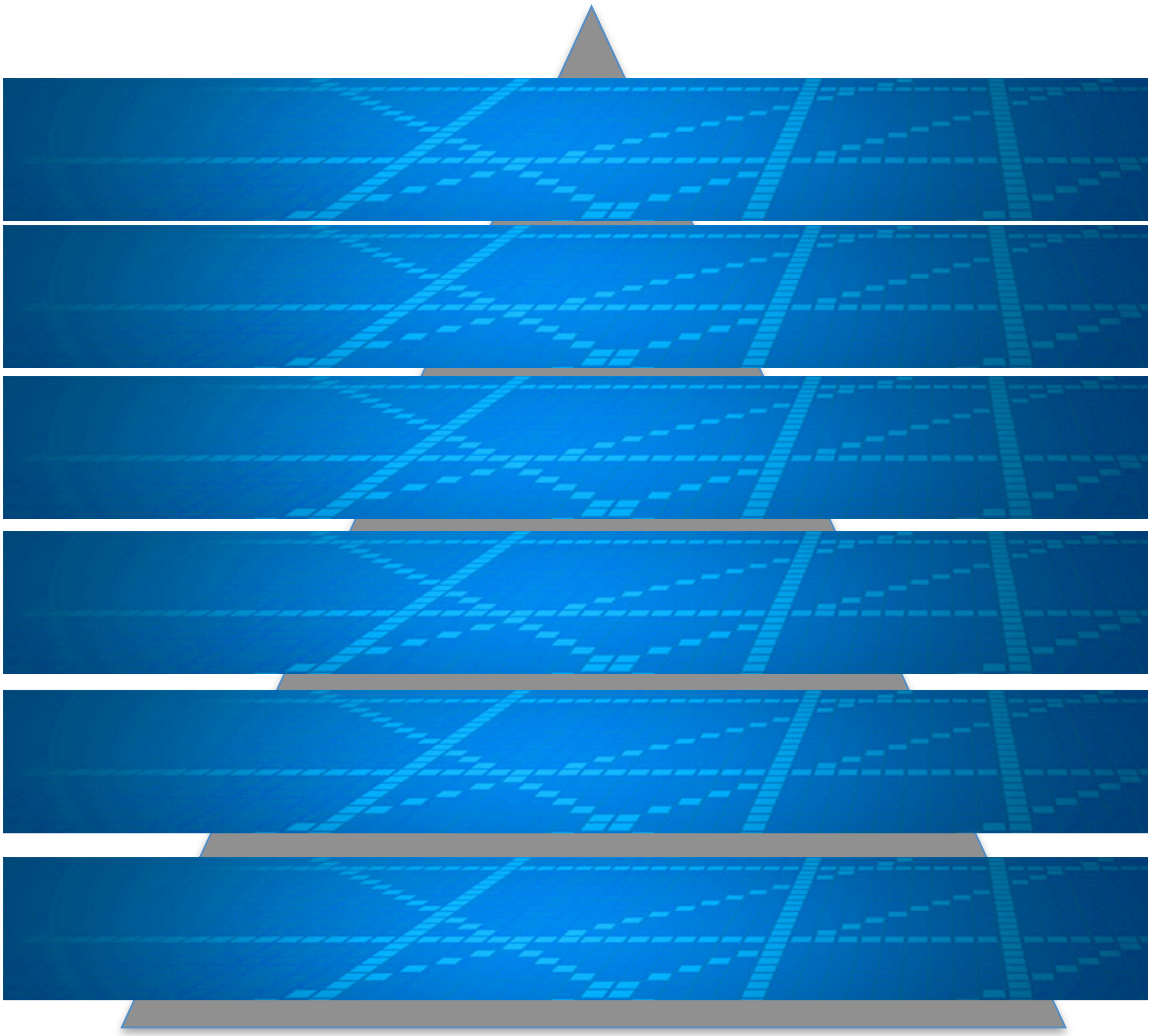
DECC / Ofgem Smart Grid Forum Workstream 3

Developing Networks for Low Carbon

The Building Blocks for Britain's Smart Grids

ISSUE 1



Prepared by the Energy Networks Association in conjunction
with members of the DECC/Ofgem Smart Grid Forum and wider industry specialists

Sponsor, Smart Grid Forum Workstream 3

CEO Electricity North West Ltd

Preface

I am delighted to introduce this report, both to encourage your readership and to invite your participation in the work that it outlines.

We have consulted widely in developing the ideas set out here, taking views not only from Workstream 3 stakeholder representatives, but also the GB network companies more widely, and those with expert knowledge in industry and academia.

The purpose of this document is to inform, to provide a high level analysis, to raise awareness of the challenges ahead, and to inspire a shared vision that results in practical implementation plans.

This report is a first deliverable from the Smart Grid Forum and is one contribution to the wider work plan; it is intended to promote further thinking in the stakeholder community, inform other Workstreams and provide the basis for further analysis by Workstream 3.

This report has a clear methodology, set out in the opening chapters, that evaluates the scenarios for change developed by government and others, assesses their impact for power networks, and proposes responses that utilise innovative techniques where that is advantageous. We have been mindful that this report should, in addition, help inform the regulatory ED1 business planning activities that will commence shortly.

The developments set out here are ambitious and extend far beyond the engineering and commercial frameworks with which we are familiar today. The scale is significant, but we believe entirely credible to deliver, and there will be creative opportunities for business, for jobs, and for national and regional economies.

I trust that you will find the report a ‘good read’ as well as being informative and setting a course for the future.

Revision History

Issue	Date	Description	Authors	Approved
1	07/10/2011	Issue 1, as submitted to the Smart Grid Forum	Jeff Douglas John Scott	W/S3 members

Membership of the Workstream 3 project group:	
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This report has been prepared by Workstream 3 of the DECC/Ofgem Smart Grid Forum. For more information about the Forum see: www.ofgem.gov.uk/Networks/SGF/Pages/SGF.aspx

Workstream 3 members are pleased to acknowledge the comments and insights from many industry parties that were received during development of this report.

Any reader wishing to offer views or seek clarifications is, in the first instance, invited to contact the Workstream 3 Technical Secretary: Mike.Kay@enwl.co.uk

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Figure References

I Executive Summary

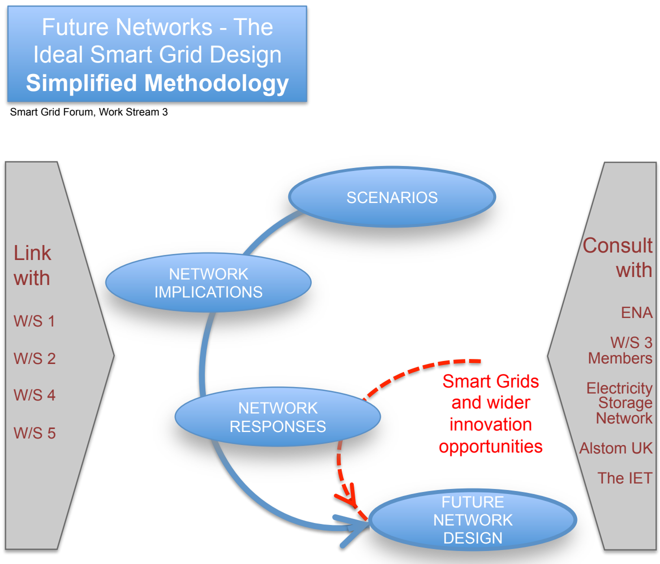
Developing Networks for Low Carbon

Electrical power networks will be a key enabler for securing future energy delivery and the achievement of the UK's low carbon objectives. The needs of tomorrow's customers will be very different from today's requirements, and power generation will also change to include more intermittent and local generation sources. Electricity usage in an efficient energy system in 2030 will therefore have very different characteristics to that which is familiar now.

This report, translates the impact of UK's future energy scenarios into key strategic directions for network development, identifying the needs for network expansion and the opportunities for smart grid techniques to drive cost-efficiency and deliver new services. It considers the enablers for change, including the necessary development of commercial and regulatory frameworks. It focuses on 2020 and 2030, and casts a forward look towards 2050 to consider the enablers for change, including the necessary development of commercial and regulatory frameworks.

In addition, the report is structured to deliver key messages that will support Ofgem, DECC and the network companies in the first stage of the ED1 regulatory business plan preparation for the period 2015-2023. The conclusions are entirely consistent with the stated objectives of the Electricity Market Reform activity.

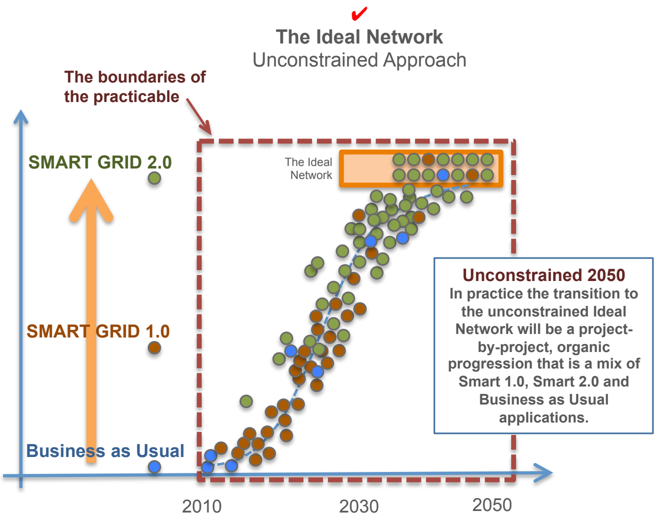
The methodology used for the analysis identifies the implications for networks of the national low carbon scenarios and develops responses that include a range of smart grid techniques. This wide range of innovative options has been consolidated into a smaller number of 'Solution Sets'. These summarise the building blocks that can be used to augment network investment.



Insights have been provided by a range of contributors that include the energy storage community, technology specialists, suppliers and academia, along with the companies responsible for the distribution and transmission networks.

This has ensured that an appropriate level of technology development and ambition is embedded in the strategy. Customer requirements, affordability and the extent of consumer engagement are key factors that have been incorporated.

The report concludes that future network architectures are likely to develop in stages with a first phase, termed Smart Grid 1.0, using largely established innovation techniques in an increasing number of projects. In the longer term a Smart Grid 2.0 stage will incorporate more ambitious innovation and the scale of deployment will become more extensive, progressively and systematically populating the network in response to local needs. A periodic review process is recommended to reaffirm the energy scenario contexts, to ensure a Systems Engineering approach, and maintain ambitions for the ultimate pathway to a cost-effective and secure low-carbon future.



There is inevitable uncertainty around the extent and timing of the increase in electricity usage, and also the characteristics of demand and generation requirements. Hence future network development needs to embrace this uncertainty within the technical, commercial and process characteristics. A set of key structural principles is proposed to support solutions that are flexible and scalable, that utilise Functional designs and open-system architectures, and also address the rising data volumes and associated complexity.

The Phase 1 analysis reported here is part of the Smart Grid Forum's work programme; it has identified a number of network company actions, or next steps most effectively pursued by network company representatives, along with an agenda for consideration by third parties. The implementation of action points will need to be set in the context of the Forum's wider agenda.

It is envisaged that a Phase 2 project will address quantitative modelling of the network developments including, for example, the likely costs of the Solution Set options and the consequences of clustering effects. This will be founded on the agreed energy scenarios and shared assumptions being developed by the Smart Grid Forum's Workstream 1, and is also closely associated with the Workstream 2 development of a cost benefit assessment for the UK smart grid. Pointers towards Phase 2 are provided in an Appendix.

In summary:

- The potential impact of future GB energy scenarios on power networks is material.
- The challenge ahead is technically demanding and of a scale not seen in 50 years
- Innovative products and architectures (smart grids) offer cost-effective solutions
- Innovation will need to be adopted in conjunction with traditional network investment
- Technology alone will not deliver the required outcomes: Commercial and Regulatory frameworks, and consumer engagement will be key enablers
- Enabling actions for the short term will accelerate advanced functionality in later years
- Customers can expect attractive new services and products, including helpful energy automation to obtain the best deals and services
- A number of points identified for further action are set out in Chapter 10.

II Methodology

The Report Methodology and Assumptions

The analysis in this report has been based on determining how the operators of Britain's power networks should best respond to the external changes and challenges that they will face in the coming years. The changes are far reaching and, in the main, arise from government policy ambitions for sustainability and a low carbon energy system in Britain.

The network companies do not operate in isolation, so this report looks critically at the operating environment for the companies, including the regulatory and legislative frameworks, and the commercial setting. Furthermore, the companies recognise the importance of understanding the interests and insights of a wide range of stakeholders, including consumers, technology developers, academics, and manufacturers.

Over the last five to ten years there has been increasing international attention directed to the opportunities that innovation offers for electrical power systems. This is commonly referred to as the Smart Grids agenda and is prompted by the significant benefits that could be achieved through developments in fields such as automation, communications, data processing, power electronics, and the application of new techniques and materials including superconductivity and storage.

There is no blueprint for the future networks required to support low carbon objectives. Smart Grids are an emerging philosophy with a new a new architecture, combining traditional and innovative techniques. They bring a new dynamic for their many stakeholders including power users – who in the future will increasingly be owners of generation and probably storage also. This requires the analysis in this report to be ambitious, yet anchored in reality; and purposeful while remaining flexible and responsive. This Phase 1 report stands alone but forms part of wider Smart Grid Forum activities, and has a close relationship with the other Workstreams.

The approach taken has been to apply unconstrained thinking to formulate a vision for future opportunities and put in place a series of building blocks, termed 'Solution Sets', that will enable a pathway to be developed in a systematic way towards the goal – rather than proposing an incremental approach that simply adds to what we have today 'to see where it takes us'.

The Logical Steps and Report Structure

The diagram below expands on the simplified model in the Executive Summary and identifies the numbered stages that have been followed. These correspond to the chapters of this report, so the diagram also offers a navigation guide for readers.

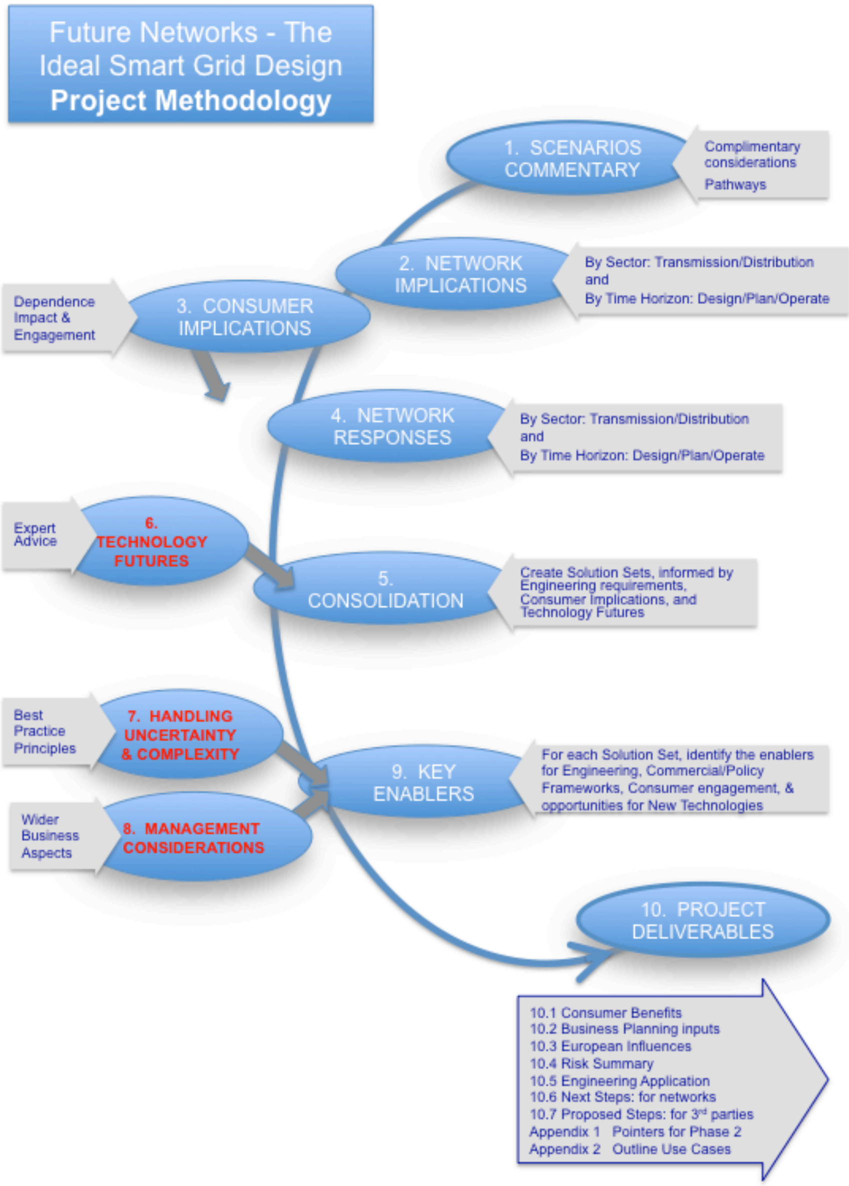


Figure 1: Report Methodology and Navigation Guide

Step 1 - Scenarios
Workstream 1 of the Smart Grids Forum will in due course provide definitive scenario assumptions. When that work is completed the analysis in this report will be recalibrated as necessary.

It is not expected that W/S1's analysis will change the Solutions Sets approach set out here. It will however have significant relevance to the quantification work that is intended to follow this report.

The analysis has been progressed using other published scenario information, the Government's Carbon Pathways, and an analysis by Redpoint Consultants, commissioned by the ENA.

Step 2 – Network Implications
The impact of key elements in the scenarios has been assessed on a broad scale (None /Moderate /Challenging /Significant) for the two sectors of Transmission and Distribution, and for three time horizons within each – Investment Planning, Operational Planning, and Real Time Operation.

Step 3 – Consumer Implications
This report has addressed consumer issues at each step but does not claim to have been exhaustive; there remains important work to take forward in this area. It is evident that the changes ahead will both need to engage the hearts and minds of consumers and the wider public, and can be expected to bring significant consumer benefits.

Step 4 – Network Responses
The opportunities for emerging and future technologies and techniques have been matched to the challenges set out for each network sector and timescale.

Step 5 – Consolidation
It is important to consolidate the multiplicity of technologies and techniques so that a manageable framework is established. Later the report also proposes to further develop terminology and a systematic approach that includes the future taxonomy. The core approach for consolidation has been the identification of 12 Solution Sets, the building blocks for innovative solutions, and these are cast in two timescales for practical achievability – short term (2020) and longer term (2030 and beyond).

Step 6 – Technology Futures
Views have been canvassed widely to capture emerging technology opportunities. This approach cannot of course be exhaustive and there will be opportunities for high value innovation that have not yet been identified. The approach in the report is to establish an open framework for change that will be capable of adaptation and responsive to new opportunities emerging internationally.

In conducting these reviews, a set of graphics developed by The Institution of Engineering and Technology (The IET) was utilised and received considerable acclaim. The IET developed their 'Wider Pictures' to promote a shared understanding of the smart grids agenda between professionals in different sectors. The pictures are provided with The IET's permission in Appendix 3. They can be accessed on the IET website with a video commentary at www.theiet.org/smartgrid-pictures

Step 7 – Uncertainty & Complexity
These characteristics will accompany the power sector as it enters a time of radical change. It will be important that responses and methodologies are 'designed-in' and this report commences the process with a number of generic principles and engineering good practice pointers.

Step 8 – Management Considerations
The network companies will need to respond to a number of issues at a corporate level and these are explored briefly. Issues include: risk profiles, partnering requirements, skills and know-how, and business planning tools and techniques.

Step 9 – Key Enablers
Recognising that the technology alone is neither the sole driver for change, nor able to deliver successful outcomes on a stand alone basis, this step of the analysis examines key enablers for: Technology, Consumers & Third Parties, Legislation & Regulation, and for Technology Development. The last of these includes a number of non-technical areas for Research and Development that have been identified as key for successful technology deployment.

Step 10 – Deliverables
This concluding step in the analysis is reported as a number of sub-sections, as indicated in the diagram. Specific action points have been identified for the network companies and an agenda for consideration is offered to third parties. In addition, it has been the aim of this analysis to provide information that will assist ED1 business planning submissions. The European and wider context is considered, particularly related activities and timing.

Appendices of this report provide inputs for a Cost Benefit quantitative valuation, and outline Use Cases. These are provided as a link to the analysis being undertaken by Workstream 2.

Identifying the Unconstrained Ideal Network

The series of diagrams below explain the approach to formulating the Ideal Network concept – meaning that we have applied an 'unconstrained vision of the future', looking to around 2050 with a pragmatic check. We have sought wide views on new solutions, and not simply incremented 'bottom up' - letting the present network dictate the future.

This is encapsulated in the Smart 1.0 and Smart 2.0 approach. However, we have not been unrealistic, recognising that truly green field opportunities are in the minority, so bold future thinking under Smart 2.0 has been set in the context of a migration path, including the opportunities for justifiable 'forward investment' in the near term to pave the way for creative outcomes in the longer term.

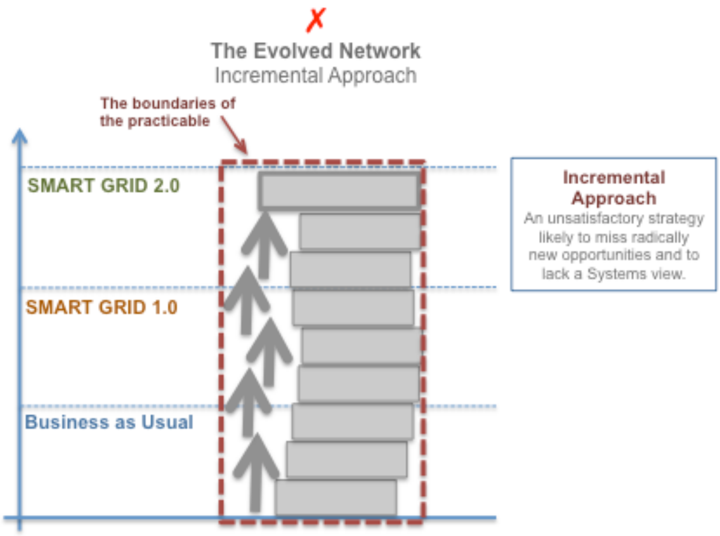
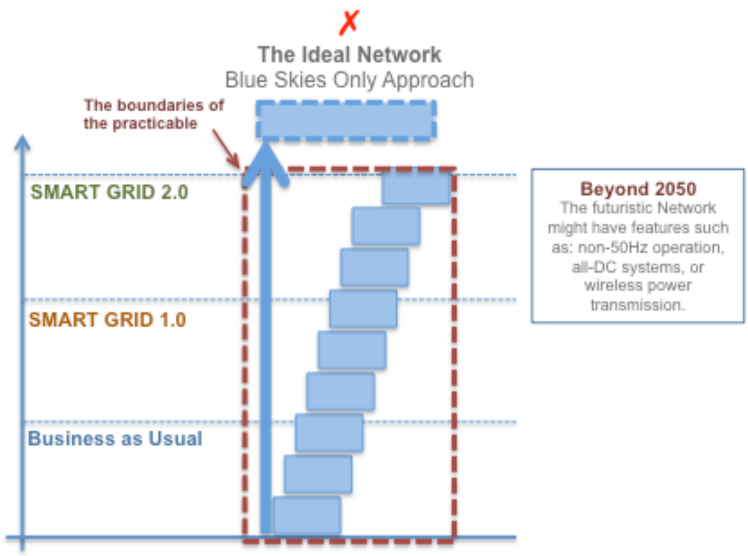


Figure 2: The Incremental Approach - rejected

A purely incremental approach was rejected, as it would be likely to miss radically new opportunities, increase the likelihood of stranded assets, and result in a stop/go approach that does not enable efficient business planning and regulatory oversight.

The red dotted box is intended to indicate the pragmatic boundaries for change, recognising that this evolution is not taking place in a green field context.

Figure 3: The Blue Skies Only Approach - rejected



Equally unsatisfactory is a totally 'blue skies' approach that creates a future vision that is in fact 'outside the red box'.

Thinking with no boundaries could readily conceive futuristic concepts that are not considered to be achievable in the broad timescale to

2050. This recognises that the large existing asset base has an inherent longevity and it is unlikely that abandoning assets and creating wholesale write offs would be in customers' interests.

The thinking here has been tested with a number of experts and compared with international developments to gain a measure of assurance that this work is not lacking in ambition. (In fact, to the contrary, the proposals for Smart Grids 2.0 as set out here are demanding, but judged to be credible options.)

