ANNEX 20: ASSESSING THE IMPACT OF LOW CARBON TECHNOLOGIES ON GREAT BRITAIN'S ELECTRICITY DISTRIBUTION NETWORKS BY EATL

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Smart Grid Forum: Work Stream 3 – Phase 3

Assessing the impact of Low Carbon Technologies on Great Britain's electricity distribution networks

Analysis of Least Regrets Investments for RIIO-ED1 and supporting evidence

Issue 1.1

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Partners and Acknowledgements

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- Chiltern Power
- Smarter Grid Solutions
- Grid Scientific

The project has taken input from a range of sources and the Network Operator project steering group:

- Energy Networks Association
- Electricity North West Limited
- UK Power Networks
- Northern Powergrid
- SP Energy Networks
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- Scottish & Southern Energy Power Distribution
- National Grid

Executive Summary

This report provides an overview of the impact of the updates made to the Transform model during the period September 2012 to March 2013 and, in particular, the conclusions that can be drawn from the modelling in regard to 'Least Regret' investments and associated actions that might be considered for ED1, in the context of the forecast investments for ED2.

The modelling changes that have been incorporated are:

- Those proposed by Element Energy in their report Task 3.2
- Those proposed by Smarter Grid Solutions (SGS) in their report Task 3.4
- Those proposed by Grid Scientific (GS) in their report Task 3.5.
- Those proposed and accepted through Governance detailed in Task 3.1

The current version of the model has been peer reviewed by leading consultancies and the GB Network Operator community. All data and modifications to the model from this review have now been added and the model (version 3.2.0) has been re-run.

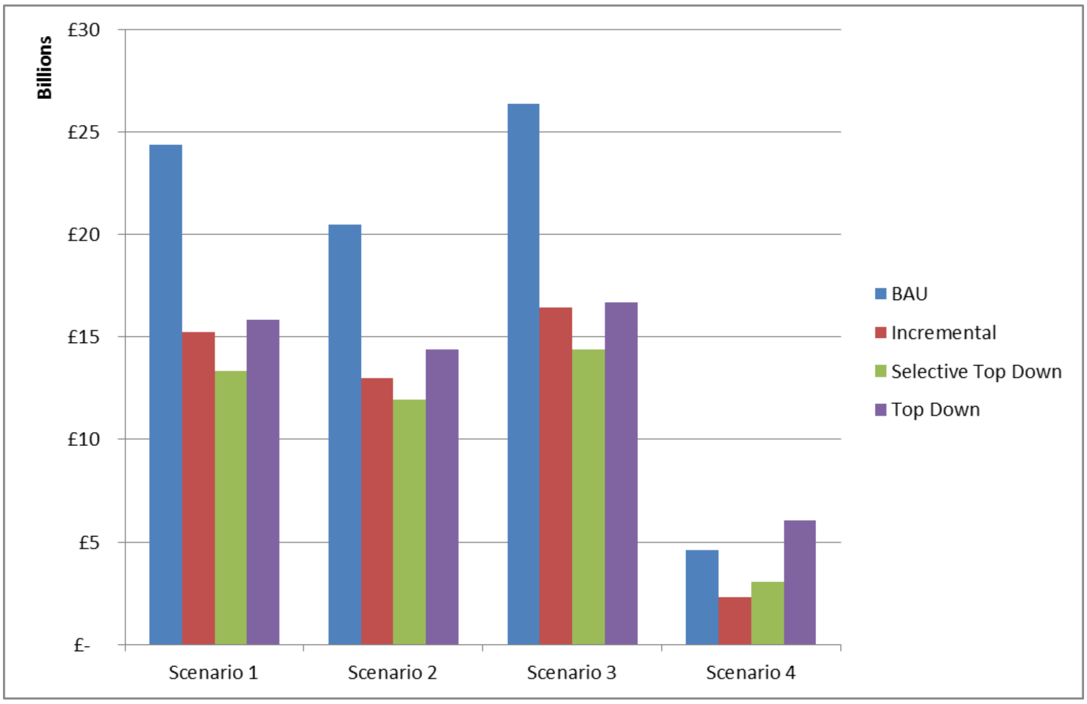
The specific focus of this work is to assess whether there are 'Least Regrets' investments or other actions that should be made in the RIIO-ED1[1] period in anticipation of achieving efficient deployments in ED2, noting the lead times involved.

The analysis shows the following findings:

- The analysis continues to show a strong cost benefit in adopting a smart investment strategy over a purely conventional investment strategy for all the DECC scenarios considered to 2050; this benefit is of the order of 25-30% of total investment costs to 2050;
- The conclusions are not sensitive to the availability of any one individual smart solution; the model continues to show that a mix of smart and conventional solutions is likely to provide the optimum investment strategy for GB;
- The model can therefore be expected to provide helpful guidance for the estimated investment trajectory whilst not being prescriptive of specific smart solutions;
- Turning off the most highly selected smart solutions in the model only increases spend by 2% to 2050;
- The model now includes Tipping Point analysis that provides early warning to DNOs for the anticipated preparation timescales and the severity of likely business impacts of specific smart solutions on a distribution company's processes and systems;
- Incorporating the impact of Tipping Points on smart solutions, where the increasing scale of deployment offers the opportunity for procurement efficiencies, gives a further predicted investment benefit of around £1billion in Totex to 2050;
- An important conclusion from the revised model, that now includes closer analysis of enabler costs, is that a "Full" top down investment strategy no longer shows a financial benefit over an incremental investment strategy;

[1] RIIO – Revenue = Incentives + Innovations + Outputs and is the new style of energy Regulation introduced to Great Britain (GB) by Ofgem from 2013. The ED1 (Electricity Distribution one) period covers an eight year timescale from 1st April 2015 – 31st March 2023.

- However, further investment benefits can be obtained through implementing a “Selective” Top Down strategy where only the enablers required for the top-ranked solutions are deployed; this results in a benefit of up to £2billion in Scenario 3 (high electrification of heat and transport) compared to a smart incremental strategy;
- These benefits are not realised in Scenario 4 (where credit purchase is used to achieve de-carbonisation);
- Modelling of the Selective Top Down strategy suggests that the optimum timing for this will be early in ED2. Added to the fact that Selective Top Down introduces additional cost in scenario 4, it would appear sensible to wait until ED2 or the mid ED1 review point before committing to this strategy.
- The present value of total expenditure to 2050 predicted by the model for the four investment strategies is shown below:



In summary, the key messages from this work are as follows:

1. The Transform model has been significantly enhanced, in regard to both its analysis capabilities and the presentation of results to assist user interpretation;
2. A material cost-benefit continues to be indicated by adopting innovative ‘smart’ technologies in conjunction with traditional network investment;
3. While confirming the economic advantages of adopting smart solutions, the model is demonstrated to be broadly insensitive to specific solutions, which reinforces the message that it should not be used as a detailed ‘solution picker’, rather it should be used to inform strategic investment decisions;
4. A ‘Full’ Top Down strategy is no longer indicated as being beneficial now that the costs of enablers are better modelled, but the alternative ‘Selective’ Top Down

strategy is shown to be beneficial; commencing this strategy in ED2 appears to provide the best investment option at this stage; and

5. The deployment of innovative solutions in ED1, while of significantly lower scale than that forecast for ED2, is nevertheless expected to create material challenges for the DNOs; this report identifies the likely solutions appearing in ED1, their deployment numbers, which of these reach their Tipping Points, and the Tipping Points anticipated for ED2 that are likely to need preparatory action to be taken in ED1.

Contents

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Date: 11th March 2013
Issue: Final 1.0

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Lead Organisation(s): EA Technology / Element Energy
Report Number: 84170_2
Date: November 2012

12 Annex 7: Brief Summary of all other Changes made to the Model

Contained at the end of this report

1 Workstream 3 Timeline

This report presents the findings of the overall work program performed for the Smart Grid Forum Workstream 3 activity from July 2012 to March 2013. The top of the diagram below indicates the various documents produced throughout the WS3 activity while the middle describes the changes to the model that have been incorporated as scenario data and parameters have been updated, the bottom indicates model releases. The current version of the model, used for all analysis in this report, shown in red is the full release of Transform™[2] version 3.2.0.

