2992	105	37502	13936
2048	684500	6483	2021	135	11906	3204	9033	1044	12207	3844	1209	1544	10250	757	1113	1806	691	2992	105	41216	17036
2049	790078	6800	2021	135	13813	3204	9033	1056	12207	3844	1213	1781	10250	757	1113	1806	710	2992	105	77090	32382
2050	819510	6886	2411	135	14813	3204	9816	1056	12207	3844	1234	1789	10849	757	1113	1806	714	2992	105	82402	32382

Distribution of EHV Tipping points is inconsistent and generally "*too distant*" (or never) after initial solution deployment

19.2 £30M, £20M, £20M

	LV	HV	HV	EHV	HV	HV	HV	EHV	LV	HV	EHV	EHV	EHV	EHV	HV	HV	EHV	HV	EHV	LV	LV
Capex	£1,000	£20,000	£24,900	£500,000	£10,000	£100,000	£6,640	£49,800	£2,000	£100,000	£40,000	£13,280	£3,000	£30,000	£150,000	£50,000	£15,000	£20,000	£20,000	£20,000	£15,000
Totex	£1,452	£27,106	£24,900	£642,124	£81,062	£101,421	£6,640	£49,800	£2,711	£102,842	£47,106	£13,280	£3,000	£32,842	£152,842	£51,421	£60,151	£20,000	£27,106	£16,212	£18,553
	DSR - DNO	Temporary	RTTR for H	Embedded	Generator	Permanen	RTTR for H	RTTR for EI	EAVC - LV I	Distributio	Active Net	RTTR for EI	RTTR for EI	Permanen	D-FACTS - I	Fault Curre	Generator	EAVC - HV	Temporary	Generator	Local smar
2012	0	0	0	0	0	0	0	0	34	0	0	0	0	0	0	0	0	0	0	0	0
2013	0	0	0	0	0	0	0								0	0	0	0	0	0	0
2014	0	0	0	0	0	0	0								0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0								0	0	0	0	0	0	0
2016	0	0	0	0	0	0	0								0	0	0	0	0	0	0
2017	0	0	0	0	0	0	0								0	0	0	0	0	0	0
2018	0	0	0	0	0	0	0								0	0	0	0	0	0	0
2019	0	0	0	3	0	34	0								0	0	0	0	3	0	0
2020	0	34	0	3	0	34	878								0	0	0	0	3	0	0
2021	738	34	0	5	0	34	895								0	0	0	0	5	0	0
2022	3542	164	0	14	101	51	1013								0	0	0	29	14	0	0
2023	6460	164	0	14	101	103	1065	38	2025	0	3	41	17	0	0	0	14	29	14	0	0
2024	8302	463	0	14	270	103	1234	139	2025	0	42	154	17	4	0	0	14	58	14	0	0
2025	18667	550	0	18	270	103	1267	207	3124	0	110	154	17	19	0	0	14	58	14	0	0
2026	23168	565	734	22	975	103	1267	218	3124	0	110	166	17	23	0	0	16	58	14	0	0
2027	25972	1437	734	22	975	103	2686	218	3968	28	110	267	45	49	0	28	16	58	14	0	0
2028	32066	1437	734	47	993	150	2715	243	3968	45	197	293	92	49	17	28	16	58	14	0	0
2029	52594	1437	749	47	1765	150	2715	246	4721	97	201	293	864	113	17	28	23	58	14	0	0