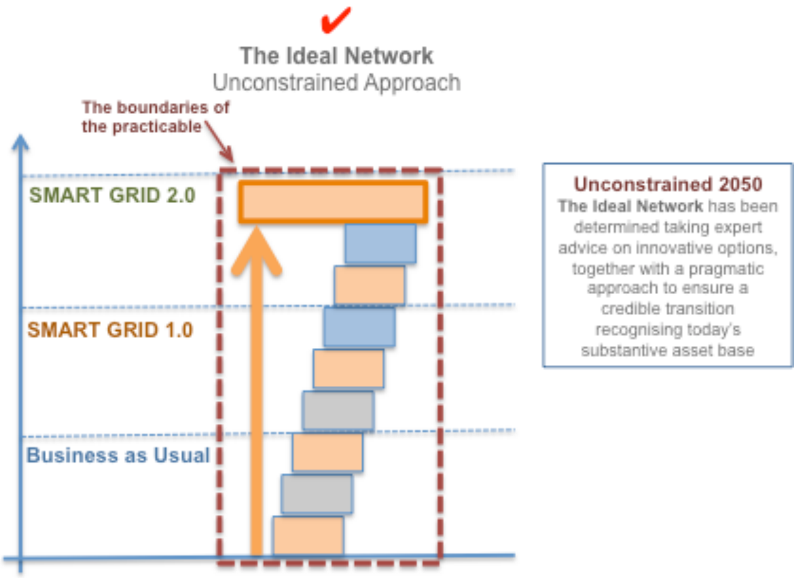


Figure 4: The Unconstrained Approach - adopted

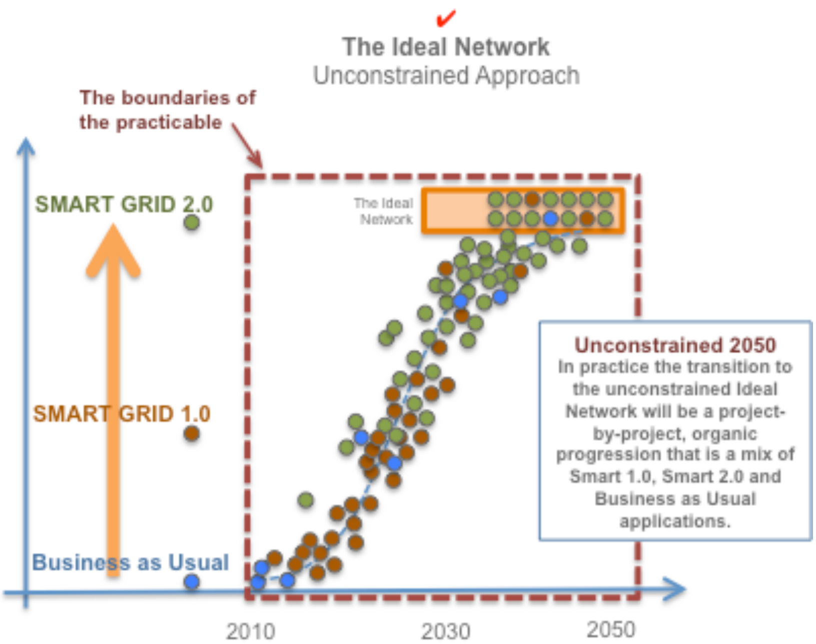
This diagram represents the approach recommended and adopted in this report. The vision is bold for the future but set within the boundaries of the practicable, as represented by the dotted red box.

Having established a credible goal, a pathway can then be built moving from today's world of 'Business as Usual' (BAU), through Smart Grid 1.0 technologies, and on to Smart Grid 2.0 with its yet more ambitious architectures and techniques.

A further stage of refinement in representation is shown below. This recognises that practical implementation is in fact a more organic process than the staircase represented in the diagram above. Also, that technologies from today's BAU context will be inter-mixed with Smart Grid 1.0 and 2.0 solutions, and that there will be early adoptions of advanced solutions ahead of replication as mainstream development.

Figure 5: The Unconstrained Approach - practical implementation

This representation is a refinement of the previous diagram to recognise the likely evolutionary nature of development, and that innovative applications will be a mix of types.



Of course, all diagrams have their limitations. The model is, we believe, relevant and expressive. However the image of tomorrow's grid described in this report should be seen as an example or a template – not a picture that applies to every situation – there is simply too much geographic, historic, social and economic difference between areas to have any homogenous view. At a simple level, however, the smart grid appears to be homogeneous in its distribution of new technology and applications and this is a helpful characteristic for communicating and progressing a complex context.

Thoughts on Implementation

We make reference here to the approach that is considered practical for taking forward the Solution Sets as described in detail in the body of this report. Following the format of the sketches above, this drawing indicates development of the Solution Sets as parallel streams of activity (with perhaps some of the 12 Solution Sets being grouped).

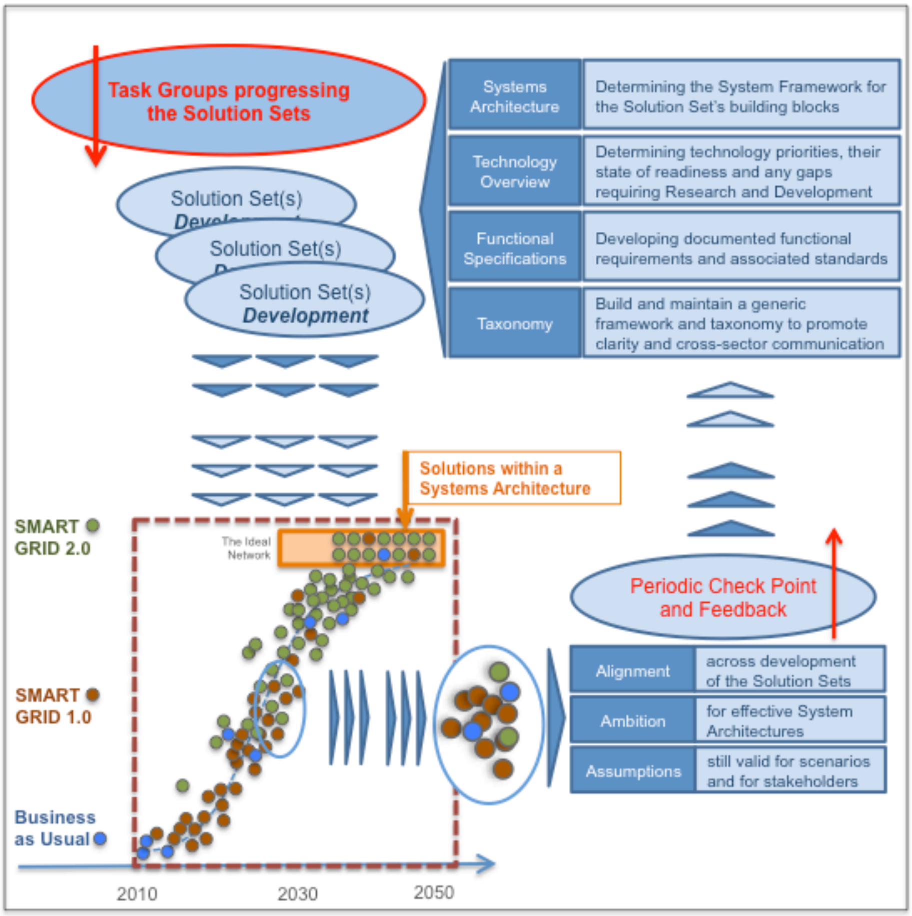


Figure 6: Embedding Ambition in Solution Set Development

The diagram indicates the 'Task Group Agenda' stating key issues that need to be progressed within each Solution Set.

To be practical this development work can be done in parallel streams of activity, focussed by topic area and expertise.

Importantly, the diagram indicates that at an Annual Check Point the work of the groups would be checked for Alignment, Ambition, and Assumptions. By this means, the end goal of an ambitious vision for innovative networks would be maintained, any changes to scenario assumptions would be incorporated, and technical developments would be aligned between the work areas to ensure that a Systems Engineering approach is achieved. This last point is important if the 'parts are to make up the whole' and the risks of unsatisfactory integration are to be avoided – for example outcomes where new technologies do not mesh with legacy systems, or innovative new features are left dormant and not utilised in practice.

1. Energy Scenarios

1. Energy Scenarios

Energy Scenarios – key points

METHOD

1. An assessment undertaken by Redpoint Energy, and complemented by the Government's 2050 Pathways Analysis, are the primary sources that inform this report
2. The Smart Grid Forum's work on scenarios will inform further stages of the analysis in this report, providing the key parameters needed for quantification
3. The 2030 timeframe is considered to be most insightful for planning development, extending as it does beyond the regulatory ED1 period
4. Some regional disaggregation and Transmission / Distribution impacts are included
5. Considerations for Climate Change impact and mitigation have been drawn from Royal Academy of Engineering/DEFRA and other reports

MESSAGES

1. The scenarios identify parameters that will have significant implications for electricity networks, both Distribution & Transmission
2. The significance of the implications is supported by published analysis and by the strategic engineering judgement of industry specialists
3. The scenarios published to date are largely based on a national model, with limited consideration of local variance
4. Regional effects and the clustering of demand and generation will significantly reduce diversity and magnify network implications at a local level
5. The responses that will need to be identified and developed for the timeframe to 2030 are likely to form the building blocks for the longer term towards 2050

COMMENTARY

1) Analysis of the scenarios has emphasised a number of key issues that must be clarified for making an accurate assessment of network impacts; for example, it is important to recognise that it is peak power demands (MW) that drive network reinforcement, rather than energy forecasts (GWh).

2) The impact of additional electricity consumption (GWh) on daily peak demand (MW) will depend critically on how consumers use new low carbon load-increasing technologies such as electric vehicles and heat pumps. For example, a tendency to recharge electric vehicles and top up home ambient temperatures during the early evening period on winter weekdays (for example as people return home from work) will contribute directly to national, and in most cases local, peak demand. With appropriate controls and/or incentives that encourage alternative behaviours (for example charging electric vehicles overnight and pre-heating homes in the afternoon) the impact of system and local peak demand would be significantly reduced.

3) National forecasts tend to look for trends and inevitably smooth out local effects such as clustering of electric vehicle charging activity that will have significant impact on network capability and energy users' experience. Regional analysis, for example to Local Authority level (or equivalent) would be a necessary minimum as it is more the combination of regional and local impacts that will give rise to the need for localised network reinforcement and/or the need for controls and/or incentives to limit the impact of clustering on local peak demands.

4) In simple terms, one might observe the caution 'beware vanilla analysis' when considering power distribution networks. This arises because at 'street level' accommodation of new demands will not have the diversity effects that greatly diminish these same effects seen in national or regional analyses.

5) In regard to Climate Change impacts the following report by The Royal Academy of Engineering and DECC is informative: www.raeng.org.uk/news/publications/list/reports/Engineering_the_future_2011.pdf

2. Implications for Networks

2. Implications for Networks

Implications for Networks – Key Points

METHOD

1. The energy scenarios inform the implications identified here for networks
2. The report recognises the need to consider the whole energy supply chain, and especially implications for transmission and distribution networks
3. System design, forecasting and real-time implications have been considered

MESSAGES

1. The implications for networks are fundamental and will need to be addressed comprehensively, to create a Systems Engineering integrated outcome
2. Electrical demand on the networks increases substantially in response to heat and transport requirements and there are expected to be new levels of local generation and community energy schemes
3. Networks must respond to drivers such as local economic growth, adoption of low carbon technologies, acceleration arising from local initiatives, and factors such as government incentives or new Supplier tariffs.
4. These factors are likely to add to the clustering of activity within local networks where the significantly reduced diversity offered by small numbers of customers will give rise to thermal or 'end of network' voltage challenges.
5. The existing early evening demand peak will be exacerbated by introduction of new heat pump demands and unconstrained electric vehicle charging.
6. Spatial effects, for example the clustering of new demand types, will cause localised network overloads requiring effective solutions – sooner not later
7. Intermittent generation output and the potential misalignment of local and national demands are important considerations
8. Implications must be addressed across each of the three timescales: System Design, Operational Planning, and Real Time Operation
9. The technical responses to address network implications will in many cases require new commercial frameworks, and associated regulatory developments
10. Business interfaces, processes and IT platforms are all affected
11. Looking towards the early 2020's most new technologies require application and implementation development; however, beyond this more fundamental research and development will be needed
12. There is certainty about ongoing uncertainty and this is addressed in the proposed way forward; network companies will require a flexible and responsive range of new capabilities

COMMENTARY

1) The major physical impacts from the scenarios have been grouped under the following headings: Electrical Demand, Generation Sources, Generation Location/Concentration, and Asset Exposures.

2) Asset Exposures includes the following aspects: Climate Change resilience (increasing storms, floods etc), Resilience to malicious threats (terrorism for example), Rising Asset

Utilisation, Increasing Asset Age and On-set of End of Life failures, and Rising consumer expectation for supply quality and responsiveness to adverse events.

3) The table below summarises the high level analysis of the key scenario 'driving parameters' showing how they are likely to impact on Transmission and Distribution systems; for each considering design, forecasting, and real time; and for the two timescales of 2020 and 2030 & beyond

key: 0 = no practical impact anticipated
/ = moderate impact, address using established techniques
// = challenging impact, utilise innovative techniques (Smart Grid 1.0)
/// = significant impact, utilise advanced innovative techniques (Smart Grid 2.0)

SCENARIO DRIVING PARAMETERS	ASSUMPTIONS AHEAD OF W/S1 UTILISING REDPOINT	POTENTIAL IMPLICATIONS for 2020						POTENTIAL IMPLICATIONS for 2030					
		Transmission			Distribution			Transmission			Distribution		
		System Design	Ops Planning	Real Time Ops	System Design	Ops Planning	Real Time Ops	System Design	Ops Planning	Real Time Ops	System Design	Ops Planning	Real Time Ops
Electrical demand													
underlying growth	steady	/	/	/	/	/	/	/	/	/	/	/	/
new demand types - EV at LV (eg home & street)	med then high penetration	/	//	//	//	//	//	/	//	//	///	///	///
new demand types - EV at MV (eg car parks)	med then high penetration	/	//	//	//	//	//	/	//	//	///	///	///
new demand types - EV rapid charging at MV	low then high penetration	0	0	0	/	/	/	0	0	0	//	/	/
new demand types - HP at LV (eg homes)	low then med penetration	0	0	0	/	/	/	/	/	/	//	//	//
new demand types - HP at MV (eg commercial)	low then med penetration	0	0	0	/	/	/	0	0	0	//	//	//
new demand clustering	impact magnification	0	0	0	//	//	//	/	/	/	///	///	///
changing customer behaviours	response to TOU tariffs etc	/	//	//	/	//	//	/	//	//	//	///	///
Generation sources													
new generation type - nuclear and fossil/CCS	new build programme	/	/	//	0	0	0	/	/	//	0	0	0
new generation type - offshore wind	expanding programme	/	//	//	0	0	0	//	//	//	0	0	0
new generation type - onshore wind	expanding programme	/	//	//	//	//	//	/	/	/	//	//	//
new generation type - domestic (PV, dCHP)	expanding programme	0	/	/	/	/	/	//	//	//	//	//	//
new generation type - community (Biomass, AD)	impact of RHI?	0	/	/	/	/	/	//	//	//	///	///	///
new generation type - marine	impact only later	0	0	0	0	0	0	/	/	/	0	0	0
new generation type - tidal barrage	uncertain; binary impact!	0	0	0	0	0	0	///	///	///	0	0	0
new generation type - DG at community scale	expansion anticipated	0	/	/	/	/	/	//	//	//	///	///	///
Generation location/concentration													
concentrated/dispersed	if high clustering	//	//	//	//	//	//	///	///	///	///	///	///
proximity to existing infrastructure	if remote from existing	/	0	0	/	0	0	//	0	0	//	0	0
impact on national/regional power patterns	if adverse for boundaries	/	/	/	/	/	/	//	//	//	//	//	//
Asset exposures													
resilience - c/change (eg storm, flood, extremes)	ENA add Govt; uncertainty	/	/	/	/	/	/	///	//	///	///	//	///
resilience - malicious threats	Cyber, terrorism attack	/	/	/	/	/	/	///	//	///	///	//	///
Asset Utilisation - rising in most cases	Significant increase	/	/	/	//	//	//	//	//	//	///	///	///
Asset Age and Health - increasing	End of Life rising failures	/	/	/	/	/	/	/	//	//	/	//	//
QoS expectations/customer dependence	Rising in both cases	0	0	0	/	/	/	0	0	0	//	//	//

Figure 7: Scenario Driving Parameters - Implications for Networks

4) Inspection of the table above reveals that the scenarios result in impact for both Transmission and Distribution networks, that they impact on all time phases from investment planning to real time operation, and that the significance of the impact becomes more onerous when considering 2030 and beyond.

5) A ranking of '//' or '///' in the table indicates significant impact for the networks that is considered to be beyond the capabilities of traditional network solutions to address efficiently (or indeed at all). This indicates the territory requiring priority attention for innovation.

3. Implications for Consumers

3. Implications for Consumers

Implications for Consumers – Key Points

METHOD

1. Recognise that customer requirements and implications are a central consideration
2. Note that there are changes ahead involving greater consumer interaction and a requirement for greater engagement
3. Financial and behavioural implications have been considered

MESSAGES

1. The report reveals a positive view of the future for consumers overall
2. Whilst network reinforcement can be anticipated, new technologies offer significant opportunities for minimising costs by extending capabilities of existing networks and deferring or avoiding new primary reinforcement
3. Increasing consumer dependency is anticipated for energy supplies, with rising expectations for security and quality, and hence greater immediacy for network company responses to any problems that arise
4. Innovative technologies will provide the opportunity to anticipate failures, deliver new services, and provide faster responses

COMMENTARY

1) Consideration of Consumer implications has not been addressed as a discrete step in the analysis, rather a continual touchstone. This has been important for a number of reasons, not least that the changes anticipated for the national electricity system will in many cases require consumer, or wider public, endorsement and engagement.

2) Some of the developments for innovative grids will be 'behind the scenes' activities as far as the public is concerned; an assessment is made in the report to highlights the areas that will have closer consumer impact. This is brought out in the Consolidation Chapter (5) and the Enablers Chapter (9).

3) There are also wider aspects emerging from the analysis, bringing considerations for community engagement and for the Government's localism agenda. It is early days for these concepts, but they hold considerable potential. To recognise this, a separate Solution Set has been identified named Smart Community Energy. It is a recommendation from this report that further work is undertaken to explore the social interaction opportunities at community level.

4) Importantly, this report draws attention to the consumer and community issues being addressed from the outset; to be truly effective these aspects need to be 'designed-in' to the engineering of an innovative power system rather than addressed as an afterthought.

5) In the Enablers Chapter (9), the report identifies a number of areas as ‘New Technology Enablers’. Many of these are technical issues that would benefit from Research & Development activities; however some are societal and social aspects that warrant similar (and integrated) attention.

6) The diagram below indicates that in some situations there may be a fast development requirement, for example to respond to customers’ requests for EV charging, but there is likely to be variability in the maturity/certainty of the network solutions. The quadrants indicate that some circumstances may require special attention to be given to the availability of solutions, or perhaps a need to develop short-term ‘fast response’ applications that create headroom for more permanent solutions. An example here might be the development of re-locatable storage devices, together with their control systems, to provide rapid network reinforcement.

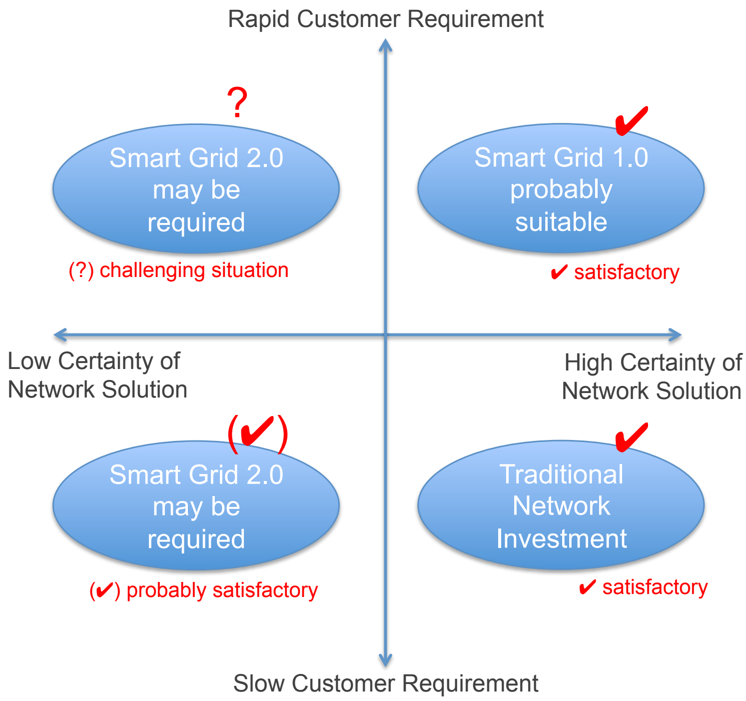


Figure 8: Responding to Consumer Needs

4. Network Responses

4. Network Responses

Network Responses – Key Points

METHOD

1. Responses include technical, policy and regulatory / commercial aspects
2. The likely time horizon for network responses is also considered
3. The responses are directed to meet functional requirements
4. Transmission and distribution responses are identified separately

MESSAGES

1. Differing types of innovation response are available to network companies
2. Strengthening of innovation capabilities can be anticipated and there are potential opportunities for network company new business
3. Solutions need to combine traditional network investment and innovation
4. Four products of innovative technology are identified – a) Asset Visibility, (b) Network Visibility c) Network Solutions d) Energy Interactions (e.g. Demand Response)
5. Two broad phases of smart grid development can be considered, relating to the shorter and longer term implications and innovation challenge: these have been termed Smart Grid 1.0 and Smart Grid 2.0
6. Some incremental strategic investment, ahead of immediate need, is expected to bring lower overall cost and higher quality of service
7. A Systems Engineering approach is important for the effective integration of new intelligent and dynamic applications to a network company's operational IT architectures and platforms
8. New business interfaces and new IT systems will be required and these have been identified in the report

COMMENTARY

1) It is expected that smart grid functionality will deliver significant customer benefits, offering as it does, the opportunity to manage some constraints without major plant investment, or deliver temporary or permanent solutions relatively quickly in uncertain conditions. However, the scale of new demand anticipated in the scenarios will require a combination of network reinforcement and smart grid techniques. Furthermore there is a good case for some more focused strategic activity and investment that will reduce the overall longer term cost for customers and provide better service. It is envisaged that some of these would be incremental investments as part of existing projects and some associated with network management platforms.

2) To provide a context for innovation on power networks, the diagram below illustrates in a generalised style, representative innovation stages for network companies. This would apply around the world and there is evidence to suggest that British companies are further advanced than many of their peers. For evidence of this we would point to the Innovation Funding Incentive annual reports available on the Ofgem website www.ofgem.gov.uk/Networks/Techn/NetwrkSupp/Innovat/ifi/Pages/ifi.aspx and the Low Carbon Network Fund developments www.ofgem.gov.uk/networks/elecdist/lcnf/pages/lcnf.aspx

3) Using the descriptions on the diagram, British network companies have in recent years progressed from 'Selective' to 'Incremental' and are in some cases now moving into 'Responsive'. An interesting feature of these developments is that, while they benefit from regulatory innovation incentives, they are not simply 'grant funded' and have the commercial engagement of the companies, within the liberalised market framework in GB.

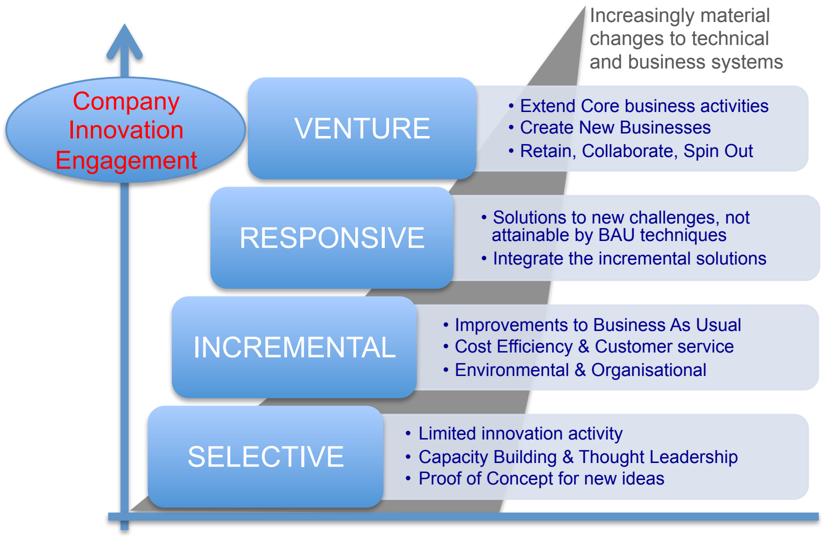


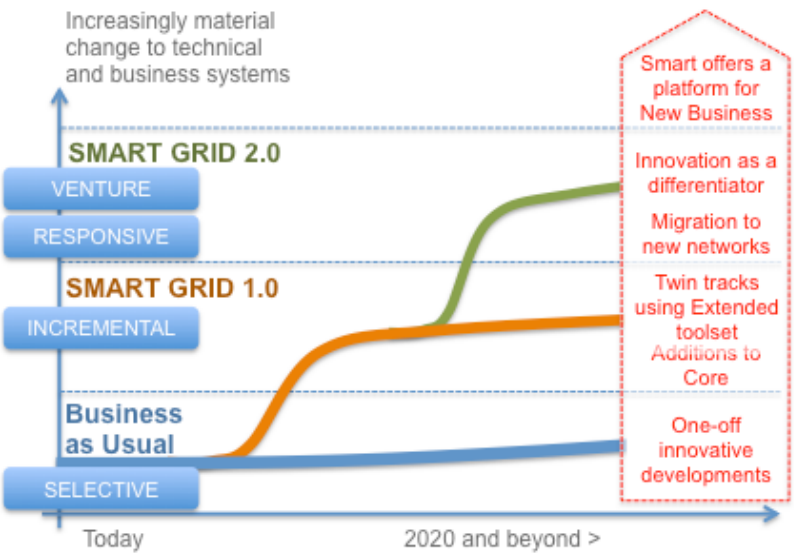
Figure 9: Choices of Company Innovation Engagement

This representation of network company engagement illustrates the drivers for each stage, the increasing technical and business complexity that arises, and the potential for new commercial opportunities that become available, if companies choose to pursue them.

