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INFRASTRUCTURE IN A LOW-CARBON ENERGY SYSTEM TO 2030: DEMAND SIDE RESPONSE

Grid Scientific Limited

1210 Parkview
Arlington Business Park
Theale, Reading
Berkshire
RG7 4TY

Telephone: +44 (0) 1491 871252

Email: info@gridscientific.com

www.gridscientific.com

A report prepared by Grid Scientific for Element Energy

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1 PREFACE

1.1 PURPOSE

The purpose of this document is to provide the findings of the Smart Grid/DSR component of the Committee on Climate Change (CCC) project to characterise low carbon infrastructure for the period to 2030.

1.2 SCOPE

The scope of this document is the Smart Grid/DSR component of the project including:

- A description of objectives and approach
- Qualitative and quantitative findings
- A model used to support the development of the results.

1.3 ACKNOWLEDGEMENTS

Grid Scientific is indebted to John Scott of Chiltern Power Limited for his review and comment on this document and its findings.

1.4 REFERENCES

1.4.1 SMART GRID REFERENCES

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1.4.2 DSR REFERENCES

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2 EXECUTIVE SUMMARY

Demand Side Response (DSR) refers to a set of capabilities that enable and encourage intervention to shift demand for electricity. In practice this means that demand is reduced during peak periods by shifting consumption to occur during periods of low demand.

DSR is one tool in the portfolio of potential smart grid solutions that will help stakeholders to address the affordability, sustainability and security of supply issues facing the electricity sector.

The study considered the implementation, introduction and operation of domestic DSR services and sought to characterise the infrastructure that would be required in the period to 2030 in support of key sector objectives. This enabled conclusions to be drawn regarding feasibility and costs as well as the role of DSR in achieving decarbonisation outcomes.

2.1 DOMESTIC DSR FEASIBILITY AND COSTS

The study investigated the costs and feasibility using qualitative review and a cost model. The main findings and observations include:

- DSR is seen by the energy sector as key for addressing issues relating to affordability, sustainability and security of electricity supply. In principle it is feasible to introduce this service into operation. However there is uncertainty regarding the technical form of the solution and even greater uncertainty regarding how to create the right regulatory, commercial, business and societal environment for it to deliver anticipated benefits successfully. This environment must be supported by the right commercial and operating models.
- A key step in addressing this uncertainty is the Ofgem consultation which is currently in progress. The outcome of this consultation is needed to inform the definition of the service, to enable forecasting of implementation and operating costs and to provide improved clarity of the path for realisation.
- The outcomes of the Ofgem consultation must as a priority establish the regulatory and commercial structure that will be applied to DSR. Without this it will not be possible to build the required business case nor to focus stakeholders on solution implementation and service delivery. In addition it will not be possible to engage fully and confidently with customers until there is clarity on these aspects for the companies concerned.
- The cost of implementing, introducing and operating DSR services will be substantial. The modelling undertaken in this study indicates (based upon moderate rates of uptake and moderate cost levels) that:
  - Cumulative costs would be c£2,600 million in the period to 2030
  - The average cost on a per DSR subscriber basis over the period to 2030 would be c£180
  - The average cost on a per DSR subscriber basis per annum in the period from 2015 to 2030 would be c£12.
- Sales and Marketing costs can be expected to be a very significant component; the modelling suggests (based upon moderate rates of uptake and moderate cost levels) that:
  - Cumulative Sales and Marketing costs would be c£1,400 million or c54% of the total cost in the period to 2030
  - The average Sales and Marketing cost on a per DSR subscriber basis over the period to 2030 would be c£97

- The average Sales and Marketing cost on a per DSR subscriber basis per annum in the period from 2015 to 2030 would be c£6.
- Whilst not infrastructure per se, these items will be key to success of the DSR service and hence early acknowledgement of their importance will assist in service design and deployment.

- It may be of interest to note that work undertaken by the Smart Grid Forum suggests that residential DSR costs could (under certain assumptions) approach £1,000 million to establish the service and £100 million per annum for operation. These costs reflect a Distribution Network Operator perspective, and whilst not directly comparable to the results of this study, do provide insight into the scale of costs that might be anticipated. (http://www.ofgem.gov.uk/Pages/MoreInformation.aspx?docid=47&refer=Networks/SGF/Publications)
- Incentives to customers to participate on a sustained basis will play a key role. The form and scale of these incentives is the subject of continuing study in the sector and may have some impact on the finances of the business case. Incentives will only be one element of gaining the willing engagement of customers.
- CCC assumptions were used regarding the availability of controllable load; these are reflected in the number of customers/households that are assumed to subscribe to and participate in DSR services. There is wide variation in the industry regarding what level of participation can be achieved. For example, CCC data suggests that in 2030, 50 percent of wet appliance load will be available to be shifted; National Grid forecasts that 5 percent will be available in 2020, implying a need for 10-times growth in the decade to 2030. This may be achieved but the wide variation suggests that further work is needed in the industry to enable more accurate planning for DSR and in particular to determine the cost of customer engagement.
- The high level of uncertainty regarding the implementation and acceptance of domestic DSR is reflected in the very wide range of costs produced by the modelling: from c£550 million to c£12,000 million. If Sales and Marketing costs are excluded, the range is from c£120 million to c£3,500million. It is reasonable to treat these costs as a first approximation in the expectation that the range will be narrowed as actions are undertaken to reduce uncertainty.
- Potential service providers will only invest to the extent required and in the timescales anticipated if they can be reasonably certain that provision of domestic DSR services represents a stable, commercially viable business opportunity. Feasibility assumes a vibrant competitive market, attractive to providers of differing scale and with differentiated service offerings.
- DSR will only be successful if customers have loads that can be controlled and if they are able and willing to participate. Over the period to 2030 it is reasonable to expect that vendors will be able to provide controllable equipment cost-effectively and that it will be extensively deployed. Less clear is the issue of customer engagement. This requires considerable effort to be expended in educating potential customers, acquiring customers and retaining them. Sales and Marketing initiatives will play key roles. This will be influenced by the nature of the business environment; for example retention must not only address keeping customers interested in providing their demand, but also in dealing with competition from other service providers.
- The introduction of domestic DSR services is expected to take advantage of the roll-out of smart meters. In addition, technical and commercial trials will be needed. In view of smart meter installation being planned for completion in 2020, it is unlikely that DSR services would be available at scale before 2025 unless priority were to be assigned to their

implementation. It is noted that there are mitigation strategies available should it be determined that coupling DSR to the smart meter roll-out is unfeasible or undesirable.

- The technical and logistic challenges of deploying DSR have parallels in other sectors such as telecommunications; the feasibility of successfully addressing these challenges has been illustrated in these other sectors.
- Application of ICT and effective system integration will play an important role and will enable relevant solution architectures, processes and approaches.

2.2 Decarbonisation

DSR supports addressing a broad set of sector objectives, including decarbonisation.

Decarbonisation may be achieved as a consequence of actions or investments in DSR which are focused on achieving other objectives such as peak generation management or network congestion management. This is referred to as indirect decarbonisation; that is, a decarbonisation outcome is achieved but it is not the primary purpose of the DSR investment or action.

Direct decarbonisation refers to carbon reduction as an objective in its own right and which is achieved through actions or investments in DSR which are undertaken specifically for that purpose.

This study considered the question whether there is a material case for direct carbonisation investment. The findings of the study include:

- The primary driver for DSR investment will be its contribution to addressing issues such as network infrastructure reinforcement avoidance/deferral, securing supply in the face of growing demand, balancing demand/supply positions, and facilitating introduction of distributed resources amongst others. Decarbonisation will be an important objective but will be delivered as a consequential outcome.
- The primary technology-based solutions for achieving decarbonisation will include reduced use of carbon-inefficient fuels for generation, increased use of renewables-based generation, demand reduction, electrification of transportation and heating and use of Carbon Capture and Storage techniques, amongst others. DSR will facilitate and support these solutions but will not in itself play a primary role.
- As noted above, the costs of defining, introducing and operating DSR services will be substantial; most if not all of these costs will be focused on addressing primary drivers and hence on achieving broad DSR based benefits. The focus will not be on decarbonisation as a primary benefit.
- Material, specific, investment for direct decarbonisation is not needed. However it is proposed that there could be a requirement for some reporting to support compliance or management tasks. In this situation modelling suggests that any such direct investment would represent an increment of less than 0.02% on the overall case for DSR investment, hence confirming that this would not be material.

2.3 Further Study

The degree of uncertainty regarding domestic DSR suggests potential areas of further work including:

- The work undertaken in this project is believed to be a reasonable approach to understanding DSR at its current level of maturity; however it would be beneficial to review and update the findings after the Ofgem consultation results are delivered. This would enable the range of costs to be narrowed by giving guidance on issues such as likely commercial structures for example. The results would also inform possible implementation plans.

- The study determines that implementing and operating a domestic DSR service is feasible; however it assumes that the principle of doing so is well founded. Further investigation relating to the nature of controllable load and the ability to engage customers would be beneficial.
- The study addresses costs and feasibility, but does not consider quantified benefits. Development of an understanding of the benefits will enable further depth of understanding.
- The Direct Decarbonisation Case was found not to be material. However there may be a direct decarbonisation opportunity that warrants further investigation. Currently carbon regulations guide generators with respect to generation mix; this is managed through the carbon market and costs that arise are reflected in the wholesale and retail prices of electricity. If DSR solutions were to interwork closely with carbon market systems and be applied to avoid carbon inefficient peak generation then the investment in such integration could deliver a direct decarbonisation benefit. Feasibility depends on the costs of acquiring allowances, the level of free allocations and the fines for non-compliance amongst others. It is unlikely that this could be realised in the timescales considered in this study.