2030	62959	2450	1274	47	2461	228	2802	250	6071	97	206	456	1638	113	17	28	23	58	14	0	0
2031	70073	2450	1274	47	2461	228	2802	250	6071	97	218	456	1683	113	17	28	26	144	14	0	0
2032	87850	2450	1274	47	2506	228	2802	258	6071	97	319	456	1683	188	17	28	93	144	14	747	747
2033	97045	2450	1274	47	2551	228	2802	258	6071	97	400	456	1683	188	17	28	93	144	27	1361	1361
2034	159688	4143	1274	47	3492	659	2830	270	6071	112	408	467	1824	188	69	734	120	144	27	3203	3203
2035	170053	4143	1289	47	4877	1590	4428	270	6105	1041	484	475	2668	281	69	1665	120	864	27	8514	8514
2036	186313	4143	1306	47	4877	1590	4876	282	6105	1041	484	488	2668	285	69	1665	123	864	27	12252	12252
2037	204211	4533	1402	47	5096	1590	4980	345	6105	1041	585	698	3150	285	114	1665	123	864	27	12999	13936
2038	210230	4533	1927	47	5621	2602	5032	426	6825	1041	653	854	3150	285	114	1665	212	864	27	13613	13936
2039	339508	5238	1927	47	5805	2602	5032	527	7669	1887	677	885	3150	285	142	1665	352	864	27	15454	13936
2040	368288	5238	1927	115	7189	2602	5065	608	8681	2412	681	986	4612	285	667	1665	356	864	27	20766	13936
2041	381447	5238	1927	115	7672	2602	5167	608	8783	2412	719	990	5890	660	667	1665	356	864	27	24503	13936
2042	434538	5238	1927	115	7842	2602	6586	608	8811	2532	820	1100	7608	660	667	1665	356	864	27	25251	13936
2043	443657	5958	1927	115	7842	2602	6615	689	8811	2532	901	1100	8133	660	667	1665	446	864	27	25864	13936
2044	547394	5958	1943	115	7891	2743	6783	692	8980	2532	951	1125	8200	660	682	1806	485	893	27	27706	13936
2045	574583	5992	1943	115	8366	3175	7301	825	11194	2548	960	1247	8659	660	682	1806	489	2243	95	33017	13936
2046	585257	5992	1992	115	8825	3175	7301	825	11194	2979	960	1247	8659	660	1113	1806	489	2243	97	36755	13936
2047	679715	6093	2021	135	10187	3204	8021	1035	11194	3000	1142	1451	10250	757	1113	1806	602	2992	105	37502	13936
2048	684500	6483	2021	135	11906	3204	9033	1044	12207	3844	1209	1544	10250	757	1113	1806	691	2992	105	41216	17036
2049	790078	6800	2021	135	13813	3204	9033	1056	12207	3844	1213	1781	10250	757	1113	1806	710	2992	105	77090	32382
2050	819510	6886	2411	135	14813	3204	9816	1056	12207	3844	1234	1789	10849	757	1113	1806	714	2992	105	82402	32382