4) The range of innovative network solutions, identified to address the scenario impacts, is set out later in this chapter. In compiling this agenda for technological developments, it became clear that two broad categories could be identified: firstly, those developments that are broadly achievable now with the necessary development and integration: and those that require further research and more fundamental, focussed action. The diagram below illustrates this and combines the concepts of the previous diagram.

Figure 10: A Migration Path to Smarter Grids & New Business Models

This diagram indicates how innovation activity in power network companies is expected to progress. Today, British network companies are progressing on the orange line, moving into Smart Grid 1.0 deployments.



5) Examples of technologies that might be described as Smart Grid 1.0 and Smart Grid 2.0 are shown below. Note that the Smart Grid 1.0 technologies are not necessarily fully commercialised and available off the shelf. Also they may only have been demonstrated

for a sub-set of applications, for example applied to urban but not rural networks, or may only exist as a concept (such as EV smart charging) but the elements to achieve them are broadly available. One might further categorise applications as 'early Smart Grid 1.0' and 'later Smart Grid 1.0'.

6) More important is the differentiation of moving to Smart Grid 2.0, where the applications are potentially demanding from a technology perspective and will need the systematic development of an ambitious technology project to achieve commercially deployable outcomes.

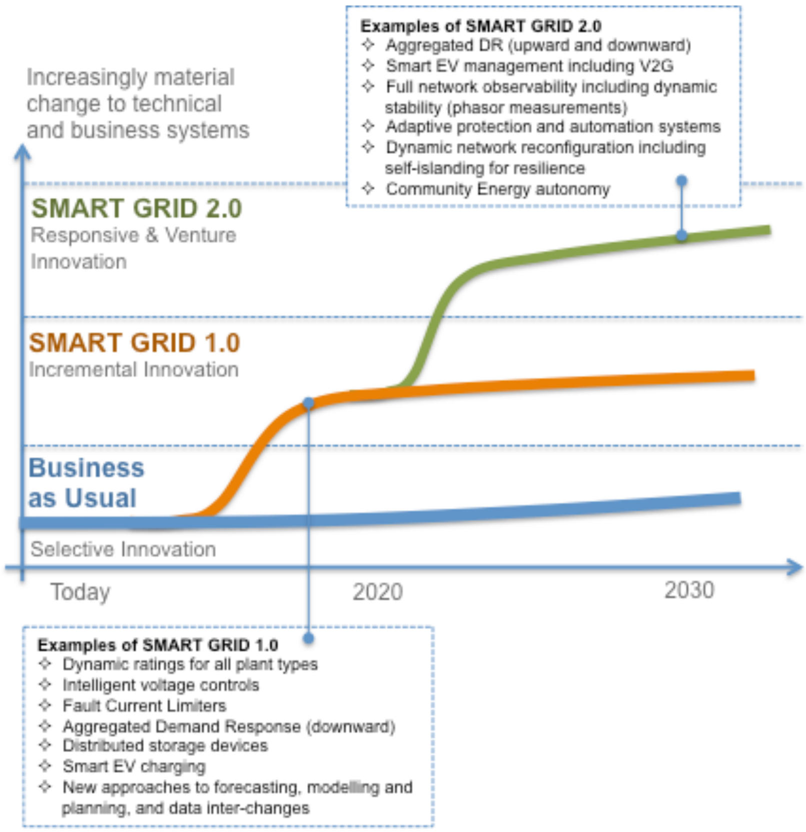


Figure 11: A Categorisation for Smarter Grids, with Examples

7) It is informative to use this diagram to explore wider aspects of this development. For example, the diagram following considers the likely requirement for consumer engagement.

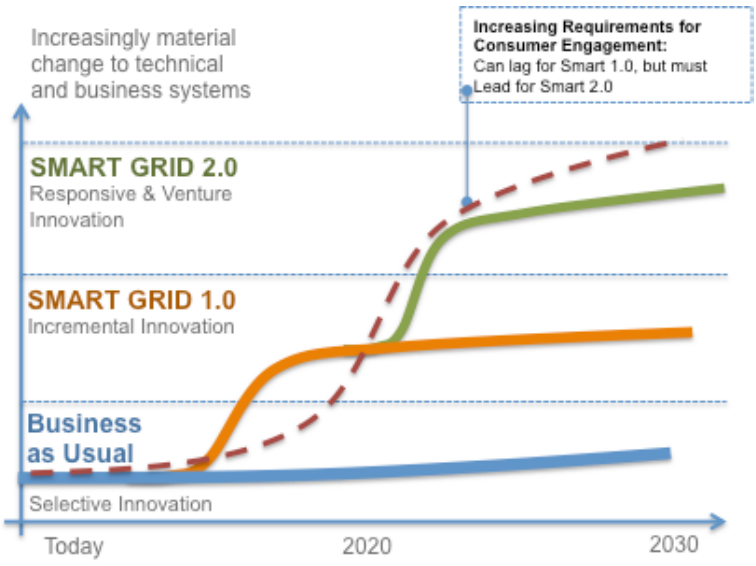


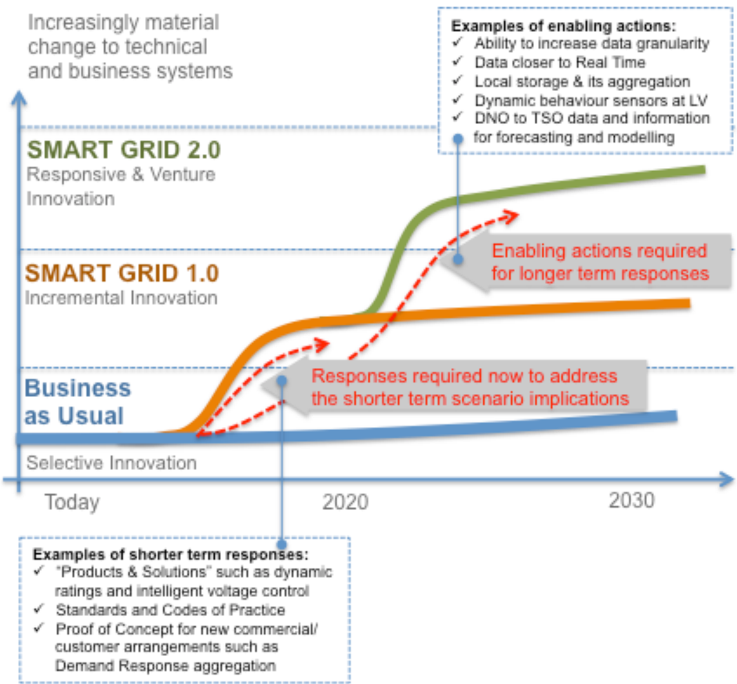
Figure 12: The Increasing Requirement for Consumer Engagement

The diagram not only shows the expected rise in consumer engagement needed as network solutions move towards Smart Grid 2.0, but also that while engagement might lag consumer engagement initially, for the later stages it will be important that it leads to technology deployment.

8) A further message that can be drawn from this diagram is the opportunity for enabling actions to lay the foundations for later migration to Smart Grid 2.0 network responses. This is shown in the diagram below.

Figure 13: Migration to Smarter Grids and New Business Models

For the shorter term, Smart Grid 1.0 solutions, there are a number of actions that can be identified as effective catalysts including development of Functional Specifications and Standards. However, enabling actions that will facilitate Smart Grid 2.0 can also be identified as shown on the diagram. These are however likely to require some financial investment ahead of immediate need. This matter has regulatory dimensions and is addressed further in 10.6



9) The table below summarises the innovative responses for addressing the network implications that are unlikely to (or simply cannot) be addressed using traditional solutions alone.

10) This table follows the format of the earlier Implications assessment, but groups the responses within the Transmission and Distribution sectors, while retaining a split across timescales. The 2020 responses can broadly be considered as Smart Grid 1.0 and the 2030 responses as Smart Grid 2.0. The latter are inevitably broader-brush and are considered to pave the way for solutions towards 2050.

SCENARIO DRIVING PARAMETERS	ASSUMPTIONS AHEAD OF W/S1 UTILISING REDPOINT	POTENTIAL RESPONSES for 2020		POTENTIAL RESPONSES for 2030	
		Transmission	Distribution	Transmission	Distribution
		System Design / Ops Planning / Real Time Ops	System Design / Ops Planning / Real Time Ops	System Design / Ops Planning / Real Time Ops	System Design / Ops Planning / Real Time Ops
Electrical demand		EV large and moveable charging load: implement new forecasting and modelling tools. Potential impact for national boundary flows and constraints.	Large EV/HP demands & loss of Diversity: implement smart charging at street level (LV), and at demand centres (MV). Street level requires high immediacy solutions. Implement network sensors/ observability, new forecasting/ modelling tools. High concentrations likely to require a combination of smart and traditional investments, including power electronic devices, and associated commercial frameworks.	EV will create large and moveable charging loads: implement advanced forecasting and modelling tools and integrate across DNOs. Implement control centre visualisation tools.	Large EV/HP demands and loss of Diversity, HP direct electrical top up for cold weather: comprehensive smart charging at street level (LV), and demand centres (MV). Comprehensive network observability, and advanced forecasting/ modelling tools. State Estimation. New commercial frameworks. Integrate DNO/DNO/TSO. Managing DG at community scale likely to benefit from Fault Current Limiters. A combination of smart and traditional investments likely.
underlying growth	steady				
new demand types - EV at LV (eg home & street)	med then high penetration				
new demand types - EV at MV (eg car parks)	med then high penetration				
new demand types - EV rapid charging at MV	low then high penetration				
new demand types - HP at LV (eg homes)	low then med penetration				
new demand types - HP at MV (eg commercial)	low then med penetration				
new demand clustering	impact magnification				
changing customer behaviours	response to TOU tariffs etc				
Generation sources		Large single loss risk for nuc and increasing wind component variability: develop fast DR and VPP aggregated services. Potential impact for national boundary flows and constraints.	Onshore wind growth increases MV network loading, and PV growth increases LV and MV loading/export: implement basic active network management, dynamic ratings, fault current limiters, enhanced intelligent switching.	High PV penetration within DNO networks creates significant and variable infeeds; implement advanced forecasting and modelling, with DNO data/ information integration.	Onshore wind growth increases MV network loading, and PV growth increases LV loading/export and harmonics: implement advanced active network management, adaptive control & protection, enhanced intelligent switching
new generation type - nuclear and fossil/CCS	new build programme				
new generation type - offshore wind	expanding programme				
new generation type - onshore wind	expanding programme				
new generation type - domestic (PV, dCHP)	expanding programme				
new generation type - community (Biomass, AD)	impact of RHI?				
new generation type - marine	impact only later				
new generation type - tidal barrage	uncertain; binary impact!				
new generation type - DG at community scale	expansion anticipated				
Generation location/concentration		Cocentration and loss of diversity will magnify the network impacts.	Concentration and loss of diversity will create new urgency for rapid solutions.	Concentration and loss of diversity will magnify the network impacts.	Concentration and loss of diversity will create new urgency for rapid solutions. Importance of scalable solutions and a Systems approach
concentrated/dispersed	if high clustering				
proximity to existing infrastructure	if remote from existing				
impact on national/regional power patterns	if adverse for boundaries				
Asset exposures		To increase resilience will require new options; C/C mitigation warrants L/T view as projections are uncertain, fresh solutions may be necessary. Ageing assets will require advanced monitoring.	To increase resilience will require new options; C/C mitigation warrants L/T view as projections are uncertain, fresh solutions may be necessary. Ageing assets will require advanced monitoring.	Network stresses uncertain: options for advanced solutions important to develop. Integrated TSO actions with self-islanding and self-resync Dist networks offers new approach to network security and investment. Smart Grid 2.0	Network stresses uncertain: options for advanced solutions important to develop. Integrated TSO actions with self-islanding and self-resync Dist networks offers new approach to network security and investment. Smart Grid 2.0
resilience - c/change (eg storm, flood, extremes)	ENA add Govt; uncertainty				
resilience - malicious threats	Cyber, terrorism attack				
Asset Utilisation - rising in most cases	Significant increase				
Asset Age and Health - increasing	End of Life rising failures				
QoS expectations/customer dependence	Rising in both cases				

Figure 14: Network Responses 2020 and 2030

11) To conclude this chapter it may be noted that, encouragingly, there is a considerable range of solutions that can be considered for addressing the network challenges. Also, there are not surprisingly overlaps between the different sectors and timescales. The next Chapter seeks to bring some order to this complex landscape by means of a consolidation process.

5. Consolidation of Responses

5. Consolidation

Consolidation of Responses – Key Points

METHOD

1. In order to incorporate more ambitious and promising technology futures, expert inputs have been included from the manufacturing, academic, energy storage and energy consultant communities
2. 'Solution Sets' have been derived that are informed by engineering requirements, consumer implications and technology futures

MESSAGES

1. The concept of Solution Sets is introduced to provide a practical way forward through what is otherwise a diffuse, multi-element, landscape
2. The Solution Sets can provide a systematic approach to network company Business planning
3. The Solution Sets are described as high level Functional Specifications that are not prescriptive and can be adapted to each company's context
4. The Solution Sets provide a basis of taking the work forward into progressively greater detail to address the technical, commercial and regulatory requirements needed for practical deployment
5. Full Functional Specifications can be developed jointly by stakeholders, setting common foundations for open systems, competitive provisioning, and cost-effective contextual localisation
6. The Set called Enterprise Wide Solutions, recognises that benefits may arise from integrated facilities, for example for data or communications
7. The Solution Sets approach can also be developed as an enabler for exports and UK job creation
8. The Solution Set proposals are ambitious but credible; Technology Futures hold considerable potential and, through an effective program, can be expected fully to deliver the ambitious elements of the 'ideal' future network

COMMENTARY

1) The Solution Sets are more than a convenient grouping of associated concepts and solutions; they have been developed to form a core for practical business planning by the network companies, provide a framework suitable for unit costing and that can support cost/benefit analysis (see Appendix 1), and establish an approach that can support deployment and, in due course, national roll-out as needs dictate.

2) The diagram below summarises the key points and the graphic has been chosen to suggest an organic approach to deployment, rather than a 'Lands End to John O'Groats' roll-out. A balance will be required to achieve national smart grids capability, between responding to local network needs and a proactive approach that anticipates needs and takes opportunities to deploy enabling facilities. This is discussed further in regard to investment ahead of need, in the Deliverables Chapter (10).

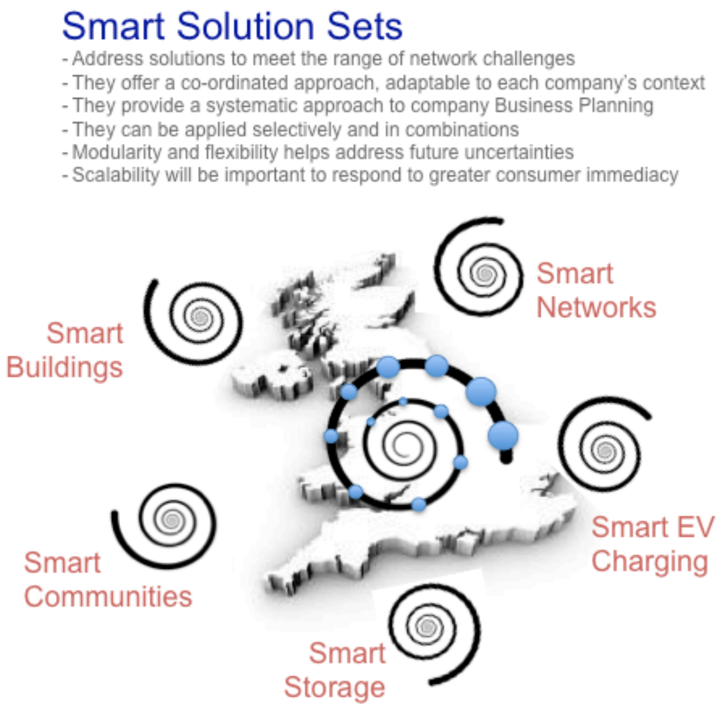


Figure 15: Smart Solution Sets

The ammonite-like graphic has been chosen intentionally to suggest an evolutionary approach to smart grids deployment.

The blue dots represent Solution Set deployment, starting small at the points of network need, and then being applied at progressively larger scale as experience is obtained and as network needs escalate.

The Solution Sets are not rigid templates and it is envisaged that core Functional Specifications could be developed in common by the network companies to gain scale and procurement efficiency, but that their deployment would be adapted and refined to the needs of each company's local context.

The diagram above, for clarity, simply indicates five Solution Sets; in practice twelve have been identified including four variants of the 'Smart LV Networks' set.

3) The diagram below provides a high level summary of the products that can be delivered by innovative 'smart grid' developments. All four provide valuable customer benefits, but only one involves direct customer interaction and engagement.

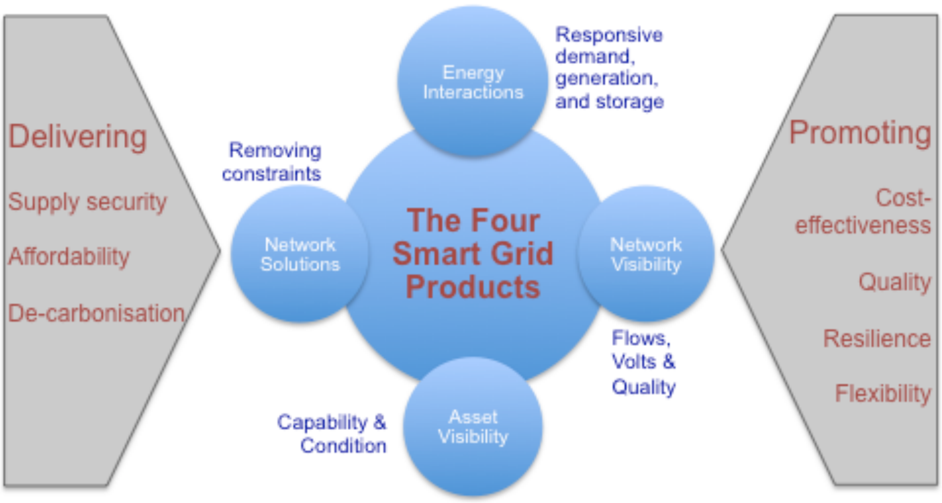


Figure 16: The Four Smart Grid Products

4) The Solution Sets are presented in the tables below and are divided, left and right, broadly for Smart Grid 1.0 and Smart Grid 2.0 applications. The notes to the left side are a shorthand summary of the Solution Set focus for application.

5) The information shown is necessarily high level; some amplification is provided in Appendix 2 that sets out preliminary Use Cases for each Solution Set. Further development of the Sets is included in the Next Steps actions set out in the Deliverables Chapter (10).

	POTENTIAL RESPONSES for 2020 **Transmission & Distribution (typically Smart Grid 1.0)** Solution Sets - capabilities for 2020	**POTENTIAL RESPONSES** for 2030 **Transmission & Distribution (typically Smart Grid 2.0)** Solution Sets - capabilities for 2030 & beyond
Focus: Quality of Supply; enhancements to existing network architecture	**1. Smart D-Networks 1 (Supply & Power Quality)** Enhanced Network Observability Automatic LV reconfiguration to enhance quality of supply - capability at LV substation fuse boards and in link boxes Intelligent switching will require sensing, comms & monitoring Options to deploy Adaptive protection & Control techniques Waveform monitoring and waveform correction devices - including: harmonic distortion, sags, surges, and flicker Real Time identification of fault positions for rapid rectification Phase imbalance sensors/correction (improve losses and capacity)	**full functionality:** Integration of storage (P/Electronics dual functionality for V and PQ) Comprehensive waveform quality management Waveform tracking through smart meters or other sensors - including pollution source identification Location of fault positions for more rapid rectification Optimise national losses/carbon across multiple voltages and companies Use sensors to track, pinpoint and respond to high losses events
Focus: DG connections, management of 2-way power flows	**2. Smart D-Networks 2 (Active Management)** Intelligent voltage control to manage 2-way power flows Fault Limiter devices to control short circuit currents Adaptive protection mechanisms Sensors and State Estimation for observability of flows/voltages Consumer volts measurement from smart meters or other sensors Data communications close to real time	**full functionality:** Utilise storage at domestic, substation and community level LV and MV phase shifters to direct power flows Deployment of PMU sensors for dynamic stability monitoring DR services aggregated for LV & MV network management Forecasting & modelling tools for DNOs Integration between DNO/DNO/TSO for data and information
Focus: plant & systems reliability, failure mode detection	**3. Smart D-Networks 3 (Intelligent Assets)** Dynamic Ratings for all plant types and multi-element circuits Condition Monitoring for ageing assets - failure advance warnings for lines, cables, transformer and switchgear Status Monitoring for intelligent control systems - pre failure alerts Use of advanced materials to increase ratings of overhead lines Use of novel tower/insulation structures to enhance route capacity	**full functionality:** Diagnostic tools for managing intelligent control systems Re-commissioning tools and techniques for extending/scaling intelligent control systems Loss optimisation techniques - utilise new devices such as D-FACTS Fault localisation and diagnostic techniques
Focus: Security of networks inc. physical threats, utilising new network architectures	**4. Smart D-Networks 4 (Security & Resilience)** Enhanced supply reliability by automatic network reconfiguration Use of meshed rather than radial architectures Greater use of interconnections & higher voltage system parallels Utilisation of 'last gasp' signals from smart meters and sensors - integrate data with SCADA systems and higher voltage levels Forecasting & modelling tools for DNOs to manage new demands Cyber & Data Security protection for network communications	**full functionality:** Self-healing network diagnostics and responses Self islanding option for extreme physical events (essential supplies) Self-restoration and resynchronisation of islands Synthetic inertia devices to support dynamic stability Utilise storage for domestic, substation, community security EVs as network security support (V2G) Advanced network topology management tools for DNOs DC networks (eg home / community) integrated with AC system Self-islanding opens opportunities for new security/investment policies
Focus: Enhancements to Transmission Networks to add to existing smart functionality & whole-system perspective	**5. Smart T-Networks (Enhancements)** Extension of dynamic ratings to all plant types Monitoring and adaptation of assets subjected to high utilisation Extension of FACTS devices for increased ac transfer capabilities Advanced dynamic sensing and stability monitoring Utilisation of aggregated D-Network DR services Utilisation of aggregated D-Network export services (DG/VPP/V2G) New and enhanced forecasting and modelling for EVs and Wind Generation impact (demand/export) Condition Monitoring for ageing assets - failure advance warnings for lines, cables, transformer and switchgear	**full functionality:** Integration of DNO/DNO/TSO data, analysis, and information Utilisation of aggregated fast D-Network DR/VPP/Storage services for response and reserve Wider use of DC internal and external links and integration of their control systems for secure and stable operation Whole system, all voltage level, integration - see (1) also

Focus: EV charging / discharging (V2G), Network Management, Demand Response and other services	**6. Smart EV Charging** Open Systems with standardised communication protocols and standardised functionality for EVs/Charging Points Architecture - distributed processing - street, substation or community level, distributed charging management, with aggregated reporting and supervision for reliability Commercial frameworks required	**full functionality:** Integration of local storage to support charging capability Demand Response aggregated services (downward/upward) Aggregated V2G services Forecasting and modelling, integrated for DNO/DNO/TSO Standardised functionality available for rapid wider roll-out
Focus: Electricity storage at domestic, LV, and MV levels, and above (static storage devices)	**7. Smart Storage** Domestic, street, community and regional facilities Storage monitoring and tracking of energy status and availability Storage management & control to enhance network utilisation Tools for optimising location of storage on networks Optimised charging/discharging to extend life of storage medium Basic commercial frameworks required, particularly for merchant energy storage services	**full functionality:** Seasonal and diurnal storage charge/discharge management Integration of storage management across the power system Standardised functionality available for rapid wider roll-out Storage management used to minimise overall system losses Deployment of multiple storage types, optimally integrated Full commercial frameworks likely to be required
Focus: Geographic and social communities in existing built environment	**8. Smart Community Energy** Enhance network performance by forging closer links with those it se Build a local sense of energy identity, ownership, and engagement Integrate Community Energy with Government's Localism agenda Develop a Technical, Commercial, and Social functionality set Energy from Waste and centralised CHP integration Trading of energy and services within local communities	**full functionality:** Demand Response optimised with a Community group Exported domestic generation traded within group Standardised functionality available for rapid wider roll-out Vibrant 'energy engagement' that maintains interest & participation Trading of energy and services between local communities
Focus: SME, C & I buildings, and all aspects of new Built Environments	**9. Smart Buildings & Connected Communities** Building management systems with standard functional interfaces Buildings provide DR services and DG services Buildings provide energy storage (heat/elec) services Private networks in similar roles	**full functionality:** Buildings and groups of buildings providing integrated services Communities managing their energy, integrated with networks Buildings with self-islanding and re-sync capability Private networks in similar roles
Focus: Ancillary Services for local and national system	**10. Smart Ancillary Services (Local & National)** Aggregation of domestic DR (downward response) Aggregation of EV charging (variable rate of charging) Commercial frameworks Aggregation of DG (eg PV) to provide Virtual Power Plant (VPP) capa	**full functionality:** Aggregation of domestic DR (downward/upward responses) Aggregation of EV charging (variable charging/discharging) DSOs manage local networks, offering integrated services to TSO National VPP capabilities. Responsive demand, storage and disptachable DG for wider balancing include post gate-closure balancing and supplier imbalance hedge New tools are increasing relevant as gen. reaches government targets
Focus: T&D control centres of the future	**11. Advanced Control Centres** Visualisation and decision support tools Data processing at lowest levels, information passed upwards Modelling & Forecasting tools for new demands, in Ops timescales	**full functionality:** GB system view, integrating TSO and DNO network management Whole GB system carbon optimisation (config., losses, storage…) Architectures and Systems platforms that support hybrid combinations of distributed/centralised applications
Focus: Enterprise wide platforms within companies	**12. Enterprise-wide Solutions** Facilities that provide cost-effective outcomes, across Solution Sets This may apply to Enterprise-wide communications, data storage etc	**full functionality:** Integration of Enterprise-wide solutions with dispersed niche provisions Flexibility to ensure that Enterprise-wide solutions do not constrain solutions to challenges not yet envisaged

Figure 17: Network Responses Grouped into Solution Sets

6) The table below maps the Four Smart Grid Products identified at the start of this Chapter to the 12 Solution Sets identified above. In many cases there is one-to-one correspondence, in some cases a Solution Set addresses to product areas. The exception is Solution Set No. 12, Enterprise-wide solutions, which will in practice be company specific and may apply to one or all four of the product areas.

