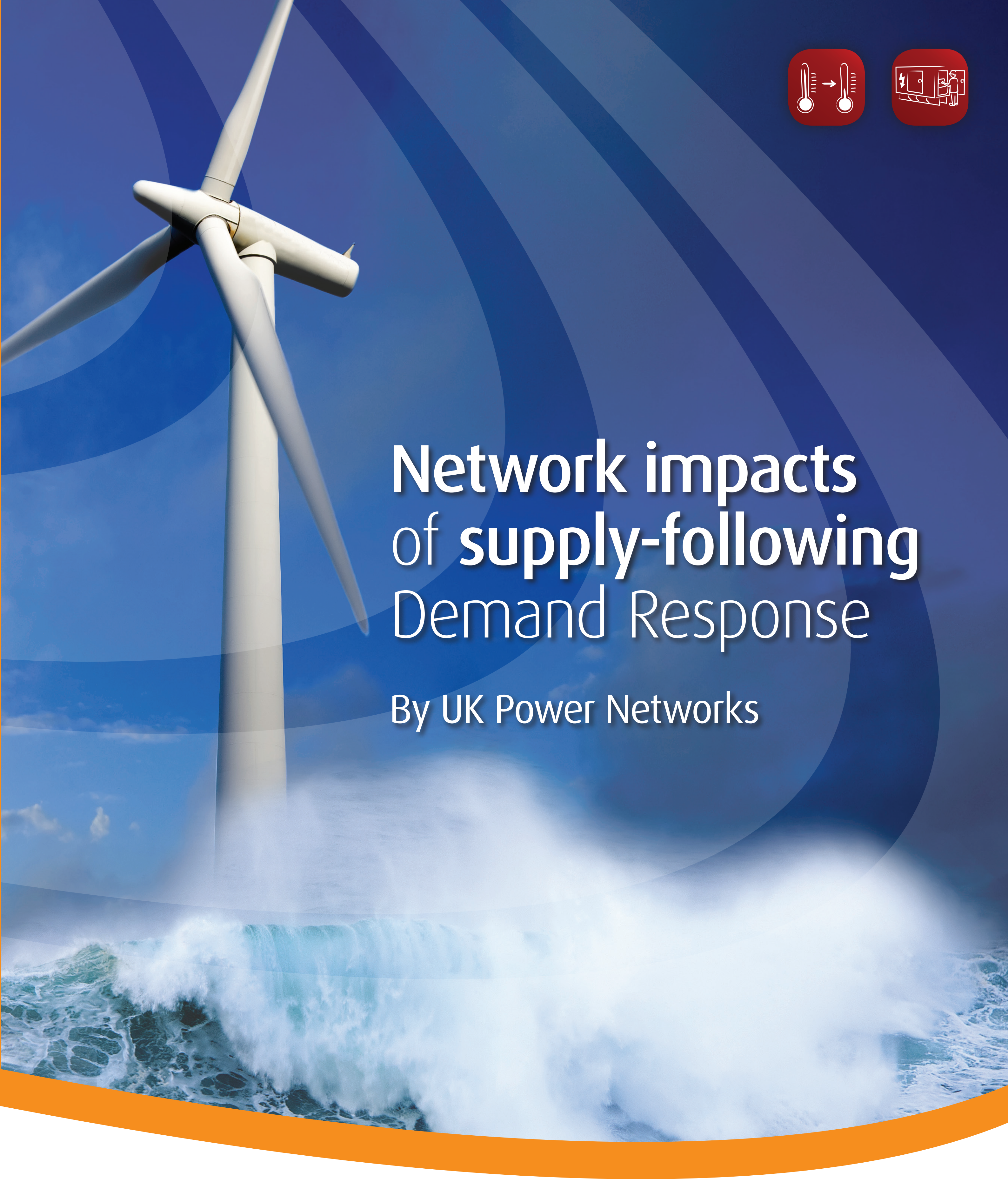

Network impacts of supply-following Demand Response

By UK Power Networks

Report A6

ukpowernetworks.co.uk/innovation

Low carbon LONDON Energising change

UK Power Networks Delivering your electricity

The impact of intermittent renewable generation on the national system will increase competition between stakeholders requiring DSR resources, including DNOs, emphasising the importance of a coordinated approach between key market players.