Some improvement in distribution of EHV Tipping Points, with most now tipping, but still some with no tipping points

19.3 £20M, £20M, £20M

	LV	HV	HV	EHV	HV	HV	HV	EHV	LV	HV	EHV	EHV	EHV	EHV	HV	HV	EHV	HV	EHV	LV	LV
Capex	£1,000	£20,000	£24,900	£500,000	£10,000	£100,000	£6,640	£49,800	£2,000	£100,000	£40,000	£13,280	£3,000	£30,000	£150,000	£50,000	£15,000	£20,000	£20,000	£20,000	£15,000
Totex	£1,452	£27,106	£24,900	£642,124	£81,062	£101,421	£6,640	£49,800	£2,711	£102,842	£47,106	£13,280	£3,000	£32,842	£152,842	£51,421	£60,151	£20,000	£27,106	£16,212	£18,553
	DSR - DNO	Temporary	RTTR for H	Embedded	Generator	Permanen	RTTR for H	RTTR for EI	EAVC - LV I	Distributio	Active Net	RTTR for EI	RTTR for EI	Permanen	D-FACTS - I	Fault Curre	Generator	EAVC - HV	Temporary	Generator	Local smar
2012	0	0	0	0	0	0	0	0	34	0	0	0	0	0	0	0	0	0	0	0	0
2013	0	0	0	0	0	0	0								0	0	0	0	0	0	0
2014	0	0	0	0	0	0	0								0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0								0	0	0	0	0	0	0
2016	0	0	0	0	0	0	0								0	0	0	0	0	0	0
2017	0	0	0	0	0	0	0								0	0	0	0	0	0	0
2018	0	0	0	0	0	0	0								0	0	0	0	0	0	0
2019	0	0	0	3	0	34	0								0	0	0	0	3	0	0
2020	0	34	0	3	0	34	878								0	0	0	0	3	0	0
2021	738	34	0	5	0	34	895								0	0	0	0	5	0	0
2022	3542	164	0	14	101	51	1013								0	0	0	29	14	0	0
2023	6460	164	0	14	101	103	1065	38	2025	0	3	41	17	0	0	0	14	29	14	0	0
2024	8302	463	0	14	270	103	1234	139	2025	0	42	154	17	4	0	0	14	58	14	0	0
2025	18667	550	0	18	270	103	1267	207	3124	0	110	154	17	19	0	0	14	58	14	0	0
2026	23168	565	734	22	975	103	1267	218	3124	0	110	166	17	23	0	0	16	58	14	0	0
2027	25972	1437	734	22	975	103	2686	218	3968	28	110	267	45	49	0	28	16	58	14	0	0
2028	32066	1437	734	47	993	150	2715	243	3968	45	197	293	92	49	17	28	16	58	14	0	0
2029	52594	1437	749	47	1765	150	2715	246	4721	97	201	293	864	113	17	28	23	58	14	0	0
2030	62959	2450	1274	47	2461	228	2802	250	6071	97	206	456	1638	113	17	28	23	58	14	0	0
2031	70073	2450	1274	47	2461	228	2802	250	6071	97	218	456	1638	113	17	28	26	144	14	0	0
2032	87850	2450	1274	47	2506	228	2802	258	6071	97	319	456	1683	188	17	28	93	144	14	747	747
2033	97045	2450	1274	47	2551	228	2802	258	6071	97	400	456	1683	188	17	28	93	144	27	1361	1361
2034	159688	4143	1274	47	3492	659	2830	270	6071	112	408	467	1824	188	69	734	120	144	27	3203	3203
2035	170053	4143	1289	47	4877	1590	4428	270	6105	1041	484	475	2668	281	69	1665	120	864	27	8514	8514
2036	186313	4143	1306	47	4877	1590	4876	282	6105	1041	484	488	2668	285	69	1665	123	864	27	12252	12252
2037	204211	4533	1402	47	5096	1590	4980	345	6105	1041	585	698	3150	285	114	1665	123	864	27	12999	13936
2038	210230	4533	1927	47	5621	2602	5032	426	6825	1041	653	854	3150	285	114	1665	212	864	27	13613	13936
2039	339508	5238	1927	47	5805	2602	5032	527	7669	1887	677	885	3150	285	142	1665	352	864	27	15454	13936
2040	368288	5238	1927	115	7189	2602	5065	608	8681	2412	681	986	4612	285	667	1665	356	864	27	20766	13936
2041	381447	5238	1927	115	7672	2602	5167	608	8783	2412	719	990	5890	660	667	1665	356	864	27	24503	13936
2042	434538	5238	1927	115	7842	2602	6586	608	8811	2532	820	1100	7608	660	667	1665	356	864	27	25251	13936
2043	443657	5958	1927	115	7842	2602	6615	689	8811	2532	901	1100	8133	660	667	1665	446	864	27	25864	13936
2044	547394	5958	1943	115	7891	2743	6783	692	8980	2532	951	1125	8200	660	682	1806	485	893	27	27706	13936
2045	574583	5992	1943	115	8366	3175	7301	825	11194	2548	960	1247	8659	660	682	1806	489	2243	95	33017	13936
2046	585257	5992	1992	115	8825	3175	7301	825	11194	2979	960	1247	8659	660	1113	1806	489	2243	97	36755	13936
2047	679715	6093	2021	135	10187	3204	8021	1035	11194	3000	1142	1451	10250	757	1113	1806	602	2992	105	37502	13936
2048	684500	6483	2021	135	11906	3204	9033	1044	12207	3844	1209	1544	10250	757	1113	1806	691	2992	105	41216	17036
2049	790078	6800	2021	135	13813	3204	9033	1056	12207	3844	1213	1781	10250	757	1113	1806	710	2992	105	77090	32382
2050	819510	6886	2411	135	14813	3204	9816	1056	12207	3844	1234	1789	10849	757	1113	1806	714	2992	105	82402	32382

Much more consistent, but still several EHV solutions which do not tip until very late after initial deployment – best approach to address this is to set specific thresholds for these solutions, rather than further calibration of the generic threshold