3 BACKGROUND

3.1 OVERVIEW OF SMART GRID

In its Smart Grid Roadmap (2010) the Electricity Networks Strategy Group (ENSG) provides a definition of a Smart Grid:

"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:

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

Smart grid capabilities seek to support timely, cost effective response to issues facing the electricity sector:

- Network infrastructure that is under stress and reaching the end of its design life
- Increasing demand and insufficient generation and transport capacity to serve it
- Security and quality of supplies
- Legal obligations to satisfy decarbonisation objectives
- Severe financial constraints and concerns for Fuel Poverty.

Implementation of smart grids will be based upon a combination of conventional and innovative ("smart") technologies and solutions. These include capabilities such as:

- Advanced Metering Infrastructure (AMI) – incorporating smart meters, communications networks, home displays, and analytics applications
- Distributed generation resources: wind, solar, biomass
- Storage at domestic and community level
- Electric Vehicles (EV) and smart charging
- Heat Pumps (HP) and aggregated DSR
- Sensors for improved network observability, particularly at distribution level
- Real-time thermal monitoring of network asset capacities
- Distribution automation and self-healing networks.

There is a substantial body of information available regarding smart grids; the reader is referred to those provided in Section 1.4.1: Smart Grid References.

3.2 UK Government Smart Grid Policy

The UK government's approach to smart grids has been summarised by DECC as:

"Building a smarter grid is an incremental process of applying information and communications technologies to the electricity system, enabling more dynamic real time flows of information on the network and more interaction between suppliers and consumers. Smart grids will make a key contribution to UK energy and climate goals. The UK is taking action now and investing in smart grid development and planning for the future:

- DECC published a vision document, Smarter Grids: the opportunity in December 2010, and the Electricity Networks Strategy Group (ENSG) published a vision and a Smart Grid Routemap, setting out a high-level description of the way in which a UK smart grid could be delivered
- DECC is rolling out smart electricity and gas meters to all UK homes by 2020. Smart meters can pave the way for a transformation in the way energy is supplied and used and are a key enabler of the smart grid
- The Office of Gas and Electricity Markets (Ofgem) is providing £500 million over the next five years through the Low Carbon Networks Fund to support smart grid trials sponsored by the Distribution Network Operator (DNO) Companies.
- DECC provided £2.8 million to 8 smaller smart grid demonstration projects through the Low Carbon Investment Fund
- DECC worked with the Electricity Networks Association to develop a framework for smart grid standards, focused on cyber security issues"

Smart grid solutions have not been mandated by the government; the government does not make technical implementation decisions of that kind. However there is growing evidence of both government and industry commitment to their implementation and deployment:

- DECC are in the process of undertaking an update of their Smart Grid Vision and Routemap
- DECC and Ofgem have formed and are leading the Smart Grid Forum (SGF) as a central body for progressing planning and thinking
- The recent submissions by the DNOs as part of the RIIO process show their commitment to move toward use of smart grid solutions
- Modelling undertaken part of SGF Work Stream 3 shows there is an economic case for applying smart solutions; they are not being driven by purely technical objectives.

In addition, within the smart metering programme;

- Contracts have been awarded for the Data Communications Company (DCC), Communications Service Providers (CSP) and Data Service Provider (DSP)
- Recent smart meter standards include smart grid enabling capabilities.

Some £110billion infrastructure investment in the electrical power sector over the next decade is projected by the government. It is noted that categorisation of all of this as smart grid investment may or may not be applied consistently by all parties.

Links to documents referenced in the DECC policy statement quoted above and to other supporting documents are provided in Section 1.4.1: Smart Grid References.

3.3 Overview of Demand Side Response

Demand Side Response (DSR) is one tool in the portfolio of (possible) smart grid solutions that will help stakeholders to address the issues facing the sector cost-effectively, utilising solutions both individually and in combination.

DSR refers to a set of capabilities that enable and encourage intervention to shift demand for electricity. In practice this means that demand is reduced during peak periods by shifting consumption to occur during periods of low demand.

Demand is defined here to be "net demand" and hence DSR encompasses functions that can accommodate local distributed generation and storage.

DSR solutions comprise a set of capabilities that address certain business, operational and technical outcomes including:

- Peak demand management/reduction
- Peak generation capacity avoidance
- Support for balancing functions (nationally and regionally)
- Network reinforcement avoidance/deferral
- Network congestion management
- Facilitation of renewables connection
- Renewable generation optimisation
- Storage optimisation
- Customer participation.

DSR does not include the reduction of demand through measures such as improved efficiency.

DSR can be applied to any customer and is typically categorised on the basis of customer type:

- Industrial, including, heavy manufacturing, steel plants for example
- Large Commercial, including office buildings/estates, retail, warehousing for example
- Small Commercial, including smaller business premises and office buildings
- Light Industry including small factories, agricultural sites for example
- Domestic, including residential and small business.

DSR may be either "static" or "dynamic":

- Static DSR: provides pre-set control signals based on average predicted demand costs and demand profiles
- Dynamic DSR: provides real-time signals based on real-time demand and costs.

There is a substantial body of information available regarding DSR; the reader is referred to those provided in Section 1.4.2: DSR References.

4 CHARACTERISATION OF INFRASTRUCTURE – DOMESTIC DSR

4.1 OBJECTIVES

The objectives of the Committee on Climate Change (CCC) study being undertaken by Element Energy and its partners, are to characterise low carbon energy system infrastructure for the period to 2030 and to provide insight into its implementation; it considers four key areas:

- Transmission networks and interconnection
- Distribution networks
- Carbon capture and storage solutions
- Smart grids, specifically Demand Side Response (DSR) solutions

The study addresses the following key elements:

- Characterisation of the type and scale of infrastructure required in 2030
- A timeline of infrastructure deployment to 2030
- Feasibility of deployment, including overcoming barriers.
- Cost of two decarbonisation scenarios, relative to a baseline

One component of the study is to consider relevant aspects of DSR as a smart grid solution. The objectives associated with this part of the study are to:

- Characterise the infrastructure that would be used to deliver DSR for domestic customers
- Describe key aspects of implementing domestic DSR, including feasibility, delivery and introduction and costs
- Determine the contribution that domestic DSR could make to the achievement of direct decarbonisation goals

4.2 SCOPE

The scope of the DSR component of the study is defined by the following attributes:

- The study considers DSR within the overall portfolio of smart grids; other smart grid solutions are not addressed except to identify relevant dependencies
- The study considers only domestic DSR; DSR also applies to grid connected heavy industry and other commercial users; however, the mechanisms for this are already in place and are unlikely to significantly change in the period to 2030
- The study address feasibility and costs of domestic DSR and considers (at high level) an implementation plan
- The study considers decarbonisation objectives and outcomes of DSR; it distinguishes between indirect decarbonisation and direct decarbonisation
  - Decarbonisation may be achieved as a consequence of actions or investments in DSR which are focused on achieving other objectives such as peak generation management or network congestion management; this may be referred to as indirect decarbonisation.

– Direct decarbonisation refers to carbon reduction as an objective in its own right and which is achieved through actions or investments in DSR which are undertaken specifically for that purpose.

4.3 APPROACH

The approach followed in undertaking the study comprised the following:

- Consider domestic DSR in the broadest sense and then focus on aspects relating to feasibility
- Develop a set of implementation considerations for the realisation of solutions that will be supportive of achieving benefits from use of domestic DSR
- Develop a model for the Base Case – the case which addresses DSR broadly
- Draw conclusions regarding the costs and feasibility of domestic DSR
- Prepare a high level view of the path to be followed in achieving a domestic DSR solution
- Consider aspects of domestic DSR that relate specifically to direct decarbonisation
- Develop a model for the Direct Decarbonisation Case – the case which addresses the incremental capabilities and costs attributable to direct decarbonisation
- Draw conclusions regarding the contribution DSR makes to direct decarbonisation.

5 DOMESTIC DSR SIMPLE REFERENCE ARCHITECTURE

Characterisation of a domestic DSR solution is made easier by using a simple reference architecture which describes the principal components and their interactions.

5.1 SYSTEM

The architecture for a domestic DSR solution can be (highly) simplified as illustrated in Figure 1.

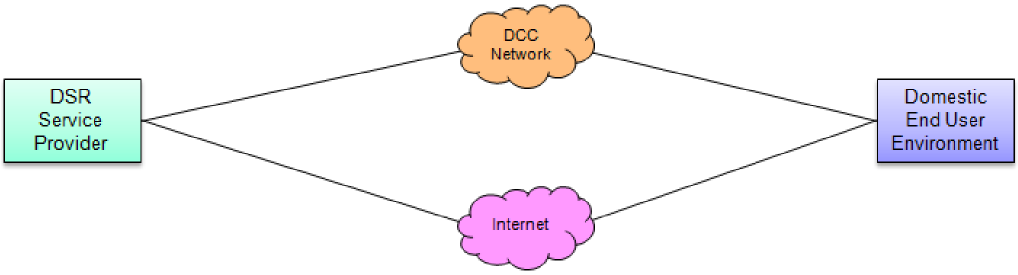

Figure 1 – Simple Domestic DSR Architecture

DSR Service Providers (DSRSP) are responsible for the management and delivery of DSR services. They interwork with customers in their respective End User Environments (a home or small business premise for example) to signal or control the shifting of loads from peak times to periods of lower demand. These shifts may be automated or manual and can be in response to pricing signals, time of days tarrifs or other signals. Actions taken and measurements of outcomes are reported from the End User Environment to the DSRSP so that it knows whether the requested demand change has been implemented. The customer will also be required to make information available regarding the amount of demand it has available to shift and when. Contracts will govern the associated commerical arrangements.

DSRSP services could be provided by aggregators, suppliers, Distribution Network Operators (DNO) or potentially other specialist organisations. For the purposes of this study, the generic term DSRSP has been used to apply to the entities involved; no specific assumptions are made regarding which entities are actually involved, or how they interact at a commercial level.

The DSRSP communicates with its participating customers through a Wide Area Network (WAN). In the UK this facility could be provided by the Data Communications Company (DCC) being created to support the comminications component of AMI. The DCC will provide both Communications Service Provider (CSP) and Data Services Provider (DSP) functions.

