Electricity Networks Strategy Group

A Smart Grid Vision

November 2009

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ENSG – who we are and what we do

The Electricity Networks Strategy Group (ENSG) provides a high-level forum which brings together key stakeholders in electricity networks that work together to support the Government and Ofgem in meeting the long-term energy challenges of tackling climate change and ensuring secure, clean and affordable energy.

The Group is jointly chaired by the Department of Energy and Climate Change (DECC) and Office of Gas and Electricity Markets (Ofgem), and its broad aim is to identify and co-ordinate work to help address key strategic issues that affect the transition of electricity networks to a low-carbon future.

The Smart Grid Working Group

DECC and Ofgem have asked the ENSG to produce a high-level vision of what a UK smart grid might look like and the challenges it would help address.

This paper outlines the vision that ENSG have developed.

The purpose of this vision is to promote smart grid debate within Government and industry.

It is not intended to define the specific smart grid path that the UK should take.

There are some assumptions on what smart metering will deliver for smart grids which will need to be subject to detailed cost benefit work in the smart meter Implementation Programme.*

* It should be noted that the Government has yet to make final decisions on the detailed smart meter functionality or communications infrastructure requirements. Any meter and communications functionality for smart grids will require extensive qualitative and quantitative analysis, including work with DNOs, for validation

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Executive summary

The ENSG endorses the Smart Grid Vision as a description of the way in which Smart Grids could contribute to the delivery of the Government's carbon targets and the delivery of benefits to end-customers.

The ENSG strongly recommends that thinking on the Smart Grid Vision should be aligned and made consistent with thinking which is supporting other parallel policy development.

The ENSG recognises that significant uncertainty surrounds the assessment of the costs and benefits of Smart Grids, however, since it is likely that Smart Grids will yield net benefits to society under some scenarios, the ENSG considers that appropriate further work on Smart Grid technology should be taken forward.

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The UK Government's low carbon strategy and Ofgem's Low Carbon Network Fund and RPI-X@20 project are the key context for the development of smart grid

Government

UK Low Carbon Transition Plan

In July 2009 the Government published 'The UK Low Carbon Transition Plan – National Strategy for Climate and Energy'. This white paper outlines the broad set of policy measures, targets and principles that will allow the UK to deliver its five-point-plan to tackle climate change. It also provides the framework against which the role of the smart grid can be identified, and offers a benchmark against which the smart grid vision must be tailored.

Renewable Energy Strategy

The UK has signed up to the EU Renewable Energy Directive, which includes a UK target of 15 percent of energy from renewables by 2020. This target is equivalent to a seven-fold increase in UK renewable energy consumption from 2008 levels: the most challenging of any EU Member State. The Renewable Energy Strategy sets out how everyone has a role to play in promoting renewable energy, from individuals to communities to businesses.

Ofgem

The Low Carbon Network Fund

In August 2009 Ofgem, the UK's energy regulator, announced that it was proposing to establish a funding mechanism of £500m over the period 2010 to 2015 to support 'large-scale trials of advanced technology including smart grids', as part of DPCR5 – the five-yearly Distribution Price Control Review that Ofgem undertakes that establish incentives, revenues and expenditure allowed by the DNOs.

RPI-X@20

The RPI-X@20 review is a two year project to review the workings of the current approach to regulating GB's energy networks and develop future policy recommendations. The review will be developed with a broad number of stakeholders.

The recommendations of the review will be reported to the Ofgem Authority in Summer 2010.

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The ENSG smart grid definition

A Smart Grid as part of an electricity power system can intelligently integrate the actions of all users connected to it - generators, consumers and those that do both - in order to efficiently deliver sustainable, economic and secure electricity supplies.

A Smart Grid employs communications, innovative products and services together with intelligent monitoring and control technologies to:

1. Facilitate connection and operation of generators of all sizes and technologies
2. Enable the demand side to play a part in optimising the operation of the system
3. Extend system balancing into distribution and the home
4. Provide consumers with greater information and choice of supply
5. Significantly reduce the environmental impact of the total electricity supply system
6. Deliver required levels of reliability, flexibility, quality and security of supply

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The ENSG smart grid vision

“The UK’s smart grid will develop to support and accelerate a cost-effective transition to the low-carbon economy. The smart grid will help the UK meet its 2020 carbon targets, while providing the foundations for a variety of power system options out to 2050.

The Vision sets out how smart grids may, directly or indirectly: maintain or enhance quality and security of electricity supply; facilitate the connection of new low- and zero-carbon generating plants, from industrial to domestic scale; enable innovative demand-side technologies and strategies; facilitate a new range of energy products and tariffs to empower consumers to reduce their energy consumption and carbon output; feature a holistic communications system that will allow the complete power system to operate in a coherent way, balancing carbon intensity and cost, and providing a greater visibility of the grid state; allow the cost and carbon impact of using the networks themselves to be optimised.”

It is essential to acknowledge that the vision goes far beyond technology. Technology will play an important role in meeting the UK’s needs but regulatory, legal, commercial, market, industry and cultural change will also be critical.

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A series of common challenges are driving global smart grid investment

Carbon reduction

- Enable and accelerate power system carbon reduction
- E.g. demand-side response to cost effectively integrate inflexible low-carbon generation

Energy security

- Increasing the network's capacity to manage a potentially diverse set of new requirements
- E.g. manage the technical risk of connecting new generation, and of changing demand patterns

Economic competitiveness & affordability

- Cost-effectively transition to a low-carbon energy system, increasing affordability
- E.g. reduce need for grid reinforcement to handle new loads

Location	Technology / capability *
Boulder, CA, US	SmartGridCity – multiple smart grid capabilities
Amsterdam, Netherlands	Various domestic and commercial capabilities aimed at cutting emissions
Various European	FENIX – virtual power plants (VPP) to aggregate distributed generation
Denmark	Cell Controller Pilot – using layered control hierarchy and distributed agent technology to manage variable generation
Skegness, UK	Dynamic Line Rating – increasing the capacity of existing connections in order to manage excess of wind generation
Mannheim, Germany	Co-ordination of information, consumption and generation, and customers are able to modify consumption based on prices
South Bend, IN, US	'gridSMART' technology, in order to reduce losses in distribution, lower operating costs, provide new services to customers
Germany	MEREGIO – Minimum Emission Regions, designed to optimise spinning reserves, provide DR and real-time pricing, reduce losses