The main body of this report presents the final report findings whilst the interim reports, detailing all changes made to the model over this period are presented in the Annexes. The annexes consist of:

- **Annex 1:** Smarter Grid Solutions' "Review of Enablers, Solutions and Top Down Modelling in Transform™"
- **Annex 2:** EA Technology's "Review of Enabler Mapping"
- **Annex 3**: Grid Scientific's "Tipping Point Analysis Report"
- **Annex 4:** EA Technology's "Review of Tipping Point Analysis"
- **Annex 5:** EA Technology's "Governance Period 1 Review Documentation"
- **Annex 6:** EA Technology/Element Energy's "Development of a licence area level feeder model"
- **Annex 7**: EA Technology's "Summary of all other Changes made to the model"

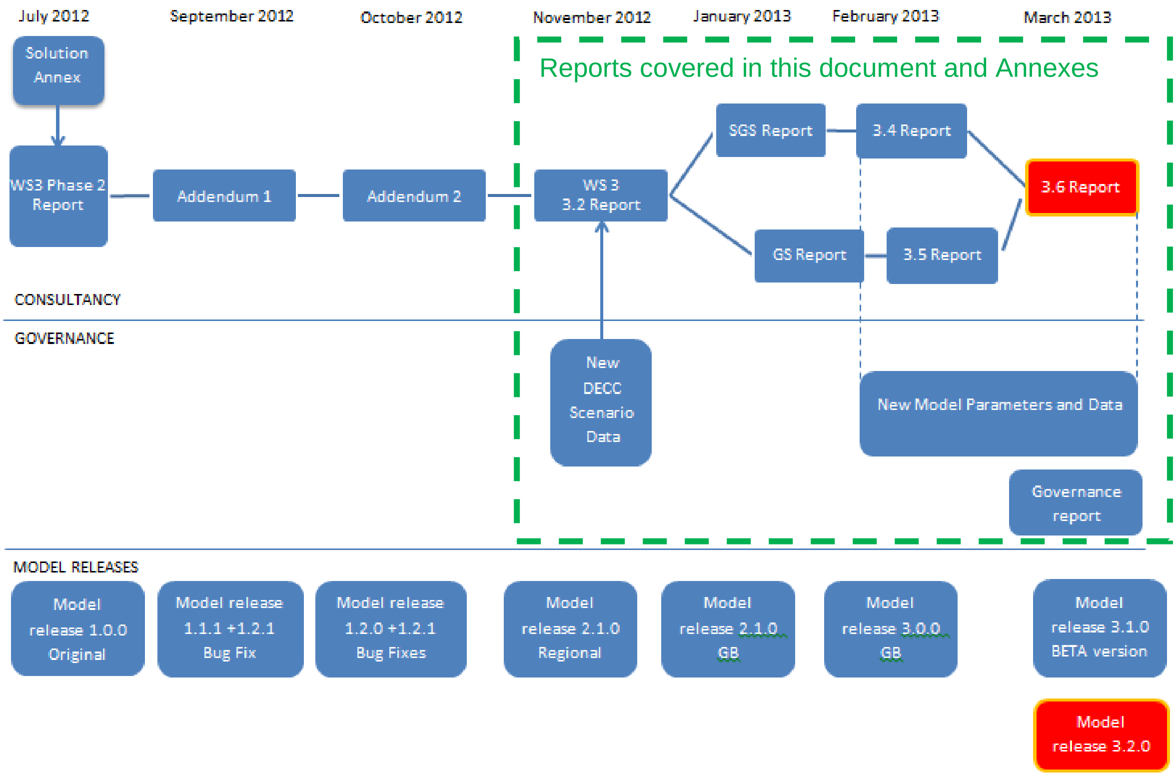


Figure 1 The Overall Smart Grid Forum Workstream 3 Phase 3 Timeline

[2] The Transform™ model is owned, developed and licensed by EA Technology. All GB DNOs, Ofgem and DECC have a royalty-free licence to use the software. Other users may access the model on a commercial basis.

2 Introduction

This report provides an overview of the impact of the changes made to the Transform™ model during the period September 2012 to March 2013. These changes include:

- Those proposed by Element Energy in their report Task 3.2;
- Those proposed by Smarter Grid Solutions (SGS) in their report Task 3.4;
- Those proposed by Grid Scientific (GS) in their report Task 3.5;
- Those proposed and accepted in Governance detailed in Task 3.1.

Each of these changes are reviewed in detail in their own separate reports, the broad outline of the detail is summarised below. Following this, the impact of these changes to the model is assessed and broad conclusions are drawn as to what early actions are predicted by the model.

The model used for testing all the assumptions is the most current version of Transform™ v3.2.0 issued to users on 13/3/13.

2.1 Overview of 3.2, Regionalisation of the Model

In task 3.2 the Transform™ model was modified to move from a national GB model to 14 discrete models covering each DNO licence area. In addition, the four scenarios for uptake of Low Carbon Technologies were modified to align with the four scenarios used by DECC in the fourth Carbon Budget (4CB).

The reader is encouraged to review report 3.2 for full information on the changes made.

2.2 Overview of 3.4, Model Review

In task 3.4 the inputs to the model were closely scrutinised by Smarter Grid Solutions Ltd (SGS). The output of this assessment was a number of enhancements to the model, all of which were reviewed and approved by SGS, EA Technology and the DNO community. The following developments to the model were included here:

- Improved data for Capex and Opex of solutions and enablers;
- Improved mapping of enablers to solutions;
- Addition of new enablers and solutions;
- Review of Optimism Bias with improved data;
- Improved mapping of solutions and enablers to cost curves.

The reader is encouraged to review report 3.4 for full information on the changes made.

2.3 Overview of 3.5, Tipping Point Analysis

In task 3.5 the impact of ‘Tipping Points’ was closely scrutinised by Grid Scientific Ltd (GS). The output of this assessment resulted in a number of enhancements to the model, all of which were reviewed and approved by GS, EA Technology and the DNO community. The following developments to the model have been included here:

- Application of Tipping Point Analysis to both solutions and enabling technologies
- Approach for the identification of Tipping Point thresholds for each solution and enabler
- Improved methodology for modelling cost curves and price changes post the Tipping Point of each solution;
- Improved mapping of enablers to solutions, including the ability to select enablers independently of specific solutions;
- Identification of timescales for preparation for Tipping Points (recognising the likely resources needed and the business challenges for network company's processes and systems);
- Review of all enablers and solutions regarding timescales for deployment, and specifically lead times for enabler deployment;;
- Improved reporting output from the model to assist user interpretation.

The reader is encouraged to review report 3.5 for full information on the changes made.

2.4 Overview of 3.1, Governance

In addition to tasks 3.4 and 3.5 the model was also subject to its first "Governance period". Under the governance mechanism, the following developments were made:

- Updated data from DECC on Distributed Generation and EV projections;
- Provision of four energy efficiency scenarios for a user to select;
- Further review and modification of enabler mapping.

In addition, a number of helpful longer-term changes to the model were proposed and these will be considered in due course for possible development funding.

The reader is encouraged to review report 3.1 for full information on the changes made.

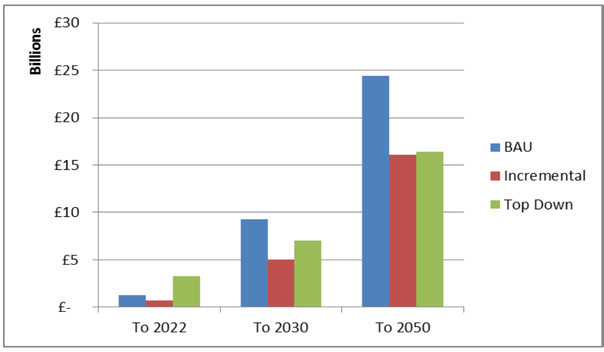
2.5 How we have arrived at the current 'baseline' model

The following sections outline the results obtained in a series of runs using the full v3.2.0 model. Firstly in section 3 we outline the results obtained through running the baseline model without Tipping Points. In section 4 we include Tipping Point analysis of cost curves and then address a number of scenarios utilising various strategies and draw out some of the sensitivities of the model in an attempt to identify Least Regrets investment options.

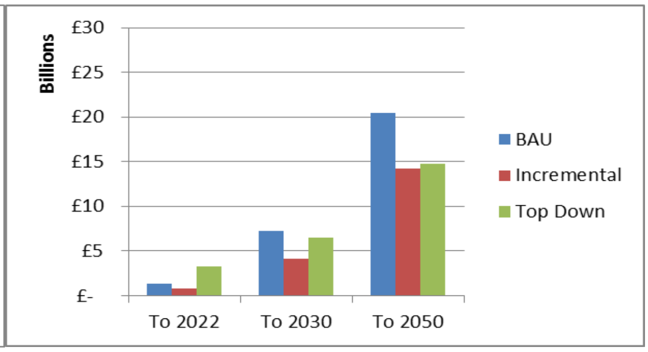
3 Model baseline results

3.1 Predicted investment by scenario and ED Period

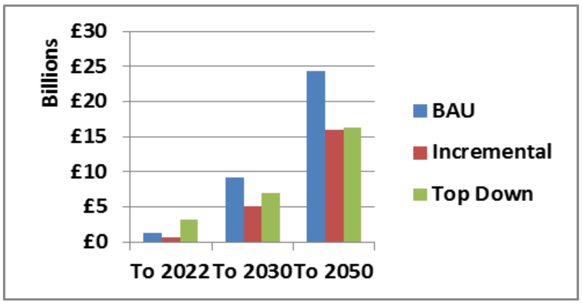
The following sets of graphs detail the predicted investment by scenario for the GB model 3.2.0, firstly split by RIIO ED periods, and then shown as a total investment cost to 2050. These results incorporate all changes to the model, but without treatment of Tipping Points.