Report A6
September 2014

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SDRC compliance

This report is a contracted deliverable from the Low Carbon London project as set out in the Successful Delivery Reward Criteria (SDRC) sections "I&C Demand Side Management" and "Wind Twinning".

Executive Summary

The electricity market in Great Britain (GB) faces significant changes, including the deployment of renewable generation and increasing price variability, there will be an increase in the scope for Demand Side Response (DSR) services and the potential benefits from DSR across the industry. However, this increase in DSR activity is likely to result in technical and commercial conflicts between supply-following DSR programmes deployed by suppliers and capacity management programmes deployed by the Distribution Network Operators (DNOs). Low Carbon London (LCL) has conducted major trials to explore the performance characteristics of DSR from Industrial & Commercial (I&C) customers. As well as enabling UK Power Networks to commit to the routine use of DSR to deliver savings of £43.4M in avoided network reinforcement costs between 2015 and 2023, these trials also allow us to understand how third party DSR programmes might impact our network and our own DSR deployment. This report examines the relative values of benefits that will motivate different buyers of DSR services and how the differences in DSR programmes will impact the distribution network.

Key Findings

The DSR market has been modelled at full industry scale, using real DSR and network data, in order to analyse the size and interactivity of DSR programmes

The electricity market in GB will face an unprecedented expansion of intermittent renewable generation, particularly from wind and solar, as GB seeks to meet EU and its own renewables and carbon emissions targets. The system will need additional flexibility to tackle the variability and unpredictability of this renewable generation on the system.

At the same time, the retirement of mid-merit coal and gas plants, prompted by the Large Combustion Plant Directive (LCPD) and the Industrial Emissions Directive (IED) legislation, will lead to the closure of some thermal capacity, reducing the flexibility available in the present system. The increased requirement for flexibility on the system will likely be met by a mixture of conventional thermal plants and ancillary services such as DSR.

In addition, electricity suppliers are already exposed to the costs of being either under or over contracted with generators for the amount of electricity they serve to customers and as the generation portfolio in GB and demand profiles become more variable, suppliers are likely to need to use DSR to assist in managing both their wholesale and imbalance costs. This use of DSR will occur in the context of DNOs developing DSR programmes in order to defer network reinforcement, where possible, and to manage outages, while the System Operator (SO) will use DSR to balance the system as a whole.

Such supply-following DSR programmes can impact demand profiles on the network, and will increase the competition for DSR resources. This report looks at both effects by examining the number of occasions in which suppliers might be calling DSR, and the frequency of events when suppliers and DNOs have conflicting requirements for DSR. Depending on the market framework for procuring and using DSR, these events may lead to suppliers, the SO and DNOs trying to out-bid each other for DSR in that time period.

Our modelling builds on the results of the LCL trial, using real data as inputs and providing key insights into how the market and regulatory framework may evolve in the future. We modelled four scenarios as part of this project, specifically the Department for Energy and Climate Change (DECC) Green, Intermittent, Electrified, and Slow Growth scenarios to reflect a range of possible outcomes in the GB electricity sector.

This modelling work has underpinned two separate stand-alone reports, specifically this report, A6, examines the impacts on the DNO network (UK Power Networks within central London in this case) resulting from "Supply following use of I&C DSR" by suppliers and the DNO. This report focuses on the security of supply issues associated with the use of DSR by those two parties.

The Report A5, which examines the "Synergies and Conflicts of I&C DSR", used locally by a DNO, and nationally the SO and suppliers, focusing on maximising the economic value when using DSR. The DSR market is forecast to expand as it can provide a no-regret decision for the GB power system.

Our analysis has shown that DSR is a no-regret decision from a GB power system cost perspective. Table 1 shows that even in a "Slow Growth" world where the penetration of renewable and electrification are the lowest, DSR from industrial and commercial sources can deliver significant benefits to the system as a whole (negative numbers in Table 1 represent a saving while positive numbers represent a cost).

The greatest savings captured through the use of I&C DSR in the Slow Growth scenario is the reduction in capacity payment costs; DSR displaces thermal plants, For Example, gas turbines, which would otherwise have been paid capacity payments. The system cost savings translate to £1 to £3 per year of average discount on domestic customer bills for all scenarios. These savings do not include any saved network reinforcement costs.