* Drawn from ENARD Annex 1 'Information sub-task – regulatory frameworks and business models conducive to the development of Smart Grids'

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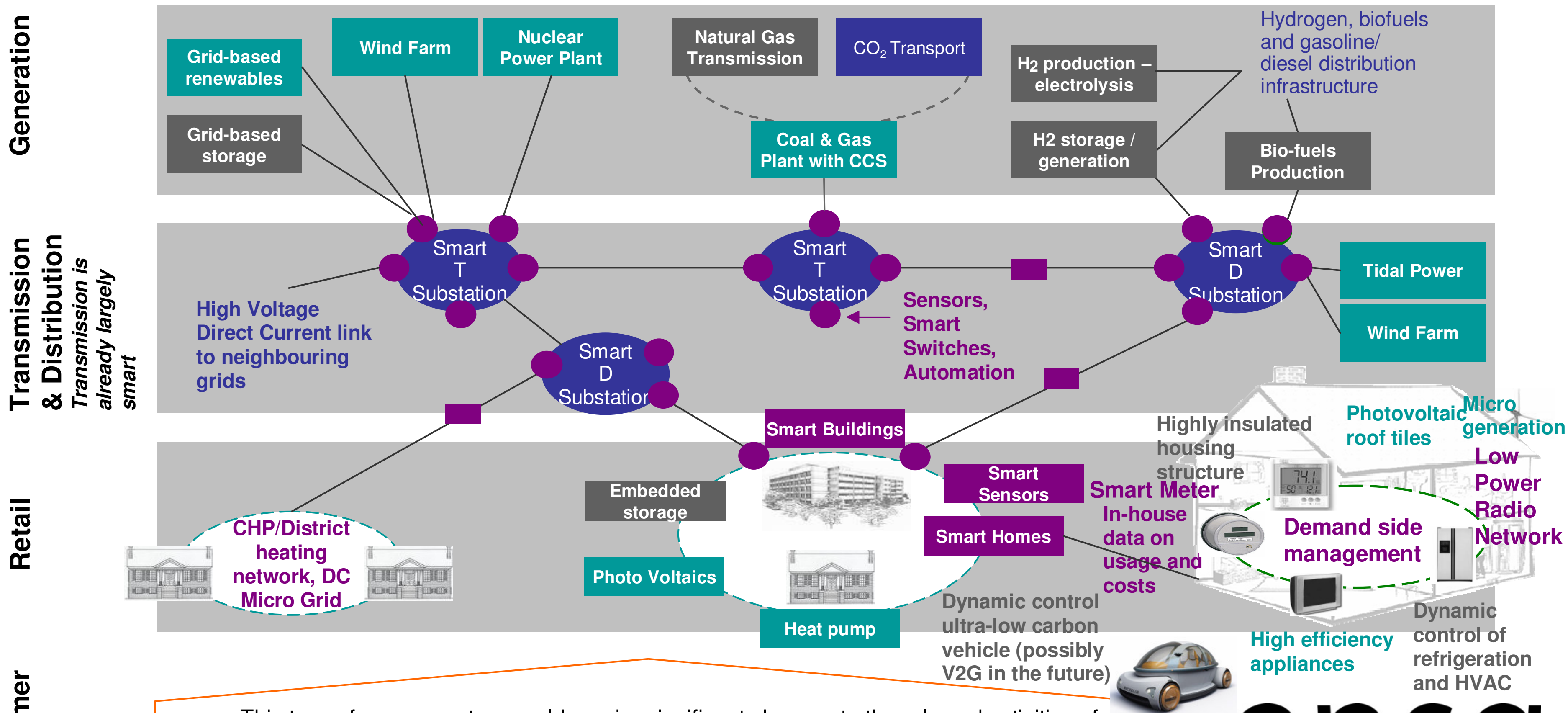
There could potentially be radical changes to the electrical power system through an incremental (localised) and evolutionary process

- Changes should be on the basis of localised needs, opportunities and legacy
- Cost-effectiveness a critical consideration
- For benefit realisation, technology-readiness isn't sufficient. The UK will also require a degree of market, industry and regulatory change from laws to culture that will enable the necessary change

Storage and demand shifting
Electricity / heat generation
Sensing, control and integration
Other infrastructure



The customer

- This type of energy system could require significant changes to the role and activities of the customer within the wider energy system allowing them to participate in the market (potential for automation of customer response)
- In transitioning to a new 'role', customers will need to be supported by energy retailers or other organisations with open access and standards widening the net for innovative products and services

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In the UK, achieving our carbon targets means the electrical power system needs to change, and smart grid has the potential to play an important role

The current electrical power system

- Power generally (degree of bi-directional travel within transmission) travels in one direction, from a small number of large power stations (the supply or production side) to a relatively large number of homes and businesses (the demand side)
- The balancing of electricity supply and demand is performed predominately by the supply side (generation), through the activities of the Transmission System Operator, with fast-acting, controllable and highly flexible (and often carbon-intensive) power plants and pumped storage responding to demand changes
- Most electricity delivered today still comes from large, central power stations

Smart grid – responding to an uncertain future

- There are a series of different paths the UK could take to meet its low-carbon aspirations, with varying degrees of end-to-end power system change
- Despite the uncertainty, smart grid investment could deliver near-term benefits whilst providing a platform for future optionality
- Specifically, smart grid could be the enabler for a radical departure from the operation of the current power system, with extensive balancing on the demand side as a fast- and zero-carbon alternative to carbon-intensive generation (real-time balancing will become even more relevant and important due to intermittent generation), a high degree of distributed generation, and enhanced network utilisation, planning and control
- This model could lower the cost of the transition to the low-carbon economy through the cost-effective management of intermittent renewables and integration of transport and heating electrification
- The functionality required to deliver any such benefits could be layered over time as the nature of the future power system becomes clearer