The Four Smart Grid Products

The 12 Solution Sets

		Network Visibility	Network Solutions	Energy Interactions	Asset Visibility
1.	**Smart D-Networks 1** (Supply and Power Quality)	/			
2.	**Smart D-Networks 2** (Active Management)		/		
3.	**Smart D-Networks 3** (Intelligent Assets)				/
4.	**Smart D-Networks 4** (Security and Resilience)		/		
5.	**Smart T Networks** (Enhancements)		/	/	
6.	**Smart EV Charging**		/	/	
7.	**Smart Storage**		/	/	
8.	**Smart Community Energy**			/	
9.	**Smart Buildings and Connected Communities**			/	
10.	**Smart Ancillary Services** (Local and National)			/	
11.	**Advanced Control Centres**		/	/	
12.	**Enterprise-wide Solutions**	/	/	/	/

6. Technology Futures

6 .Technology Futures

Technology Futures – Key Points

METHOD

1. In order to incorporate more ambitious and developing technology opportunities, expert inputs have been sought from the manufacturing, academic, energy storage and energy consulting communities
2. Technology Futures have been interpreted flexibly to include associated disciplines such as social aspects where interactions associated with new the engineering developments are identified

MESSAGES

1. There is evidence of innovative technology development that is expected fully to emerge as part of future network solutions
2. It would be erroneous to think of these technologies as discrete elements to be ‘bought and plugged in’; it will be important to integrate them with existing facilities and with each other, ensuring a whole-Systems view and confirming operational robustness
3. Some technologies currently applicable to transmission systems (e.g. power electronics) are expected to have application at distribution level
4. The transfer of technology from transmission (large scale, small numbers) to distribution (small scale, large numbers) is likely to require fundamental re-thinking of approach to achieve commoditised and cost-effective solutions for wide scale application.
5. This report makes a number of references to ‘designing-in’ certain features from the outset (such as effective consumer interfaces or diagnostics)
6. A checklist of engineering good practices, identified in discussions and from early field applications, is included in the Deliverables Chapter (10.5)
7. Note that new technologies not infrequently require commercial arrangements to deliver benefits (and may benefit the commercial systems): for example, integrated smart ancillary services could optimise not only D and T networks, but also mitigate volatility in market spot prices by optimising the balance between demand and variable generation
8. The scale of adoption opportunities and unit cost of new technologies for budgetary purposes will require assessment in a subsequent phase of W/S3

COMMENTARY

1) Technology futures applications have been incorporated in the Solution Set summaries and are considered also in the Key Enablers Chapter (9).

2) The table that follows sets out a first listing of high-potential technologies, showing their likely relevance to power systems, and indicating their maturity.

3) Maturity is described by the internationally recognised Technology Readiness levels (TRLs) as defined below. The assigned TRLs should be considered indicative only.

Definition Of Technology Readiness Levels
TRL 1 Basic principles are observed and reported: Transition from scientific research to applied research. Essential characteristics and behaviours of systems and architectures. Descriptive tools are mathematical formulations or algorithms.
TRL 2 Technology concept and/or application formulated: Applied research. Theory and scientific principles are focused on specific application area to define the concept. Characteristics of the application are described. Analytical tools are developed for simulation or analysis of the application.
TRL 3 Analytical and experimental critical function and/or characteristic proof-of- concept: Proof of concept validation. Active Research and Development (R&D) is initiated with analytical and laboratory studies. Demonstration of technical feasibility using representative data.
TRL 4 Component/subsystem validation in laboratory environment: Standalone prototyping implementation and test. Integration of technology elements. Experiments with full-scale problems or data sets.
TRL 5 System/subsystem/component validation in relevant environment: Thorough testing of prototyping in representative environment. Basic technology elements integrated with reasonably realistic supporting elements. Prototyping implementations conform to target environment and interfaces.
TRL 6 System/subsystem model or prototyping demonstration in a relevant end-to-end environment: Prototyping implementations on full-scale realistic problems. Partially integrated with existing systems. Limited documentation available. Engineering feasibility fully demonstrated in actual system application.
TRL 7 System prototyping demonstration in an operational environment: System prototyping demonstration in operational environment. System is at or near scale of the operational system, with most functions available for demonstration and test. Well integrated with collateral and ancillary systems. Limited documentation available.
TRL 8 Actual system completed and "mission qualified" through test and demonstration in an operational environment: End of system development. Fully integrated with operational hardware and software systems. Most user documentation, training documentation, and maintenance documentation completed. All functionality tested in simulated and operational scenarios. Verification and Validation completed.
TRL 9 Actual system "mission proven" through successful mission operations: Fully integrated with operational hardware/software systems. Actual system has been thoroughly demonstrated and tested in its operational environment. All documentation completed. Successful operational experience. Sustaining engineering support in place.

NEW TECHNOLOGY	**POTENTIAL POWER NETWORKS APPLICATIONS**	**READINESS (TRL)**	
		Dist.	**Trans.**
1. D-FACTS, STATCOMS, power electronic controllers	A range of new solutions to system voltage, power factor and power flow control at LV and MV; adaptation from existing (established TRL 9) transmission applications required. Likely to be effective in dynamic situations created by distributed generation and storage, and large new demands. Ability to improve capacity of existing assets and reduce system power losses.	**6/7**	
2. Solid State tap changers	A new approach to voltage control at the interfaces between different system voltages that at present are in effect a fixed	**3**	**1/2**

	transformation ratio. This would eliminate the weaknesses of traditional solutions that involve moving parts and oil insulation.		
3. Interconnection of D-STATCOM devices to create a controllable DC network overlay	A completely new LV, MV network architecture suited to meet high density demands and provide control of power flows and improve sharing between circuits. This builds upon introducing STATCOM / D-FACTS devices for other reasons, so creating this opportunity for gaining the benefits of 'DC distribution' systems. (These devices have an internal DC busbar that in principle can be accessed as a DC power source and to which DC energy storage devices can be connected.)	**1/2**	
4. DC networks at Domestic, LV and MV including multi-terminal systems	Extending the principle stated above to create multi terminal flexible local networks, potentially including domestic DC services. Well suited to meet high density demands, connecting DC demands and generation devices, and provide controllable power flows	**1/2**	
5. Superconducting and other designs of fault current limiters	An emerging solution for limiting the magnitude of power that flows under short-circuit conditions on networks, especially attractive for those networks with high DG penetration, to avoid switchgear replacement and maintain safe operation. Solid state devices are under development for D and T systems.	**7**	**3**
6. Soft Open Point power electronics	A new type of device to enable new LV and MV running arrangements and controls to enhance supply security. This would be an intelligent and controllable alternative to mechanical open points between LV and MV networks.	**1/2**	
7. Intelligent switching logic and adaptive protection and control	Active networks and dynamic system reconfiguration presents challenges for the settings of control and protection systems so that they operate correctly over a wide range of system conditions. This technology is established but not widely applied at present but can be expected to have potential as networks become more intelligent and responsive to changing demands, generation, and system events.	**3/5**	**3/5**
8. Power electronics for synthetic inertia	This is a promising technique using power electronic control to simulate the effects of mechanical inertia, important to electrically stiffen the dynamic performance of intentionally islanded networks. Wind turbine applications also arise here.	**5**	**5**
9. Solid State transformers	A new concept for power systems, eliminating traditional magnetic circuit and steel-cored devices. All electronic solutions have the potential to save space, weight, and losses, and enhance the control of voltage, waveform and fault power.	**1/2**	
10. Inductive EV charging	Wireless charging for EVs has been demonstrated using resonant techniques. Understand and control its impacts for networks if used at large scale.	**3/4**	
11. Cyber-secure communications and interfaces	New techniques for ensuring cyber security at the many communications interfaces anticipated in the future. Importantly this must	**3/6**	**3/6**

	address the challenge of facilitating integration of innovative solutions with legacy systems and provide for diagnostics and remote support to distributed intelligent systems.		
12. Electricity storage devices of several types and differing applications	Storage of electricity at industrial scale is an emerging technology with a wide range of technical solutions becoming available and at differing stages of development. Some require early-stage R&D, others are at the prototype stage and require attention to progress them through the 'valley of death' that is faced time and again by such developments. This topic would appear to require attention if it is believed that electricity storage is a key enabler for the future energy system.	**3/7**	
13. Potential for hydrogen production and storage	The 'hydrogen economy' remains a concept with potential for the medium and longer term. Continuing R,D&D effort would be expected here.	**2/4**	
14. Micro-grid control systems for intentional islanding utilising distributed energy resources	Intentional islanding and re-synchronisation to the main national system of networks with distributed energy resources has been identified in this report as an option that could have significant benefits for the longer term. There is considerable scope for developing and proving the technology components and the control systems for this and useful lessons could be learned from national and international micro-grid (islanded power systems) developments.	**3/6**	
15. Phasor Management Units (PMUs) and Wide Area Monitoring, Control and protection (WAMPACs)	Phasor measurements (power system dynamic parameters tracked in real time) are an emerging technology internationally at transmission level and their wider application and integration is expected to have benefits here. Work is required to consider the merits of deploying them on lower voltage systems where there is high penetration of distributed generation and under conditions of intentional islanding.	**1/3**	**7/8**
16. Forecasting and modelling techniques and visualisation tools for planning and operational timescales	This report identifies a number of areas where entirely new tool sets are required (e.g. for EV charging and for storage control). These techniques need development and integration across system voltage levels and temporal and geographic boundaries.	**1**	**1**
17. State Estimation for network observability	Active control of distribution networks requires measurement sensors to be applied where none exists at present. Smart meters may assist here at network end-nodes. As control systems become more sophisticated (and critically dependent on such measurements) it is established good practice at transmission level to apply State Estimation techniques. This utilises a power system mathematical model to 'fit' the measured data and identify anomalies and fill in measurement gaps or sensor failures. This technology has not been deployed at distribution level and a number of challenges will need to be resolved.	**2/3**	**9**

18. Distributed generation interfaces	LV and MV power electronic converters are useful solutions for connecting distributed DC generation equipment into LV or MV grids (DC generation sources include: PV, Fuel cells, storage and any other DC energy sources).	**2/3**	
19. Custom Private Networks	AC/DC, DC/DC and/or DC/AC converters at LV and MV levels will enable custom private networks to be created. Such networks could be airports, harbours, sensitive factories, etc where sources or energy exist within the facilities sufficient for minimum needs under emergency conditions. The custom network can reduce its dependency on the grid when necessary.	**4/5**	
20. Microgrids	Microgrids are an emerging approach to power generation in which small community networks are able to generate their own electricity and heat. The community could be a cluster of small generators serving local loads including office buildings, industrial parks, and homes. A Microgrid appears to the larger grid as if it's any other customer and it can quickly switch between operating on and off the grid: when the grid offers cheap electricity, the Microgrid can purchase it, but if prices rise or there's a power failure, the Microgrid can isolate itself (self-islanding). Microgrids are a potentially useful new component to network design, enabling distributed generation resources (DER) to properly come on stream. As the demand for more distributed generation increases, the need for Microgrids is expected to escalate. To control power quality within a Microgrid, energy storage devices will need to be integrated.	**4/7**	
21. Hybrid technologies	Exploiting the possible correlation between production and consumption or other controllable equipment (e.g. storage) through introducing the appropriate converters, and integrating the control of multiple energy sources.	**3/5**	

4) The summary above indicates a range of maturity levels; the topics having lower maturity require systematic Research, Development and Demonstration (R,D&D) effort to bring them to commercial viability. A co-operative approach with national bodies such as the Research Councils, the UK Energy Research Centre, and the Energy Technologies Institute will be helpful.

7. Complexity & Uncertainty

7. Complexity & Uncertainty

Complexity and Uncertainty - 10 Key Structural Principles

METHOD

1. The extent of uncertainty has been acknowledged, including electrical demand, technology, timing, localisation, and customer engagement. W/S3 identifies a number of structural principles that help bring order to the network response in such uncertain circumstances
2. Also acknowledged is the level of complexity of data, technology interaction and business interaction, including across sectors and across disciplines

MESSAGES

1. The methodology set out in Chapter 2 for developing an unconstrained approach to the ideal network recognizes the evolutionary nature of a new grid architecture; this by definition requires an approach that manages uncertainty
2. The sources of uncertainty are multiple, including Technical, Commercial, Volume and Human aspects
3. The nature of the complexity and likely best approaches for managing it need to be differentiated; one solution will not 'fit all'
4. It will be helpful from a regulatory perspective to understand the financial value of providing flexibility and addressing uncertainty
5. The core approach to managing uncertainty is to maintain flexibility, for example by modular approaches (the Solution Sets are designed to form building blocks)
6. There are well established engineering and project management techniques in this field: the use of Functional Specifications (defining the 'what' not the 'how'), development and adoption of open standards, certification and testing, and effective Change Control are all examples.
7. The GB environment of a privatised and regulated networks sector brings opportunities for ingenuity and competitive behaviours; care will be needed in this complex setting to balance this independence with an appropriate level of co-ordinated actions to bring benefits to all parties, including consumers

COMMENTARY

1) Understanding the elements of uncertainty and complexity is key so that responses can be developed in a systematic way. The diagram below provides a high level summary of the sources of complexity, from which uncertainties can also be deduced.

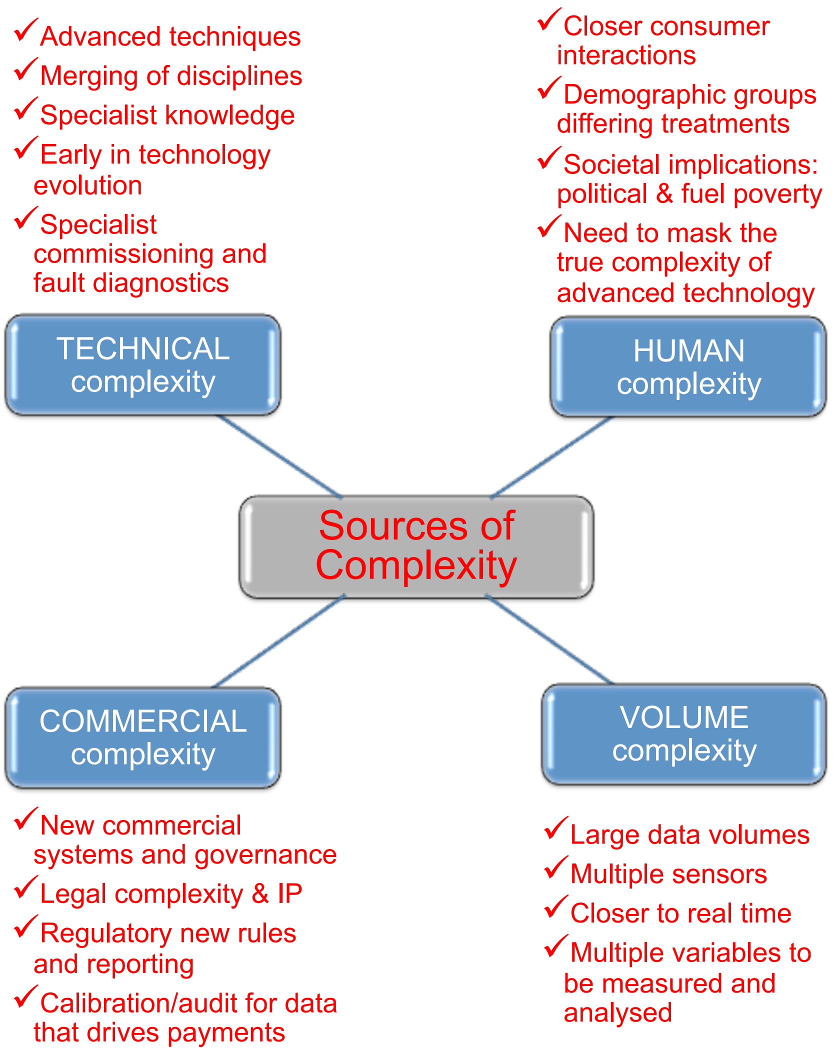


Figure 18: Sources of Complexity

This diagram indicates the four main sources of complexity and shows in red examples of the aspects of smarter networks that contribute to each.

2) The table below sets out the Structural Principles that are offered as a checklist for the development of innovative solutions so that they have a capacity to enable companies to respond to uncertainty and complexity.

3) We note here that costs are likely to be involved in establishing a flexible and responsive way forward; it would be helpful for regulatory purposes to understand the scale of costs and benefits in this area.

4) In this table there are a number of references to the benefits of implementing a co-ordinated approach, developing common (Functional) standards, and for certification and testing. The benefits become evident in efficient procurement, inter-operability, consistency for consumers, and de-risking new technology. While these approaches are well established in the engineering sector, including competitive markets, they require a systematic approach and an investment of time and resource. This is one of the action points identified in Chapter 10 for the network companies.

	Ten Structural Principles for Addressing Uncertainty
1.	**FLEXIBLE & SCALABLE SOLUTIONS:** modularity, adaptability, common frameworks for efficient wide deployment; this needs consideration starting from the first demonstration project, to create a designed-in capability for adaptation elsewhere and up-scaling
2.	**STANDARDISATION**: adopt a Functional approach, work to recognised architectures, use a 'common language' to identify key elements and their interfaces that is understood across different disciplines
3.	**ACCESSIBLE PLATFORMS**: applications should enable third parties to create new service offerings; experience from other sectors indicates that it is likely that highly valuable new services for network companies and for consumers will come about by later adaptations and cross-sector developments; sharing of data requires security considerations to be designed in
4.	**OPEN SYSTEMS**: avoid lock-ins to single solution paths, multiple vendor arrangements are both commercially attractive from a procurement perspective and also facilitate later upgrading
5.	**SUPPORTABLE SYSTEMS**: in service diagnostics, maintainability, rapid repair and failure prediction are key to more complex systems, especially where consumer dependency is raised and responses must be rapid
6.	**RISK & RELIABILITY**: know-how retention needs to be considered from the outset, especially in an emerging field where developments may be rapid, independent test/certification has traditionally been beneficial in engineering projects for risk management and 'right first time' application
7.	**CLOSING DOORS**: avoid lost opportunities for synergies with related projects; work here with W/S4 will be advantageous
8.	**DATA ANALYSIS**: with increasing volumes of data it is important to develop a systematic approach; for example a good principle would be that data analysis should only be done once and at lowest level, and the information/results passed upwards to other users
9.	**HIGH VOLUMES**: new solutions, especially for distribution networks, must have potential to be robustly cost-effective when applied in large numbers; commoditisation is required, not bespoke systems; also multiple vendor base is helpful (which also spreads the know-how)
10.	**INTER-OPERABLE**: new applications must be able to integrate with existing systems and sources, both within the power sector and to associated sectors such a ICT, gas, storage and heat. Development/adoption of common standards is a proven engineering approach in this situation

8. Management Considerations

8. Management Considerations

Management Considerations - Wider Business Aspects

METHOD

1. In addition to developing technological and commercial responses, a number of wider considerations have been identified for network companies
2. These can be expected to feature in all company business plans, and some require further scoping at a national level

MESSAGES

1. The innovative solutions described in this report are rarely of the 'plug and play' type, they are not simply vendor products, rather they are elements of new systems that require associated commercial and business frameworks
2. Accompanying innovation will be new knowledge and new know-how; this is described further in this chapter and may be a key element to effective risk management
3. Comprehensively responding to a new business context is likely to bring benefits at the interface with Regulators, owners and investors
4. It is evident that new skills will need to be available to design, implement and operate the innovative and more advanced systems that will support the electrical power system in the future; this is a significant challenge, viewed at both a company level and from a national perspective

COMMENTARY

1) The table below sets out at high level a number of factors for corporate consideration. None of these is a show-stopper or outwith the capabilities of today's company management to address effectively.

2) However, the issues are non-trivial and they may take a number of years to address to full effect; there may be advantage therefore in considering them as part of a company's strategic direction and business planning.

Network Company – Management Considerations
1. **CORPORATE RISK PROFILES:** understanding risk exposures and mitigating actions; for example, increasing operational dependency on advanced systems, real-time services provided through third parties such as communications providers, data consolidators, and aggregators – who may not have an established relationship with the network company. Note the Sources of Complexity diagram in the previous chapter. Safety Cases may need to be reviewed. The regulatory treatment of 'legitimate' innovation failure and stranded assets may require review.

2.	**KNOW-HOW:** as new technology becomes more pervasive in network company systems, there will be an accompanying increase in 'know-how'. Know-how is more than the information in a manual; it includes aspects such as *why* something has been done the way it is, not just *how* it works, and why alternatives were rejected. This deep knowledge becomes important when systems develop problems, or need to be adapted, or replicated in a similar but non-identical situation. Options for retaining access to deep knowledge need consideration; should it be resident solely in a supplier or partner, or indeed a single person on the company staff.
3.	**SKILLS:** new skills will be required in network company core businesses; these may be extensions of traditional power systems engineering skills, or new technical skills concerned with data management and intelligent processing, or the organizational skill for the management of specialist partners, or skill sets aligned to customer engagement and social/community considerations. Set against the existing demographics of the sector and the relatively low numbers of professional and technician staff in training, this is a topic that warrants early attention if it is not to become a critical path barrier to progress. Further consideration with the relevant Sector Skills Council would be helpful.
4.	**TOOLS & TECHNIQUES**: the Solution Sets reveal areas where new forecasting, modeling and policy evaluation tools will be needed for investment planning, operational planning, and real time operations. These will need specialist development in many cases, and integration into company business and control systems.
5.	**PARTNERING:** the Solution Sets and Enablers table identify many topics and techniques that are outside traditional network company territory; it is likely that new relationships will be required with service providers and partners. This will require continuing attention to contractual frameworks, relationships, shared risk and shared rewards. There is likely scope for innovation here.
6.	**EUROPEAN FACTORS:** GB is not an island when considering the business context; setting aside network company ownership considerations, wider European factors need to be considered in company strategies and plans; this may involve EU Directives, EU Standardisation, working with Vendors who have large EU manufacturing and client bases, EU partners and service providers, and EU network R&D incentives and collaboration opportunities. There is a recognised overhead in EU participation and there may be benefits in adopting a collaborative approach between network companies.
7.	**KNOWLEDGE SHARING:** this is likely to have increasing importance, within & between companies; knowledge of innovation problems may be more valuable than the showcase successes.
8.	**CUSTOMER INTERFACING:** new approaches are likely to be required to ensure that advanced systems interact smoothly for users, whether generation, storage or demand parties.