The Internet can serve as an alternative or complementary network for provision and management of DSR services. The specific solution is not yet fully known. The DCC has very recently completed the procurement stage and complete information regarding its capabilites are not yet known. For purposes of the study it is assumed to play a key role; however if it is not available on a timely basis, mitigation is provided by the ubiquitous availablity of the Internet.

5.2 DSR SERVICE PROVIDER

Figure 2 below shows core functions required to support DSR within a DSRSP. The functions shown are not intended to be a full and complete list of all those needed, nor is it intended to imply any specific architecture or implementation strategy; the main intent is to indicate a minimum set of core capabilities which will be required for DSR services to be delivered and managed, and which will have a material cost impact for development and deployment.

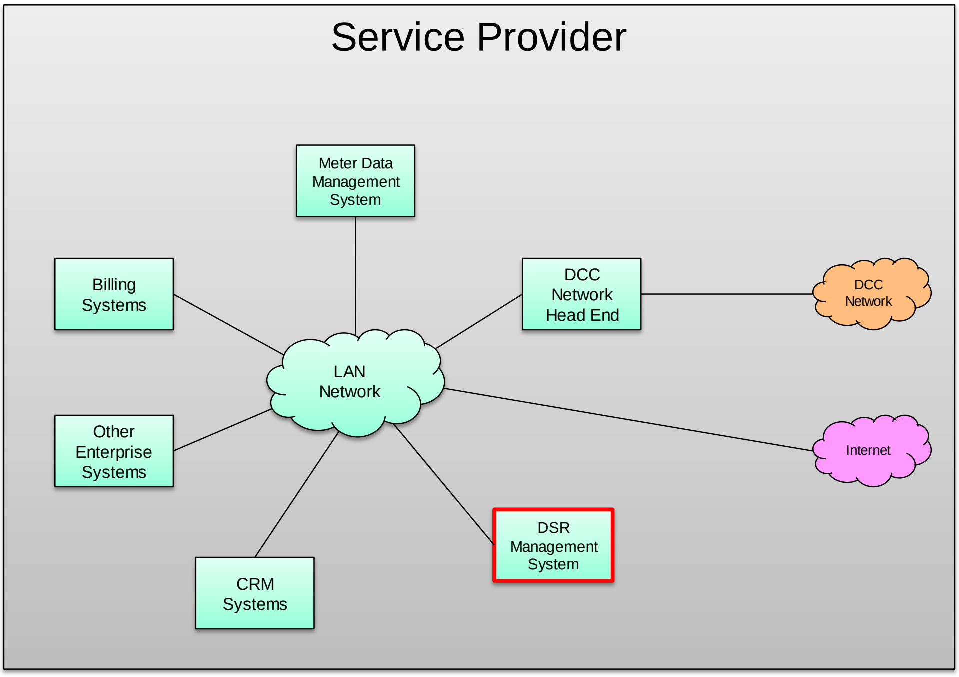

Figure 2 – Domestic DSR Service Provider Environment

The majority of the identified functions (e.g. meter data management, billing, customer management etc.) will exist independent of the DSR function, but may require significant enhancements to support the DSR services. For example, enhancements would be needed to the billing system(s) to support more complex tariffs based on Time of Day usage and the associated DSR events and incentives.

The DSR Management System is a generic term used to refer to one or more IT applications which will utilise the available data relating to prevailing and forecast demand and generation capacity and various constraints within the network. It will determine the required DSR actions to ensure optimum performance of the network especially during peak periods.

5.3 COMMUNICATIONS INFRASTRUCTURE

Figure 3 below shows the typical communications infrastructure required to support DSR including all necessary communications between the DSRSP and the domestic end user.

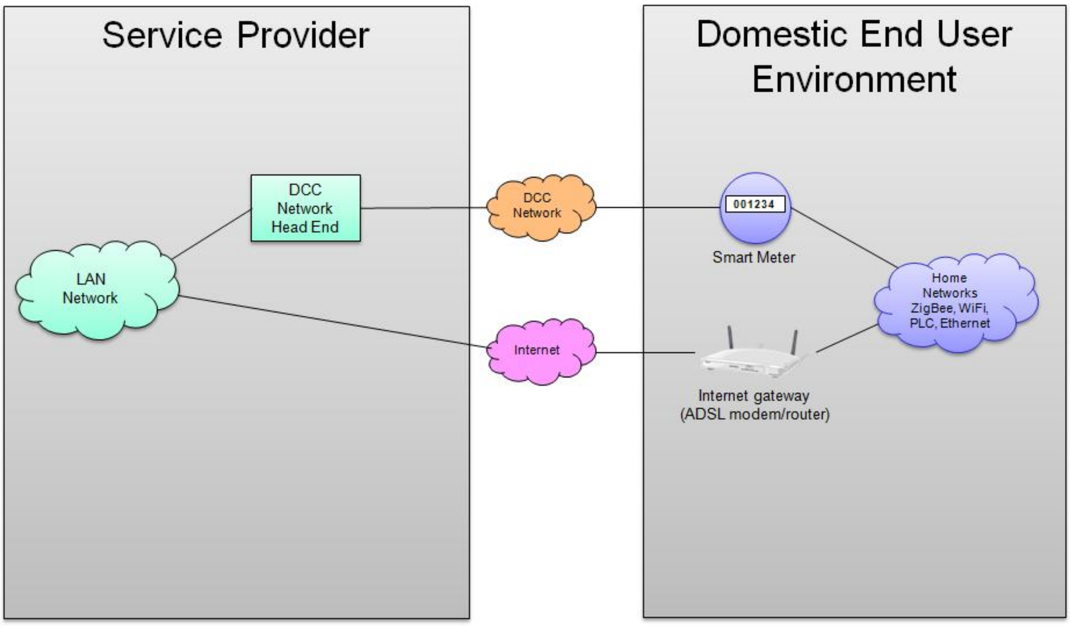

Figure 3 – Domestic DSR Communications Infrastructure

DECC has announced plans for the forthcoming deployment of smart meters to domestic users in the period 2015 to 2020. This programme includes the formation of a new Data and Communications Company (DCC), incorporating a dedicated communication network operated by one or more Communication Service Providers (CSPs). The programme has very recently completed the final stages of the procurement process; full details of how the DCC/CSP will operate, exactly what services will be available to which entities and the commercial structure governing such services are not yet finalised.

As a result, this study assumes that the DCC/CSP network will be used as a minimum to collect the required electricity usage data that is required by the DSRSP. Other DSR communications relating to download of DSR schedules, upload of DSR status (e.g. of devices) and specific DSR instructions (e.g. for time-shifting or curtailment) may flow via the DCC/CSP network, or via a standard (secure) internet connection. This study assumes that it is a prerequisite for all domestic DSR users to have a broadband based internet capability to support this.

5.4 End User Environment

Figure 4 below shows the primary components likely to found in a typical DSR domestic end user environment. The diagram includes a list of potentially DSR controllable devices (e.g. EVs, Heat Pumps and smart appliances), although individual DSR subscribers may have only a subset of these devices.

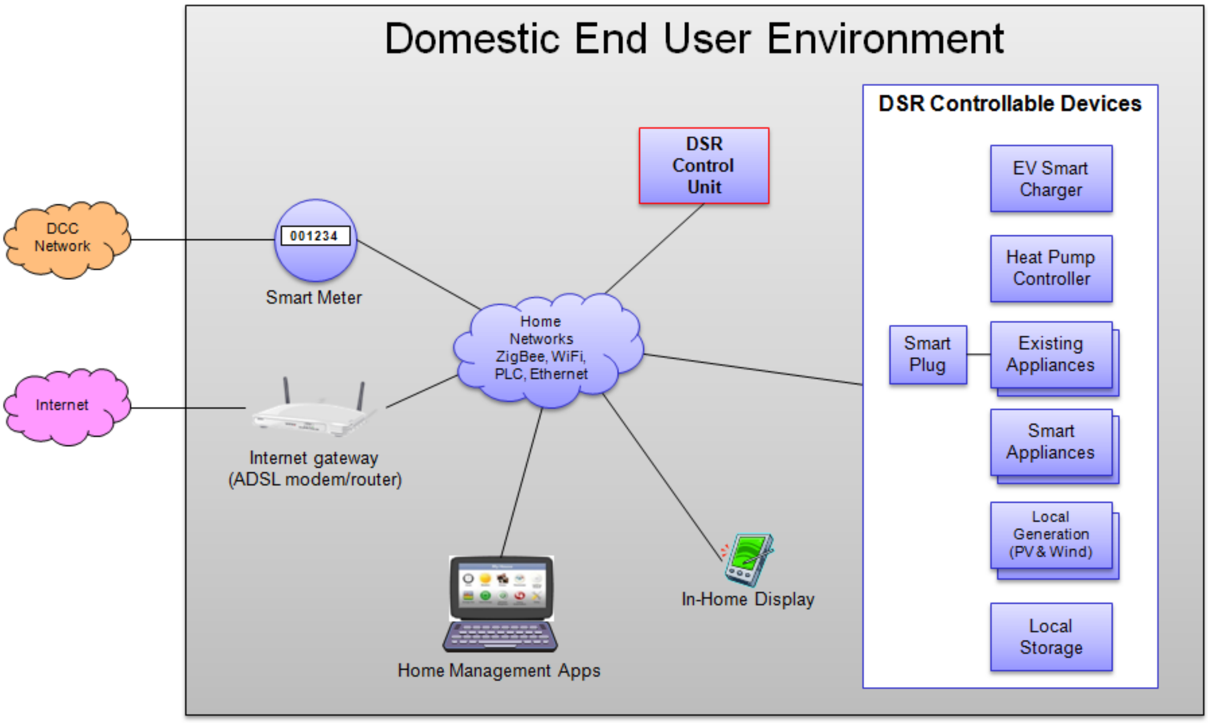

Figure 4 – Domestic DSR End User Environment

The UK smart meter requirements specification includes some capability to support DSR, but specific implementation and capability details vary, and are unlikely to be fully stable until mass deployment of smart meters is underway.