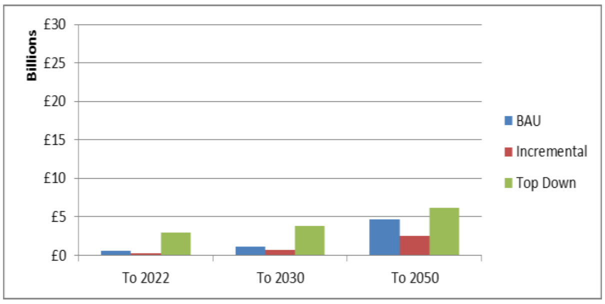
Scenario 1 (High abatement in low carbon heat)



Scenario 2 (High abatement in transport)



Scenario 3 (High electrification of heat and transport)



Scenario 4 (Credit purchase)

Figure 2 Predicted investment (Present Value [PV] of Totex[3]) by scenario to 2050

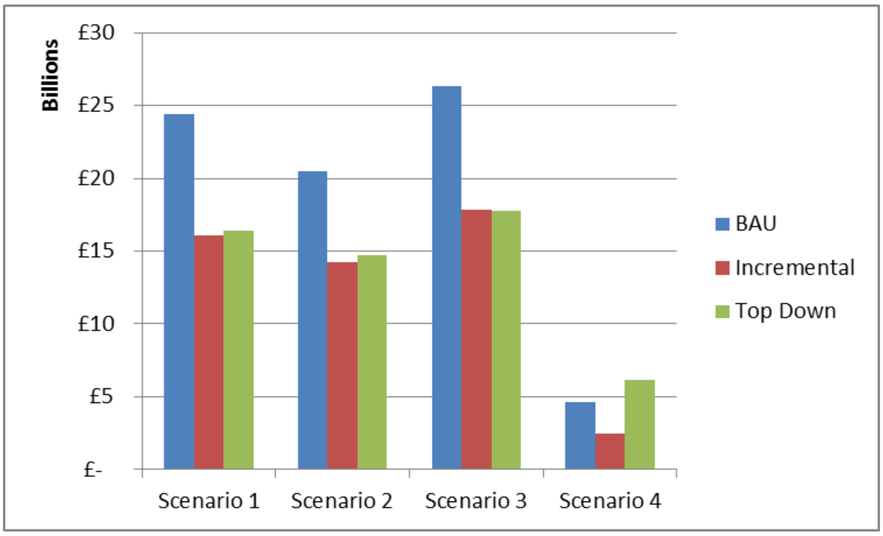


Figure 3 PV of Totex to 2050 of all scenarios by the three investment strategies

[3] Totex is the sum of capital and operating expenditure.

As can be seen, the Incremental smart investment strategy shows savings in all scenarios and in all time periods, compared with BAU investment only, through to 2050. This is particularly evident in the early years.

Compared with the previous (Phase 2) model results, the BAU costs have remained broadly similar whilst the smart incremental costs have reduced substantially (by nearly a quarter). However, unlike the previous analysis, the Top Down investment strategy is no longer indicating additional savings and, apart from Scenario 3, is more expensive than the smart incremental strategy. In section 4.1 we develop a ‘Selective Top Down’ strategy to address this new understanding of the full top down strategy. These results have been analysed following the model changes made, which confirms that this outcome for the Top Down approach can be attributed to the greater number of enablers (and therefore costs) now included in the model, making an initial investment in all enablers under a Top Down approach, more expensive on a PV Totex basis.

3.2 Solutions selected, by number deployed

Looking at the solutions and enablers being selected in the model we see the following as the top 10 in terms of number of times deployed in Scenario 3, smart incremental, to 2050.

Table 1 Top enablers/solutions selected by times deployed (note not by cost)

Solution/Enabler	Times Deployed	Year first deployed
Generator Providing Network Support - LV	598,573	2017
LV Circuit Monitoring (along feeder)	541,282	2015
Communications to and from devices - LAST MILE ONLY	463,580	2013
HV/LV Tx Monitoring	419,110	2017
LV feeder monitoring at distribution substation	395,700	2015
LV Ground mounted 11/LV Tx	253,174	2016
Permanent Meshing of Networks - LV Urban	211,875	2018
RTTR for HV/LV transformers	211,798	2022
DSR - DNO to residential	151,553	2022
Permanent Meshing of Networks - LV Sub-Urban	118,992	2020

The solutions and enablers all have different lifetimes so to give a sense check as to the total coverage of each solution/enabler on the network, these values need to be associated with their lifetimes (and the total number of feeders on the network) as shown below.

The table shows the effective coverage of each solution/enabler assuming the total number of feeders (EHV, HV and LV) remaining static at around 1,000,000 and dividing the time to 2050 by the assumed lifetime of each technology.

Table 2 Top enablers/solutions selected by network coverage

Solution/Enabler	Times Deployed	Lifetime (years)	Network Coverage to 2050
LV Circuit Monitoring (along feeder)	541,282	20	30%
LV Ground mounted 11/LV Tx	253,174	40	26%
Communications to and from devices - LAST MILE ONLY	463,580	20	26%
HV/LV Tx Monitoring	419,110	20	24%
LV feeder monitoring at distribution substation	395,700	20	22%
Permanent Meshing of Networks - LV Urban	211,875	45	22%
Permanent Meshing of Networks - LV Sub-Urban	118,992	45	12%
RTTR for HV/LV transformers	211,798	15	9%
Generator Providing Network Support - LV	598,573	5	8%
DSR - DNO to residential	151,553	5	2%

Readers should draw their own conclusions as to how realistic these predictions for deployment of solutions and enablers are for their particular network and innovation strategy; solutions/enablers that are not appropriate or are judged to be unsuitable can of course be “switched off” by a user when determining the best strategy for their context.

It is interesting to note the mix of smart and conventional solutions determined by the model. It is also informative to look at the timing of deployment of each of the smart and conventional solutions. The Graph below (again from Scenario 3 incremental analysis) shows the deployment of smart and conventional solutions out to 2050. This shows periodic peaks in activity and shows that deployment of smart solutions is predicted to diverge significantly and exceed conventional solution deployment, by cumulative numbers installed after 2030 and then rise rapidly higher from 2033.

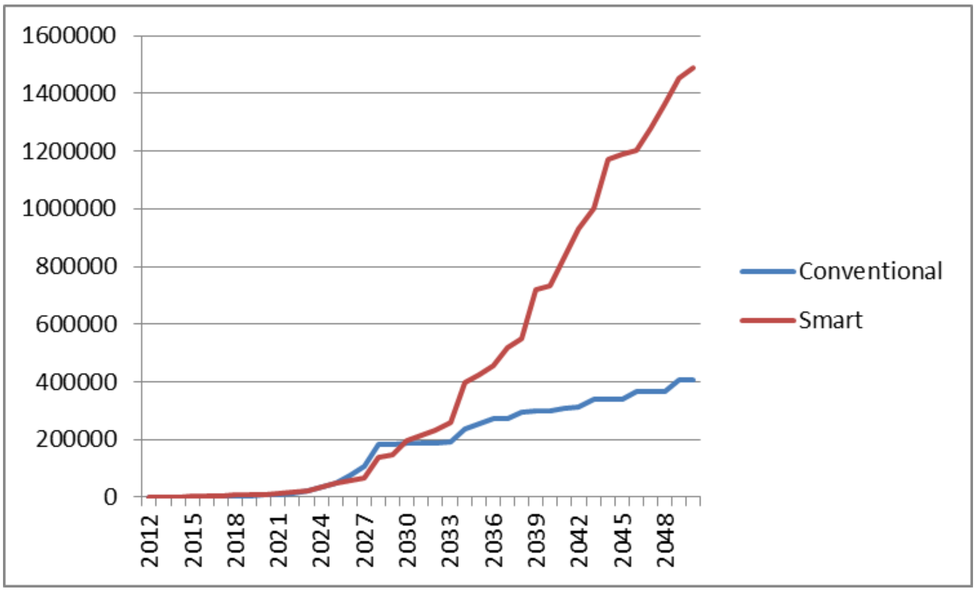


Figure 4 Cumulative Deployment of Smart and Conventional solutions to 2050 (Scenario 3 without tipping points)

Repeating the analysis with Tipping Point treatment of cost curves, shown on the following graphic, identifies that the dominance of smart technology solutions over conventional is brought forward to 2028.