This role could be reflected in new power system functionality embedded in networks, meters, electrical devices – and beyond, into markets, consumer behaviour, and commercial and regulatory arrangements

Power system objectives	Possible functionality (not exhaustive)
• Balance consumption and production to optimise the output of low carbon sources and integrate intermittent renewables • Where economic and sustainable, reduce the need for network reinforcement, in relation to heating or transport electrification or the connection of new renewable generation • Use grid functionality to, where possible, create an optimised balance between capex and opex solutions, considering cost effectiveness, flexibility and security of supply • Introduction of energy-market and operational balancing, in response to Time of Use (TOU) tariffs, smart metering, etc	• Open access and standards and mechanisms to drive innovation and align provision with evolving customer needs and aspirations • New commercial, regulatory and market structures and operation, including integration of energy market and network management • More sophisticated balancing and forecasting tools to accommodate renewable intermittency • Customer response to fixed/day-ahead price signals • Autonomous control of (e.g.) refrigeration according to system operation needs • Market and system capability to integrate distributed energy resources – virtual power plants • Integration and operation of embedded storage potentially including vehicle to grid (V2G in the longer term) • Universal half-hourly real/reactive/voltage information • Selected 'real time' real/reactive information to assist system operation • Enhanced voltage control with remote sensors and distributed active devices • Improved fault detection and enhanced condition monitoring • Further and more advanced automation, reducing restoration times and allowing optimised operation of local grids • Greater automation of Transmission Network operation, e.g. more extensive use of Flexible AC Transmission System (FACTS) devices

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A degree of functionality is already in place, providing solid foundations for further development

It is important to recognise that there are a number of trials of smart grid technologies happening in the UK at the moment – the findings from these pilots will be invaluable when the pace of installing smart technologies across the grid speeds up.

Location	Technology/capability
Skegness, Lincolnshire*	Due to the connection of both onshore and offshore wind, Skegness generates more electricity than it requires. Exporting the power to the local town of Boston would, using traditional solutions, require reinforcement of the existing lines. Instead, dynamic line rating technology monitors the weather conditions in real time and dynamically assesses the line rating, increasing the capacity of the existing lines without the need for physical reinforcement.
Orkney*	An innovative Active Network Management (ANM) scheme has provided the basis for the connection of multiple new renewable generators, which are managed to meet network constraints at several monitoring locations on the Orkney network in real time. The deployment of ANM and the accompanying commercial arrangements are a quicker and cheaper alternative to network reinforcement to connect more renewable generation to the Orkney network. The technical and commercial aspects of this work are repeatable and are applicable to many existing distribution networks.
Martham, Norfolk*	An advanced network voltage control system has been installed to enable the connection of additional wind farms to an existing MV network. The system fine-tunes the substation source voltage according to the output of the generators, so preventing voltage-rise issues. A Lithium Ion battery storage system is now being installed which will mitigate the intermittency of the wind farm output and enable further distributed generation to be connected. The technology has wide potential application to rural MV networks.
Isle of Wight	The Isle of Wight is currently the location of a pilot scheme to evaluate the performance of next generation network automation to automatically reconfigure the network into isolatable sections. It is evaluating both the overhead and underground plant functionality and how they can interact on mixed networks. Using 'intelligent' auto-reclosers there is no restriction imposed by protection discrimination – this being achieved using a high -speed radio link with banks of auto-reclosers having the same protection settings. These auto-reclosers will detect the faulted section, reclose for transient faults, isolate permanent faults and reconfigure the network. The control engineer would only see permanent faults. Real time load management and network constraints will allow the load management to be automated easing issues associated with Distributed Generation and load growth.

* These trials are part of Ofgem's Registered Power Zones (RPZ) scheme

The UK can take near-term actions – essential steps, despite future uncertainty

Near-term electrical power system objectives	Smart grid role
• Direct grid carbon reduction	• Enhanced grid information can allow investment and operation to reduce technical losses and better manage end user voltages
• Connection and risk management for concentrated Ultra-Low Carbon Vehicle and distributed generation (DG) take-up	• Allow observation of the impact of increased DG and Ultra-Low Carbon Vehicle (ULCV) take-up and management of DG dispatch, EV charging and broader system management to reduce network risks
• Reduced scale of peak-plant running and build, particularly in relation to rapid expansion of intermittent on and offshore wind	• Accelerate and maximise demand-side management capacity and allow effective operation across the end to end electrical power system with an emphasis on system balancing
• More cost-effective transmission connection of new generation	• Enhanced reactive compensation to increase transmission capacity across new key power flow boundaries
• Reduce the reinforcement costs associated with the low-carbon transition	• Use increased grid data and enhanced voltage control to optimise planning and asset utilisation, avoiding and deferring reinforcement and replacement investment
• Manage uncertainty in a potentially rapid and unevenly changing power system	• Subject to appropriate rules and protections, use smart meter consumption information and other market intelligence, grid data, trials and pilots to identify new patterns and develop capabilities and insight
• Engage and empower consumers and communities	• Provision of information and the opportunity for new forms of power system engagement – taking the market into the home

- Wider grid opportunities recognised and assessed as smart meter programme develops
- Early smart grid investment to tactically increase grid intelligence. Locally defined according to legacy and needs
- Utilising Ofgem’s Low Carbon Network Fund to provide real-world demonstration of smart grid technologies and business processes in order to facilitate move to wider deployment in later phases

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Smart metering can play a crucial role in enabling the realisation of network benefits and generating future optionality

Core smart metering principles in relation to smart grid and the wider power system	**Potential smart meter functionality to support smart grid, drawing from ENA and ERA draft specifications**
• Facilitate distributed energy resources to reduce peaking requirements and cost effectively manage wind intermittency • Provide means to ensure that high localised concentrations of electric vehicles and distributed generation can be identified and cost-effectively integrated into the network • Communications model and meter specification provides grid operators with access to the required data in the required time span to manage emerging requirements and optimise grid operation • Ability to support microgrids and islands by providing local data and Distributed Energy Resources (DER) control	• The meter would be capable of initiating consumer appliance load switching and demand management – in addition to TOU and Critical Peak Pricing (CPP) tariffs which will provide the appropriate price signals, direct control may be necessary • The metering system may provide voltage profile data, which will detect whether voltage levels are being maintained at customer terminals – particularly important with the anticipated increase in distributed generation and micro-generation • The meter would support power outage detection by remote interrogation of meter energisation status – the grid operator would be able to poll a selection of meters to establish the location of an outage • Smart meter information communications system would be integrated with Network Operators' network management systems to both enable real-time (automated) network operations - and inform planning timescale network management decisions.