This study assumes that relevant standards and protocols required to allow inter-working between smart meters, DSR Control Units and relevant DSR controllable devices will be in place on a timely basis and with a sufficiently rich feature set to allow the DSR Control Unit to perform its function of managing the relevant devices.

Primary devices for DSR control will include high consumption items such as EV's and heat pumps, and may also include local generation devices such as PV or wind turbines. The study also assumes that other appliances such as dishwashers, washing machines can be subject to DSR; in this case, they will either be "smart" appliances, with such capabilities built-in, or may use "smart plugs" to enable existing appliances to be used.

The DSR solution will provide status information via the In-home display and/or home management applications or web portals provided by the DSRSP.

6 Domestic DSR

6.1 Overview

A DSR Solution may be said to provide a set of DSR services. These services could be the time shifting of charging an EV, the management of operation of smart appliances, the control of local generation such as PV to lower net demand at a peak time, amongst many others.

The services are realised in DSR Applications that may function independently of each other or in cooperation. They can be viewed as existing in a modular form that implies new services can be added over time as new services are defined, new technologies are deployed or new demand management requirements are identified. For example, applications may be updated or new applications introduced to address the move to Dynamic DSR from Static DSR as more real-time supporting capabilities become available.

The DSR Applications are built on a DSR Platform. This platform provides common services to the applications. These could include communications functions, data management services, user interfaces, amongst others.

The DSR Solution is expected to take advantage of the Smart Metering Infrastructure that is planned to be in place to enable a broad set of smart services for customers. This infrastructure can provide the wide area communications required to connect to customers, but a principal function will be the delivery of associated usage metering information that will enable monitoring and verification functions as well as support delivery of financial benefits to customers. The Smart Metering Infrastructure is expected to be a key enabler of the smart grid.

Further information is provided in Figure 5 which summarises the key components needed to enable a DSR solution technically.

	Key Components	Supported Outcomes
DSR Solution	Controllable loads Controllable distributed generation resources Customer premise control device Device control upgrades Communications Control applications Coordination applications IT platform Integration with enterprise systems Contracts Tariffs Analytics	Peak management/reduction Peak generation capacity avoidance Balancing Renewable generation optimisation Network reinforcement avoidance/delay Network congestion management Storage optimisation Customer participation …
Smart Metering Infrastructure	Smart meters WAN Meter data management Analytics	Usage measurement and reporting Secure assured data transport Data control and distribution Customer premise gateway …

Figure 5 – Domestic DSR Components

Figure 5 also refers to supported outcomes. These are the functions or capabilities associated with the infrastructure components, either individually or when acting as a system.

6.2 DSR Solution Investment

The infrastructure investments required to address identified issues in the electricity sector will draw on both conventional and "smart" solutions; DSR is one such solution.

The principal function of DSR is to shift demand from periods of peak demand to periods of low demand. This function can deliver outcomes that will contribute significantly to addressing sector objectives. However it is unlikely that DSR would provide the most substantial contribution to addressing any one of these objectives and hence is seen as playing a secondary (but important) role. This is summarised in Figure 6. Conventional and other smart solutions would be the primary basis for infrastructure investment.

Issue	Conventional and Smart Actions and Investments	DSR Investment
Network infrastructure that is under stress and beginning to crumble	Primary	Secondary
Increasing demand and inadequate generation and transport capacity to serve it	Primary	Secondary
Security of supply	Primary	Secondary
Legal obligations to satisfy decarbonisation objectives	Primary	Secondary
Severe financial constraints	Primary	Secondary

Figure 6 - DSR Investment

The secondary role can be illustrated by example. The legal obligation to satisfy emission reduction targets will be met through deployment of renewables based generation, the electrification of transport and heating, and the retirement of carbon inefficient generation, amongst other measures. DSR will play a role in that smoothing of demand peaks may enable the generation mix to be cleaner by virtue of better use of renewables or reducing reliance on carbon inefficient peak plants. DSR therefore may support emissions reduction but on its own, is neither necessary nor sufficient to do so.

6.3 DSR AND DECARBONISATION

Decarbonisation may be achieved as a consequence of actions or investments in DSR which are focused on achieving other objectives such as peak generation management or network congestion management. This is indirect decarbonisation; that is, a decarbonisation outcome may be achieved but it is not the primary purpose of the investment or action. In this study the case for investing in DSR to achieve the broad set of DSR enabled benefits (including that of indirect decarbonisation) is referred to as the Base Case.

Direct decarbonisation refers to carbon reduction as an objective in its own right and which is achieved through actions or investments in DSR which are undertaken specifically for that purpose. A Direct Decarbonisation Case for DSR describes these investments for direct decarbonisation.

The relationship between investment cases and outcomes is illustrated in Figure 7. As shown, the Direct Decarbonisation Case is incremental to the Base Case.

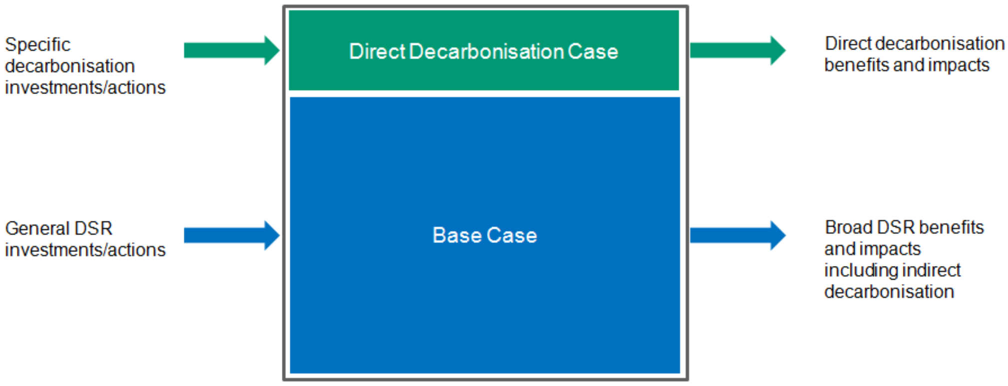

Figure 7 – DSR Investment Case Relationships

Figure 8 considers the relative positioning of the two cases in responding to sector issues with outcomes supported by DSR functionality.

Issue	Key DSR Supported Outcomes	Base Case	Direct Decarbonisation Case
Network infrastructure that is under stress and reaching the end of its design life	Peak management/reduction Peak generation capacity avoidance Network reinforcement avoidance/delay Network congestion management Renewable generation optimisation	Leads	Follows
Increasing demand and inadequate generation and transport capacity to serve it	Peak management/reduction Peak generation capacity avoidance Support for balancing functions (nationally and regionally) Network reinforcement avoidance/delay Network congestion management Facilitate renewables connection Renewable generation optimisation Storage optimisation Customer participation	Leads	Follows
Security and quality of supplies	Peak management/reduction Peak generation capacity avoidance Support for balancing functions (nationally and regionally) Facilitate renewables connection Renewable generation optimisation Storage optimisation Customer participation	Leads	Follows
Legal obligations to satisfy decarbonisation objectives	Peak management/reduction Peak generation capacity avoidance Facilitate renewables connection Renewable generation optimisation Storage optimisation Customer participation	Leads	Follows
Severe financial constraints and concerns for Fuel Poverty	Peak management/reduction Peak generation capacity avoidance Support for balancing functions (nationally and regionally) Network reinforcement avoidance/delay Network congestion management Renewable generation optimisation Storage optimisation Customer participation	Leads	Follows

Figure 8 - DSR Base and Direct Decarbonisation Cases

The conclusion is drawn that the Base Case “leads“ or drives the case for implementation and that the Direct Decarbonisation Case “follows” in all identified instances. The outcomes supported by DSR capability are required to address all sector issues and no supported outcome is unique to achieving direct decarbonisation benefit. This means that the investment in DSR is driven more broadly than just by decarbonisation considerations and hence that the decarbonisation impact is primarily indirect and not direct.

Consideration of incremental functionality that could be provided through a dedicated Direct Decarbonisation Case leads to the proposition that this would be limited to specialised reporting to support compliance requirements that might arise. Such reports may also have use in sales and marketing and for internal management purposes. They would be implemented as a Direct Decarbonisation Reporting Application, which would be one DSR Application. Costs associated with this application are not anticipated to be material in the context of the overall Base Case.

6.4 Qualitative Conclusions

Consideration of domestic DSR solutions leads to the following conclusions:

- DSR will play an important role in addressing challenges currently facing the electricity sector. This role will primarily to enable and facilitate other measures such as network reinforcement avoidance/deferral or increased use of renewables for example.
- DSR is only one of many capabilities that will be used; it exists in an ecosystem of conventional and smart grid technologies and solutions; there is a notable relationship with smart metering as an enabler.
- Viewing the DSR solution as comprising a platform and applications in a flexible and modular structure can assist in responding to requirements in an open and incremental way as they develop and evolve, and in building an understanding of the key component costs.
- Decarbonisation benefits delivered by DSR will be founded in that they enable other decarbonisation strategies to be viable, deployment of EVs and HPs for example
- DSR will enable lower emissions by virtue of reducing peak generation capacity requirements and by facilitating the connection and use of renewable generation but no unique DSR capability is required to achieve this, and the capabilities that are required will be delivering more broadly based impacts.
- Decarbonisation benefits delivered by DSR will be indirect and hence are addressed within the Base Case.
- Consideration of incremental functionality that might be delivered through a dedicated Direct Decarbonisation Case leads to the proposition that this would be limited to specialised reporting to support compliance requirements that might arise. Such reports may also have use in sales and marketing and for internal management purposes.
- The majority if not all investment will be within the Base Case and not the Direct Decarbonisation Case.
- The implementation of DSR assumes that the smart metering infrastructure is (or will be) in place and that the required elements of the smart grid infrastructure (principally controllable loads) are available.