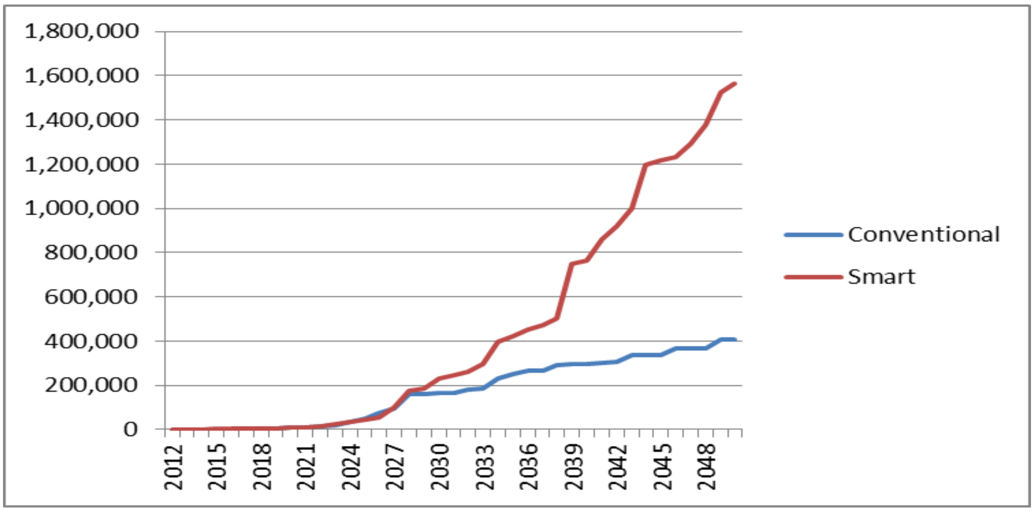


Figure 5 Cumulative Deployment of Smart and Conventional solutions to 2050 (high electrification of heat and transport, Scenario 3 with Tipping Point treatment to cost curves)

We will look at the impact of Tipping Points on the model in more detail in section 4 and we will see in section 4.3, this change in year of dominance of smart solutions is driven by a large number of solutions and enablers reaching their thresholds in 2025 to 2027 and therefore driving down the costs of these technologies.

3.3 Sensitivities of individual smart solutions

We noted in section 3.2 that certain smart solutions are frequently selected in the current runs of the model. To identify how sensitive the model is to the acceptability and success of these smart solutions we have run the model with each of these smart solutions individually “turned off”. To achieve this, the availability of each solution in turn is set to 2051 in the model. We have done this individually for each of:

- Permanent Meshing Solutions
- Permanent and Temporary Meshing
- Generator Led response
- DSR

Giving the following outputs:

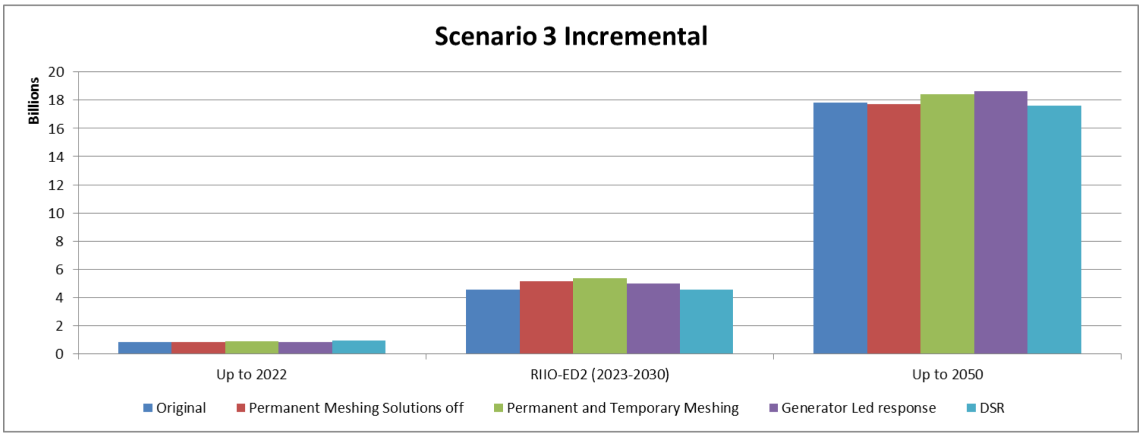


Figure 6 Effect of disabling individual smart solutions on Totex in scenario 3 incremental

This shows that the model outputs to 2050 for the smart incremental strategy are highly consistent and are not strongly dependent on one particular smart solution. In the shorter term, there is very little difference in spend in ED1 (2015-2022) but in ED2 (2023-2030) the extra spend is considerably higher and is highest when meshing is not allowed, (£5.3billion versus £4.6billion).

Where all meshing is not allowed and where generator led response is not allowed there is an overall increase in spend to 2050 of 3% and 4% respectively. Whereas where permanent meshing is not allowed and where DSR residential is not allowed there is actually a decrease in spend of 0.5% and 1% respectively. This decrease in spend is due to the timeframe selected for looking for optimum solutions. In the vanilla model we use a timeframe of 5 years and thus the model selects the optimum solutions for the next 5 years. This can be more expensive than the optimum investment to 2050. To sense check this analysis we can look at the same analysis in Scenario 4 (credit purchase) where lower numbers of electric vehicles and heat pumps are on the grid and hence there is a much lower rate of increase in electricity demand. In this scenario we see:

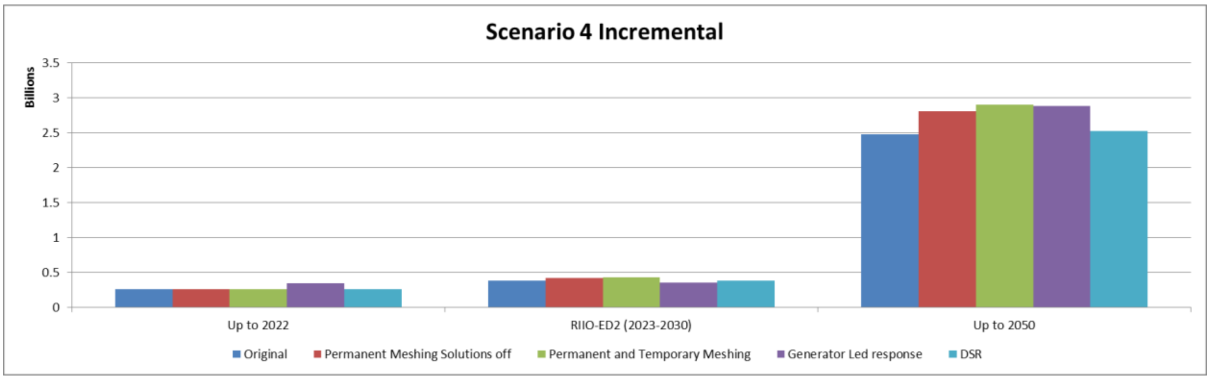


Figure 7 Effect of disabling individual smart solutions on Totex in scenario 4 incremental

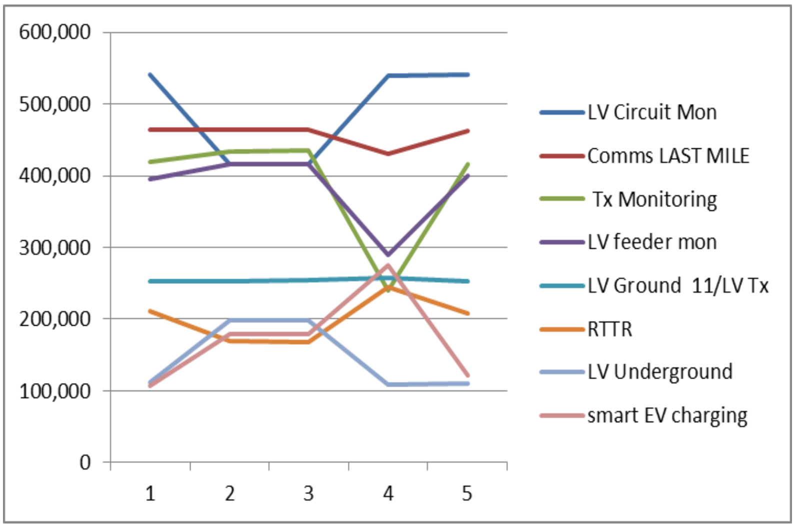
In this scenario we see that the lowest cost (just) is achieved with all smart solutions available. It is clear that the modelling results are relatively insensitive to the performance of individual smart solutions and as such the model provides a good guide to the overall cost of a “smart incremental” strategy and should therefore not be interpreted as providing a definitive menu for individual smart technology “winners”. In the table below we detail the impact on deployment of solutions of turning off individual smart solutions:

Table 3 Solutions and enablers deployed after turning off individual solutions

Solution/Enabler	Number Deployed				
	Original	No Permanent Meshing	No Meshing	No Generator Led response	No DSR
Generator Providing Network Support - LV	598,573	736,364	735,079	0	560,468
LV Circuit Monitoring (along feeder)	541,282	416,264	416,264	539,352	541,156
Communications to and from devices - LAST MILE	463,580	464,408	464,090	430,467	462,956
HV/LV Tx Monitoring	419,110	433,853	434,646	239,192	416,243
LV feeder monitoring at distribution substation	395,700	416,264	416,264	289,653	399,658
LV Ground mounted 11/LV Tx	253,174	253,174	254,621	257,407	253,174
Permanent Meshing of Networks - LV Urban	211,875	0	0	215,895	211,875
RTTR for HV/LV transformers	211,798	168,943	167,336	244,635	207,697
DSR - DNO to residential	151,553	308,012	308,012	209,591	0
Permanent Meshing of Networks - LV Sub-Urban	118,992	0	0	103,646	117,497
LV Underground network Split feeder	111,835	197,742	197,742	107,900	110,562
Local smart EV charging infrastructure	107,774	178,420	178,420	274,392	121,865

From the table above we can see that as expected, when certain solutions are turned off there are big rises in other solutions, for example when meshing is not allowed there is a big rise in DSR. In some circumstances, some solutions reduce. So we see that RTTR actually reduces when meshing is turned off. This is because the model chooses the optimum combination of solutions and in this case with no meshing, RTTR becomes a little less favoured as RTTR is often associated with meshing as a solution in the model.

Looking at these five different study cases we can see that some solutions and enablers remain constant over the five study cases shown, whilst others vary. The biggest change is made in option 4 (no generator side response) since this has an impact on a range of other technologies as shown below in the chart of numbers of deployments in each solution set:



Solution Sets Used:

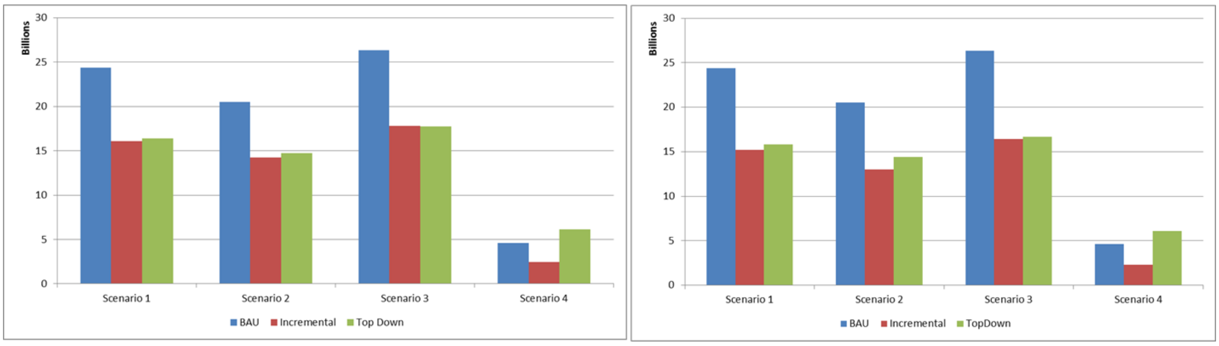
1. All solutions
2. No permanent meshing
3. No meshing
4. No generator led response
5. No DSR (Residential)

Figure 8 Number of deployments of key solutions across different study cases

4 The Model with Tipping Point Analysis

We now rerun the model using the Tipping Point analysis methodology provided by Grid Scientific. There remains more work to be done for cost curve analysis and to identify exact cost curve behaviour, to identify threshold values for each enabler and solutions, and to analyse further the business impact of a Tipping Point being reached,. It is hoped to gain more information on these through the next Governance period with input from BEAMA, DNOs and as field trial findings become known (eg from projects in Ofgem's Low Carbon Networks (LCN) Fund).

In the interim, we take the simplified approach that after its Tipping Point each solution moves to a "lower" cost curve, recognising the scale benefits that will be available from volume deployment. Thus cost curve 1 solutions move to cost curve 2 etc. Cost curve 5 solutions receive a one off reduction of 10%. Threshold values are maintained at the same values as used in WS3-Phase 2. This gives the following results (shown compared to without Tipping Points):



Without Tipping Points With Tipping Points

Figure 9 PV of Totex to 2050 of all scenarios with and without Tipping Point cost curves

This shows that a substantial further reduction in Totex spend is achieved by adding in the Tipping Point impact on cost curves. In scenario 3 this reduction takes Totex from around £17billion to around £16billion. We still observe no relative reduction in the costs of following a full Top Down strategy in any of the scenarios versus smart incremental.

4.1 Developing a "Selective Top Down" Strategy

The analysis to date has identified few savings for following a full top down versus a smart incremental strategy. This has led us to consider a new strategy, which we refer to as "Selective Top Down".

In this selective top down strategy, initial investment is made in only selected enablers, all other enablers are implemented in a smart incremental manner. Here we have considered three options based on combinations of the most commonly selected enablers, and solutions:

1. **All LV monitoring enablers** – the most commonly selected enablers
2. **All monitoring enablers** – a variant on 1
3. **All Comms and DSR Products** – these are associated with the most commonly selected solutions

From the analysis in Scenario 3 (high electrification of heat and transport) we can see that the best "Selective Top Down" strategy is the one where only the enablers required for the top solutions are deployed. This suggests a significant saving is achievable by investing in a selected number of smart enablers.

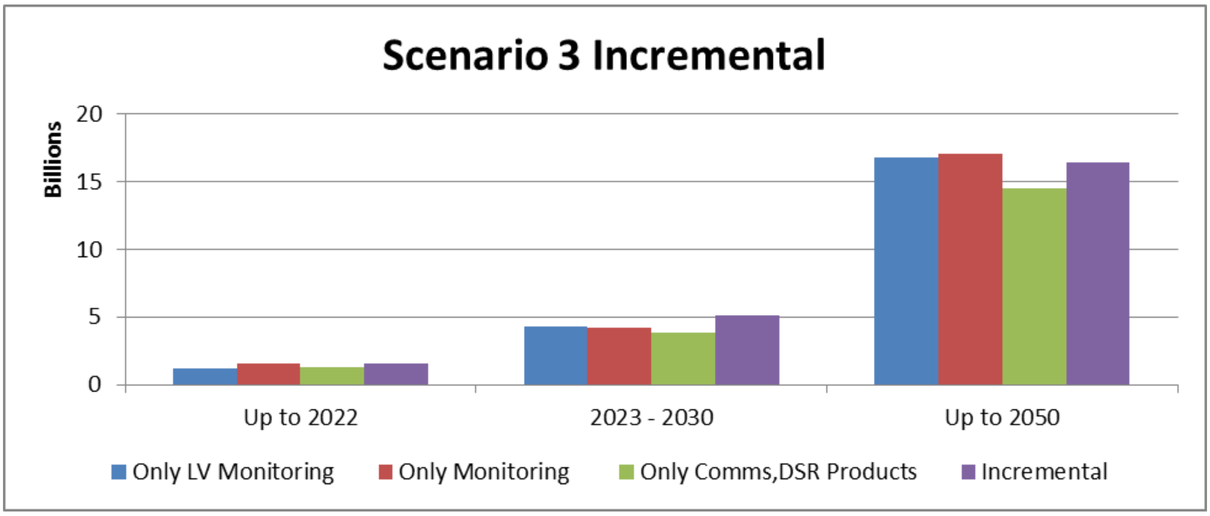


Figure 10 Overview of the three "Selective Top Down" investment strategies versus the original smart incremental strategy (as a comparison)

The chart above shows spend in ED1 (up to 2022), spend in ED2 (2023-2030) and total spend to 2050 for the three "selective top down" strategies investigated. In all three time periods, the most cost effective is the green "Only Comms, DSR Products" enabler strategy. In this strategy only comms and DSR enablers are purchased in a top down manner and all other enablers are purchased in a smart incremental manner – i.e as and when required.