Table 1: NPV savings for end consumer

	Wholesale costs (£m)	Capacity payment costs (£m)	Renewable subsidy costs (£m)	Total (£m)
Green World	-776	-669	40	-1304
Intermittent World	-453	-1080	-51	-1584
Slow Growth	-202	-861	27	-1036

Negative numbers represent a saving while positive numbers represent a cost.

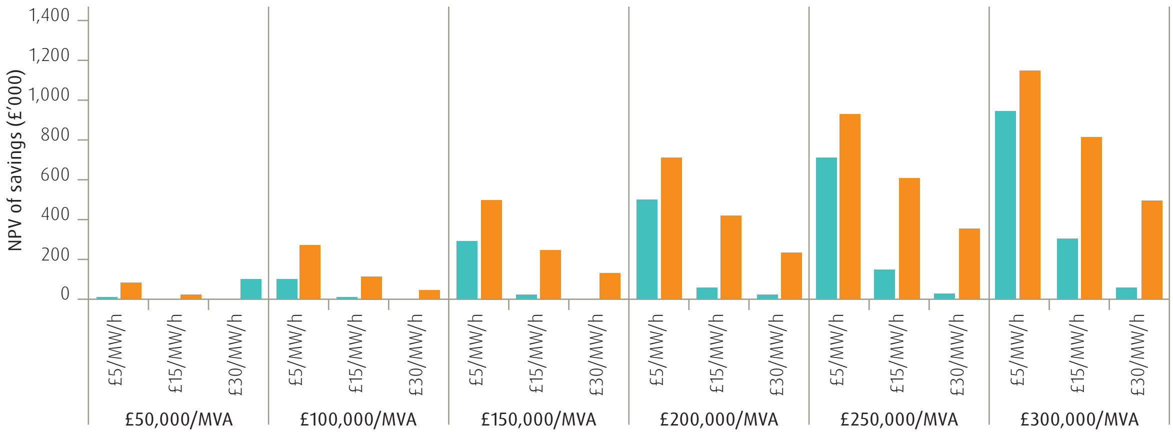
The most significant opportunities occur in the Intermittent World. In this scenario, the reduction in capacity payment costs is significant as more flexible capacity is displaced by the DSR compared to the Green World and more flexible generation or demand is needed to tackle the variability and unpredictability of wind.

DNO deployments of DSR can be economically viable as alternatives to network reinforcement

DSR will be used much more infrequently by the DNO compared to the SO, therefore any availability prices (assuming the business model implemented through the trial is to be used) will need to be more attractive than those available from the National Grid to provide an incentive for parties to contract with the DNO. This assumes that the DNO and the SO procure their DSR separately; shared procurement may assist in sharing the costs of DSR between multiple parties.

Our analysis has shown that cumulative savings increase significantly as availability payments decrease, since higher annual savings are realised over a longer period. Given Short Term Operating Reserve (STOR) availability payments are between £1.50/MW/h and £4/MW/h, an availability payment of £5/MW/h would compete favourably and would significantly lengthen the period of reinforcement deferral. This is clearly more attractive compared to the higher £30/MW/h availability payment rate previously forecast. The cumulative savings from using DSR to defer traditional network reinforcement using different availability payments and limiting the use of DSR to a maximum of 20% of the firm capacity rating are shown in Figure 1.

Figure 1: Cumulative savings at Clapham Park Road NPV (£'000) for different DSR availability prices and network reinforcement costs



Our analysis has shown that as technical solutions become more reliable, confidence in the use of DSR by the DNO increases and commercial arrangements mature, there is significant potential to exploit DSR for network reinforcement deferral above the 20% limit, assuming there is enough available DSR in the vicinity of the substation.

This expanding market means that network impacts of supply-following DSR do occur and are most likely to arise on winter peak nodes

The use of DSR by the supplier will impact on the use of DSR by the network. Figure 2 summarises the use of DSR at the national and local level, showing the use of DSR by the DNO on four typical types of network, by suppliers (mainly in the winter to tackle high peak prices), and the use of DSR by the SO throughout the year for reserve purposes.