These conclusions are studied using a financial/cost approach in the following sections.

7 Domestic DSR Cost Model

7.1 Overview

The Domestic DSR Cost Model provides a mechanism to develop understanding of the costs associated with introduction and operation of a DSR solution. The high degree of uncertainty recognised in the sector with respect to the form of the DSR solution and how it will operate technically and commercially, is accommodated in the model. Key parameters and assumptions can be readily changed in the model to enable the user to develop further insights.

The Domestic DSR Cost Model comprises a Base Case Model and a Direct Decarbonisation Case Model. The emphasis of the work is on the Base Case Model; the Direct Decarbonisation Case Model is included for completeness and to provide a mechanism for confirming the qualitative conclusion that it is not material in the context of the Base Case.

7.2 Base Case Model

7.2.1 Description

The Base Case Model may be described as follows:

- A cost model for the Base Case
- Acknowledges that the state of development of domestic DSR is not mature and there are variations in possible solutions that could be deployed.
- Addresses the likelihood that there will be multiple DSR Service Providers of different scale (Small: <300,000 subscribers; Medium: >300,000 <600,000 subscribers; Large >600,000 subscribers), offering different service portfolios
  - Drawn from DNOs, Supplier and aggregators
  - Will enter the market over time.
- Makes the following assumptions relating to customers:
  - A DCC/CSP connected smart meter is a pre-requisite for participation
  - Controllable loads (EVs, heat pumps, smart appliances, upgraded standard appliances) are or will be available
  - Customers will participate, subject to the right contractual and incentive arrangements being in place.
- Addresses costs comprising two principal types:
  - Those relating to the development, introduction and on-going operation of the service
    - Solution licence costs for initial deployment
    - Solution delivery and introduction services
    - Solution refresh at 5 year intervals (updating underlying platform technologies for example)
    - Solution enhancement and evolution (adding new services for example)
    - Solution costs arising from the scale of the solution (in addition to base licences)
    - Services costs for achieving scaling
    - Integration of the DSR Solution with other systems such as billing

        - Legal and other costs to develop standard contracts for provision of services
        - The subscription for use of the DCC, CSP and DSP infrastructure (assuming a subscription and transaction model will apply)
        - Operating costs of the DSR solution
        - Sales and marketing costs including an average cost per potential customer to inform them regarding DSR opportunity; average cost to engage with a potential customer (and convert them to customer); average cost to maintain a customer for purposes of avoiding churn (in addition to incentives).
    - Those relating to the delivery of the service to customers
        - The transaction cost for use of the DCC, CSP and DSP infrastructure (assuming a subscription and transaction model will apply)
        - Cost of base device (assumes smaller premise) delivered to premises; no installation costs
        - Cost of enhanced device (assumes larger premise)delivered to premises; no installation costs
        - Cost of upgrades to enable appliances to be controlled (supply of smart plugs for example)
        - Cost to provision and activate service for a customer who wishes to subscribe (logistics and internal processes)
- Supports the Base Case with information regarding the anticipated costs of relevant underlying smart meter infrastructure: the electricity component of the smart meters, use of communications (CSP) and data management services (DSP)
- The model does not include the following costs:
    - Controllable loads: EVs, HPs, smart appliances; these are not within the scope of developing and providing the service, hence the DSR costs modelled would be incurred whether customers deploy these devices or not
    - Local generation sources that may be deployed (and contribute to net demand).
- The important role of incentives was recognised but not modelled.

7.2.2 PARAMETERISATION

Parameterisation of the model allows different views to be established using two categories:

- Relating to the rate at which underlying infrastructure is deployed, the market becomes DSR capable and that customers engage; this may be either “slow” (market reluctance or deployment delay factors), “fast” (good market pull and strongly executed deployment plans) or “moderate” where moderate represents a perspective on the slow and fast cases
- Relating to the costs of the components of the DSR solution, its introduction and operation; these may be “low (simple or limited services or low complexity integration of operations environments), “high” (sophisticated service offering or high complexity integration or operations environments) or “moderate”, where moderate represents a perspective on the low and high cases.

Cases may be selected in combination to give insight into the potential impact of rate of adoption and the range of potential costs.

7.2.3 UPTAKE

The rates of uptake used in the modelling of domestic DSR are shown in Figure 9, Figure 10 and Figure 11 for the “slow”, “fast” and moderate views respectively.

The slow view is a pessimistic one and assumes there will be reluctance to engage with DSR in the period to 2030. The fast and moderate cases have differing profiles but by 2030 are taken to have achieved the level of moveable load indicated by the CCC.

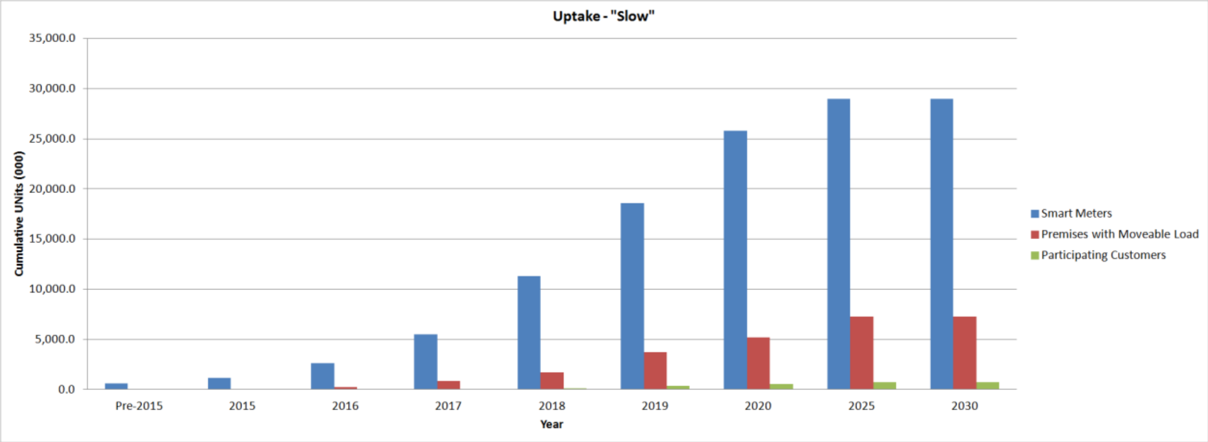

Figure 9 – Domestic DSR: “Slow” Uptake

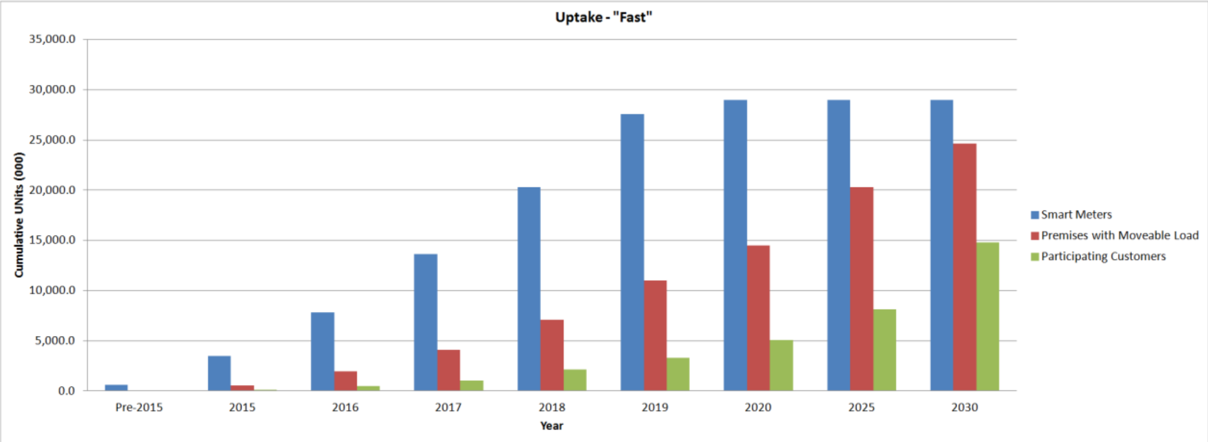

Figure 10 – Domestic DSR: “Fast” Uptake

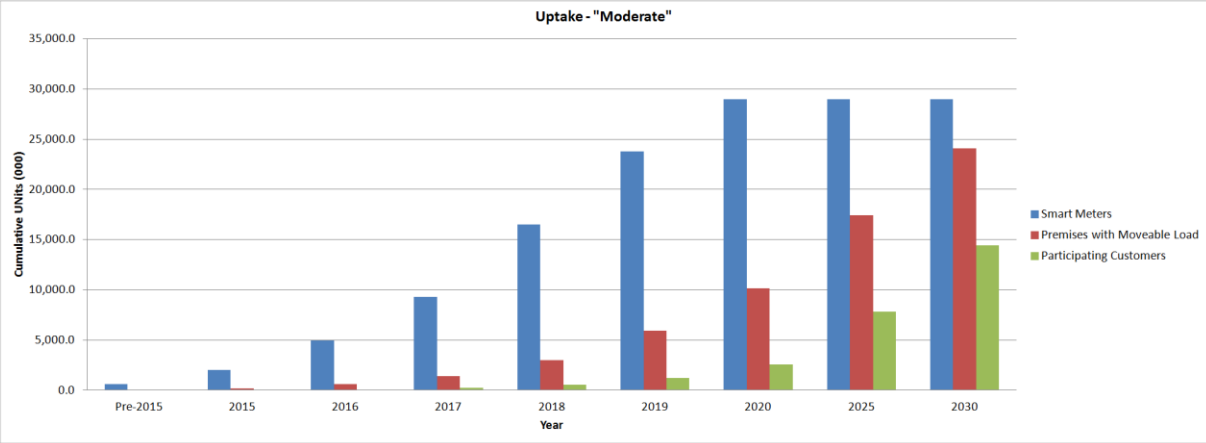

Figure 11 – Domestic DSR: "Moderate" Uptake

7.2.4 Results

The results obtained using the parameters as provided in the embedded version of the model are given in Table 1 – Domestic DSR Base Case Costs.