- **These are not a set of firm requirements as any meter and communications functionality will need to consider the appropriate cost / benefit trade-offs**
- **They are reasonable aspirations for smart meter functionality but require extensive qualitative and quantitative analysis, including working with DNOs, for validation**

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In the longer run, the smart grid is likely to become progressively more important, with a possible move from running generation to suit demand to running demand to suit zero-carbon generation

Challenge	Implications	Smart grid response
New power flows – heating / transport electrification and distributed energy resources (DER – includes distributed generation and demand response)	• Significant increase in electricity demand • New power flow and system management challenges • Links with Smart Meters • Integration with a variety of domestic devices to enable active demand response	• Delivers enhanced grid planning and improved utilisation to defer and optimise capital spending • Enable integration and optimised operation of virtual power plants • Distribution system operation (from DNO to DSO) with increased intelligence and control • Enhanced end-to-end power system integration • New customer-supplier relationships and commercial mechanisms • Integrated management of appliances, electric ULCV charging etc. with wider power system
Higher levels of intermittent generation	• Need for cost-effective power-system management of intermittency, both distributed and centralised	• Enabler of DER and end-to-end optimisation of power system
Maximising embedded storage capability	• Embedded storage and ultimately V2G as a potential means to balance the system	• Provide necessary intelligence to optimise usage considering marginal system benefit and battery lifetime cost
Commercial challenges	• New regulatory and market structures to drive the required behaviours and investment decisions (see Ofgem's RPI-X@20 project)	• Provide necessary data and functionality for market and wider commercial operations

- More broadly, the low-carbon transition will bring about uncertainty and a higher degree of complexity, with new patterns of demand generation and usage
- This uncertainty and complexity has to be managed in a cost-effective way, that also maintains security of supply
- Improved information and new tools for end-to-end power system planning and management will be critical
- Smart grid is a significant provider of required data, intelligence and control

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A number of scenarios for energy system development have been considered in the long term, but there are a number of positive near-term steps that can be taken

Informing shape and focus of subsequent phases → | **High degree of uncertainty** (2020-2050)

	2010-2020		2020-2050
Phase -1	Phase 0	Phase 1	Phase 2
Current state	**Near-term steps**	**Large scale investment to meet near term requirements and establish future optionality**	**Providing the foundations for a variety of power system options out to 2050**

▪ Variety of successful smart grid projects under IFI and RPZ
▪ Justified on basis of individual project business cases
▪ Enhanced understanding
▪ Demonstrated a variety of applications for smart grid functionality
	▪ Extending on current foundations
	▪ Further trials, pilots and capability development
	▪ Identifying opportunities for deeper and wider change
	▪ Smart metering links and synergy identification
	▪ Investigate options for rapid large scale change
		▪ Large scale demonstration projects – combination of geographical scale and functional depth
		▪ Optimised transmission and distribution connection of new generation
		▪ Responses to localised needs and legacy
		▪ Interaction with smart metering
		▪ Data gathering and risk avoidance e.g. localised ULCV take-up
		▪ Looking for bigger change and benefits
		  ▪ Demand side development
		  ▪ System optimisation
		  ▪ Capital planning
		  ▪ Asset management
			▪ Extensive development of distributed energy resources with increasing smart appliance, smart homes, embedded storage (ultimately integrating V2G if possible) and distributed generation penetration and use of virtual power plants
			▪ Network growth to handle greater volumes of energy (transport and heating electrification), minimised by smart design and enhanced voltage control
			▪ Increased automation, intelligence and control throughout the network

Ofgem Low Carbon Network Fund & DECC Low Carbon Investment Fund →

Policy, regulation and commercial development across end to end power system and related institutions →

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Quantitative analysis has been performed to develop and evaluate the smart grid vision and provide foundations for future thinking and discussion

Context

- High degree of uncertainty over the post 2020 power system
- There is no single smart grid solution
- Specific solutions will often be defined by local and circuit level context – legacy infrastructure and challenges and opportunities
- Small scale pilots already delivered through RPZ and IFI projects
- The UK is already committed to a significant amount of network innovation spend – £500m during DCPR5 (2010 to 2015) through Ofgem's Low Carbon Network Fund (LCNF)
- There is a high degree of interdependence between the functionality of smart meters and the associated systems and smart grid

Objectives of cost benefit analysis

- Quantitative sense check on key vision messages
- High level assessment of vulnerability of near term investments to future uncertainty
- Framework to consider the impact of possible future scenarios
- Provide the foundations to begin to develop a deeper understanding of smart grid economics
- Help inform at a high level the smart meter implications for smart grid development
- Inform the LCNF process by providing a view of where further data and insight is required

- **The CBA is indicative and does not represent a smart grid proposal for delivery. The ENSG does not suggest that the UK builds this solution**
- **The CBA does not provide quantitative support for concrete decision making or specific policy formation**
- **Further analysis will need to be done on specific smart grid projects considering local circumstances and needs. It will reflect the LCNF, the smart metering roll out and other opportunities and challenges**
- **More extensive and robust analysis will be developed from pilot projects, which will provide real world data**

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The CBA takes one of many possible smart grid investment paths as an indicative framework for high level analysis and insight development

- The CBA is not meant to define the 'right' smart grid path. Instead it selects a possible path as a framework to meet the CBA objectives
- The smart grid in the CBA is defined by substation sensing linked into smart meter communications (other solutions could potentially achieve the same benefits)
- The CBA also considers the in home developments required to enable the demand side and the utility back office functionality to utilise new data flows and deliver the associated benefits
- The CBA is split across two phases to account for the high degree of uncertainty post 2020 and enable an evaluation of the long run implications of near term investments