9. Key Enablers

9. Key Enablers

Key Enablers

METHOD

1. Technical solutions, if considered alone, are unlikely to be successful - wider aspects such as commercial and policy enablers have been considered
2. Future technology opportunities, identified in the Solution Sets, have been reviewed to understand barriers and enablers
3. The degree of engagement needed by consumers and third parties has been reviewed.

MESSAGES

1. A concerted program of commercial and regulatory actions will be required if the potential for innovative solutions is to be realised as the new ‘Business as Usual’, rather than simply isolated demonstrations of innovation. While these are valuable in themselves, alone they will not achieve the network responses needed to meet the challenges set out in the scenarios
2. The program of work to be addressed is potentially large and will require prioritisation and effective project management; it may be helpful for the companies and Ofgem to agree a number of No-Regrets immediate responses in areas such as distribution planning assumptions.
3. New Technology, even that which is reasonably mature, will require application and deployment development to integrate it with network company operational processes and legacy systems
4. Demonstration applications of new devices, particularly those not traditionally owned by network companies (such as storage), cannot usually be supported solely on a straight economic basis from the outset; support of some form is likely to be necessary
5. ‘Research’ for longer term solutions (Smart Grid 2.0) will need to include not only technical issues but also associated consumer interfaces, and social and societal dimensions.

COMMENTARY

1) The Solution Sets have been evaluated to consider key enablers, against four headings: Engineering Content, Consumer & Third Party Engagement, Commercial/Policy Implications, and New Technologies. Other information is recorded in the Notes column.

2) The analysis identifies that innovative applications do not operate in isolation, they are part of a wider and complex system, and their deployment in a network company brings challenges for ways of working including aspects such as data management, decision support, skills requirements and partnering. Ofgem’s RIIO framework and forthcoming ED1 business plans will benefit from holistic consideration of innovation, not only the technology but including its deployment and integration within business processes. This can be a demanding stage in the innovation cycle.

3) The tables that follow summarise the analysis.

9. KEY ENABLERS/1

SOLUTION SETS		Engineering Content	Consumer & 3rd Party Engagement	Commercial/Policy Implications	New Technology Enablers	Notes
Focus: Quality of Supply; enhancements to existing network architecture **(1) SMART D-NETWORKS 1 (Supply & Power Quality)**	2020	Common Functional Standards. Observability requires Sensor devices for use at LV, connectable without system outages. Understand changing consumer voltage performance and trends.	Low/Moderate consumer engagement required initially for this Solution Set. Active engagement required with manufacturers/researchers of power system equipment, domestic appliances, EV chargers/ invertor interfaces. Mandatory standards?	Consider whether the case for waveform management supports mandated standards for invertor interfaces. Policy impact for new loads; revise ADMD assumptions.	Intelligent/adaptive control and protection techniques. Intelligent analysis of smart meter data to detect new load types. LV State Estimation techniques. Harmonic source detection & mitigation. Soft Open Points for power networks.	Need to address immediacy (faster solutions). Notification of EV and HP new loads? Also, should the case be explored for mandatory minimum performance standards for invertors? Risk here of waveform pollution resulting in 'hidden' but substantial costs for the network companies to deal with harmonic current overloading and waveform correction.
	2030	Storage management control systems. Integration of power electronic interfaces (eg associated with storage and DG) to also assist local voltage control.	Use of power electronic interfaces (eg in PV or Storage) for network conditioning will require the co-operation of consumers. Active engagement required with manufacturers/ researchers.	Use of power electronic interfaces (eg in PV or Storage) for network conditioning may warrant commercial recognition for consumers.	Cost-effective mass application devices for waveform improvement. Power Electronic device 'clean' interfaces. Compliance with the '10 Key Structural Principles'.	New skills needed by DNOs, self-monitoring systems that warn of failure or impending failure of advanced controllers.
Focus: DG connections, management of 2-way power flows **(2) SMART D-NETWORKS 2 (Active Management)**	2020	Common Functional Standards. Network measurement data will be needed close to real time. Available from the DCC or are separate arrangements required? Sensors for phasor monitoring required plus real time communications. Consider forward investment for site space and comms. Need to link home automation and network automation.	Active Management will benefit from Responsive consumer demand and DG (DR/VPP techniques). Significant consumer engagement here. Also active development with equipment manufacturers and researchers. Third party links here for smart meter data and home automation.	DR/VPP by consumers will require aggregation, commercial frameworks, and communication links operating close to real time. Special focus needed on deployment at scale. Policy impact for new loads; revise ADMD assumptions. Standards/protocols needed between home automation, intelligent appliances, and intelligent network schemes.	LV voltage control devices, including power electronics for D-FACTS and Tapchange. Fault Limiter devices, including superconducting techniques. Power control devices optimised for LV & MV. State Estimation at LV and MV for network observability. D-FACTS could be interconnected at DC for power flow management. Solid state transformers. Silicon Carbide and CVD devices.	New design/control philosophies needed to integrate traditional centralised control with dispersed local controllers. Roles emerging here for Service Providers, including 3rd parties. Migrations from military applications hold promise here (compact, high power devices). Opportunities for DSO roles.
	2030	Rapidly deployable storage solutions could provide an effective 'immediate' solution to network constraints created by new demand types. As devices become more dynamic and intelligent it will be important to consider the company's Systems Architecture for data management, decentralised processing, control room and asset management platforms.	High consumer engagement needed to integrate/aggregate domestic DR/VPP and storage for network purposes. Third party links here for smart meter data and home automation, home DG and storage devices.	Fully commercial systems integrated with other developments such as Smart Ancillary Services, see below.	Cost-effective mass application devices for voltage, fault level & power flow control. DC multi-terminal grids at LV and MV. DC/DC converters. DC circuit breaker solutions needed. Controllers for Plug & Play LV storage solutions. Management of networks with very low fault infeeds needs new protection solutions.	Active control systems across wide geographies, multiple voltage levels, and different consumer types will require special care to avoid unmanageable complexity and adverse interactions. Risk Management requires a Systems approach.
Focus: plant & systems reliability, failure mode detection **(3) SMART D-NETWORKS 3 (Intelligent Assets)**	2020	Common Functional Standards. Extend today's Proof of Concept applications (eg Dynamic Ratings) to fully commercial applications across all asset types. Anticipate asset failure modes and identify requirements for new monitoring devices. Note also new materials and designs to improve the performance of assets in their setting (eg space/height or EMFs)	Limited consumer engagement required here, with the important exception of assets that require Planning Consents. Development area with researchers and manufacturers.	Limited commercial or policy impacts anticipated here.	Gas Insulated Lines (GIL), New tower designs, Failure mode detection in insulation (eg Partial Discharge), Mechanism diagnostics (eg tapchangers and circuit breakers), have increasing potential merit if effective and economic.	Increased monitoring will create significant data volumes. Intelligent processing required and architecures for data transmission and storage. Potential role for service providers. Policy needed for information sharing (NEDERS future role?). On wider matters, note that new technologies may assist obtaining Consents (eg improved conductor and insulation materials enabling more power through the same line corridor)
	2030	Integrate new materials and designs (eg line conductors and towers) to both improve route capacities and ease consenting. Loss minimisation will be important for high utilisation networks.	As above, but noting that data exchange (two-way) between network assets and consumer assets will increase. New territory here that needs care and consideration.	Loss minimisation needs to be a system level optimisation (eg trade offs across voltage levels); this is likely to require Regulatory Incentives to be revisited.	Cost-effective mass application devices for condition monitoring. Comply with the '10 Key Structural Principles'.	Asset data close to real time will become a key management tool. Data quality control and intelligent filtering will be key competences. Note that circuit load sharing and connectivity is as important as individual capacity enhancements.

	SOLUTION SETS		Engineering Content	Consumer & 3rd Party Engagement	Commercial/Policy Implications	New Technology Enablers	Notes
Focus: Security of networks inc. physical threats, utilising new network architectures	**(4) SMART D-NETWORKS 4 (Security & Resilience)**	2020	New thinking is needed in regard to long-standing 'givens' for networks. Radical new philosophies (eg intentional islanding using distributed resources) may be justified to address significant uncertainties around threats arising from climate change and to enable policy changes to network security standards that will reduce infrastructure costs Important to engage with ongoing national CC mitigation plans led by government. These are cross-sector.	Significant consumer impact: perhaps necessary to understand the concept of 'essential load' rather than 'always on'. Interfacing to home energy management systems for limiting to essential loads and for DR and local storage controllability: EV charging and V2G consent. Development with researchers and manufacturers, also inter-sector infrastructure impacts.	Entirely new technical standards (inc. ESQCR, & P2/6) and regulatory licensing and incentives and Output Measures likely to be required for intentional islanding utilising distributed resources. This could be a show-stopper preventing early Proof of Concept developments.	Research and modelling required for islanding feasibility. International lessons from micro-grids relevant. Proof of Concept for Synthetic Inertia devices for islanded networks. Island controllers that integrate DR and Storage. Techniques for real-time topology selection. Knowledge of network boundary condions required for topology and protection reconfiguration. Re-synchronisation techniques.	Increasing network resilience can be viewed as a CC mitigation response; however identical outcomes apply when considering terrorism (malicious attack). Note wider benefits for islanding in regard to security of supplies investment policies. The radical nature of developing this capability is likely to include presenting a Safety case. Note that micro-grids are receiving close attention from the US military (oil dependency reduction).
		2030	A high standard of Systems thinking will be required, spanning distribution and transmission, and consumers. An evaluation & migration project in its own right?	A new consumer relationship needs to be established for the long term; requiring a conceptual appreciation of energy supplies. Unlike many smart grid issues where consumer engagement can be minimised by automation, this situation differs. Potentially a new national approach to develop with government for critical infrastructure resilience.	New frameworks required that are integrated with wider sector impacts (see Community Energy and Connected Communities). As innovative applications become proven, the task will become achieving wide application (making them Business as Usual); this is a challenging aspect of the innovation cycle that needs to be recognised under RIIO. It requires highly effective innovation in itself.	Commercial solutions for the control devices for islanded networks, integrating DR and Storage. Techniques for real-time topology selection. Re-synchronisation techniques.Mass application needs low cost solutions.	See Smart Community Energy and Smart Buildings and Connected Communities for further opportunities. Note that power electronic devices could be designed for 'soft failure' ie partial operation rather then no operation in the event of malfunctions; this raises the concept of planning standards that recognise, say, 'N-0.3' operation.
Focus: Enhancements to Transmission Networks to add to existing smart functionality	**(5) SMART T-NETWORKS (Enhancements)**	2020	Many aspects of the GB transmission system are already 'smart' when compared with the current stage of evolution of distribution networks. For 2020, deployment of existing techniques will continue, but with the emergence of increased network intelligence, embedded DC links, more automated post fault response and dynamic ratings.	Little or no impact on consumers connected to D-Network (except indirectly for Planning Consents). Potentially greater engagement required for T-connected consumer and generators. Research and manufacturer engagement.	Limited impact for policy and regulatory frameworks to 2020. although the basis of investment signals for the network as a whole needs to reflect the potential benefits of anticipatory investment in place of today's incremental investment approach. Commercial frameworks need to be implemented to utilise D-Network aggregated services for constraint management (delivering moderately fast response but not real time).	Techniques for forecasting & modelling new demands (eg EVs). Integration of this with DNOs for data, once-only processing, and upwards consolidation. Techniques for real time stability/dynamic assessment addressing both D and T voltage levels.	See also the Solution Set for Advanced Control Centres. A new approach will be required to whole-system, multi-voltage level operational intehgration and optimisation. This will extend to smart buildings and private networks.
		2030	For 2030 it is likely that new solutions and smarter systems will need to be developed for the transmission system, including the wider use of DC, more interconnection with continental Europe and Ireland, and advances to respective control systems. Closer DNO/DNO/TSO operational integration.	Transmission system management can be expected to be deploying aggregated DR and VPP and Storage export services from consumers connected to D-Networks. Consumer engagement needs to be High, but most likely interfaced by parties other than the TSO itself.	The closer integration of D and T Networks and their consumers and services is likely to require re-appraisal of T network planning and security of supply policies. Commercial frameworks need to be implemented to utilise D-Network aggregated services including response/reserve (delivering responses close to real time).	PMUs and WAMPACs (Wide Area Monitoring Protection & Control integrated solutions.	Quality and robustness of service provision aggregated from D-Networks will be critical, yet not under the direct management of the TSO. New levels of DNO/DNO/TSO integration and partnering required. Highly robust comms needed for WAMPACs.
Focus: EV charging / discharging (V2G), Network management, Demand Response and other services	**(6) Smart EV Charging**	2020	Common Functional Standards required both for network functionality and for the interfaces to EVs. Rapidly deployable solutions needed to meet consumer immediacy. Recognition that smart charging may not be the whole solution and that traditional reinforcements will be required to a greater or lesser extent. These would not obviate the value of EV DR for wider system benefits.	Medium/high level of engagement with EV drivers required. This is needed before EVs start to cause network overloads in a locality. Perhaps a linkage to the car point of sale and/or the installation of home charging facilities. Research and manufacturer engagement, also charging facility providers.	Essential to have commercial arrangements in place that reward the EV owner for engaging in Demand Response (and V2G). Value 'saved' by the DNO in deferral of LV reinforcement could be shared with EV owners. Important to develop standards so that EVs will interface smoothly with smart charging network applications.	Plug & Play, low cost for mass deployment, solutions including: network state estimation to make loading visible, smart charging controller logic (intelligence), communication channels and standardised protocols, self managing systems with overview level integration to DNO control centre. Wireless (inductive) charging.	Essential to have active co-operation with EV manufacturers and/or promote retrofit kits for EVs. Rapid roll out will be key to satisfying consumer expectations. EV solutions require commonality across Europe.
		2030	Enabling these facilities to be implemented at local level will require suitable secure space to be available, perhaps combined with storage at LV level. Consideration of forward investment for space and communication channels.	More comprehensive consumer engagement required to extend these facilities for V2G energy export. International stanardisation, especially for Europe to consider for Evs and charging points and systems.	Aggregation across multiple local smart charging schemes will be needed to offer Ancillary Services or wider network constraint management.	Forecasting and modelling with integration of analysis between DNO/DNO/TSO required. V2G should be integrated with other local storage sources, requiring System leveloptimisation for charging and discharging.	EV charging is likely to be high sensitivity for consumers (if charging is more expensive than should be necessary, or if charging is insufficient). Management of data quality, controller integrity, and diagnostics will be crucial.

9. KEY ENABLERS/3

	SOLUTION SETS		Engineering Content	Consumer & 3rd Party Engagement	Commercial/Policy Implications	New Technology Enablers	Notes
Focus: Electricity storage at domestic, LV, and MV levels, and above (static storage devices)	**(7) Smart Storage**	2020	Common Functional Standards for devices and their interfaces. Proof of Concept at domestic, street, community and system levels. Practical solutions for siting, safety and environmental compliances.	Domestic elec storage requires Med/High customer engagement. Aggregation and commercial frameworks essential for new services (import/export). EVs as storage (DR & V2G) offers strong benefits - requires high consumer engagement. Research and manufacturer engagement.	Forward investment implications of reserving space in new developments for storage (eg in new LV substations). Licence/ ESQCR/ P2-6/ Output Measures/ Planning Policies all require urgent consideration as they are serious roadblocks to progress. Clarity required regarding which parties may own and operate storage.	Autonomous local controllers harmonised with system-wide integrated controllers. Combine network observability with energy balancing and carbon optimisation. Alternative devices include: Lithium Ion, NaS, Cryogenic CAES, Isentropic, Redox flow, flywheel, Modern Lead/Acid. Future Graphene applications perhaps. Note also heat storage as hot water, molten salts or metals.	Potential appears to be strong for storage to provide rapidly deployable network solutions. Physical/practical issues need early consideration - consider space reservation at new developments? For storage devices attention may be required to address the safety case and demonstrate it. Storage solutions require suitable charge/discharge control and commercial frameworks.
		2030	Tracking and management of ageing of storage devices and their reducing storage capabilities. Optimisation of the national storage fleet.	New energy storage mediums may become attractive at community scale deployment and above. New definition of 'consumer' required and new approaches. Research and manufacturer engagement.	Cross-vector energy developments (elec/gas/ heat/etc) require consideration of legal and regulatory frameworks.	Controller architectures for system wide optimisation, combining central co-ordination with dispersed control management and monitoring.	Opportunities for integrating energy storage across different vectors. New service and business opportunities. EV battery '2nd Life' possibilities for static applications.
Focus: Geographic and social communities in existing built environment	**(8) Smart Community Energy**	2020	Interfaces to community groups, technical content, social responses and so on need to be blended with the networks engineering provision. Define and create a new societal dynamic. Develop integration of elec/gas/heat/water and establish practical solutions.	New approaches needed to consumer engagement. Social and legal constructs required. New third parties to engage here to bring social interaction development.	Commercial frameworks for energy 'trades' between community members. Further analysis needed to define an 'energy community', especially in urban areas.	In addition to the technical developments noted elsewhere, including self-islanding using distributed resources, this Solution Set requires development of social/technical interaction aspects, beyond simply consumer engagement. Opportunities for efficient central HPs.	Potential for strong consumer engagement, sense of energy ownership with new community incentives for change. Basis for smoother Consents processes. Integration of Smart Buildings with community network management. Experience from international micro-grid developments relevant here.
		2030	Potentially alignment here with Smart D-Networks 4, self-islanding. Storage locations (and future provisions) require consideration. Also the potential for community scale DG/Heat optimisation.	In a world of strong 'Localism' there are likely to be new requirements at the interface between the energy system and the local social/political mechanisms. Mechansims of local democracy to engage with also.	Integration of community energy and regional/national energy management and carbon optimisation.	Development required for integration of autonomous Community Energy schemes with System level management and optimisation.	At a community level, consider AD/Biogas integration. Gas as local storage medium. New service opportunities, including scope for 3rd parties.
Focus: SME, C & I buildings, and all aspects of new Built Environments	**(9) Smart Buildings & Connected Communities**	2020	Inter-sector engineering engagement required between the Networks and Built Environment professionals. Shared functional standards essential for efficient progress and minimum cost and risk.	Medium/High consumer engagement, noting that the consumer may be a management service operator for a commercial building, a community building (eg leisure centre), or a municipality/community. Increasing links to the Building Automation sector.	Network Investment Planning policy and reglatory frameworks will require revisiting.	Consideration of technologies that may be more effective and efficient at increased scale, such as Heat Pumps.	Note the Smart Communities and the Smart Networks - 4 Solution Sets. Lead opportunities likely at Eco-town developments.
		2030	Engagement with Town Planners required to understand the opportunities and risks as urban and rural developments become more 'connected'. This underpins regeneration, jobs and exports.	In the longer term there will be links here to Localism Agendas, with a potentially wider role for energy that spans energy sectors and Critical National Infrastructure.	Network Investment Planning policy and reglatory frameworks will require revisiting; also the concept of supply security and resilience.	New opportunities for 'district heating' schemes where low carbon and higher efficiencies may make this economically and socially attractive.	Connected Communities require consideration of communications and transport infrastructures in addition to all utility services.
Focus: Ancillary Services for local and national system support	**(10) Smart Ancillary Services (Local & National)**	2020	DR closer to real time required for new aggregated fast-response/reserve offerings. Faster comms, data processing & Q/A validation required.	Medium/High customer engagement required for aggregated DR services. Links with all sizes of consumers to be considered here.	Aggregation and commercial frameworks required for domestic and SME consumers to ensure efficient and secure deployment of DSR. Operating standards need to be developed at Distribution level.	Fast data handling and processing required 'on demand'. Opportunities for establishing fast-tracking of this particular service through the DCC systems, or is a dedicated parallel system required?	Industrial DR assumed to be largely established although new opportunities may be opened by smart techniques (eg integration with building management systems). DSO roles may be attractive here, or services by 3rd party providers.
		2030	Extend the above principles to power export from DG/VPP/V2G/Storage opportunites for new services.	Super-aggregation required of DR services across homes/communities/buildings to consolidate into a national provision to the TSO. New thinking required about who is the customer and who manages the relationships.	Aggregated DR/Export services have high potential market and networks value. An impartial 'Services Operator' may be needed to ensure resolution of conflicting service calls by the interested parties.	Engineering & Commercial system robustness will be esential if new services are to relied upon at a national system level, including during times of system/data high loads and stress.	Integrated Systems thinking needed if the many elements are going to coalesce to deliver a high quality, high value new service. Government, Regulator, & Industry joint leadership needed.

SOLUTION SETS		Engineering Content	Consumer & 3rd Party Engagement	Commercial/Policy Implications	New Technology Enablers	Notes
Focus: T&D control centres of the future **(11) Advanced Control Centres**	2020	Visualisation/operational management techniques required for aggregated D-Network services and data (eg DR, VPP, V2G and Phasor Monitoring of stability).	No direct customer engagement necessary. Manufacturer/ researcher links required.	At control centres the direct commercial implications will be call-off and settlement mechaisms for new services, typically derived form D-Networks and their consumers.	Operator interface techniques required for handling complex, multi-source services. Stability monitoring required across multiple voltage levels.	Consideration needed for how these new opportunities will be integrated into a European Supergrid, and the impacts of increased national interconnections.
	2030	Integrated methodologies required between DSO/DSO/TSO to avoid needless duplication and data delays. Hierarchy of data collection, processing and consolidation required.	No direct customer engagement necessary.	With increasingly complex and inter-dependent systems, data quality and platform robustness will become key.	Increasing automation and intelligent advice will be needed to relieve operator burden and determine optimal outcomes for security, cost and carbon.	Interactions with the controllers of growing numbers of DC links will require attention for optimisation decisions.
Focus: Enterprise-wide platforms within companies **(12) Enterprise-Wide Solutions**	2020	Policy development for technical and commercial aspects of shared platforms, ensuring flexibility for future unknowns	No direct customer engagement necessary.			Potentially, inter-company platforms may be benficial, including provision by third parties
	2030	Intelligent systems able to operate seamlessly with dispersed niche solutions.	No direct customer engagement necessary.			

Figure 19: The Enablers Summary Table

4) The table below shows a more detailed, but still high level, assessment of the new commercial frameworks likely to be needed and their level of refinement. A summary panel at the foot indicates the impact for 2020 and 2030.

Commercial Frameworks

SOLUTION SETS	Year	New Commercial Needs	Application
(1) SMART D-NETWORKS 1 (Supply & Power Quality)	2020	0	(data from smart meters and home devices)
	2030	1	home devices provide power quality services
(2) SMART D-NETWORKS 2 (Active Management)	2020	0	Mainly Proof of Concept initially; ad hoc frameworks
	2030	2	DR services for networks and data DSO/DNO/TSO
(3) SMART D-NETWORKS 3 (Intelligent Assets)	2020	0	(data from smart meters and home devices)
	2030	0	
(4) SMART D-NETWORKS 4 (Security & Resilience)	2020	2	(data from smart meters and home devices)
	2030	3	Demand/DG/ Storage/ V2G interactions for network islanding
(5) SMART T-NETWORKS (Enhancements)	2020	1	Mainly Proof of Concept initially; ad hoc frameworks
	2030	3	TSO aggregation of consumer DR/ DG/ Storage/ V2G
(6) Smart EV Charging	2020	2	basic smart charging for EVs domestic, street, and car parks
	2030	3	full smart charging for EVs domestic, street, and car parks inc V2G

SOLUTION SETS	Year	New Commercial Needs	Application
(7) Smart Storage	2020	2	basic commercial frameworks for home and 3rd party devices
	2030	3	full commercial frameworks for home and 3rd party devices
(8) Smart Community Energy	2020	2	basic aggregation/ local trading within communities
	2030	3	advanced aggregation/ local trading/ between communities
(9) Smart Buildings & Connected Communities	2020	1	DR/ DG/ Storage services traded by buildings and private networks
	2030	3	DR/ DG/ Storage services traded by buildings and private networks
(10) Smart Ancillary Services (Local & National)	2020	2	TSO aggregated DR/ DG/ Storage services from LV & MV
	2030	3	Comprehensive TSO/DSO procured national services inc V2G
(11) Advanced Control Centres	2020	0	Control Centres wil be impacted by the other services described above
	2030	0	
(12) Enterprise-Wide Solutions	2020	0	Enterprise solutions may adapt or create frameworks
	2030	0	

No Impact	0	
Limited Impact	1	existing system functionality, development and replacement
Moderate impact	2	new commercial arrangements required - basic eg availability/use fees
High Impact	3	new commercial arangements required - comprehensive eg Data Handling/Data Analysis/Funds transfers/trading pe

SUMMARY OF THE INITIAL ASSESSMENT

		2020	2030
No Impact	0	5	3
Limited Impact	1	2	1
Moderate impact	2	5	1
High Impact	3	0	7

10. Project Deliverables

10. Project Deliverables

Project Deliverables

METHOD

1. This section draws together the key conclusions and Next Steps actions
2. It recognises that actions will need to be taken forward by a broad constituency of stakeholders, and considered alongside the wider agenda of the Smart Grid Forum
3. The twin requirements for elemental development (Solution Set building blocks), and for strategic development (a whole systems view) have been considered
4. Corporate and management issues have been identified
5. The Solution Sets are proposed as the building blocks for next steps

MESSAGES

1. The significant number of separate parties involved in delivering effective smart grid solutions for Britain will require concerted project co-ordination
2. A broad plan is needed that identifies critical 'intervention points', for example windows of opportunity linked to DECC or Ofgem developments and RIIO work programmes
3. Innovative solutions commonly span traditional boundaries of voltage level and distribution/transmission classifications, and extend to third parties
4. An overview of business impacts for network companies is set out and concludes that a number of challenging issues can be expected for both technical and management agendas, and that they will require sustained attention over a number of years
5. There will be increasing interaction with network company business plans and a shared expectations will be need to be developed with the regulator
6. Phase 2 of the project will be the opportunity to establish a quantitative assessment of the Solution Sets, and the extent of their application considering regional and economic variations, urban / rural applications and the effects of clusters of new demands, storage, and generation types

COMMENTARY

1) The scale of the work described in this report is significant, when compared with the last 50 years of GB network development. The probable pace of the changes required is perhaps a greater challenge than the magnitude of the task.