DSR Solution Costs (£M)		Rate of Deployment/Engagement		
		Slow	Fast	Moderate
Cost Level	Low	554.5	1,330.8	1,199.3
	High	5,735.0	12,044.2	10,832.5
	Moderate	1,336.0	2,987.0	2,611.5

Table 1 – Domestic DSR Base Case Costs

Further detail relating to the case in which there is assumed to be a moderate rate of uptake and moderate cost levels in provided in Table 2 – Domestic DSR Base Case Costs - Detail. In the case modelled there will be 17 DSRSPs (of varying sizes) coming to the market as illustrated in Figure 12 and there will be c14.4 million DSR subscribers by 2030.

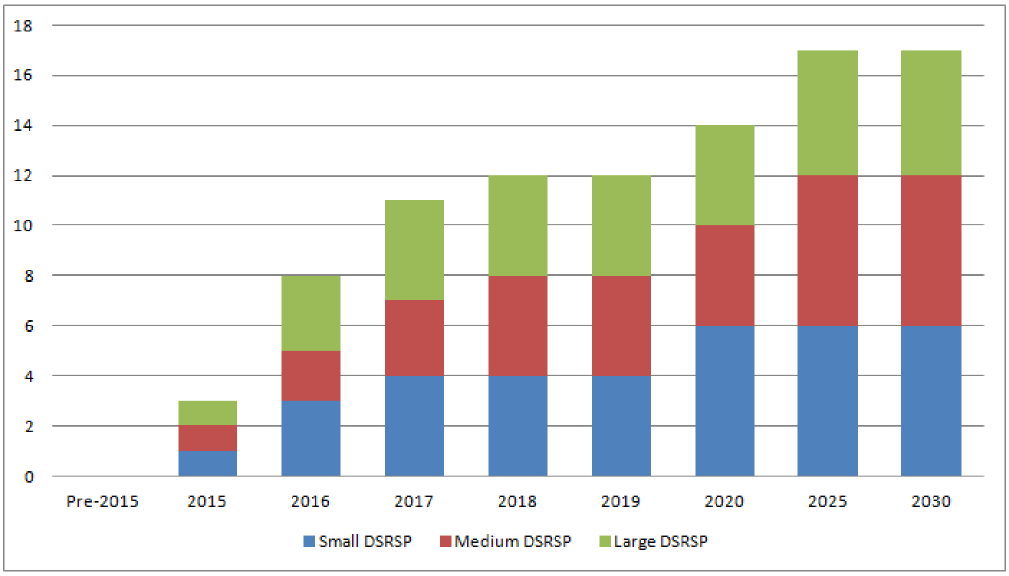

Figure 12 – DSRSPs in the Market in Moderate Uptake

Domestic DSR Base Case Costs (Moderate uptake, moderate costs)		TOTAL to 2030 (£M)
Service Development, Introduction and Operation	Base DSR Management System (DSRMS)	23.0
	Base DSRMS integration and delivery services	23.0
	5 year DSRMS refresh	8.5
	DSRMS - scaling	33.3
	DSRMS services - scaling	33.3
	Enterprise systems integration (Billing, CRM etc)	77.0
	Contract development	49.0
	DCC Communications (subscription)	6.5
	DSRSP Operating costs	38.8
	DSRMS Enhancements and Evolution	5.4
	Sales and Marketing - Inform	519.3
	Sales and marketing - Acquisition	552.3
	Sales and Marketing - Retention	347.7
Service Delivery	DCC Communications (transaction)	341.4
	Base Customer DSR Device - Cost	80.0
	Enhanced Customer DSR Device - Costs	119.1
	Device upgrades cost (e.g. smart plugs)	36.1
	Provisioning and activation of service	317.7
	Total:	2,611.5

Table 2 – Domestic DSR Base Case Costs - Detail

The wide variation is costs amongst the views highlights the level of immaturity of the opportunity and the degree of uncertainty with respect to approaches to be used in implementing solutions. However it is clear that the costs are substantial and depend upon the rate of introduction, the complexity of the service portfolio, the obstacles in customer engagement and the number of operators that are attracted to the business.

There are two primary factors which contribute to the impact on costs of the Slow, Fast and Moderate rates of deployment/engagement:

- The Moderate case reflects the data provided by CCC for the availability of controllable load and leads to residential customer subscription levels of c50 percent. The Fast case is slightly more aggressive. The Slow case represents the situation in which subscription is very low in the period to 2030 (2.5 percent). Fewer customers imply lower costs.

- The number of DSR Service Providers attracted to provide residential services varies in the three cases with it being assumed there will be 15, 23 and 17 for the Slow, Fast and Moderate cases respectively. The rather higher number for the Fast case suggests a more active and aggressive market commensurate with the faster engagement rate. Fewer service providers imply lower costs as there will be less investment in infrastructure.

Solution costs are directly impacted by the assumed costs for the Low, High and Moderate cases. Of note are the following contributing components:

- DSR solution cost: The High cost case is intended to reflect a more extensive or complex service offering requiring more sophisticated IT applications and systems; this will mean the initial solution will be more costly and that costs of on-going operation, maintenance and renewal will also be higher. The Low case describes a more basic solution with limited integration. The Moderate assumes a likely solution cost and level of integration.
- Contract development cost: The High cost case reflects the situation where more complex services will require more effort to be expended in developing and managing service contracts. Other influencing factors could arise from regulatory or market structures.
- DSR Control Unit cost: The cost of these units could vary depending on the level of sophistication of the device; device upgrade costs could also be similarly affected. The High case addresses more costly devices.
- Service provisioning costs: the costs associated with provisioning a customer's service will be impacted by service complexity and the sophistication of the tools and organisation (or organisations) delivering the services. The High case addresses situations where the provisioning of a service instance is more costly.
- Communications costs: The High case assumes higher cost for access and use of the required communications.

An indication of the underlying differences that result in the wide cost variations in the Moderate rate of deployment/engagement case is provided in Table 3 – Indicative Cost Differences . These arise for the reasons noted above.

Cost Differences (£M) Moderate Uptake Case	Between Low and Moderate Costs	Between Moderate and High Costs
DSR solution costs	119.4	220.0
Contract development costs	28.5	48.5
Control unit costs	55.5	226.9
Service provisioning costs	65.0	1,054.3
Sales and Marketing costs	931.0	6,328.9
Communications costs	212.8	342.5

Table 3 – Indicative Cost Differences

Exclusion of Sales and Marketing costs associated with customer engagement, acquisition and retention as given in Table 4 – Domestic DSR Base Case Costs Ex Sales and Marketing shows that these costs represent a substantial component to be considered in the introduction of domestic DSR services. The High case seeks to address the uncertainty regarding how much effort will be required in order to educate the market and acquire customers and assumes this may be relatively significant. Higher cost could also result if a more complex service offering is assumed meaning more education and sales effort would be needed.

DSR Solution Costs (£M) Ex Sales/Marketing		Rate of Deployment/Engagement		
		Slow	Fast	Moderate
Cost Level	Low	123.5	802.0	711.0
	High	542.3	3,480.6	3,084.5
	Moderate	245.7	1,384.0	1,192.1

Table 4 – Domestic DSR Base Case Costs Ex Sales and Marketing

Information relating to the costs of supporting smart meter infrastructure is provided in Table 5 – Domestic DSR Underlying Smart Meter Costs

Relevant Smart Meter Costs (£M)		Rate of Deployment/Engagement		
		Slow	Fast	Moderate
Cost Level	Low	1,870.0	1,870.0	1,870.0
	High	4,045.0	4,045.0	4,045.0
	Moderate	3,320.0	3,320.0	3,320.0

Table 5 – Domestic DSR Underlying Smart Meter Costs

The smart meter programme in the UK is the subject of a government mandate for implementation. The time line and costs are the subject of a recently initiated delivery process and of related work associated with the development of standards and commercial models. The costs are provided to indicate the scale of cost and are based upon best available information; these could reasonably be expected to change and become somewhat higher. The programme recently announced a delay for both start and completion; this has been accounted for in the costs used.

The same rate of deployment is assumed for all cases; this can be varied in the model. Relevant costs are taken as those associated with the electricity component of the smart meter (excluding the gas component) and with the CSP infrastructure.

The total cost of the full UK smart meter programme (addressing both electricity and gas requirements) is currently forecast to be c£12billion.The apportionment of smart grid costs to DSR is difficult as there are variations amongst stakeholders' opinions regarding which costs are smart grid costs, lack of clarity regarding when certain investments are to be made and concerning the dependency relationship between certain technologies and DSR. This is exacerbated by open questions regarding who will seek to be a DSR Service Provider; will DNOs seek to do so, for example.

The equipment (such as EVs, HPs and smart wet appliances) which provide the controllable loads are not included as the costs of making the service available would be incurred in any case, whether customers had bought this equipment or not.

It is noted for information that the Smart Grid Forum Work Stream 3 Phase 3 findings are that DNO "smart" investment will be c£15billion to 2050 and c£5billion to 2030.

7.3 Direct Decarbonisation Case Model

7.3.1 Description

The Direct Decarbonisation Case Model may be described as follows:

- A cost model for the Direct Decarbonisation Case
- Estimates the costs associated with the mooted Direct Decarbonisation Application; that is, with differences in the DSR solution that would be implemented with the specific objective of realising direct decarbonisation benefits.
- Qualitative analysis concluded that this incremental cost would relate to reporting only; these reports would be used to demonstrate compliance, to support customer marketing activities or for internal management purposes.
- Uses the Base Case Model as its basis.
- Addresses incremental costs comprising two principal types:
  - Those relating to the development, introduction and on-going operation of the service
    - Solution licence costs for initial deployment
    - Solution delivery and introduction services
    - Solution refresh at 5 year intervals (updating underlying platform technologies for example)
    - Solution enhancement and evolution (adding new services for example)
    - Solution costs arising from the scale of the solution (in addition to base licences)
    - Services costs for achieving scaling
    - Integration of the DSR Solution with other systems such as billing
    - Operating costs of the DSR solution.
  - Those relating to the delivery of the service to customers
    - Cost to activate service for a customer who wishes to subscribe (logistics and internal processes)

7.3.2 Parameterisation

Parameterisation of the model allows different views to be established based upon the anticipated complexity and extent of the reports generated.