2010-2020	2020-2050
Phase 1 – base and low scenarios	Phase 2

2010-2020 — Phase 1 – base and low scenarios

Evaluating the potential for UK smart grid

- The purpose of the phase 1 analysis is to assess the potential for UK smart grid and understand some of the key assumptions and dependencies
- The opex costs, capex financing and capex replacement costs are, like the benefits, calculated out to 2050
- Limited reliance upon future power system developments
- For example, it does not assume any V2G benefits before 2030, makes very conservative assumptions about the level of DER and does not capture the potential reinforcement saving that could be realised if the UK pursues large scale electrification of heating and transport
- Due to these assumptions the vulnerability of phase 1 NPV to benefit erosion under possible future scenarios that reduce the value of smart grid functionality is reduced
- The phase 1 investments also provide the foundations for future optionality

2020-2050 — Phase 2

A conservative consideration of smart grid upside in the context of uncertainty

- The purpose of phase 2 is to assess how wider power system changes and smart grid opportunities might further support the case for smart grid
- All the benefits are in addition to those captured out to 2050 by phase 1
- Phase 2 considers significant growth in DER (V2G post 2030 has a particularly big impact) in addition to reinforcement associated with transport electrification
- For this reason the phase 2 benefits are more vulnerable to the alternative paths that may be presented by the future energy system
- For example a system relying on centralised storage with limited DER or transport electrification (e.g. fuel cell displaces electrification) would not deliver the same benefits
- The opex costs, capex financing and capex replacement costs like the benefits are calculated out to 2050

- **This CBA makes various assumptions about smart metering functionality both in terms of the meter and the communications model. Decisions on the smart metering functionality have not been decided. Communication via the substation is assumed in this analysis. ENSG does not necessarily believe that this is the best comms model – it is purely indicative for the purpose of the calculations**
- **Any benefits from additional transformer sensing and control need to be considered in relation to those provided by smart meters on their own when carrying out detailed power system design. This CBA has been based on the principle of avoiding overlap with the Government's smart meter impact assessment not splitting benefits between different technologies and capabilities**
- **It is also important to consider the critical need for consumer engagement to realise distributed energy resource benefits**

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The CBA is based upon a high degree of smart meter synergy and both demand side and grid operation and planning benefits

Phase 1

Approach

- 2010 to 2020 investment in enhanced substation control and sensing and home based demand response functionality

Relationship with smart metering

- There is an opportunity to link smart meter and smart grid communications to reduce the combined communication cost. But certain grid or DER functionality could have very different communications requirements (including bandwidth, latency etc.), and hence costs, than delivering benefits such as eliminating meter reading costs
- The functionality and cost of the communications network to support smart grid benefits could be reduced through; reporting by exception, data compression and distributed intelligence. For example, intelligence at the substation can reduce data flows by only reporting exceptions as opposed to ongoing performance data to be analysed at the centre
- This CBA has not involved a detailed assessment of the communications requirements. However, at a high level, analysis has been completed to determine whether a communications solution that could deliver the stated smart grid benefits using where possible and appropriate the assumptions used in the smart meter impact assessment analysis from May 2009. This analysis has been completed on a discounted cost basis out to 2050 with the communications solution selected (purely for the analysis) suggesting a requirement for an additional £350m of discounted cost for the phase 1. The model sends meter communication via the substation. This is indicative of a possible approach, and does not represent a fully worked-up or defined solution. It is acknowledged that work is needed to consider and define the communications infrastructure for smart meters and the requirements for grids before decisions are made or functionality finalised
- This assumption is a critical point for discussion and further analysis

Benefit delivery

- Smart meter data at the edge (home etc.) and at the transformer provide significant increases in grid information (possibly real time and after the event). This enables enhanced grid operation and planning. Benefits include: energy saving from voltage optimisation, reduced technical losses, predictive maintenance, reduced customer minutes lost (CMLs) and a reduced need for reinforcement
- Smart meter two way communications, smart appliances and demand response control functionality enable load control . Load control and DG dispatch together deliver DER benefits. These benefits are limited by the amount of selectable load or dispatch and the response of customers. The benefits are calculated on the basis of displaced peaking capacity

Phase 2

Approach

- 2020 to 2030 investment in DER expansion and increased grid sensing and control
- Majority of costs relate to DER investment – smart appliances, direct control functionality, home area networks and DER IT (aggregated demand side management systems, in home control, registration and dispatch)

Benefit delivery

- Predominately demand side benefits from interruptible loads and ultimately V2G dispatch
- Also realise increased reinforcement saving benefits on account of transport electrification
- No system operation benefits are realised as presumption is that increased DER and utilisation will actually make things harder to manage and increase losses. Whilst smart grid will help manage this, exclusion of these benefits is assumed to be a fair and conservative approach

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- The CBA does not separately calculate the direct or indirect carbon benefits delivered by the suggested smart grid infrastructure. The capacity of smart grid to deliver a cost efficient low carbon transition is included within the assumed electricity price out to 2050. This is based upon the principle that the European Trading Scheme will be the key mechanism for carbon abatement and that tradable carbon reduction will be integrated within the electricity price. The CBA has been performed at a high level and so makes the high level assumption that the price of electricity is £0.1 per KWh out to 2050 – intention of conservatively factoring in the cost of new decarbonised electricity infrastructure. The benefits are sensitive to the price of electricity out to 2050
- The level of distributed generation and transport electrification, are taken from the Government's Low Carbon Transition Plan. A consideration of external dependencies for each phase is shown on the CBA output slides
- CBA is constructed on a societal basis. The costs to society are the ongoing opex and the regulated DNO WACC for all smart grid up front and replacement capex. The costs and benefits go out to 2050. The net cash flows are discounted at standard Government discount rates – 3.5% to 2030 and 3% beyond.
- There are potentially complex trade-offs between smart grid benefit streams. These have not been modelled but it is hoped that by taking a conservative view of the potential scale of the benefits benefit over statement is avoided

The CBA analysis has identified a number of phase 1 benefits, which can be delivered across a range of plausible values