4.2 Identifying the optimum years for Enabler investments

We have seen that the “Selective Top Down” Investment strategy can offer significant benefits over the Smart Incremental strategy and we now look at identifying the best timing for making this investment. We have assumed that a Selective Top Down strategy would take two years to roll out and, cognisant of the RIIO framework, we have looked at following the “Selective Top Down” Investment strategy in three different timeframes:

- 2019-2020 (Mid RIIO-ED1)
- 2020-2021 (Late RIIO-ED1)
- 2023-2024 (Early RIIO-ED2)

Following these investment timeframes gives the following outputs:

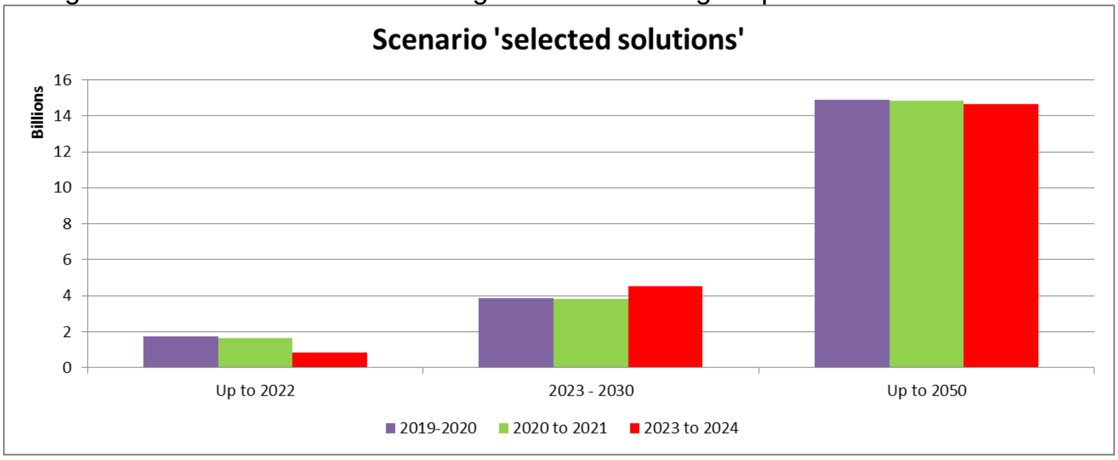


Figure 11 Comparison of Selective Top Down strategy investment in ED1 or early ED2

The graph above shows the total investment required for the three cases, where strategic top down investment is made in the selected enablers either in 2019-2020, 2020-2021 or 2023-2024. This shows only a small variation in total spend to 2050 with the overall most cost effective solution being to defer the strategic investment until the start of ED2 i.e in 2023 to 2024 (£14.6billion vs. £14.8billion).

Given the greater level of knowledge which will be available on both the performance of smart solutions and the market penetration of LCTs, the optimum strategy therefore appears to be to follow a smart incremental strategy in ED1 followed by a “Selective Top Down” strategy in ED2.

In addition it may be noted that in Scenarios 2 and 3 the saving made is smaller and in Scenario 4 (credit purchase), it is actually more costly to follow this strategy. It therefore appears most sensible to follow a smart incremental strategy through ED1 and assess this strategy either at a mid-point review of ED1 or in the RIIO-ED2 submissions when it can be expected that the level of knowledge of smart solutions and LCT penetration will be much clearer.

4.3 Summary of the impact of the investment strategies

During this analysis we have seen that the initial three strategies (BAU, Smart Incremental and Top Down) can usefully be supplemented with a further possible investment strategy, namely “Selective Top Down”. Further we have seen that this strategy is predicted to be most cost effective if implemented in early ED2. To summarise, it can be concluded that the optimum investment strategy is to follow a smart incremental strategy up to the end of ED1, then at the start of ED2 all Comms and DSR enablers are implemented in a strategic top down manner, all other enablers being purchased in a smart incremental manner. The chart below compares the outcome of these strategies for all four investment strategies.

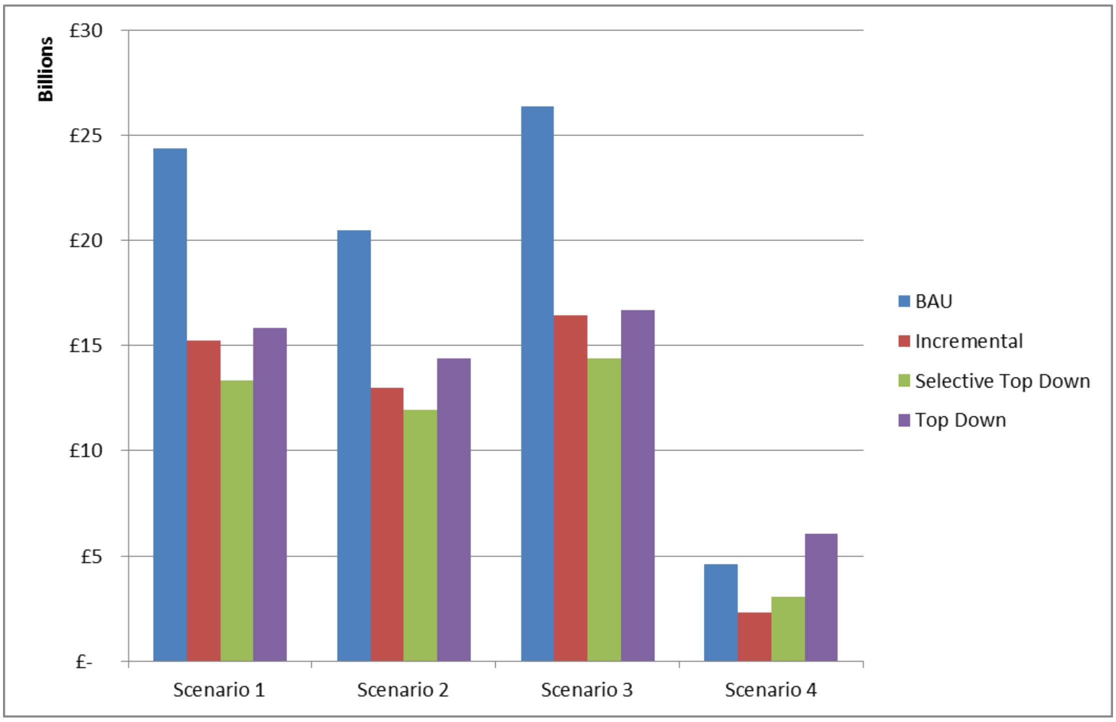


Figure 12 PV of Totex to 2050 of all scenarios by the four investment strategies

We now see that there are significant savings in scenarios 1-3 for following the selective top down strategy in early ED2. It is interesting to note that there are no savings in scenario 4 (credit purchase) where the proliferation of LCTs is low.

4.4 Major ED1 and ED2 Investments

It is informative to examine the individual smart solutions employed and their timescale for deployment. The Transform model now generates a Tipping Point report which, for scenario 3, gives the outputs shown below for the ED1 and ED2 periods. The trigger and tipping points are colour coded dependent on their likely impact on DNO business systems and processes, where 5 is the biggest impact. The business impact at the Tipping Point is defined as follows:

5: Very High - the solution will impact on processes and systems within the business, requiring substantial intervention, including management involvement

4: High - the solution will have impact that will require significant intervention, including management involvement

3: Medium - the solution will have impact that can be readily managed

2: Low - the process for introducing solution change at the tipping point will have some impact on the processes and systems within the business

1: Very Low - the process for introducing solution change at the tipping point will have limited impact on the processes and systems within the business

Note that the above is a measure of the impact of the solution on the processes and systems in a DNO's business, not a measure of the impact of the solution on solving network issues. A solution with low business impact can give a high value return (and vice versa).

The 'Tip' indicated below is the year when the solution (or enabler) reaches the assigned cumulative cost tipping point threshold, and the 'Trigger' indicates the number of years in advance of the tipping point that it is considered the DNO will need to start preparing its systems, processes and staff for the tipping point occurrence so that scale benefits can be secured and holistic systems integration achieved. If the Tipping Point for a solution is not addressed there is a highly adverse risk that solutions will be deployed in an ad hoc manner, without gaining the significant benefits of standardisation and thought-through integration with company business systems. Benefits of addressing the Tipping Point (described as creating an Integrating Framework) will be evident in areas such as: procurement, stores holdings, skills and training, international standards alignment and open systems, future-proofing, and data management that brings benefit to the business and its customers most widely.

The formats shown in the following two tables are now included as a report in the Transform model.

Table 4 Smart solutions deployed in ED1

Solution Name	2015	2016	2017	2018	2019	2020	2021	2022
Permanent Meshing - LV Urban		Trigger	----	Tip				
Permanent Meshing - LV Sub-Urban				Trigger	----	Tip		
RTTR for HV/LV transformers								Trigger
Switched capacitors – LV		Trigger	Tip					
Communications - LAST MILE ONLY	Trigger	----	Tip					
DSR - Products remotely control loads					Trigger	----	----	Tip

It can be observed that five smart solutions reach their tipping point during ED1; and six trigger points are identified including one for a smart solution that tips in ED2. There are no high business-impact solutions (red) reaching their tipping point during ED1 but two are moderately high impact (yellow). This indicates a reasonably material set of new challenges for DNO's to address in ED1. This is further addressed in the analysis below.