2) The scale of what is anticipated is not insurmountable, but there is an urgency to consider mobilisation, particularly in regard to long lead-time elements.

3) In regard to scale, it may be instructive to consider, for example, data requirements: it has been estimated that all GB smart meter data for 15 minute resolution for one whole year is 10^6 times less than the internet traffic in one month.

4) Other sectors have demonstrated their ability to put in place significant engineering and commercial infrastructure in a relatively short time; the mobile phone industry is a case in

point. They had the advantage of a green-field situation, but nevertheless their achievements are considerable. A key lesson from their sector has been that, the highly competitive market notwithstanding, there has been close co-operation between the players to put in place common descriptions, common standards, and testing; this has been co-ordinated through the GSM Association. www.gsm.org/. Parallels with the mobile phone industry can be illuminating, but inevitably have their limitations; a significant difference is of course the very high customer pull for their products.

5) There is a span of action points in this report for consideration by the Smart Grid Forum, requiring evaluation alongside the Forum's overall agenda, and noting the need for a project approach that identifies critical paths and dependencies, and flags up the windows of opportunity (intervention points) arising from, for example, DECC and Ofgem initiatives and the RIIO programme.

6) The broad span of actions in this report also requires consideration of the twin approaches to development, which it is important are harmonised. The diagram below represents these approaches.

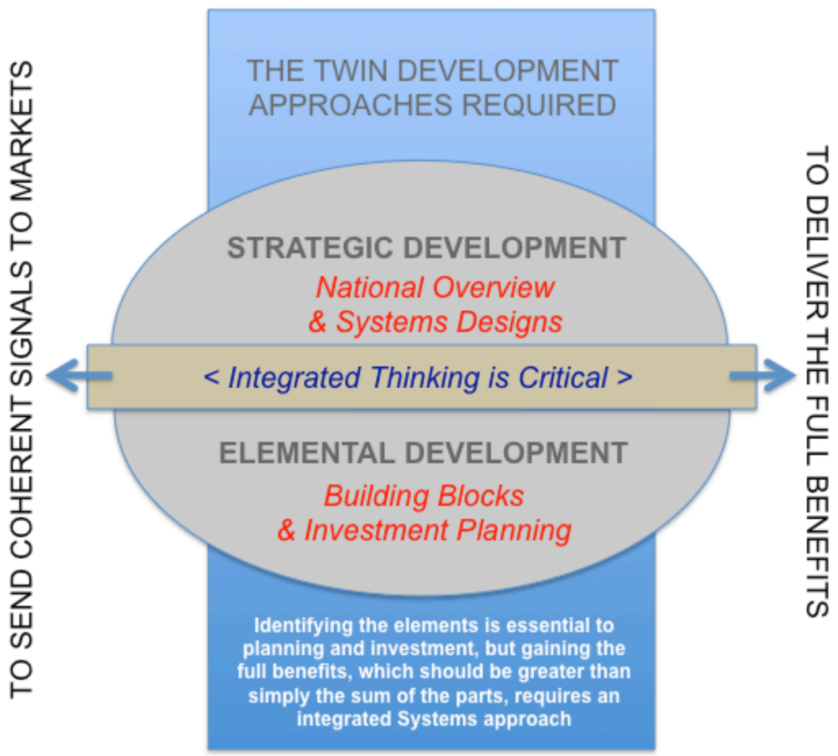


Figure 20: The Twin Development Approaches

The diagram indicates the twin development approaches: Strategic and Elemental.

The latter results in the building blocks necessary for investment planning, while the former is essential for bringing together the component parts into a coherent whole.

The integration of the two is needed to achieve the full benefits and to send coherent signals to markets and stakeholders. The Strategic/Systems approach needs to be assessed at a number of levels: for example at a company level, a System Operator level, and a National level. The national level might consider for example the GB generation portfolio, its mix of generation types, its operability across different load profiles, and integration with other energy sources including community heating. The implementation of aggregation systems (say for demand response, distributed generation, or distributed storage) will result in local actions having regional and national impacts.

7) A high level business impact assessment for the Solution Sets is shown in the following table; it has been made against the following headings: Degree of Innovation Challenge, Opex Impact, Capex Impact, and New Skills (for DNOs). The simple scoring system is

indicated in the Legend, and for interest the scores for each line are summed in a column to the right.

Indicative Assessment of Solution Sets – business impact for Networks Companies

Business Impact Overview for Networks

SOLUTION SETS	Year	Maturity Degree of Challenge	Opex Impact	Capex Impact	New Skills for DNOs	TOTAL
(1) SMART D-NETWORKS 1 (Supply & Power Quality)	2020	2	1	2	1	6
	2030	3	1	2	2	8
(2) SMART D-NETWORKS 2 (Active Management)	2020	2	2	2	2	8
	2030	3	2	2	3	10
(3) SMART D-NETWORKS 3 (Intelligent Assets)	2020	1	1	1	1	4
	2030	3	1	2	2	8
(4) SMART D-NETWORKS 4 (Security & Resilience)	2020	2	1	2	2	7
	2030	3	2	3	3	11
(5) SMART T-NETWORKS (Enhancements)	2020	1	1	2	1	5
	2030	3	1	2	3	9
(6) Smart EV Charging	2020	2	2	2	2	8
	2030	3	2	3	3	11

SOLUTION SETS	Year	Maturity Degree of Challenge	Opex Impact	Capex Impact	New Skills for DNOs	TOTAL
(7) Smart Storage	2020	2	1	2	2	7
	2030	3	1	2	3	9
(8) Smart Community Energy	2020	1	2	1	2	6
	2030	3	2	2	3	10
(9) Smart Buildings & Connected Communities	2020	1	2	1	2	6
	2030	2	2	2	3	9
(10) Smart Ancillary Services (Local & National)	2020	2	2	1	1	6
	2030	3	2	1	3	9
(11) Advanced Control Centres	2020	1	1	2	2	6
	2030	2	1	2	2	7
(12) Enterprise-Wide Solutions	2020	1	1	2	1	5
	2030	2	1	2	2	7

No Impact	0	
Limited Impact	1	Extensions to established activities
Moderate impact	2	Innovative solutions, selective application, moderate costs
High Impact	3	Innovative solutions, potentially challenging, wide application

Figure 21: Indicative Impact of Solution Sets for Network Companies

8) The following subsections address specific Observations and Next Steps.

10.1 Consumer Benefits

10.1 Consumer Benefits

Consumer Benefits

METHOD

1. It has been implicit throughout this report that networks are important facilitators of a low carbon future, and therefore must fundamentally deliver effective and affordable solutions for customers
2. Furthermore, these solutions will commonly require engagement by consumers and third parties and this report seeks to ensure that such aspects are 'designed in'

MESSAGES

1. New consumer requirements, such as connecting domestic-scale generation, or charging electric vehicles are likely to be met most cost-effectively and with least disruption through innovative smart grid solutions
2. Consumers are expected to have an increasing dependency on secure and high quality electricity supplies and smart solutions offer many opportunities to enhance service levels and responsiveness
3. Demand Response techniques can benefit the electricity supply chain by helping accommodate the balancing of intermittent renewable sources, thereby reducing back-up generation support (system reserve); this is a valuable service with potential for returns for consumers
4. Opportunities will develop for consumers to play an increasingly active role in energy delivery and ancillary services, and this can be expected to be economically attractive to them as well as satisfy wider public aspirations for energy efficiency and the use of clean power sources
5. It is recognised by the companies in the power sector that the level of understanding and interest by typical consumers is at present low, as regards the power network and how the overall system works; it is therefore essential that attention is given to 'designing-in' attractive consumer interfaces, providing automation and intelligent systems, and providing informative explanations and attractive commercial offerings.

COMMENTARY

1) There is overall a positive message here for consumers as regards service quality, new offerings and opportunities, and cost-effective solutions for networks as they are adapted to the new scenarios ahead. Other aspects have been discussed previously in Chapter 3.

2) The issue of explanations and communications with consumers and the wider public warrants further consideration by all the stakeholders. A balance is needed to establish a shared basic level of understanding (e.g. common concepts and terminology to avoid creating confusion), while encouraging the best of competitive offerings from different players.

3) The table below summarises the Consumer engagement likely to be required for each of the Solution Sets:

			Consumer Engagement by 2020 / = Low // = Moderate /// = High	Consumer Engagement by 2030 / = Low // = Moderate /// = High
Solution Sets	1.	**Smart D-Networks 1** (Supply and Power Quality)		/
	2.	**Smart D-Networks 2** (Active Management)	/	///
	3.	**Smart D-Networks 3** (Intelligent Assets)		
	4.	**Smart D-Networks 4** (Security and Resilience)	/	///
	5.	**Smart T Networks** (Enhancements)		//
	6.	**Smart EV Charging**	//	///
	7.	**Smart Storage**	/	//
	8.	**Smart Community Energy**	/	///
	9.	**Smart Buildings and Connected Communities**	/	//
	10.	**Smart Ancillary Services** (Local and National)	//	///
	11.	**Advanced Control Centres**		
	12.	**Enterprise-wide Solutions**		

4) This high level analysis indicates that not all Solution Sets require consumer engagement, but 8 of them will require Moderate or High engagement by 2030. In many cases, including those indicated as requiring 'High' engagement, there will be little burden on consumers provided they are willing to engage with automation systems – these must be engineered from the outset to be effective and have attractive and intuitive user interfaces. A new challenge perhaps for the power sector and its engineers.

10.2 Business Planning Inputs

10.2 Business Planning Inputs

Business Planning Inputs

METHOD

1. It is acknowledged that each company will develop plans that reflect its own operating environment and objectives
2. A key deliverable of this report is to offer a structured approach to company business plans that helps provide consistency for planning and subsequent design, procurement and implementation, and regulatory oversight

MESSAGES

1. This report proposes a systematic approach to the smart grid implementation agenda, setting out a framework of Solution Sets and Use Cases
2. In each there is much detail to be developed, but the approach here is one of developing Functional Specifications that will facilitate open systems and multi-vendor opportunities
3. There will be investment (both opex & capex) and skills implications for each company to consider against its local context, and a need for developing strategic approaches that mitigate risk and take best advantage of knowledge sharing
4. A systematic and co-ordinated approach can be expected to bring advantages to network companies, the regulator and key third party stakeholders; while each company will wish to make its own implementation plans, there is however a strong case for laying the foundations on a common basis – for example, developing Standards and common Functional specifications; this will provide economy of effort, ensure consistency of interfaces for users and their appliances connecting to the networks; create procurement efficiencies; minimize technology risk and create open systems that encourage competition and avoid lock-in.

COMMENTARY

1) Appendix 1 provides pointers for utilising the Solution Sets as the building blocks for cost benefit analysis by the Smart Grid Forum, and utilising the 'unit costing' of the Sets and their component elements for Business Plan development under ED1.

2) An open approach to Solution Set development and related actions will provide helpful regulatory transparency.

10.3 European and Wider Influences

10.3 European Influences

European and Wider Influences

METHOD

1. It is acknowledged that UK needs to interface effectively with European network developments and policy formulation
2. Attention should also be given to developments elsewhere that may be formative internationally, notably the USA (NIST standards for example)
3. Some aspects of engagement may take the form of representation to ensure that national exceptions are taken into account, and others will be opportunities to gain from contributing to the development of European standards, engaging with energy projects, benefitting from incentive funding, and shared learning from European Research and deployment projects

MESSAGES

1. There will be opportunities for gaining knowledge, skills, products and, on occasion, funding by means of increased European engagement
2. Timing is a key issue to ensure that opportunities are not lost and it is possible that the Smart Grid Forum Horizon Scanning Workstream may assist here
3. Engagement with EU activities can be time intensive and requires deep knowledge expertise; a shared-industry approach is likely to have benefits for GB stakeholders
4. Experience shows that there is only limited opportunity to shape European policy once it reaches the stage of formal public consultation; to be certain of influence it is necessary to be 'in at ground level', to contribute to working groups, and establish a network of international relationships

COMMENTARY

1) There are a number of significant European programmes running that have UK representation; however there are others where we have little or no engagement. The European agenda is expanding including significant infrastructure proposals such as the 'European Super Grid. This is envisaged to be a long-distance, high power transfer, DC network overlay connecting all Member States. A UK government Select Committee has recently published its findings and is supportive of the concept.

2) European institutions now active in the smart grid agenda include EII for industry, EERA for research, ERA-NET, EIT-KIT, as well as the SET Plan being at the heart of the European strategy.

3) To accelerate Smart Grid deployment, the Commission proposes to focus on: developing technical standards; ensuring data protection for consumers; establishing a regulatory framework to provide incentives for Smart Grid deployment; guaranteeing an open and competitive retail market in the interest of consumers; and providing continued support to innovation for technology and systems.

10.4 Risk Summary

10.4 Risk Summary

Risk Summary

METHOD

1. The report acknowledges the many aspects of risk and the changes likely in response to the implications of low carbon enablement
2. Risk mitigation has been considered, particularly as part of the references to systems thinking and the management of uncertainty.

MESSAGES

1. There are risks to consider and mitigate for projects, corporate business, Customers, and the Government/Regulator
2. Some changes in risk will require mitigation by policy changes, some may become embedded in the commercial framework of network companies, others will benefit from open knowledge sharing where that does not conflict with commercial or other confidences
3. These have been noted in Chapters 7 and 8

COMMENTARY

1) Risk issues are referenced in Chapters 7 and 8, and the Engineering Application section that follows can be viewed as part of risk mitigation.

2) The table below identifies some of the risks identified when considering the innovation agenda for networks.

Some Risks Associated with Innovative Network Developments
• The quality of data and the reliability of its communication links is key to intelligent and real time systems; reliable sensors, data validation and systems monitoring therefore have increasing importance
• Cyber security and Data privacy are growing risk areas and defences need to be designed-in to new systems and captured in new business policies
• System stress testing, especially associated with large data volumes, commonly only happens on real systems with real customers
• In moving to applications that are more complex, dynamic and distributed, attention needs to be given to a company's Systems Engineering design to avoid incompatibility between applications, a 'house of cards' cumulative complexity risk, and functionality restrictions that diminish the operational and commercial value of

new applications
• Good technology will fail to deliver results if necessary consumer engagement is absent
• If incentives are misaligned across the supply chain, there is a danger that the benefits of electricity storage will go untapped; the EMR could play a role here
• Aggregated systems, for example Demand Response, could provide key real time system management services; however in the early years while numbers are small it may be problematic to derive the commercial benefits, even proportionately, because a statistical critical mass has not been reached
• Noting the likelihood that all residential and most SMEs will have a smart meter by 2019, a pressing need arises for DNOs to determine the implications for their existing IT systems if they are to be fit for purpose in being able to make full use of the rich new information that will become available
• Increasing rental trends (combined with landlord disincentives for engagement) may impact adversely on smart facilities in homes and buildings
• Loss of diversity in demand after Demand Response and similar interventions
• Shortages of skilled staff (technical and commercial) in network companies result in new innovative projects being deferred and successful demonstration projects not being rolled out for wider deployment
• Successful technology innovation at demonstrator scale may not provide evidence of its ‘outputs’ and network benefits, particularly in its early years (e.g. where constraints have not started to bite or critical fault events do not arise)
• Whole system benefits optimisation is at risk unless regulatory and/or commercial frameworks evolve sufficiently to ensure an integrated (inter-party) approach to investment cases based on holistic benefits
• While focus is understandably given to deployment activities, including Low carbon Network Fund smart grid projects, it will be important to attend also to the innovation ‘supply pipe’. The innovation sequence from Research, through Development, to Demonstration and Deployment (R,D,D&D) has an unavoidably lengthy time cycle and a balance is needed for the attention of time and funding to ensure that the supply pipe remains primed. Effective research programmes in the power systems area invariably require the engagement of manufacturers and network companies from the outset.
• There is risk in *not* doing things, including failure to meet the Government’s carbon and energy efficiency targets

10.5 Engineering Application

10.5 Engineering Application

Engineering Application

METHOD

1. In reviewing expert advice, and experiences from existing smart grid developments, a number of generic engineering good practices were identified
2. These are expressed at high level and intended to act as prompts for promoting good practices, learning from lessons elsewhere, and promoting 'right first time' smart grid developments

MESSAGES

1. There is merit in establishing key principles that can inform the development of physical trials, and also help the review of conclusions
2. Technical design should run in parallel with development of commercial and regulatory frameworks, and user interfaces
3. Engineering applications are rarely stand-alone and must be integrated with a company's Systems Architecture, at a physical network level and in regard to data management, processing and IT platforms: this may be a challenging task and requires early attention
4. Technical robustness, low maintenance overheads and the application cost / price are important defining features for the high volume products envisaged in wider smart grid deployment, particularly on distribution networks

COMMENTARY

1) The table below sets out Good Practice recommendations for innovative applications:

	Engineering Application – good practice recommendations
1.	Functional Specifications and Open Systems standards should be the basis for all smart network applications.
2.	Power networks are highly integrated and new applications should consider at an early stage the Systems Engineering requirements for their integration with company architectures for data management, data processing, operational control, and asset management.
3.	Smart network applications commonly impact on the real time operation of network assets and their connected customers; it is therefore important that they are designed to 'fail safe' in the event of practical problems such as temporary communications or sensor failure.
4.	Smart Applications should 'fail safe' to a stable network operating position, not requiring control room intervention against a time deadline.

5.	When smart applications go to fail safe mode, consideration should be given to the option for self-restart when the problem that initiated the close-down is restored.
6.	Where the actions of a smart application impacts adversely on consumers or other third parties, consideration should be given to the generation of automated status reports that can be sent to the affected parties (e.g.by text, email or webpage) to advise them; this is likely to minimise calls to the network company, especially if the automated messaging advises likely restoration of normal operating service.
7.	Messaging to consumers should be in plain language; this also applies to company staff such as standby engineers who may not have close familiarity with the scheme details.
8.	Control room and field staff familiarisation using simulators, briefings and handbooks should be designed in to the project plan; similar induction arrangements should be considered for external stakeholders with provision for periodic refreshers.
9.	It is helpful for control room staff to have 'what to do when…' guidance rather than having to think through a situation from first principles each time, perhaps when under operational pressure.
10.	Control room displays usually benefit from simplicity and clarity, with the complexities of the smart application in effect 'hidden'; however it is generally good practice to ensure human oversight, enabling control staff can see the operational logic being implemented by the smart system, confirm that all is well, and if necessary intervene should there be unexpected events.
11.	Where a third party provides a key service (e.g. communications) it is important to ensure that the smart application can pinpoint the failed element and provide evidence – avoiding the third party being uncertain that it is their equipment that has failed, rather than another party in a series chain.
12.	Rising data volumes require an integrated approach for efficient handling across the relevant parties; in principle data processing should take place at the lowest level and derived information should be passed upwards.
13.	Devices for mass application, for example on lower voltage networks, need to be low cost and robust ('elegant solutions'); it is important therefore to consider simplifications and approximations rather than optimal outcomes – provided the devices are self-monitoring and the error band is tracked to ensure secure operation that protects assets and consumers.
14.	Where an application needs a safety case, the provision and collection of relevant data should be designed-in, especially from early pilots ahead of commercial deployment. Consider also data for regulatory evidence purposes.
15.	Systems should be self-monitoring, give advanced warning of failure, and have soft-failure modes (e.g. fall-back to partial capability).
16.	Power consumption of advanced systems should be minimised to both limit losses and extend operational capability when on substation emergency battery supplies (e.g. black start conditions).

10.6 Immediate Next Steps: Networks

10.6 Immediate Steps - Networks

Immediate Next Steps - Networks

METHOD

1. The report has been reviewed to identify action points that, subject to agreement, are within the remit of the network companies to progress

MESSAGES

1. Many of the networks responses identified require not only engineering content, but also technical or commercial frameworks or policies to be modified or developed
2. Wider views and inputs to the material presented here will be helpful, including Consumer and other third party implications
3. Develop the Solution Sets and the Outline Use Cases appears to be a logical next step; also development of the 'common language' definitions for smart grid structures and interfaces, internal and external to the power sector
4. Some important policy changes may have long lead times for resolution (e.g. Investment Planning Policies), and these have implications for investments
5. Other long lead time topics have been identified in the body of this report including the availability of suitably skilled staff, and raising consumer awareness and engagement
6. A gap analysis to highlight opportunities for new LCNF and IFI projects would be helpful, such that proof of concept is achieved progressively for the full range of solutions encompassed by the Solution Sets
7. The impact of these proposals needs to be addressed for Business Planning and company submissions under RIIO that will commencing next year; the Ofgem Network Innovation Allowance and Network Innovation Competition (which will supersede LCNF and IFI) will also require consideration
8. Opportunities have been identified for strategic 'forward investment', by DNOs in particular, to both accelerate network solutions and set the pathway for advanced smart solutions (described in the report as Smart Grid 2.0)

COMMENTARY

1) The table below list actions for consideration by the GB network companies, both distribution and transmission.

2) Appendix 3 provides a more detailed listing of issues for consideration in the shorter term by the distribution network companies as part of the Ofgem ED1 business planning process.