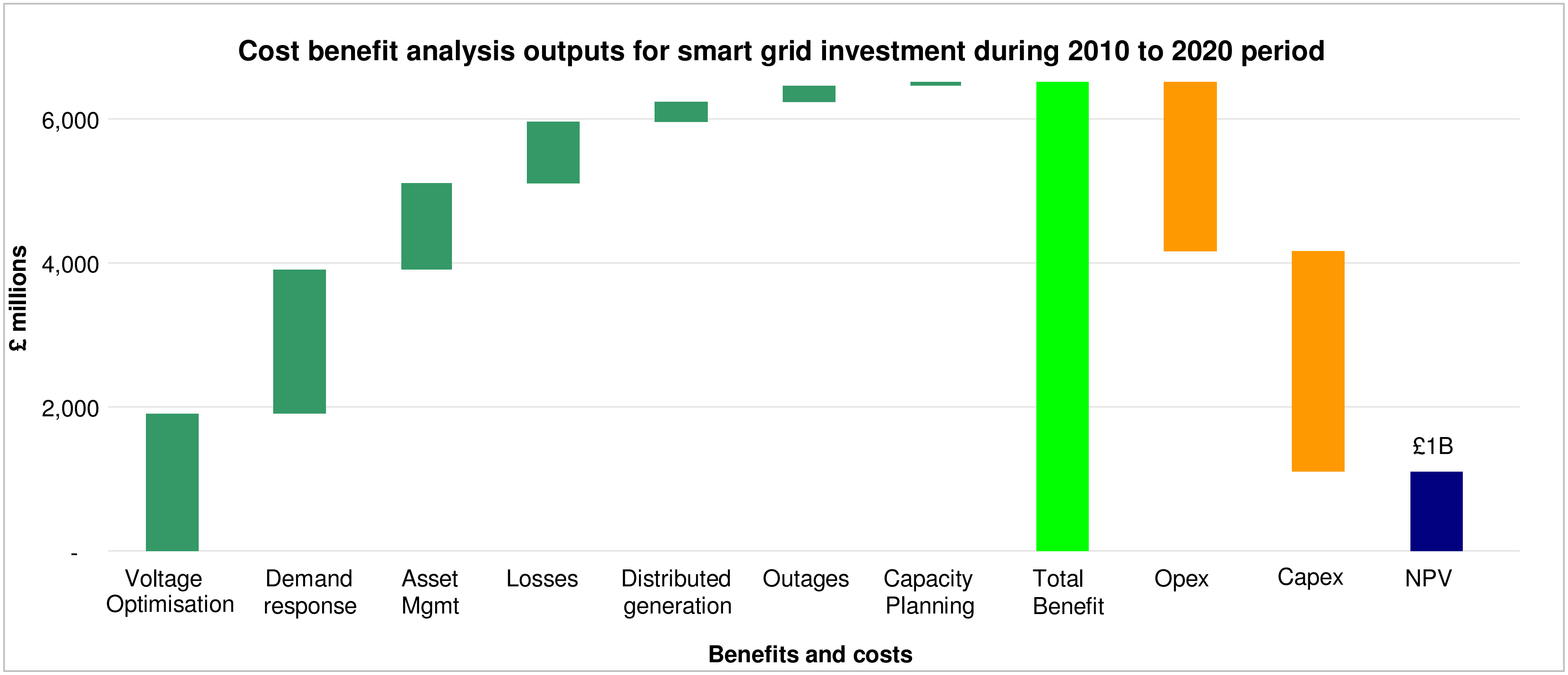
Target benefits	Description	Discounted value benefit range (out to 2050)* – Low	Discounted value benefit range (out to 2050)* – Base	Range drivers
Voltage Optimisation	• Controlling distribution voltage levels so as to minimise energy consumption while maximising use of the statutory voltage window to accommodate future electricity demands and higher levels of DER	1,435	1,913	• Actual degree of voltage reduction achievable • Quality of voltage profile data available
Demand Response^	• Displacement of peaking power generation capacity through peak demand reduction	1,030	1,981	• Customer engagement and demand response take up – 12% vs. 2%
Asset Mgmt	• Reduced asset failure rate through better asset management	1,145	1,205	• Asset management capabilities • Regulatory incentives
Losses	• Reducing peak current flows by load-shifting, reduced system voltage and better phase balance	628	838	• Opportunities available and quality of data available
Distributed generation	• Displacement of peaking power generation capacity through peak dispatch of DG	186	279	• Availability of DG at peak – 30% vs. 20%
Outages	• Reduction in customer minutes lost through enhanced network operation	212	223	• Capacity to integrate enhanced information into network operation and field activities
Capacity Planning	• Reduced need to reinforce network through enhanced utilisation and planning	64	67	• Capacity to increase utilisation and build increased information into capacity planning

*Demand response and distributed generation benefit ranges are based upon changes to customer take up and DG availability at peak respectively. The other ranges are generated through percentage adjustments based upon their indicative sensitivities (high 75% of base and low 95% of base)
^Reducing the level of demand response take up also reduces capital expenditure on smart appliances and smart demand control devices

Base scenario

The CBA is constructed at a high level with limited UK proven empirical data. It should be considered indicative and for discussion purposes only

The phase 1 base scenario suggests that a set of potential smart grid investments could deliver a number of benefits and a positive NPV



Key outputs

£1B +ve NPV out to 2050
£1.65B 2010 to 2020 capex:

- £600m substation sensing and control
- £210m transformer installation
- £194m smart appliance costs
- £130m demand response control equipment
- £165m IT capex
- £350m additional comms cost vs. Gov smart metering CBA (on 2010 to 2050 discounted cost basis)

Key dependencies

- Capacity for voltage optimisation to deliver energy savings
- Customer uptake and framework to enable demand response
- Smart metering communications links
- The price of electricity

Key messages

- Positive NPV is feasible on the basis of a plausible set of assumptions
- The level of capex is not large relative to likely network investments during the period
- This core infrastructure would also provide a degree of future optionality
- There is a high degree of interdependence with smart meters