Table 5 Smart solutions deployed in ED2

Solution Name	2023	2024	2025	2026	2027	2028	2029	2030
DSR - DNO to residential					Trigger	----	----	Tip
Generator Network Support - HV					Trigger	----	Tip	
Generator Network Support - LV	Trigger	----	Tip					
RTTR for EHV/HV transformers					Trigger	----	Tip	
RTTR for HV Overhead Lines	Trigger	----	Tip					
RTTR for HV Underground Cables					Trigger	----	Tip	
RTTR for HV/LV transformers	----	Tip						
Temporary Meshing - HV	Trigger	----	Tip					
Advanced control systems - HV	Trigger	----	Tip					
EHV Circuit Monitoring		Trigger	----	Tip				
HV/LV Tx Monitoring			Trigger	----	Tip			
LV Circuit Monitoring (along feeder)	Trigger	----	Tip					
RMUs Fitted with Actuators	Trigger	----	Tip					
Dynamic Network Protection 11kV	----	Tip						

It can be observed that in ED2 fourteen solutions reach their tipping points and there is a range of business challenges represented here including one 'red' and six 'yellow' categories. This indicates a potentially highly challenging context in ED2. Further insight can be gained if we also examine the projected capex outlay by regulatory period and the year of first deployment for each of these solutions. Note that comparing the first year of deployment and the tipping point year provides an indication of the rate of take-up for each solution. Note also the co-incident years of first deployment, indicating the potential for high workload peaks in ED1. See the table below:

Table 6 Capex and first deployment for smart solutions in ED1 and ED2

Smart Solution	Year First Deployed	Tipping Point Year	Ramping Period	Capex ED1 £M	Capex ED2 £M
Communications - LAST MILE ONLY	2013	2017	4	17	135
Switched capacitors - LV	2015	2017	2	34	0
LV Circuit Monitoring (along feeder)	2015	2025	10	8	82
Generator Network Support - LV	2017	2025	8	2	129
HV/LV Tx Monitoring	2017	2027	10	1	32
Permanent Meshing - LV Urban	2018	2018	0	38	99
RTTR for HV Overhead Lines	2019	2025	6	3.4	61
EHV Circuit Monitoring	2019	2026	7	1.6	27.5
Permanent Meshing - LV Sub-Urban	2020	2020	0	69	750
RTTR for HV/LV transformers	2022	2024	2	2.5	87
DSR - Products remotely control loads	2022	2022	0	33	202
DSR - DNO to residential	2022	2030	8	2	17
Generator Network Support - HV	2022	2029	7	1.4	29
Temporary Meshing - HV	2022	2025	3	4	42
Advanced control systems - HV	2022	2025	3	1	12.5
RMUs Fitted with Actuators	2022	2025	3	2	21
Dynamic Network Protection 11kV	2022	2024	2	3	31
RTTR for EHV/HV transformers	2027	2029	2	0	61
RTTR for HV Underground Cables	2029	2029	0	0	14

It is important to note that almost all the smart solutions deployed in ED1 and ED2 are shown to have their first deployment during ED1. This suggests that ED1 will be a period of significant learning for the DNOs for deployment of new smart technologies. Also, a very large number are projected to be deployed in 2022 which may be too late for learning from operational experience to be capture in ED2 business plan submissions.

It should be further noted that some technologies reach their tipping point very quickly following deployment (and in some cases in their first year of deployment) whilst others take many years to reach their tipping points. This is shown in the table as the ramping period. Understanding the speed of this cumulative deployment may help the DNOs further develop their plans for handling the build up of resources and manpower for deploying these technologies.

Finally it is clear that there are some ambitious assumptions surrounding these technologies and the figure for investment in permanent meshing in ED2 is particularly challenging. It was demonstrated in section 3.3 that the projections for spend are not dependent on individual technologies and the list above should be treated as an indication of possible solutions to consider rather than as a prescribed menu of solutions.

4.5 Cost implications for ED1 and beyond

The chart below shows the non-discounted cumulative Totex spend in each ED period looked at firstly in the boundary conditions, that is to say highest electrification (Scenario 3) together with the least attractive spending strategy (BAU) versus lowest electrification (scenario 4) with best spending strategy (smart incremental for scenario 4).

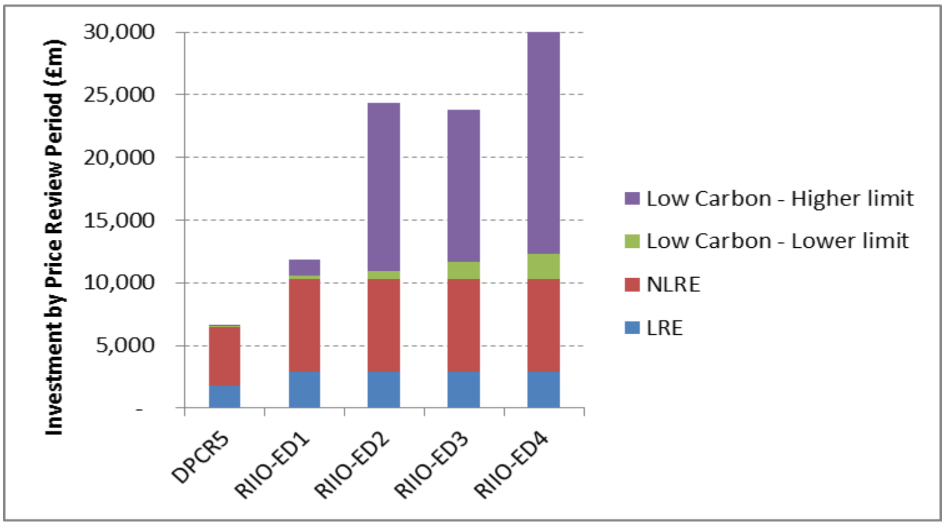


Figure 13 Non discounted cumulative Totex for the best and least attractive spend strategies for the next four RIIO periods[4]

This shows a very significant range in possible spend profiles for ED2. It is perhaps unrealistic to compare these two extremes, so below we look at the same chart but compare

4 **Load related expenditure** (LRE) – investment driven by changes in demand, i.e. that in response to new loads or generation being connected to parts of the network (connections expenditure) and investment associated with general reinforcement. LRE was £1.8bn in DPCR5. **Non-load related expenditure** (NLRE) – other network investment that is disassociated with load. The dominant area of investment in this category is asset replacement (76% of the NLRE for DPCR5). NLRE was £4.6bn for DPCR5. **LRE and NLRE** have been simply scaled by 8yrs/5yrs to correlate to the longer Price Control Periods for RIIO in this illustration.

the best spending strategy in the highest and lowest electrification scenarios. So we compare Scenario 3 Selective Top Down to Scenario 4 smart incremental:

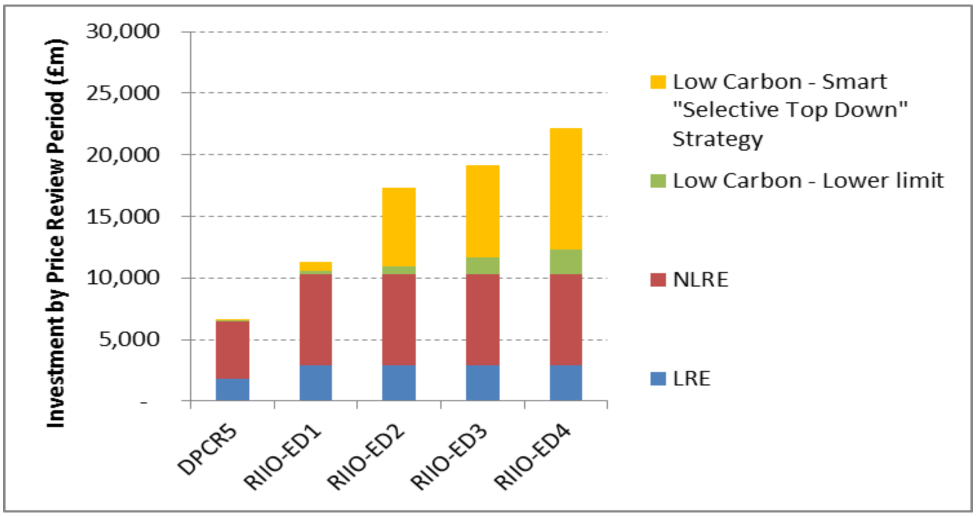


Figure 14 Non discounted cumulative Totex for best possible spend (using the two most extreme scenarios)

We still see a very large differential in spend in ED2 and beyond. This provides some insight to the range in possible investment required dependent upon the uptake rate of LCT's. This demonstrates the level of uncertainty that must be addressed and the sensitivity to the current level of understanding of future use of LCTs.