	Action Points for Consideration by the Network Companies
1.	Examination of the scenario implications reveals a number of pressing points for consideration that should be addressed as part of ED1 business planning and investment forecasting for DNOs. This will raise the question of the case for DNOs undertaking strategic investment ahead of need and its regulatory treatment. Derogations may be relevant here. **Action – implement an urgent review of underlying network planning policies, for example the ADMD assumptions for LV networks where new demands (EV and HP) are anticipated. More fundamental issues will need to be addressed in the run up to and during ED1, for example: re-examining national Planning Policy document (P2/6) to assess the impact of Demand Response, Distributed Generation, and local storage. P2/6 should also be re-examined with a view to incorporating contracted services for demand response, dispatchable DG, and storage to provide network security support. (Note: P2/6 permits consideration of DG, but on a probabilistic rather than contracted basis and so potentially underplays its potential contribution). Consider whether an accompanying standard on how to operate such networks is needed. Consider the case for strategic investments ahead of need, noting those identified in section 10.6 of this report. Finally, consider the ESQC Regulations, including the continuing appropriateness of deterministic voltage standards.**
2.	Many of the innovative solutions for networks outlined in the Solution Sets, will require integration with company's operational, control and management systems. These applications become dynamic building blocks that will have wider implications for the management of common data, the blend of distributed and centralised processing, and the design of control centre IT platforms. In some cases performance at a national, whole system, level will also need to be confirmed. **Action – it is recommended that a Review is undertaken of network company Intelligent and Dynamic Systems and their platform architectures; this should establish an understanding and definition of the new thinking required, and determine a migration path to move from today's systems to platforms that will support, in full, Smart Grid 1.0 and Smart Grid 2.0 applications.**
3.	Smart solutions will not be the answer in every case (for example where there are very high concentrations of new HP/EV loads); traditional capital investment solutions will also be needed and continuing attention to cost-effectiveness may be assisted by innovative developments. **Action – as part of maintaining the focus on cost-effective traditional network investment options, bring to bear innovative variants and integration with new solutions.**
4.	The case for electricity storage and its integration with other forms of energy storage has considerable merit in smart grid architectures. If the case for storage is confirmed it would be helpful to consider its place in incentivisation frameworks (e.g. alongside FiTs, and Regulatory performance and innovation incentives). However there are some fundamental road blocks to be addressed including planning standards, operating standards, and Safety cases. The EMR may present opportunities. Derogations may be relevant here. Investment planning and system control philosophies need to be established for these devices as

	they are new to the GB system. **Action – implement a review of underlying network policies and standards impacted by storage developments, including national Planning Policy document (P2/6). Consider the merits of the DNO being able to trade the energy content (and to cover the cost of the losses). There could be a primary legislation barrier to be addressed; also consider the positioning of storage in incentive frameworks.**
5.	This report proposes a number of Solution Sets to provide recognisable building blocks for innovative solutions within company investment plans. These are not prescriptive and are set out as high-level Functional descriptions that companies can adapt and scale to meet their own requirements. They will also be helpful for manufacturers, researchers and other stakeholders as an industry-wide framework for development. **Action – develop the Solutions Sets, together with the outline Use Cases set out in the Appendix, to form comprehensive Functional descriptions, together with budget unit-costing information. Some Solution Sets require developments of commercial and regulatory frameworks, and network companies will benefit in many cases if Standards and Codes of Practice are progressed in parallel.**
6.	The importance of standardisation arises a number of times in this report; it is at present unclear who has the action to lead this, should GB Codes of Practice and other Guidance be put in place as de-facto standards to enable early progress to be made. More widely, a review is needed of the old model of Licensees specifying system requirements and British Standards being used for consumer equipment. The European Grid Code now under development will in fact contain product standards – who has primacy and who is first mover? EC have given CEN the task of developing smart grid standards; there appears to be a need for the ENA and member companies to keep close to this. This is a complex area of work that has the potential to be a serious barrier to both smart grids progress and UK competitiveness and export potential. **Action – put in place work to address the future balance/interaction between GB legal/licence codes and international standards and to review the continuing suitability of GB's internal standards framework for the power sector.**
7.	Looking to the longer term there may be benefits in having the options to use entirely new network architectures, for example self-islanding networks (sometimes termed 'off-grid' operation) that can disconnect from the main grid and operate in isolation for a period. This may, for example, be an effective solution should Climate Change future threats worsen, or as a response to increasing malicious threats. It could also open new opportunities for network security, providing an alternative to a 'third circuit' for maintenance outages. The government has identified that new thinking may be needed to develop infrastructure that has a 'soft failure' mode and sustains limited service in extreme conditions. There is considerable synergy here with smart grid philosophies, for example self-islanding networks. **Action – put work in hand to develop the thinking for self-islanding networks, draw learning from international micro-grid developments, and consider whether such a philosophy has potential for improvements to security of supply standards and investment efficiency.**
8.	Solution Set 8, Smart Community Energy, could be seen as at the margins of a technical smart grid report. However, there appears to be considerable

	potential to raise consumer engagement in smart solutions by approaches at a community rather than individual level. This also has resonance with government Localism agendas. **Action – examine the potential for community energy initiatives, drawing on UK and international experience, establishing links between the stakeholder groups best positioned to evaluate this and consider next steps if appropriate.**
9.	Appendix 1 sets out pointers for Phase 2 work for cost quantification. **Action – progress with Workstream 2 the costing and scaling required to develop the cost-benefit assessment and provide information for business planning under ED1.**
10.	The report identifies a number of commercial frameworks required to support innovative network solutions. **Action – consider with other stakeholders a more comprehensive assessment of commercial frameworks, their prioritisation, and agree a suitable development project.**
11.	The report has identified the changing nature and complexity of the engineering and commercial systems that will support the future electrical power system. The skills required at both a professional and technician level will need to be available 'at a national level' (whether or not directly employed, for example, by the network companies). This is a significant challenge in view of the sector's demographics and the relatively small numbers in training. It is potentially a critical path barrier to implementing the network solutions identified in this report. **Action – recognising the exceptionally long lead times involved for the skills supply chain, develop and implement an action plan with the Energy and Utility Skills arm of the Sector Skills Council and also consider shorter term 'cross-training' opportunities from other sectors.**
12.	A review of the actions proposed in this report, the content of the Solution Sets, and the new commercial frameworks identified, prompts some fundamental questions about the structure of the GB power sector. **Action – against the background of the changing situation for electricity networks and consumer engagement described in the report, consider the merits of: establishing a Distribution System Operator role (DSO); the ownership of new devices such as storage; and whether the changes across the power sector maintain incentives to invest, especially where this may result in returns from traditional sources being eroded.**

4) The table below identifies some initial ideas for 'forward investment' ahead of need that will be enablers for innovative network developments and, in due course, Smart Grid 2.0 facilities. It is envisaged that a cost/benefit evaluation of these would be a next step, prior to including them as No-Regret actions in ED1 business plans:

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)

10.7 Proposed Steps: Third parties

10.7 Proposed Steps – 3rd Parties

Proposed Steps: Third Parties

METHOD

1 The analysis in the report has identified a number of areas for further work, some of which are beyond the scope of the network companies
2 It is not the intention of this work to commit third parties, rather to offer the topic areas for further consideration

MESSAGES

1 A significant R&D agenda has been identified; both for power technology and wider disciplines, in part for the period to 2020 but in particular for the later timescales
2 R&D for the earlier period requires attention to solve the challenges for integration and practical deployment of innovative solutions
3 Third Party actions arise notably in the areas of Smart Appliances, Electric Vehicles, Community Energy schemes, Aggregation, Commercial Frameworks, Storage providers
4 Government Policy and Regulatory frameworks will require further consideration in a number of areas

COMMENTARY

1) The table below lists the topics for consideration by Third parties

Agenda for Consideration by Third Parties
1. Home Automation controls – ensure these are linkable to Appliances, EVs, aggregators, and community energy schemes
2. EVs require interfaces that will link smoothly to the Smart Charging Solutions Set; need for common Functional specifications and standards with agreed protocols, recognising international developments
3. Smart Appliances from white goods manufacturers will need to communicate with home automation devices and directly or indirectly with network automation applications
4. ESCOs and third party service providers will require standardised functionality that provides for Open Systems, that integrate DNO/TSO/3rd Party facilities (e.g. storage needing to link with network management)
5. DC/AC invertors, likely to be coming into widespread use (e.g. PV connections, EV charging) have the potential, depending on their design, to interfere with the sinusoidal waveform of the local network; this can result in serious problems for local consumers and costs for rectification actions by the network company: consideration is needed for minimum standards regarding the performance of invertor equipment
6. Opportunities for integrated 'energy optimisation' will require common standards between sectors addressing electricity/gas/heat and so on
7. How could effective 'energy communities' be developed, especially in urban areas where natural boundaries and identities may not be apparent
8. Should EV and other significant new demands be notified to the DNO, i.e. a requirement, perhaps at the time of purchase
9. Independent networks (IDNOs) may in the future form an electrical part of an active network, or be 'electrically close' to it; consideration should be given to the need for certain minimum instrumentation from the IDNO network, sufficient to enable State Estimation accuracy on the adjacent DNO network
10. Who should be licensed to own and operate storage? In view of the several opportunities for storage identified in this report, might it be strategically advantageous for demonstration applications at distribution level to be considered for acceleration.
11. The above topics and others are likely to form part of the Phase 2 work outlined in Appendix 1; there are likely to be points of common interest with third parties

APPENDIX 1: Developing The Quantitative Assessment

Pointers towards Phase 2 further work

This report outlines the network response to Britain's low carbon objectives. It is expected that a second phase of the work will address the quantitative assessment and build an analytical framework to estimate the generic network development activities and cost.

This Appendix describes the three stages currently envisaged for the development of these models.

The first stage is to characterise existing DNO networks and the current demands they support. Likely segmentation could include domestic house type, age and size; industrial and commercial loads; urban, suburban, rural etc. Demand profiles for such classifications are already possible, and these profiles could be flexed over time in accordance with Workstream 1 scenarios.

The second stage will develop a modelling approach that applies the Workstream 1 energy scenarios to the network segments developed above, which includes the translation from electricity consumption (GWh) to demand (MW) and its likely time of day profile. In addition, it will be important to assess statistically how customer responses will cluster, in order to determine the additional challenge beyond that implied by a homogenous situation.

The final part will be to model the network response for each segment and to apply reinforcement and smart grid solutions from the Phase 1 work. This will include an assessment of the future unit cost of implementation for the techniques within the smart grid Solution Sets proposed in this document, and an overall cost estimation of the network response. This final stage of the work will link closely with Workstream 2 in identifying both the 'traditional' network reinforcement cost and that augmented by smart grid techniques, essentially evaluating the business case for smart grids. It is a matter of current discussion between WS2 and WS3 as to how the two Workstreams tackle this joint work.

The work will develop a number of building blocks with a common specification and base cost. DNOs will subsequently be able to combine the building blocks in a manner appropriate to their own networks when submitting a RIIO business plan to Ofgem, modified by any high level adjustment that they believe it is appropriate to apply.

The proposed process is shown diagrammatically below -

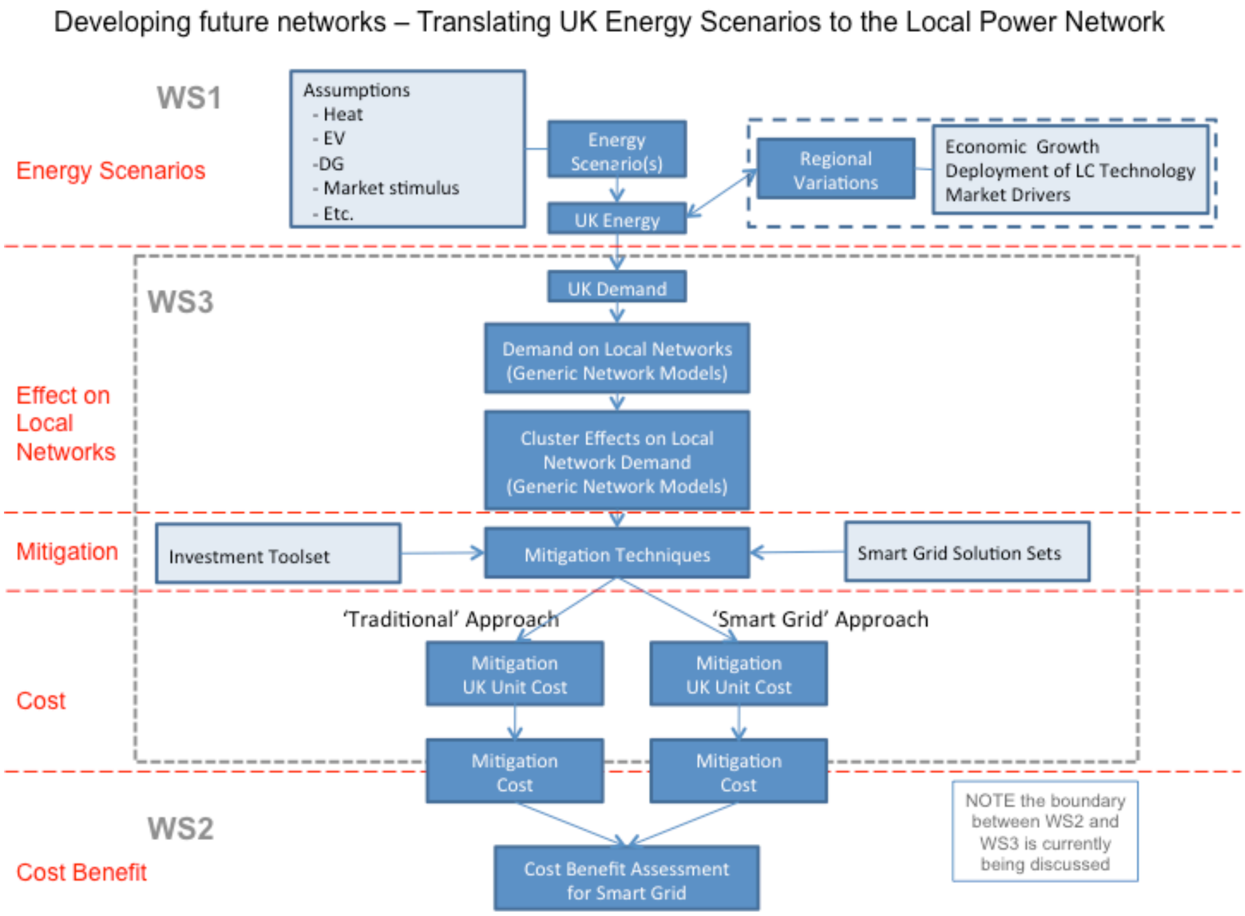


Figure 22: Developing the Quantitative Assessment

APPENDIX 2: Outline Use Cases for Smart Solution Sets

Smart Grids have been defined and described in many ways during their early stages of development internationally. The introduction of 'Use Cases' for smart grids in this paper is designed to provide a structure within each of the twelve Solution Sets which themselves define the collective functionality. Each individual Use Case within the Solution Set is described in terms of the service product or outcome it provides.

It is expected that the set of Use Cases will evolve and also require further definition over time, and is also likely that each of the Use Cases will need the subsequent development of a Functional Technical Specification, in some cases supported by an appropriate commercial framework.

The elements of functionality within the use cases will help form the structure for Phase Two of the project, where the associated benefits and implementation costs of the smart grid functionality will be developed.

SOLUTION SETS	USE CASES	Business Need & Benefit	Action	Actors	Prerequisites	Timing	Standards
(1) Smart D-Networks 1 **(Supply & Power Quality)**	Network Observability (Network Information)	**Business Need** Provide power flow and voltage information from within the network, combined with data from smart meters. **Business Benefit** Enable more efficient design and operation of networks, including more timely connection.	Deduce power flows from smart meter data using network models. Includes use of State Estimation techniques.	DNO DCC Suppliers	Smart meter implementation. SM telecoms. SM data availability / confidentiality. SM data process. DNO systems to interpret data.	Local requirements from 2015	
	Reduce losses	**Business Need** Enable design and operation of the network such that system losses are minimised as part of an optimisation of other parameters. **Business Benefit** Reduced energy requirement and associated generation capacity.	Optimise networks at design and in real time to minimise losses, (subject to minimisation of carbon across energy system).	DNO IDNO	Smart metering data Substation load data Network model / losses module. Regulatory framework. Carbon intensity of each local network.	Ongoing	Measure-ment and reporting framework (that accounts for demand increase)

	Provide power reliability for the digital economy	**Business Need** Anticipate or identify network configuration conditions that require intervention and initiate mitigation. **Business Benefit** Avoidance or minimisation of unplanned outage risk and maximised accommodation of local generation sources	Design and operate specific networks to provide premium power quality.	DNO IDNO	Commercial / regulatory framework.	Local requirements from 2015	Design and operation standards.
(2) Smart D-Networks 2 **(Active Management)**	Active Network Management for thermal constraints	**Business Need** Enable design and operation of the network such that thermal constraints are managed in real time, potentially using DSR, FACTS devices, energy storage. **Business Benefit** Enable more efficient design and operation of networks, including more timely connection.	Reconfigure system normal in response to rising (or falling) demand Or Response to unplanned outage	DNO TSO	Remote Control Real time and forecast load data at key nodes Dynamic ratings Real time load flow analysis etc	From 2015.	ESQCR (voltage constraints) P28 (V Fluctuation) D Code voltage step changes Comms / data
	Active Network Management for Voltage constraints *(Active Voltage Control)*	**Business Need** Enable design and operation of the network such that voltage constraints are managed in real time, potentially using DSR, FACTS devices, energy storage, 'all electronic power transformers', LV switching, on load tap changers etc. **Business Benefit** Enable more efficient design and operation of networks within statutory limits, including more timely connection.	Reconfigure system normal in response to rising (or falling) demand Or Response to unplanned outage	DNO	Remote Control Real time and forecast load data at key nodes Dynamic ratings Real time load flow analysis etc	From 2015.	ESQCR (voltage constraints) P28 (V Fluctuation) D Code voltage step changes Comms / data
	Reactive power management	**Business Need** Enable design and operation of the	Ensure reactive	TSO DNO	Range of compensation	~2015	Design and operation

	and compensation	network such that reactive power impacts are minimised. **Business Benefit** Enable more efficient design and operation of networks.	power component is minimised or optimised during design, and operation.	IDNO Customers	design tools. Network modelling tools.		standards. Commercial treatment of reactive power costs
	Modelling of more dynamic systems and data	**Business Need** Provide sound basis on which to invest in primary assets and associated control mechanisms. Provide optimised operating procedures and configurations **Business Benefit** Optimised asset investment and operating costs	Design networks to manage dynamic stability of the synchronous network	DNO	Synchronous generator population and constaints	From 2020	Design standard. Connections contributions .
	Home / commercial customer demand interfaces *(see also Smart EV charging)*	**Business Need** Facilitate information or instruction to modify customer demand or generation in response to system conditions. **Business Benefit** Enable more efficient design and operation of networks, including more timely connection. Maximise renewable resource usage and provide system stability response.	Request customer to follow load managemen t profile	DNO Customers Suppliers Aggregato rs	Responsive demand/applian ces etc. Smart charging for EVs. Customers' energy management systems Communication to customer Real time and forecast load data at key nodes Dynamic ratings Real time load flow analysis etc. Cost benefit assessment – relating availability of DSR at each voltage to the cost of traditional reinforcement.	~2017.	SM telecomms. Data availability / confidential-ity. Smart home / appliance products. DNO systems. Technology and network operating standards. Industry agreement on prioritisation. Industry process. Commercial framework ESQCR (voltage constraints) P2/6
	Home / commercial customer generation/ storage interfaces for Demand Response (*see also Smart EV charging)*	**Business Need** Facilitate information or instruction to modify customer generation or storage in response to system conditions. **Business Benefit** Enable more	Request customer to modify parameters of active components (e.g.gener-ator and/or storage; pf correction)	DNO Customers Suppliers Aggreg-ators	Customer active components Customers' energy management systems Communication to customer Real time and forecast load	~2020	ESQCR (voltage constraints) Network Operating Standard Commercial arrangement s between actors

		efficient design and operation of networks, including more timely connection. Maximise renewable resource usage and provide system stability response.			data at key nodes Dynamic ratings Real time load flow analysis etc		Appliance interface standards
	Forecasting demand and generation variation	**Business Need** Accurate forecasts of overall energy balance and local balance **Business Benefit** Market facilitation Maintain security of supply Reduce system operating costs	Week(s) ahead / day ahead / 4 hours ahead /real time to underpin balancing and network configuration and control	DNO Customers Suppliers Aggregato rs TSO	Forecast parameters. System. Network model. Commercial framework. DSO / TSO interface	~2020	
	Fault Current Limitation	**Business Need** Reduction of fault current in feed exacerbated by distributed generation. **Business Benefit** Avoidance or minimisation of replacement investment in otherwise appropriate assets – maximisation and reduced cost of DG connection.	Introduce fault current limiting devices, either to customer connections or specific network locations to avoid plant reinforce-ment.	DNO	Reliable technology	~2015	Design and operation standards.
(3) **Smart D-Networks 3** **(Intelligent Assets)**	Network Diagnostics	**Business Need** Understand in real time and over time, the status or condition of critical asset components. **Business Benefit** Reduce unplanned network outages and system disturbances, also reduce maintenance costs.	Associate real time network configuration with legacy asset data to identify new criticalities.	DNO TSO	Operational telecoms. DNO systems to interpret data. Innovation - new applications.	Ongoing.	Design and operation standards.
(4) **Smart D-Networks 4** **(Security & Resilience**	Intentional islanding (off-grid operation)	**Business Need** Enable continued operation and subsequent grid synchronisation during upstream outage conditions. **Business Benefit** Reduce unplanned network outages and system disturbances.	Design and operate networks with appropriate DG such that supply is maintained during upstream outages.	DNO IDNO	Operational telecommunic-ations. DNO systems. Technology standards. Commercial framework.	From 2015.	Design and operation standards. IIS.

	Anticipate & respond to system disturbances (self-heal)	**Business Need** Anticipate emerging or apparent network fault conditions that require mitigation. **Business Benefit** Avoidance or minimisation of unplanned outage risk.	Systematically identify potential 'next fault' conditions. Systematic-ally develop mitigation. Action mitigation when required.	DNO IDNO	Network analysis / forecasting tools. Network automation.	From 2015	Design and operation standards.
	Use of DC for Transmission and Distribution for – Interconnect-ion Embedded in AC systems (FACTs) Offshore connection (including multi terminal HVDC)	**Business Need** Market Interconnection – facilitating market operation Access to shared reserve capacity and surplus generation / deficit demand High capacity network for demand and generation integration. Increased AC interconnection stability **Business Benefit** Reduced system operator costs Reduced generation capacity requirements Minimisation of network reinforcement and associated physical disturbance. Maximisation of generation or demand integration. Alternative provision of Black Start with Voltage Source Convertors (VSC) Security of supply	Apply DC technologies where cost beneficial.	TSO DNO	Technology standards.	~2020	Design and operation standards.
	Resilience against attack and natural disaster	**Business Need** Incorporated system-wide resilience solution to attackers and natural disasters. **Business Benefit** Reduced physical and cyber vulnerability whilst enabling rapid recovery from disruptions.	Design networks against common risk framework. Design smart metering and smart grid telecomms and data transfer to	TSO DNO	Risk framework	Ongoing	Risk framework for networks. Telecoms and data security standard.

			remove the risk of disruption				
(5) Smart T-Networks **(Enhance-ments)**	Anticipate & respond to forecast or apparent system conditions (e.g.network conditions based on forecast demand or generation).	**Business Need** Anticipate or identify network configuration conditions that require intervention and initiate mitigation, including developing the interfaces between parties. **Business Benefit** Avoidance or minimisation of unplanned outage risk and ensure maximum accommodation of local generation sources.	Balance the system for NGET purposes or to suit commercial needs of Supplier or Aggregator	DNO Customers Suppliers Aggregat-ors TSO	Customer active components Customers' energy management systems Communication to customer Real time and forecast load data at key nodes Dynamic ratings Real time load flow analysis etc		ESQCR (voltage constraints) Network Operating Standard Commercial and technical arrangements between actors Appliance interface standards
	Systems Integration and Control	**Business Need** Short term (Balancing Mechanism) market operation Ability to perform specific actor actions within overall supply chain Ability to control proliferation of FACTs in concert **Business Benefit** Maintain security of supply Market facilitation Reduce market operating costs and therefore consumer bills	Co-ordination, information exchange and prioritization of Market, Suppliers, Networks and System Operator(s) actions to deliver an efficient, secure and economic energy system. This may also include interactions with European markets and gas networks.	DNO Customers Suppliers Aggregators TSO	Customer active components	~2020	Network Operating Standard Commercial and technical arrange-ments between actors
(6) Smart EV Charging	EV charging load interfaces for Demand Response	**Business Need** Facilitate information or instruction to modify customer demand or generation in response to system conditions. **Business Benefit** Enable more efficient design and operation of networks, including more timely connection. Maximise	Request customer to follow load management profile	DNO Customers Suppliers Aggregators	Responsive demand/appliances etc. Smart charging for EVs. Customers' energy management systems Communication to customer Real time and forecast load data at key nodes Dynamic ratings Real time load	~2017.	SM telecomms. Data availability / confidential-ity. Smart EV charging. DNO systems. Technology and network operating standards. Industry agreement on

		renewable resource usage and provide system stability response.			flow analysis etc. Cost benefit assessment – relating availability of DSR at each voltage to the cost of traditional reinforcement.		prioritisation. Industry process. Commercial framework ESQCR (voltage constraints) P2/6
	EV storage interfaces for V2G Demand Response	**Business Need** Facilitate information or instruction to modify customer EV storage export in response to system conditions. **Business Benefit** Enable more efficient design and operation of networks, including more timely connection. Maximise renewable resource usage and provide system stability response.	Request customer to modify parameters of active components (e.g.storage; pf correction)	DNO Customers Suppliers Aggregators	Customer active components Customers' energy management systems Communication to customer Real time and forecast load data at key nodes Dynamic ratings Real time load flow analysis etc	~2020	ESQCR (voltage constraints) Network Operating Standard Commercial arrange-ments between actors Appliance interface standards
	Intelligent integration of EV	**Business Need** Intelligent charging of electric vehicles using data link between vehicle and local network. **Business Benefit** Avoidance or minimisation of network reinforcement. Expedited use of EVs and frequency response provision. Reduced network losses in response to peak flattening.	Introduce intelligence in EV / charger to communic-ate with local network (and indirectly national real time and forecast carbon intensity) to minimise network impact, and carbon content of charge.	DNO Suppliers Vehicle manufacturers	Communication to customer Real time and forecast load data at key nodes Dynamic ratings Real time load flow analysis etc	~2020	Network Operating Standard
(7) Smart Storage	Local energy storage,	**Business Need** Availability of local energy storage. **Business Benefit** Maximise output of renewable, particularly intermittent sources. Reduce network investment. Some reduction potential in unplanned outage risk.	Deploy local energy storage – potentially various network levels.	DNO IDNO Customers Aggregators	Technology solution. Commercial framework.	~2020	Design and operation standards. IIS.