7.3.3 Results

The Direct Decarbonisation Case costs are summarised in Table 6..

Direct Decarbonisation Application Costs (£M) Incremental		Rate of Deployment/Engagement		
		Slow	Fast	Moderate
Cost Level	Low	0	0	0
	High	1.4	2.9	2.3
	Moderate	0.2	0.7	0.6

Table 6 – Domestic DSR Direct Decarbonisation Case Costs

The costs for the Direct Decarbonisation Application vary from nil (referring to the situations where adequate reporting is provided by the base solutions, or where no reporting is needed) to a few million pounds over the period. When considered in the context of the Base Case it is seen that the Direct Decarbonisation Case costs are not material and can be disregarded.

7.4 Conclusions

Findings and observations that can be drawn from the cost model include:

- The cost of implementing, introducing and operating DSR services will be substantial. The modelling undertaken in this study indicates (based upon moderate rates of uptake and moderate cost levels) that:
  - cumulative costs would be c£2,600 million in the period to 2030
  - the average cost on a per DSR subscriber basis over the period to 2030 would be c£180
  - the average cost on a per DSR subscriber basis per annum in the period from 2015 to 2030 would be c£12.
- Sales and Marketing costs can be expected to be a very significant component; the modelling suggests (based upon moderate rates of uptake and moderate cost levels) that:
  - cumulative Sales and Marketing costs would be c£1,400 million or c54% of the total cost in the period to 2030
  - the average Sales and Marketing cost on a per DSR subscriber basis over the period to 2030 would be c£97
  - the average Sales and Marketing cost on a per DSR subscriber basis per annum in the period from 2015 to 2030 would be c£6.
  - Whilst not infrastructure per se, these items will be key to success of the DSR service and hence early acknowledgement of their importance will assist in service design and deployment.
- CCC assumptions were used regarding the availability of controllable load; these are reflected in the number of customers/households that are assumed to subscribe to and participate in DSR services. There is wide variation in the industry regarding what level of participation can be achieved. For example, CCC data suggests that in 2030 50 percent of wet appliance load will be available to be shifted; National Grid forecasts that 5 percent will

be available in 2020, implying the need for 10-times growth in the decade to 2030. This may be achieved but the wide variation suggests that further work is needed in the industry to enable more accurate planning for DSR.

- The high level of uncertainty regarding the implementation and acceptance of domestic DSR is reflected in the very wide range of costs produced by the modelling: from c£550 million to c£12,000 million. If Sales and Marketing costs are excluded, the range is from c£120 million to c£3,500million. It may be reasonable to treat these costs as a first approximation in the expectation that the range will be narrowed as actions are undertaken to reduce uncertainty.
- The primary driver for DSR investment will be its contribution to addressing issues such as network infrastructure reinforcement avoidance/deferral, securing supply in the face of growing demand and facilitating introduction of distributed resources amongst others. Decarbonisation will be an important objective but will be delivered as a consequential outcome.
- The primary technology-based solutions for achieving decarbonisation will include reduced use of carbon inefficient fuels for generation, increased use of renewables- based generation, demand reduction, electrification of transportation and heating and use of Carbon Capture and Storage techniques, amongst others. DSR will facilitate and support these solutions but will not in itself play the primary role.
- The costs of defining, introducing and operating DSR services will be substantial; most if not all of these costs will be focused on addressing primary drivers and hence on achieving broad DSR based benefits and impacts including indirect decarbonisation.
- Material, specific, investment for direct decarbonisation is not needed. However it is proposed that there could be a requirement for some reporting to support compliance or management tasks. In this situation modelling suggests that any such direct investment would represent an increment of less than 0.02% on the overall case for DSR investment, hence confirming that this would not be material. This conclusion is consistent with that obtained by qualitative review as described in Section 6.4.

8 DSR Implementation – Feasibility

8.1 Overview

Feasibility of implementation of DSR services is not limited to technical considerations. Whilst there is a degree of technical uncertainty, it is important to note that there is even greater lack of clarity regarding policy, regulation and the commercial, business and operations environment in which services would be made available. Customer engagement is a very significant variable and not subject to predictability.

8.2 Dependencies:

	Dependency
D-1	Smart metering infrastructure (or a functional equivalent) delivers meter and communications infrastructure that supports the DSR function.
D-2	Customers have/acquire controllable loads.
D-3	Customers engage with the DSR concept and make flexible demand available for shifting.
D-4	Regulatory environment permits commercially viable delivery of the service.
D-5	DSR Service Providers will enter and remain in the market.

Table 7 – Domestic DSR Dependencies

8.3 Assumptions:

	Assumption
A-1	Smart meters are a pre-requisite for domestic DSR
A-2	Smart meter deployment will align with DECC timelines, currently scheduled for the period 2015-2020
A-3	Smart meters will include some DSR capabilities to allow relevant meter usage data to be collected for analysis and action.
A-4	Additional DSR communications will be via internet access and all DSR customers are assumed to have internet access.
A-5	Smart Meter usage data will be collected and made available to the DSR Service Providers via the DCC/CSP.
A-6	Home appliances may be “smart”, or may be retrofitted with “smart plugs” to enable existing appliances to be used.
A-7	The electricity network will be capable of supporting the DSR service – whether this is by conventional or “smart” infrastructure and systems.

Table 8 – Domestic DSR Assumptions

8.4 RISKS:

	Risk	Probability	Impact	Mitigation
R-1	The smart meter programme does not deliver coverage of domestic premises on a timely basis. Delays of one year for completing the mass rollout have recently been announced. Smart meter availability has been assumed to be a pre-requisite for domestic DSR.	Medium Issues remain concerning standards and interworking. Commercial models are not yet finalised. Logistics planning for installations is not yet visible. The smart meter programme is no longer seen as the top priority for the government's energy strategy.	High Smart meters provide two key functions for domestic DSR: communications support and the provision of usage information which enables achieving financial benefits for customers.	The communications support function could be served using other communications mechanisms, broadband/internet. Security matters would need to be carefully considered. Some usage information could be obtained through the use of auxiliary "clip-on" devices, but this may not be satisfactory. The introduction of DSR could be aligned with the smart meter deployment plan.
R-2	The DCC CSP/DSP may not be available on a timely basis to support mass rollout of smart meters	Medium The procurement process is still in progress. A deeper testing phase has been added to the programme. These factors could lead to delays for commercial or technical reasons or both.	Medium Delay in the availability of the DCC has the effect of delaying the smart meter programme and hence the rollout of DSR.	The DCC provides WAN transport of data which will support DSR. This could be achieved using broadband/internet. Security would need to be a key consideration.
R-3	The smart meter programme is cancelled. Technical and commercial challenges are unable to be solved and a new approach is deemed necessary.	Very Low There is strong government and industry commitment to the programme, it is advanced in its development and there is substantial momentum behind it.	High Smart metering is seen as a central component of the country's energy strategy as they will support managing the cost of energy to consumers, reducing carbon emissions and enabling customer engagement.	DSR could potentially be delivered using other communications and metering options but would be limited to static services. Benefits would be more difficult to deliver and measure.

R-4	The complexity of the regulatory, market and business models required delays or prevents creation of a viable business/service offering.	Medium	High	Current Ofgem consultation in progress to address. Reasonable regularory definition could "!pull" viable commercial models.
R-5	Customer participation does not align with forecast levels	High The service does not deliver expected/promised benefits.	High	Contract definitions. Customer incentives. Provider incentives/business model viability
R-6	Penetration of controllable loads does not reach a level to make the DSR service offering viable	Medium Requires uptake on EV and HP usage. Benefits from uptake of controlled appliances	High	Customer education and incentivisation. Manufacturer incentives.
R-7	DSR Service Providers do not enter or remain in the market	Medium Requires clarity that there is a sustainable business case.	High Essential to the service.	Ofgem activities and determination focused on addressing creating the right environment for DSR services. Customer engagement to ensure there isa critical mass of moveable demand.

Table 9 – Domestic DSR Risks

8.5 High Level Implementation Planning

A high level implementation plan is shown in Figure 13.

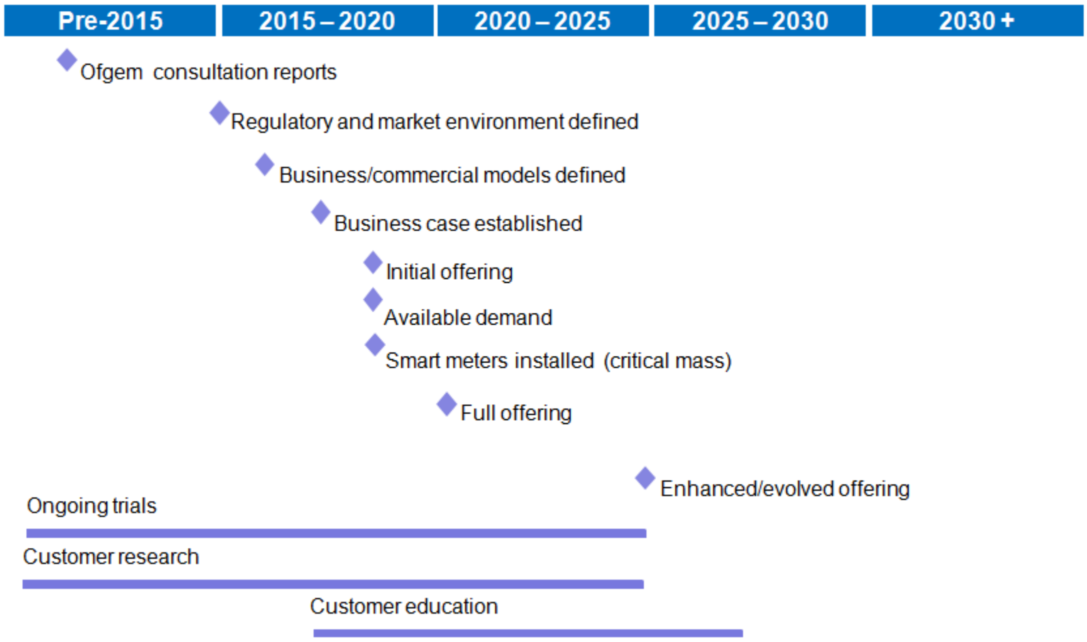

Figure 13 – Domestic DSR: "Moderate" Uptake

The high level plan seeks to emphasise the pre-requisites of establishing regulatory, commercial and business "platforms" for designing and deploying a domestic DSR solution. It also highlights the on-going need to remain focused on the question of customer engagement.