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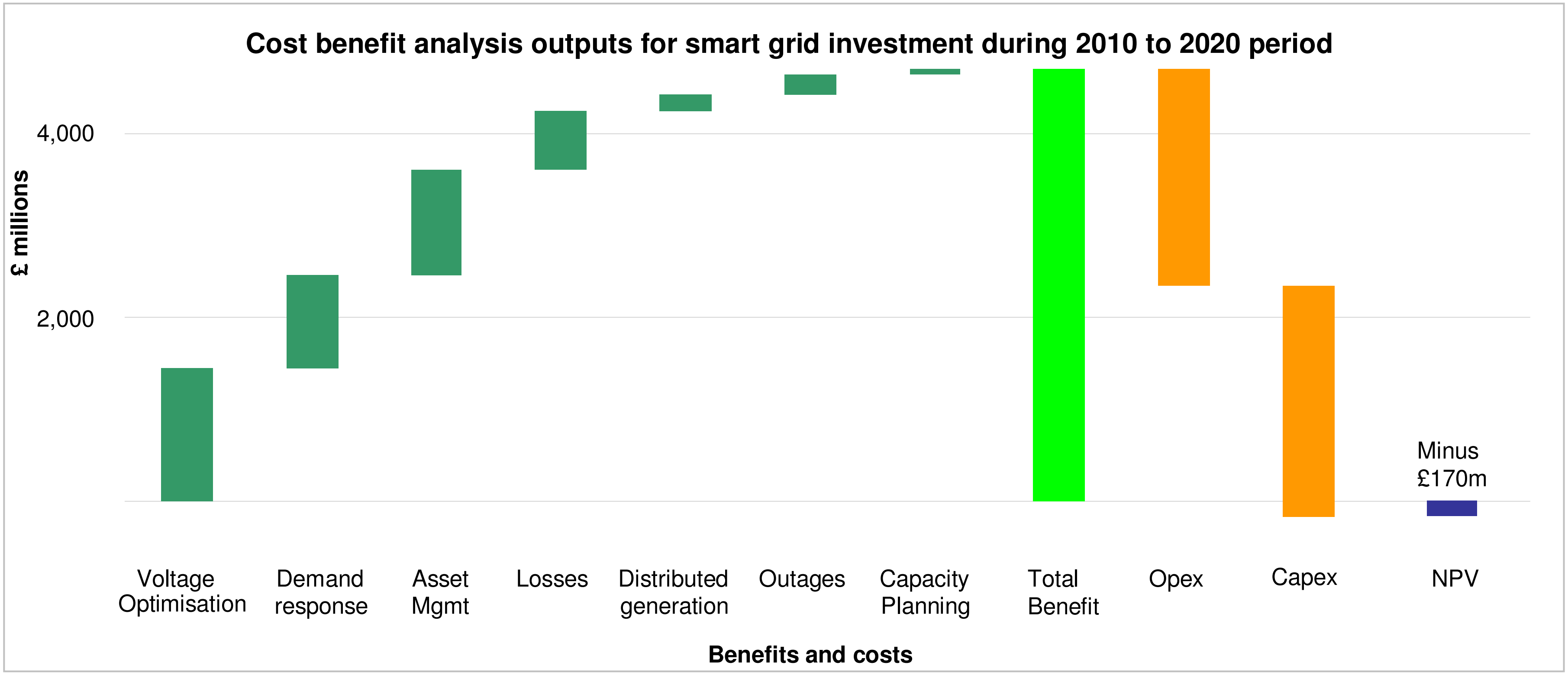
Low scenario

The CBA is constructed at a high level with limited UK proven empirical data. It should be considered indicative and for discussion purposes only

But the phase 1 low scenario suggests that within a plausible benefit range the NPV may be negative



- The quantitative analysis suggests that smart grid could have an important role to play in the UK's future power system
- But smart grids benefits and costs need to be better understood. This will be done through 'on the ground' trialling of end to end technologies and the associated commercial and regulatory frameworks and industry capabilities
- The Low Carbon Network Fund will be a key mechanism for delivering this important insight. This will be explored in detail within the ENSG routemap document (planned for publication early 2010)

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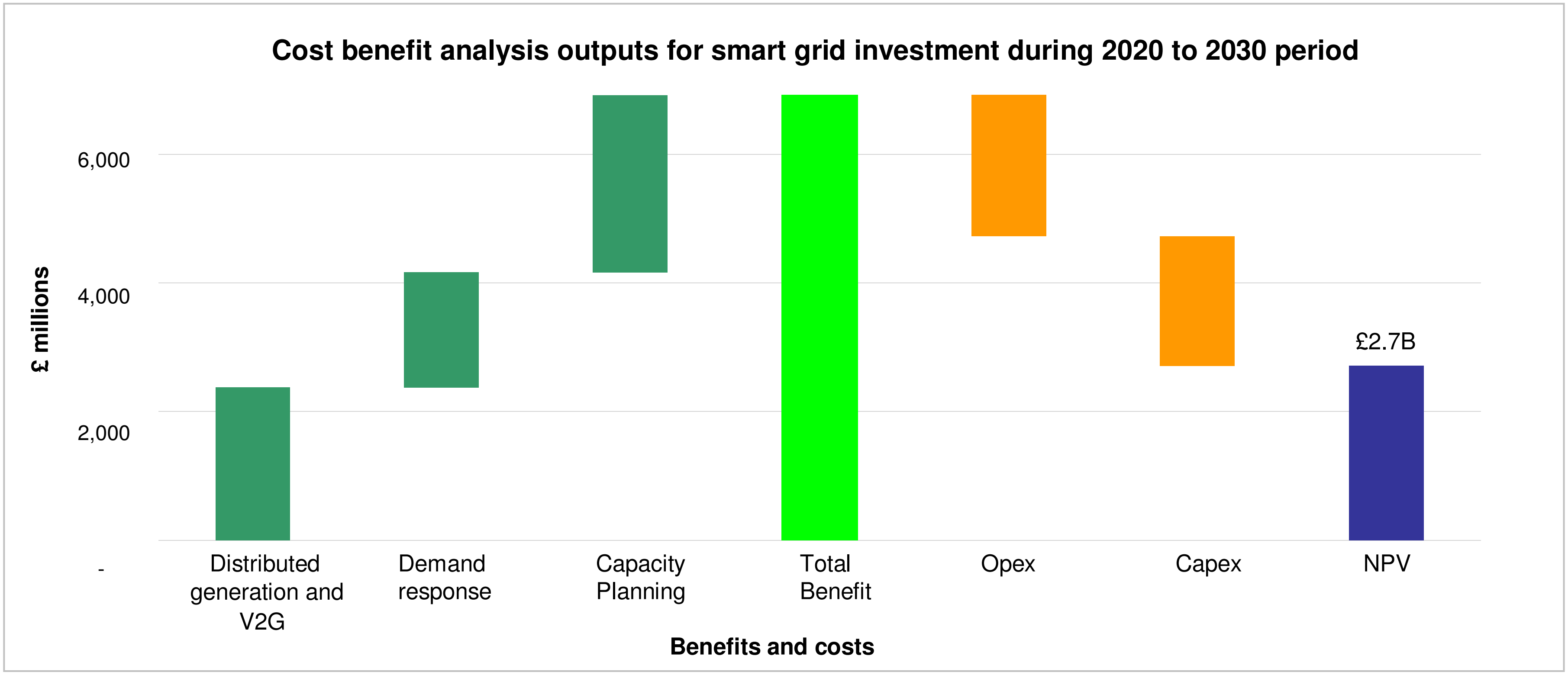
The CBA is constructed at a high level with limited UK proven empirical data. It should be considered indicative and for discussion purposes only