Figure 2: Use of DSR locally versus nationally (2023, Electrified World)

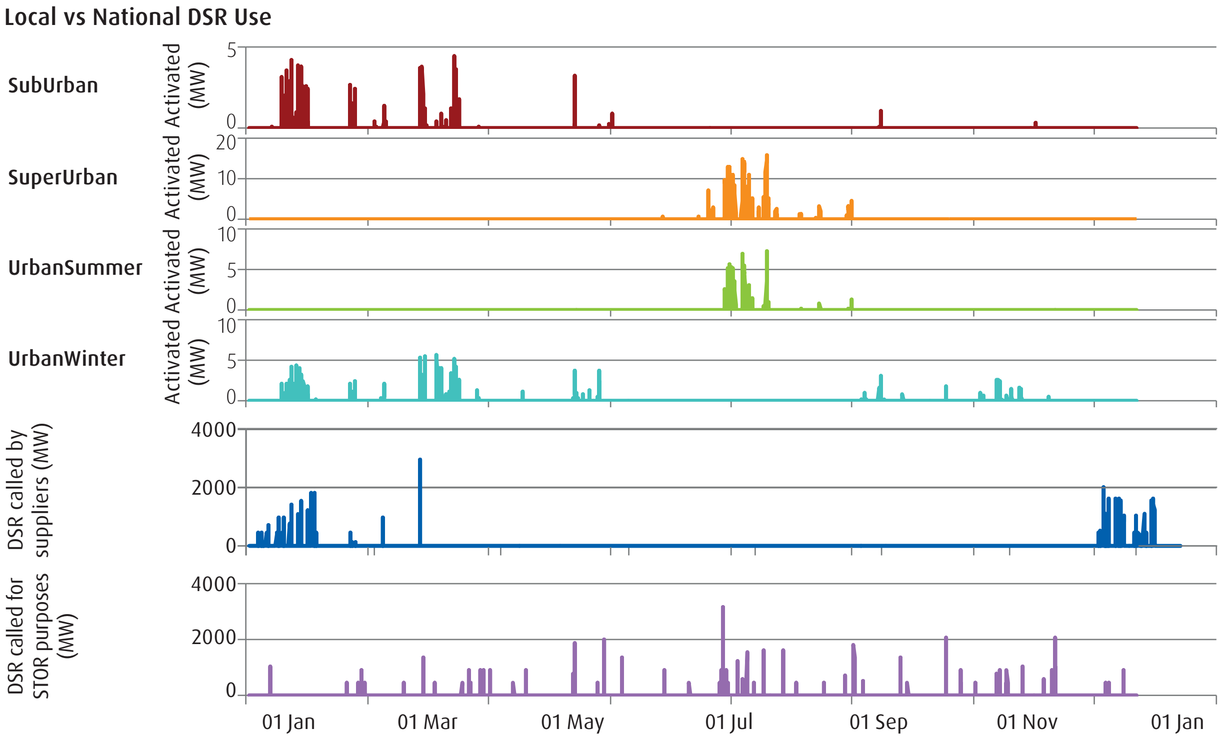


Figure 2 highlights the stark difference in the volumes of DSR needed by various parties (MW for the DNO and GW nationally). In addition, we can see the clear conflicts which may occur in the use of DSR between the national picture and the local picture.

While the summer peak nodes only require DSR in the summer, the requirements for DSR on the winter peak nodes increase in frequency over time, with rising penetration of renewables and flexible demand, extending into the spring and summer months by 2023 as shown in Figure 2.