(8) Smart Community Energy	Integrated generation, demand, storage, heat	**Business Need** Optimise community energy **Business Benefit** Minimise overall carbon production	Integrate power, heat, local generation, transport	DNO IDNO	Technology solution. Commercial framework.	~2015	
(9) Smart Buildings & Connected Communiti es	Integrated generation, demand, storage, heat	**Business Need** Optimise community energy **Business Benefit** Minimise overall carbon production	Integrate power, heat, local generation	DNO IDNO	Technology solution. Commercial framework.	~2015	
(10) Smart Ancillary Services **(Local & National)**	Short term reserve STOR, VPP, DSR	**Business Need** Availability of short term capacity / demand increments for short term balancing including frequency response. **Business Benefit** Avoid generation investment and introduction of commercial opportunity.	Used embedded generation, storage or demand participation to provide ancillary services.	DNO IDNO Customers Aggregat-ors	Commercial framework.	~2017	Design and operation standards.
(11) Advanced Control Centres	Control room visualisation tools	**Business Need** Clear indication and prioritisation of system status and issues **Business Benefit** Maintain security of supply Reduce system operating costs	To manage greater volume of data, number of variables and automate resultant control room actions	DNO	Technology solution.	~2020	Operation standards
(12) Enterprise-wide Solutions							

Figure 23: Outline Schedule of Use Cases for each Smart Solution Set

APPENDIX 3: Emerging Topics for ED1 Business Planning

	Subject	Action	Comment
ENERGY SCENARIOS	Network Impacts	Translate / reconcile national energy scenario to network demand	First stage - UK study as part of Phase 2
		Translate network demand scenario to primary network plant and circuits – assess capacity provision / investment requirement	“
		Translate scenario to HV and LV network plant and circuits – assess capacity provision / investment requirement	“
		Develop approach for future technology cost assessment – efficient costs and the transition to large scale production	To be informed by Phase 2
NETWORK INVESTMENT	Strategic Investment	Assess the benefit case for specific strategic network investment in accordance with 2030 / 2050 projections	“
		Assess the benefit case for network sensor installation in accordance with 2030 / 2050 projections	“
	Telecommunications	Consolidate assumptions around telecommunications requirements to facilitate future networks	
	Network Management Platforms	Identify new IT system requirements to support future networks– e.g. assimilating smart meter data	
	Systems and Business Processes	Review the integrated functionality of new platforms to ensure effective interfaces and operational coherence	
SERVICES / COSTS	Customer Service	Assess new service requirements for customers – e.g.	

		facilitating, community energy support, data services to communities	
	Policy Development	Assess industry policy development requirements and resources	
	Skills Development	Assess the requirement and approach to resources and skills development	Continuation
	Network Constraints	Assess impact of remedial measures to mitigate smart meter informed network constraints e.g. voltage regulation	To be informed by Phase 2
FRAMEWORKS / INCENTIVES	Smart grids Incentives	Identify approach to encourage smart grid implementation in support of traditional investment	
	Uncertainty	Assess arrangements to deal with business plan / actual requirements variance – volumes and cost	
	Demand Response	Outline demand response approach and payments framework requirements	
	Connection Costs	Consider appropriateness of connection charge structure for demand and generation	
	Network Losses	Assess requirements and incentives for network losses responding to increased utilisation	
	Depreciation	Consider impact of 'short life assets' on depreciation framework	
	Risk	Assess by qualitative approach the potential risks to companies, customers, government	
	Innovation	Identify framework for continuing future networks innovation	Incorporate continuing new 'low readiness' activities and the translation of innovation to application

APPENDIX 4: The IET 'Wider Pictures' for smart grids

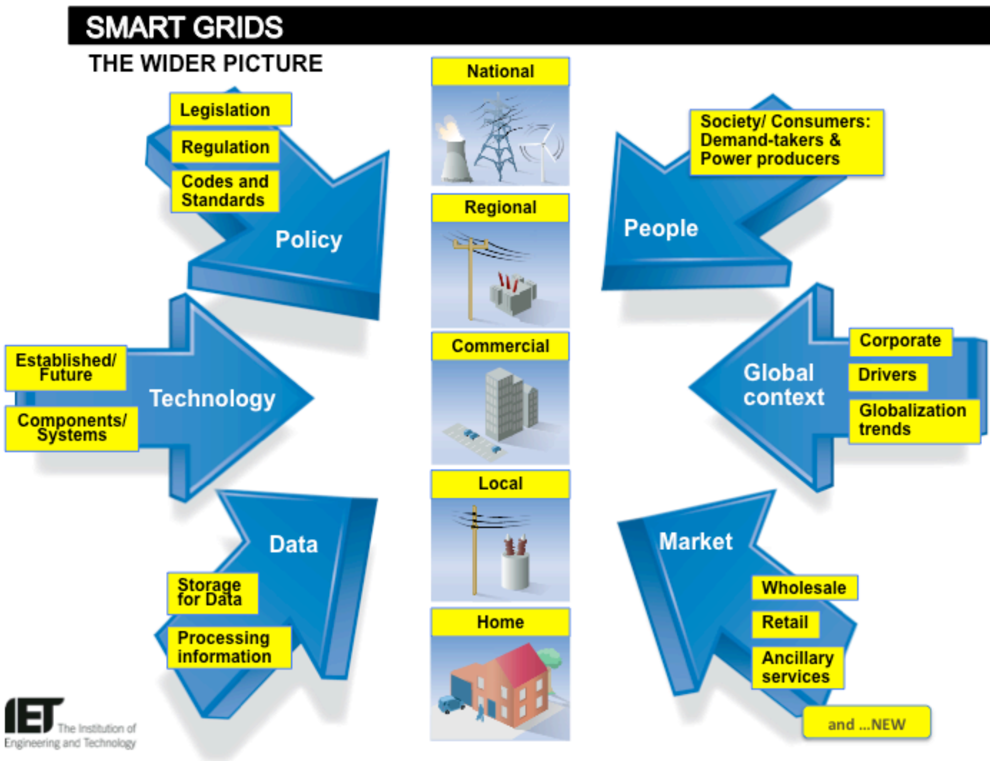
The pictures that follow were developed by The Institution of Engineering and Technology (The IET) to promote a shared understanding of the smart grid agenda and its challenges.

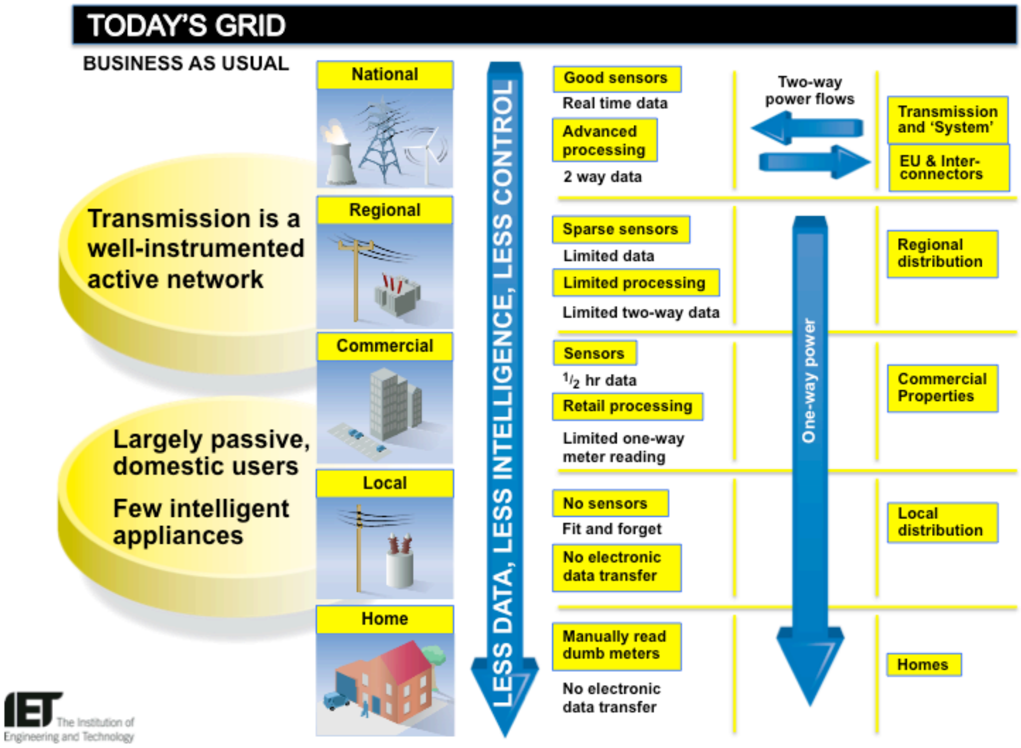
The IET initiated this work having become aware of the lack of a common appreciation between professionals in different sectors (arising from differences of terminology as well as lack of topic familiarity).

Two final slides start to explore the opportunities for developing a structure and taxonomy for smart grids; this is prompted by the effective work done in the telecommunications sector to establish the OSI model. See: http://en.wikipedia.org/wiki/OSI_model

In preparing this report for Workstream 3 of the Smart Grid Forum, a number of discussion meetings were held and the Wider Picture set was used as an introductory step. This received strongly positive responses from different audiences and they are provided here for wider interest. We are pleased to acknowledge the permission of the IET to reproduce them here and note that they can be accessed on the IET website with a video commentary.

See: www.theiet.org/smartgrid-pictures





TODAY'S GRID
BUSINESS AS USUAL
Transmission is a well-instrumented active network
Largely passive, domestic users
Few intelligent appliances
National
Regional
Commercial
Local
Home
LESS DATA, LESS INTELLIGENCE, LESS CONTROL
Good sensors
Real time data
Advanced processing
2 way data
Sparse sensors
Limited data
Limited processing
Limited two-way data
Sensors
1/2 hr data
Retail processing
Limited one-way meter reading
No sensors
Fit and forget
No electronic data transfer
Manually read dumb meters
No electronic data transfer
Two-way power flows
One-way power
Transmission and 'System'
EU & Inter-connectors
Regional distribution
Commercial Properties
Local distribution
Homes
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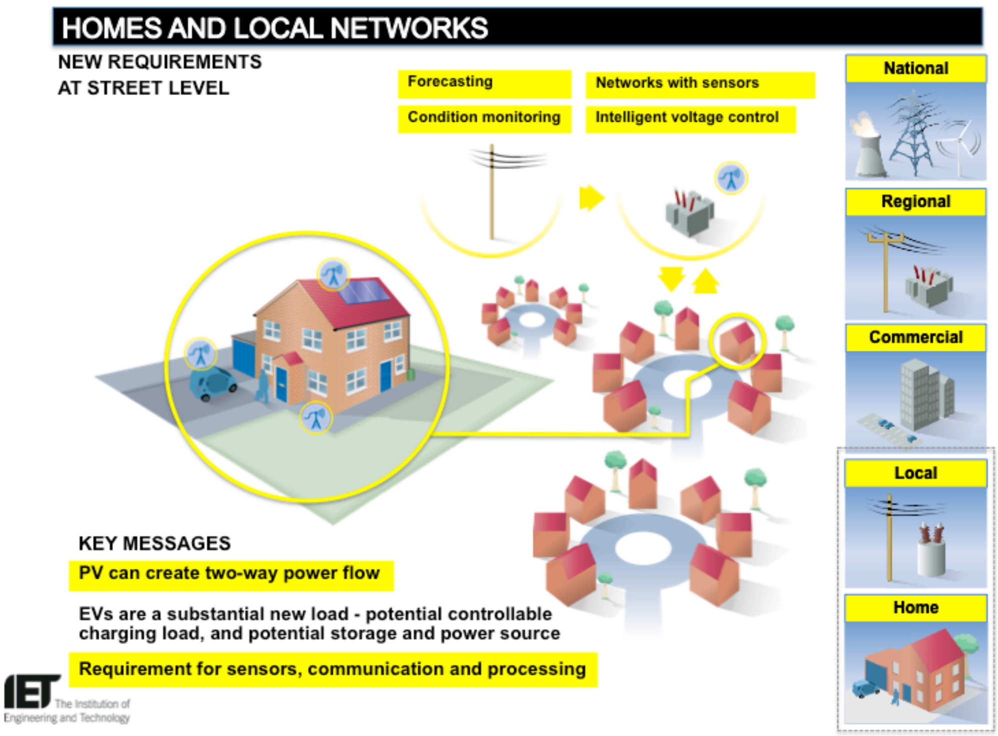

HOMES AND LOCAL NETWORKS
NEW REQUIREMENTS AT STREET LEVEL
Forecasting
Condition monitoring
Networks with sensors
Intelligent voltage control
National
Regional
Commercial
Local
Home
KEY MESSAGES
PV can create two-way power flow
EVs are a substantial new load - potential controllable charging load, and potential storage and power source
Requirement for sensors, communication and processing
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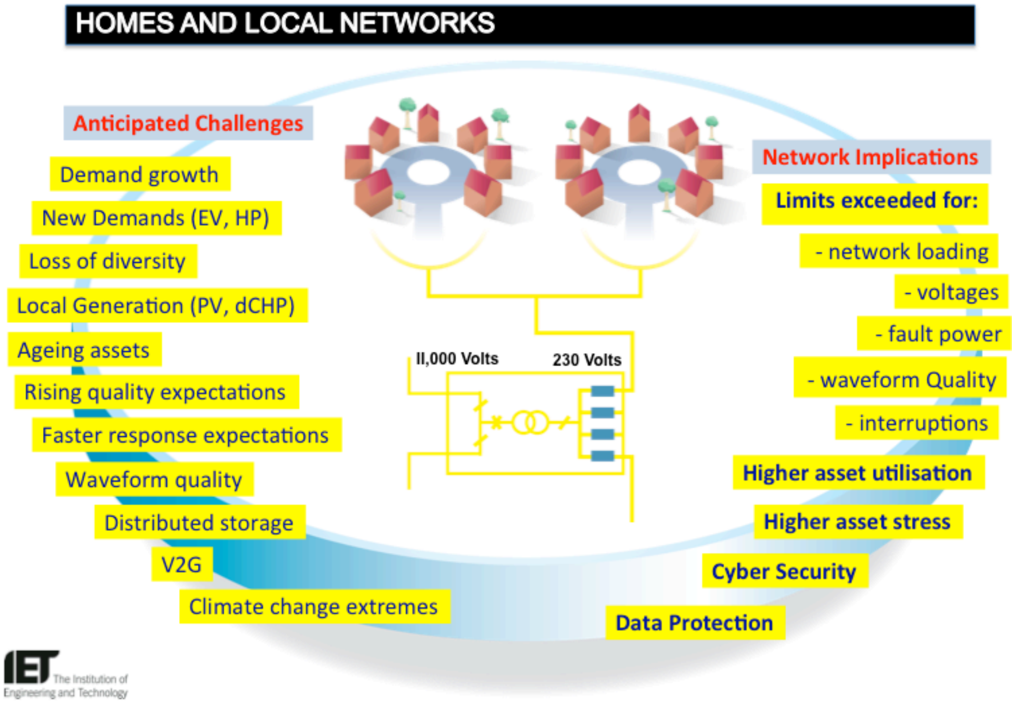
HOMES AND LOCAL NETWORKS
Anticipated Challenges
Demand growth
New Demands (EV, HP)
Loss of diversity
Local Generation (PV, dCHP)
Ageing assets
Rising quality expectations
Faster response expectations
Waveform quality
Distributed storage
V2G
Climate change extremes
II,000 Volts
230 Volts
Network Implications
Limits exceeded for:
- network loading
- voltages
- fault power
- waveform Quality
- interruptions
Higher asset utilisation
Higher asset stress
Cyber Security
Data Protection
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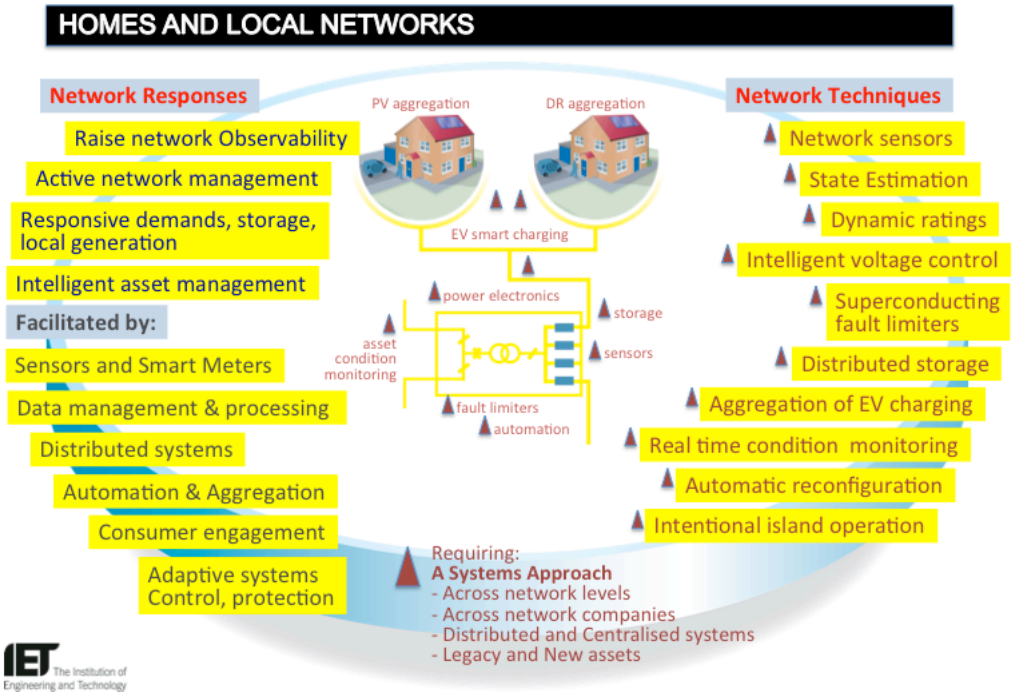
HOMES AND LOCAL NETWORKS
Network Responses
Raise network Observability
Active network management
Responsive demands, storage, local generation
Intelligent asset management
Facilitated by:
Sensors and Smart Meters
Data management & processing
Distributed systems
Automation & Aggregation
Consumer engagement
Adaptive systems Control, protection
PV aggregation
DR aggregation
EV smart charging
power electronics
storage
sensors
asset condition monitoring
fault limiters
automation
Network Techniques
Network sensors
State Estimation
Dynamic ratings
Intelligent voltage control
Superconducting fault limiters
Distributed storage
Aggregation of EV charging
Real time condition monitoring
Automatic reconfiguration
Intentional island operation
Requiring:
A Systems Approach
- Across network levels
- Across network companies
- Distributed and Centralised systems
- Legacy and New assets
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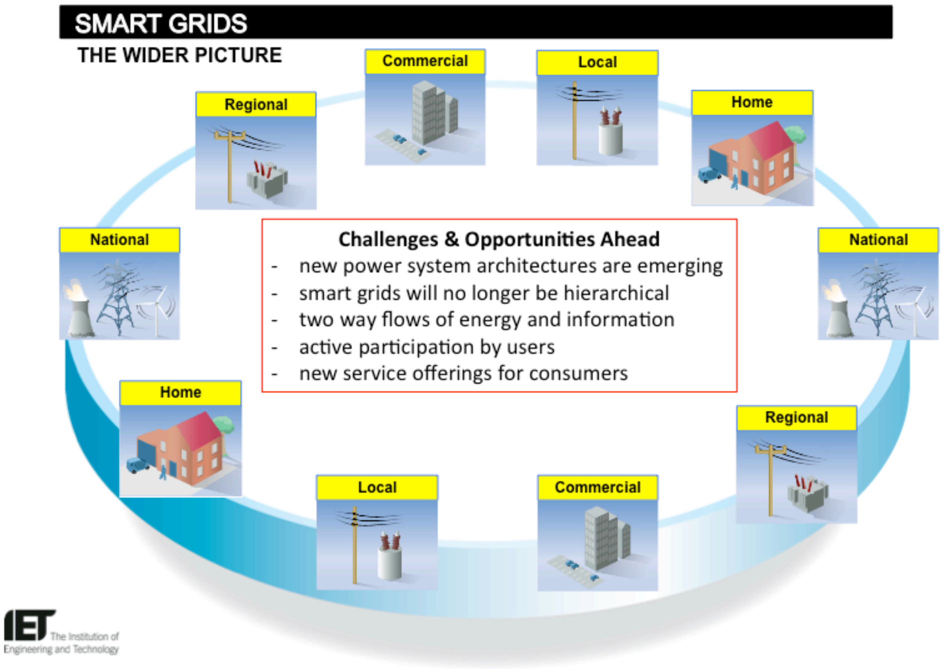
SMART GRIDS
THE WIDER PICTURE
Commercial
Local
Regional
Home
National
National
Challenges & Opportunities Ahead
- new power system architectures are emerging
- smart grids will no longer be hierarchical
- two way flows of energy and information
- active participation by users
- new service offerings for consumers
Home
Regional
Local
Commercial
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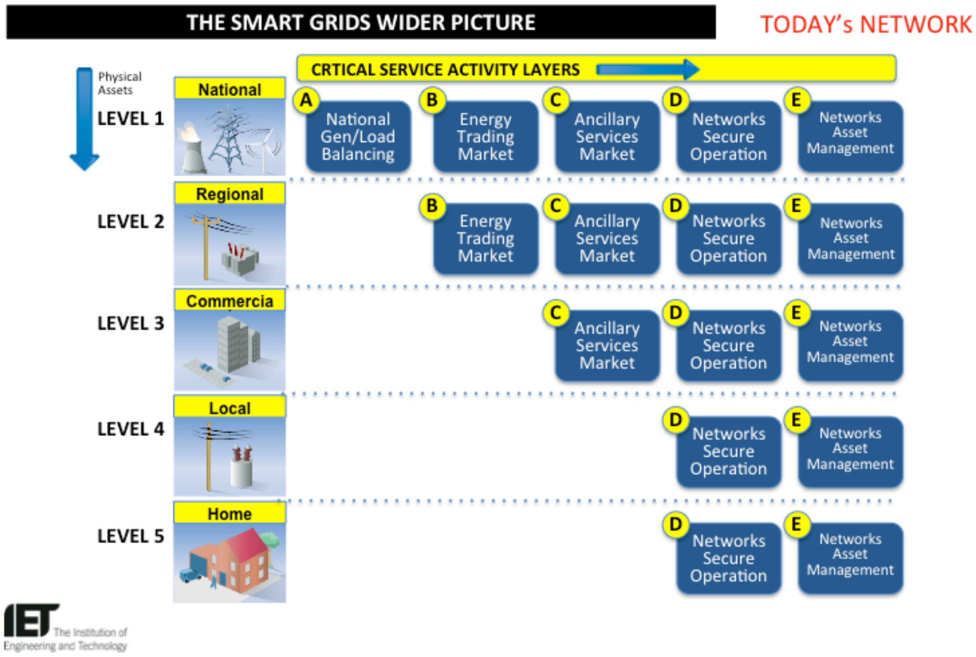
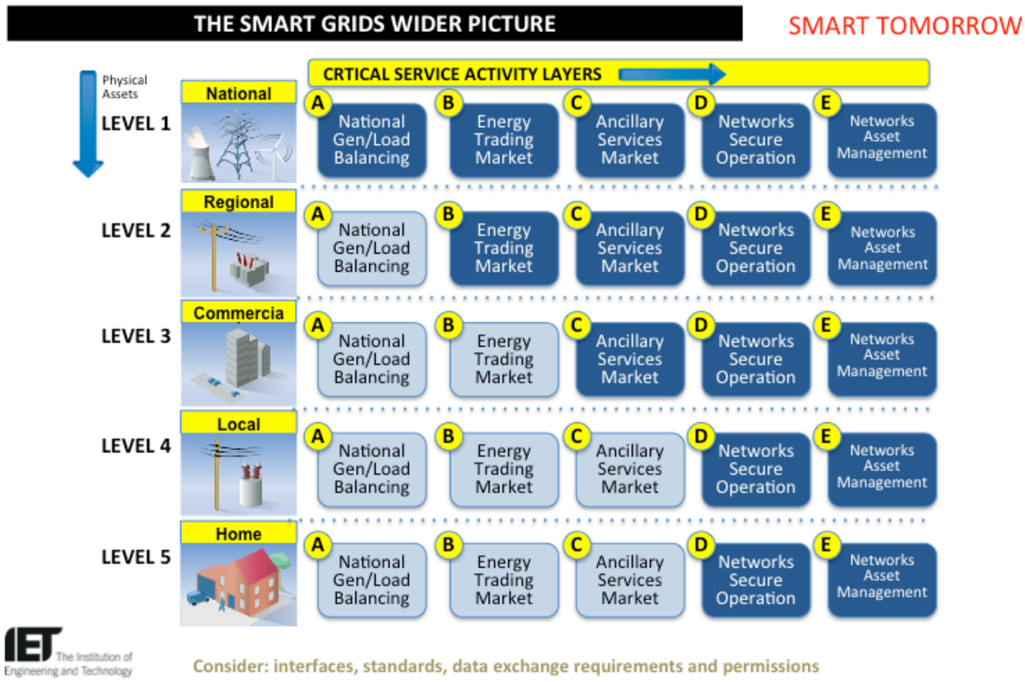


Consider: interfaces, interface standards existing & required, also external interfaces; data exchange requirements and permissions



Consider: interfaces, standards, data exchange requirements and permissions

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