The phase 2 analysis suggests that there could be further future benefits if certain energy system developments occur



Key outputs	Key dependencies	Key messages
£2.7B +ve NPV out to 2050 **£1.5B 2020 to 2030 capex:** • £95m feeder sensing • £20m additional comms • £270m substation automation • £14m capacitor banks • £6m faulted circuit indicators • £700m smart appliance costs • £240m demand response control equipment • £178m IT capex	• **Higher degree of dependency on a particular scenario emerging** • Extensive transport electrification • V2G realistic at scale from 2040 • High degree take up of demand response – 20% • The price of electricity	• DER and transport electrification could allow the delivery of significantly bigger benefits

The CBA provides a framework to further consider the impact of different future energy scenarios on smart grid

	Benefits	Potential scenario impact
Distributed energy resources and the role of the customer	• Displacement of low load factor peaking plant to meet peak demand and manage wind intermittency	• DER offers the potential to attach significant benefits to the smart grid • But DER is highly dependent upon customer engagement with the energy system, electricity demand patterns and the amount of interruptible load, the relative development and costs of other means to manage peaks and intermittency and technologies such as smart home and V2G and the development of commercial and market frameworks • Low cost storage could act as a disruptive technology displacing demand response
Reinforcement savings, distribution connected wind and increasing loads	• Increased utilisation and enhanced network planning reduces need for reinforcement • Peak shaving (DER) could also contribute	• Distribution connected wind (and other generation) offers opportunities to reduce reinforcement spend by increasing asset utilisation (see Skegness RPZ) • This means benefits are in part dependent upon the level of distributed generation • A potentially bigger factor is the possibility of significantly increasing loads due to transport and heating electrification
Optimising grid operation and a radically changing power system	• Increased grid intelligence, control and automation increases network efficiency, decreases CMLs and enhances asset management	• Smart grid can probably deliver a degree of system optimisation benefits irrespective of the future power system • If the power system alters radically with extensive DER and complex end to end balancing and optimisation linked across generation, transmission, distribution and the demand side then smart grid will be critical to making such a system work • If this becomes the UK's lowest cost trajectory to meet its energy needs then smart grid will be a fundamental part of this transformation

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Delivery of the smart grid vision will involve important roles for a variety of different players

The customer

Engage and participate

New entrants

- Bring innovation and new capabilities into the industry e.g. communication providers delivering low-cost fit-for-purpose smart comms networks, appliance manufacturers developing smart appliances or virtual power plant operators offering aggregation services

Generation and trading

- Help address wind intermittency and play a role in establishing a liquid market for distributed energy resources

Transmission

Potentially enable greater integration

- Cost-effective connection of new large-scale generation and preparation for possibility of transport and heating electrification, and the need to manage distributed energy resources

Distribution

Potentially enable greater integration

- Investment to ensure the grid is an accelerator not a constraint, capability development to maximise the benefits of enhanced grid intelligence and preparation to potentially become Distribution System Operators

Supply

- Engaging with the customer and articulating the benefits case, developing new services and offerings and constructing the capabilities to manage more complex customer offers and interactions ,e.g. ULCV billing or commercial arrangements for demand-side response

Ofgem

- Developing the regulatory framework to encourage innovation to deliver the most efficient network solutions and providing clarity over the long run incentives for large investments

Government

- Setting clear policy objectives, clearly articulating the societal benefit case to the public and ensuring link-up to related Government policies where pertinent, e.g. Digital Britain

To make progress a number of challenges must be overcome but these must not prevent rapid action to realise near-term benefits

1. Convey to consumers why smart grid is good for the UK's power system
2. Realising a single smart power system vision linking both smart grid and smart meter
3. Developing smart grid opportunities under DCPR5
4. Real-world data needed to formulate a robust, long-run business case
5. Need for customer engagement and acceptance
6. Utilisation and integration of new technology
7. Aligning new market, commercial, regulatory and technical structures

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ENSG next steps – developing a roadmap to realise the smart grid vision in the light of the challenges faced

- In early 2010 ENSG will be publishing a roadmap to articulate the changes that need to occur to deliver the stated smart grid vision
- The roadmap will look at policy, regulation, market and industry structures, investment and customer engagement

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ENSG smart grid group members

Organisation
AEA
Association of Electricity Producers
CE Electric UK
Centrica Energy
DECC
EDF Energy Networks
Electricity North West Limited
Energy Networks Association
Energy Research Partnership
Energy Retail Association
E.ON Central Networks
Energy Technologies Institute
Intellect
National Grid
Ofgem
Renewable Energy Association
RLtec
RWE Npower
Scottish & Southern Energy
Scottish Executive
Scottish Power
The Centre for Sustainable Electricity and Distributed Generation
Smarter Grid Solutions
The Carbon Trust
Western Power Distribution

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