4.6 Comparison to WS3-Phase 1

In the first phase of WS3, the report "Developing Networks for Low Carbon" was released (October 2011). This identified a number of potential investments "ahead of need" and it is interesting to look at whether the current analysis provides support for these. The table below is from p 61 of the above report:

	Initial Thoughts – Strategic Investment Ahead of Need
1.	Discontinue LV tapering; note that loss-savings can be expected; however, new network infrastructure may be provided in a competitive environment, so additional costs would probably have to be socialised through DUoS (not paid for by a developer)
2.	Make provision for rich communications links (e.g. optic fibre)
3.	Revise LV planning methodologies including ADMD assumptions, especially in the interim period towards 2020 while smart meter data is incomplete; consider the planning assumptions now needed for DG and voltage rise; consider the fundamental change of demand profiles arising from HP and EV loads
4.	Enlarge the layout/footprint of LV substations for additional equipment, including storage, intelligent controls, provision for sensors; however, note here the pressure for minimum footprints (and the fact that new substation provision for new developments is subject to competition)
5.	Reconsider pole-mounted substations and their adaptation for smart facilities (e.g. land space at the foot of pole mounted substations)
6.	Reconsider the specification of package substations
7.	Full review of P2/6 methodology including intentional islanding (off-grid operation) and system operating standards
8.	Revise network design policies including P2/6 (incorporate DR, DG, Storage, and Resilience)
9.	Note the importance here of resolving standardisation issues (see the proposed next steps action)
10.	Commence review and development of the architecture evolution for network company Intelligent and Dynamic System Platforms to ensure that they enable the future applications of Smart Grid 1.0 and Smart Grid 2.0 (see next steps action)

Figure 15 Initial Strategic Investments proposed in the Phase 1 report

Overall, the model outputs give good support for the early actions identified in phase 1, although much of this work will be preparatory for a larger effort in ED2 dependent on proliferation of LCTs meeting the data suggested in DECC Scenarios 1-3, rather than the lower numbers in Scenario 4.

Specifically the recent analysis gives support to most of the issues raised in points 1-4 and 6-8 of the table. However it is important to emphasise that, for instance, the current lack of support for electricity storage in the Transform™ outputs does not mean that this is a poor technology and research should stop. It simply reflects that, using the cost assumptions in our model, more work needs to be done to make this technology cost competitive.

5 Conclusions

This report has reviewed the impact of the changes made to the GB Transform™ model during the period September 2012 to March 2013.

These changes have resulted in the following outputs from the model:

- The analysis continues to show a strong cost benefit in adopting a smart investment strategy over a purely conventional investment strategy for all the DECC scenarios considered to 2050; this benefit is of the order of 25-30% of total investment costs to 2050;
- The conclusions are not sensitive to the availability of any one individual smart solution; the model continues to show that a mix of smart and conventional solutions is likely to provide the optimum investment strategy for GB;
- The model can therefore be expected to provide helpful guidance for the estimated investment trajectory whilst not being prescriptive of specific smart solutions;
- Turning off the most highly selected smart solutions in the model only increases spend by 2% to 2050;
- The model now includes Tipping Point analysis that provides early warning to DNOs for the anticipated preparation timescales and the severity of likely business impacts of specific smart solutions on a distribution company's processes and systems;
- Incorporating the impact of Tipping Points on smart solutions, where the increasing scale of deployment offers the opportunity for procurement efficiencies, gives a further predicted investment benefit of around £1billion in Totex to 2050;
- An important conclusion from the revised model, that now includes closer analysis of enabler costs, is that a "Full" top down investment strategy no longer shows a financial benefit over an incremental investment strategy;
- However, further investment benefits can be obtained through implementing a "Selective" Top Down strategy where only the enablers required for the top-ranked solutions are deployed; this results in a benefit of up to £2billion in Scenario 3 (high electrification of heat and transport) compared to a smart incremental strategy;
- These benefits are not realised in Scenario 4 (where credit purchase is used to achieve de-carbonisation);
- Modelling of the Selective Top Down strategy suggests that the optimum timing for this will be early in ED2. Added to the fact that Selective Top Down introduces additional cost in scenario 4, it would appear sensible to wait until ED2 or the mid ED1 review point before committing to this strategy.

In summary, the key messages from this work are as follows:

1. The Transform model has been significantly enhanced, in regard to both its analysis capabilities and the presentation of results to assist user interpretation;
2. A material cost-benefit continues to be indicated by adopting innovative 'smart' technologies in conjunction with traditional network investment;

3. While confirming the economic advantages of adopting smart solutions, the model is demonstrated to be broadly insensitive to specific solutions, which reinforces the message that it should not be used as a detailed ‘solution picker’, rather it should be used to inform strategic investment decisions;

4. A ‘Full’ Top Down strategy is no longer indicated as being beneficial now that the costs of enablers are better modelled, but the alternative ‘Selective’ Top Down strategy is shown to be beneficial; commencing this strategy in ED2 appears to provide the best investment option at this stage; and

5. The deployment of innovative solutions in ED1, while of significantly lower scale than that forecast for ED2, is nevertheless expected to create material challenges for the DNOs; this report identifies the likely solutions appearing in ED1, their deployment numbers, which of these reach their Tipping Points, and the Tipping Points anticipated for ED2 that are likely to need preparatory action to be taken in ED1.

6 Annex 1: Review of Enablers, Solutions and Top-Down Modelling in TRANSFORM

Lead Organisation: Smarter Grid Solutions

Report Number: 200109-05C

Date: 13th February 2013

Issue: Version C (Final Issue)

7 Annex 2: Review of Enabler Mapping

Lead Organisation: EA Technology

Report Number: 84170_3.4

Date: 11th March 2013

Issue: Final 1.0

8 Annex 3: Tipping Point Analysis Report

Lead Organisation: Grid Scientific

Report Number: GSWS3.3DOC06

Date: 13th February 2013

Issue: 1.0 Issue

9 Annex 4: Review of Tipping Point Analysis

Lead Organisation: EA Technology

Report Number: 84170_3.5

Date: 11th March 2013

Issue: Final 1.0

10 Annex 5: Governance Period 1 Review Documentation

Lead Organisation: EA Technology

Report Number: 84170_1

Date: 11th March 2013

Issue: Final 1.0

11 Annex 6: Development of a licence area level feeder model

Lead Organisation(s): EA Technology / Element Energy

Report Number: 84170_2

Date: November 2012

NB. This report also includes a 5 page Addendum “Modifications to the WS3 Phase 2 methodology and assumptions”, issued December 2012

12 Annex 7: Brief Summary of all other Changes made to the Model

This document captures the changes that have been made to Transform™ since the Phase 2 release in July 2012. In all cases the scale of the change has been recorded by showing whether it increases the costs predicted by the model (represented by one, two or three ↑ depending on the magnitude of the increase), decreases the costs (again shown by one, two or three ↓ depending on scale of change) or if it makes no change to the model output costs (▬).

The changes to the model are grouped in the following three sections:

1. Changes made under 'Phase 3' activity (tasks 3.2, 3.4 and 3.5)
2. Changes made under governance (task 3.1)
3. Changes made to fix elements of the model that were found to contain bugs

The following tables summarise these changes.

Table 7 Changes made under tasks 3.2, 3.4 and 3.5

Change	Effect
Solution costs refined through Task 3.4 (Opex and Capex)	↑↑↑
Optimism bias revised down	↓
Apportionment of conventional solutions across feeders revised (e.g. pole mounted transformers)	↑
Solution/Enabler Mapping enhanced	↑
Tipping points now available for enablers as well as solutions	▬
Tipping points now allow solutions to be moved to 2 different cost curves and be subjected to 2 different multipliers.	▬
A summarising tipping point report is integrated into the model	▬
Feeder loads have been regionalised into the fourteen licence areas	▬
Spreadsheet created for generating regionalised scenarios automatically from revised scenario data	▬
Average GB feeder loads very slightly adjusted as a result of detailed analysis while conducting regionalisation	↔
Added capability to make strategic investments effectively removing certain enablers and directly injecting cost to the model.	▬
Added capability to set time at which enablers start/stop being charged for.	▬
Increased substation intervention threshold in GB model for HV4 to 75% in line with slightly increased loads from re-regionalising data	↓
Adjusted structure for generating top down costs	▬
Adjusted the mechanism used to calculate the required deployment of enabling technologies for a top down strategy and simultaneously refined the costs of using a top down strategy	↑↑

Table 8 Changes made under governance

Change	Effect
Addition of LV generation other than PV at LV	—
Different DG/PV /PiV(low) dataset	↑
Explicit handling of Wind at HV/EHV	—
Different energy efficiency scenarios availible through drop down menu	—

Table 9 Changes made to resolve bug fixes

Change	Effect
Housing profiles now contain correct amount of electric heating	↑
Function to enter different DSR uptake scenarios to local Network Model added	—
Removed anomalous multiplier for transformer costs	↓
Energy efficiency applied to wet appliances	↓
Enablers now applied correctly in all instances	↓
Opex optimism bias no longer hard coded	—
Opex optimism bias no longer compounded with capex optimism bias for merit order purposes	—
Credit Purchase scenario adjusted such that it is now composed correctly of all low scenarios	↓↓↓
Automatic carry through of adjusted discount rate	—
Correction of GB model bug causing apparent changes in investment within same scenario	—

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