An indicative description of the key stages in DSR deployment is provided in Table 10 – Domestic DSR Planning Matrix. The matrix identifies the key activities/components and associates with them the expected roll-out for capability. The stages may be broadly described as:

- Pre – 2015: Definition and planning
- 2015 – 2020: Proof of concept and early stage operation
- 2020 – 2025: Established operation and growth
- 2025 – 2030: Penetration/Business As Usual.

Component		Pre – 2015	2015 – 2020	2020 – 2025	2025 - 2030
Regulatory	Permitted commercial interactions	Consultation and definition	Initial operation	Established	Evolution
	Licences	Interested parties	Initial participants	Additional participants	Additional participants

Market	Pricing levels/tariffs	Definition	Initial operation	Respond to operational experience and evolving regulation	Respond to operational experience and evolving regulation
Service	Static		Limited	Static	Complex services
	Dynamic		Static	Early Dynamic	
DSR Service Provider	Business model and structure	Definition	Initial implementation and operation	Established	Evolution
	Systems ready	Proof of concept	Development and initial operation	Full operation at scale; incremental functionality	New functionality and technology refresh
	Contract readiness	Investigation	Initial	Established	Evolution
	Sales and marketing	Study	Education and engagement	Education, recruitment and retention	Education, recruitment, retention and incremental sales
	Incentives	Study	Early stage offering	Standard offering	Sophisticated offering
Customer Premises	Controllable loads:				
	- EVs	Very limited	Limited	Significant	Wide scale
	-HPs	Very limited	Limited	Significant	Wide scale
	-Appliances	Smart plug; Very limited	Smart plug/some smart appliances; Limited	Smart appliance/some smart plug; Significant	Predominantly smart appliances; Substantial
	Control Device		Initial	Standard	Evolution
Customer	Interest in participating	Very limited	Limited	Growing	Significant
	Agreement to participate	Negligible	Very limited	Material	Significant
Smart Metering	DCC available	Broad coverage; initial capability	Full coverage; additional capability	Enhancements (including new capabilities, technology refresh)	Enhancements (including new capabilities, technology refresh
	Smart meter rollout	Some non-standard meters installed for trail or commercial advantage reasons	Smart meter roll-out complete	Business As Usual	Business As Usual
Smart Grid	Network	No identified direct dependency	No identified direct dependency	No identified direct dependency	No identified direct dependency

Table 10 – Domestic DSR Planning Matrix

8.6 Conclusions

The study considered feasibility of implementing, introducing and operating a successful DSR service and drew the following key conclusions; supporting information is provided in the sections that follow:

- DSR is seen by the energy sector as key for addressing issues relating to affordability, sustainability and security of electricity supply. In principle it is feasible to introduce this service into operation. However there is uncertainty regarding the technical form of the solution and even greater uncertainty regarding how to create the right regulatory, commercial, societal and business environment for it to deliver anticipated benefits successfully. This environment must be supported by the right commercial and operating models.
- A key step in addressing this uncertainty is the Ofgem consultation which is currently in progress. The outcome of this consultation is needed to inform the definition of the service, to enable forecasting of implementation and operating costs and to provide improved clarity in the path for realisation.
- The outcomes of the Ofgem consultation must as a priority establish the regulatory and commercial structure that will be applied to DSR. Without this it will not be possible to build the required business case nor to focus stakeholders on solution implementation and service delivery. In addition it will not be possible to engage fully and confidently with customers until there is clarity on these aspects for the companies concerned.
- DSR will only be successful if customers have loads that can be controlled and if they are able and willing to participate. Over the period to 2030 it is reasonable to expect that vendors will be able to provide controllable equipment cost-effectively and that it will be extensively deployed. Less clear is the issue of customer engagement. This requires considerable effort to be expended in educating potential customers, acquiring customers and retaining them. Sales and Marketing initiatives will play a key role. This will be influenced by the nature of the business environment; for example retention must not only address keeping customers interested in providing their demand, but also in dealing with competition from other service providers.
- The introduction of domestic DSR services is expected to take advantage of the roll-out of smart meters and other smart grid infrastructure. In addition, technical and commercial trials will be needed. In view of smart meter installation being planned for completion in 2020, it is unlikely that DSR services would be available at scale before 2025 unless priority were to be assigned to their implementation. It is noted that there are mitigation strategies available should it be determined that coupling DSR to the smart meter roll-out is unfeasible or undesirable.
- The technical and logistic challenges of deploying DSR have parallels in other sectors such as telecommunications; the feasibility of successfully addressing these challenges has been illustrated in these other sectors.
- Application of ICT and effective system integration will play an important role and will enable relevant solution architectures, processes and approaches.

9 FURTHER WORK

The following are noted as possible areas of further study:

- The work undertaken in this project is believed to be a reasonable approach to understanding DSR at its current level of maturity; however it would be beneficial to review and update the findings after the Ofgem consultation results are delivered. This would enable the range of costs to be narrowed by giving guidance on issues such as likely commercial structures for example. The results would also inform possible implementation plans.
- The study determines that implementing and operating a domestic DSR service is feasible; however it assumes that the principle of doing so is well founded. Further investigation relating to the nature of controllable load and the ability to engage customers would be beneficial.
- The study addresses costs and feasibility, but does not consider quantified benefits. Development of an understanding of the benefits will enable further depth of understanding.
- The Direct Decarbonisation Case was found not to be material. However there may be a direct decarbonisation opportunity that warrants further investigation. Currently carbon regulations guide generators with respect to generation mix; this is managed through the carbon market and costs that arise are reflected in the wholesale and retail prices of electricity. If DSR solutions were to interwork closely with carbon market systems and be applied to avoid carbon inefficient peak generation then the investment in such integration could deliver a direct decarbonisation benefit. Feasibility depends on the costs of acquiring allowances, the level of free allocations and the fines for non-compliance amongst others. It is unlikely that this could be realised in the timescales considered in this study.

10 APPENDIX A – EV AND HEAT PUMP DEPLOYMENT VOLUMES

The following deployment volumes have been provided by the CCC via Element Energy.

10.1 ELECTRIC VEHICLES

Services Needed: Demand Response

- Adoption of electric vehicles (EVs) will have a significant impact on utilities and the grid. Charging EVs during the peak hours of the day might increase a typical home's peak electricity demand dramatically. "Load shifting" or "demand side response" could help cut electricity demand during peak periods. As a base case assumption, CCC have indicated a significant proportion of EV charging would be done overnight; therefore, it is assumed that "load shifting" services would be needed for each **charging point**. However, it is not certain whether active management is needed for each charging point (e.g. EV charging demand could be managed passively or by using tariffs).
- Electric vehicles could also be used for grid ancillary services including frequency control by demand management. Through commercial arrangements, charging demand of electric vehicles could be reduced as required within a defined response period.
- The number of charging points is calculated assuming one charging point is needed for each electric vehicle:

Measure	Unit of deployment	Deployment				
		2010	2015	2020	2025	2030
Electric cars	1,000s of vehicles	5	125	664	1,816	3,785
Plug-in hybrid electric cars	1,000s of vehicles	0	120	1,035	3,162	7,659
Electric vans	1,000s of vehicles	0	10	74	183	265
Plug-in hybrid electric vans	1,000s of vehicles	0	2	61	303	904
Total charging points	**1,000s of points**	**5**	**257**	**1,834**	**5,464**	**12,612**

10.2 HEAT PUMPS

Services needed: Demand side response

- Similarly to electric vehicles, heat pump load could also be shifted from peak periods if thermal storage is available. CCC assumed that around 25% of heat pump demand is movable in 2030. The table below shows the number of heat pumps with thermal storage by 2030.

Measure	Unit of deployment	Deployment				
		2010	2015	2020	2025	2030
Residential ground source heat pump	1,000s of units	0	68	326	1,265	2,483
Residential air source heat pump	1,000s of units	0	51	244	1,316	4,349
Total number of heat pumps	**1,000s of units**	**0**	**119**	**570**	**2,581**	**6,832**

10.3 Wet Appliances

Services needed: Demand side response

- Wet appliances make up 15% of non-heat, non-transport residential demand. 50% of this demand is assumed to be movable in 2030.
- Movable demand increases linearly from 0% in 2020, up to 50% in 2030 – this reflects a view that it will only occur once smart meters are in place and it will take some time for people to adapt their behaviour.

10.4 Conventional Electric Heating

CCC has assumed that 50% of "non-heat pump" electric heating demand is movable in 2030; however, 30% of this is assumed to be movable under the existing tariffs (e.g. economy 7 tariffs).

10.5 Micro-Generation

Smart grids could play an important role handling bidirectional energy flows due to distributed renewable energy generation such as small scale PV or wind; micro-generation technologies will affect net demand.

10.6 Industry Load-Shedding

Industry load-shedding is available as business-as-usual.

10.7 Onshore and Offshore Wind

No additional infrastructure is assumed to be needed as the output from wind farms is already being monitored and managed.