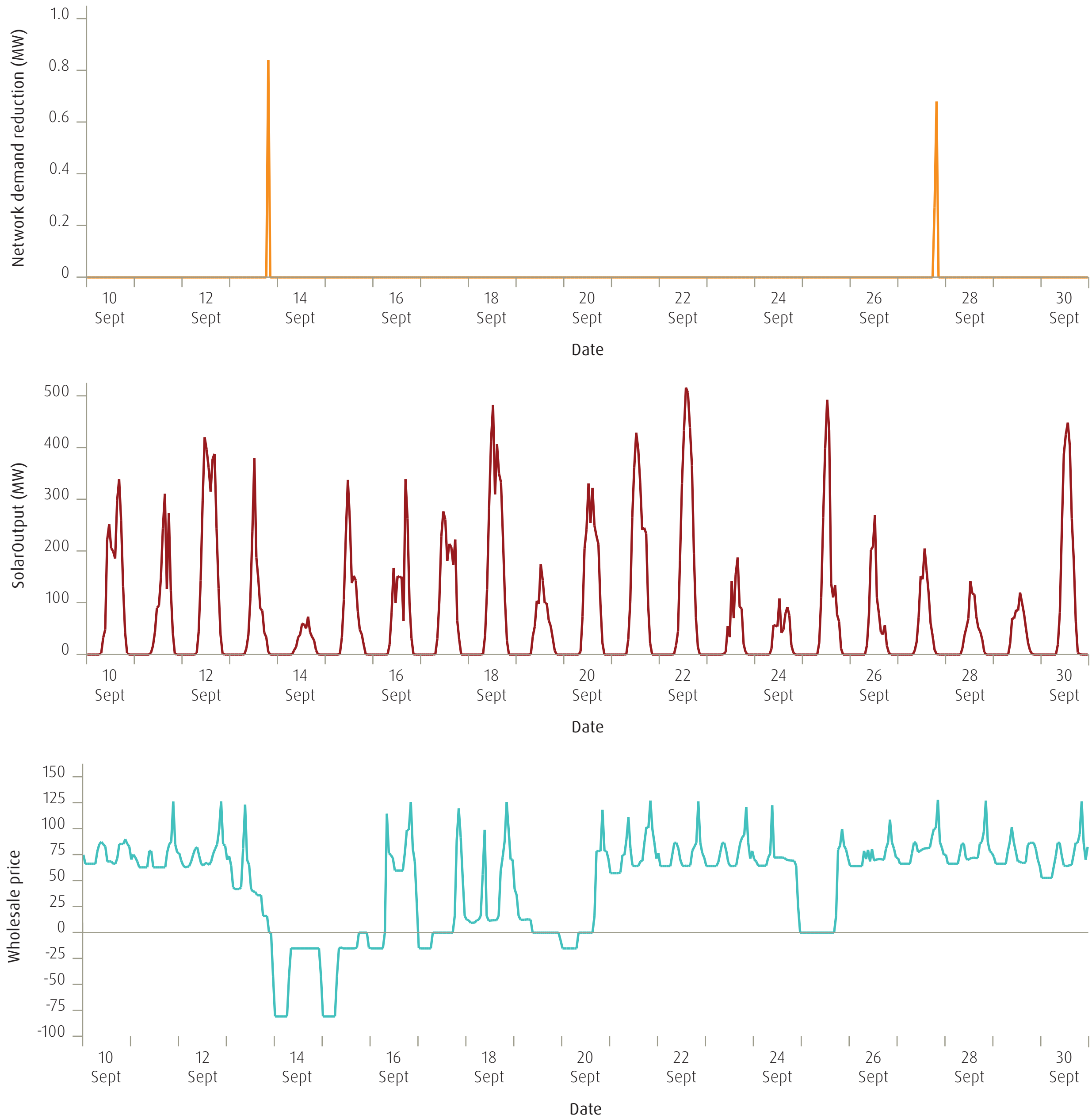
DSR could therefore potentially be used throughout the year on specific winter peaking networks.

Supplier usage is concentrated in the winter, and also extends into spring and autumn as intermittent generation becomes more prevalent. Therefore, the use of DSR by suppliers is most likely to conflict with the use of DSR by the DNO on winter peak nodes.

Finally, our analysis has shown that we can anticipate instances of conflicts in the future when the system has to deal with peaks in solar generation. In particular, flexible Electric Vehicles (EV) and Heat Pump (HP) demand could be shifted in order to accommodate excess solar generation on the system. Significant solar and wind output can lead to periods of negative prices. Suppliers can incentivise customers to increase their consumption through the use of ToU tariffs at those times.

Figure 3 shows an example of an instance when the excess solar and wind generation in the system creates a conflict between the DNO and suppliers. On September 13, excess solar and wind generation lead to negative prices in the wholesale market thus providing a signal to suppliers to increase their customers' demand, through the use of ToU tariffs. At the same time, the DNO requires a reduction in demand on the network which conflicts with the signal from the wholesale market. Similar situations are expected to arise in the future in a world with increased levels of distributed solar generation in the network.

Figure 3: Conflict when demand is increased to "soak up" solar and wind, high solar sensitivity, 2030, Historical Year 2010, September 10th-30th



Commercial and regulatory frameworks will need to adapt to optimise the value of DSR to various parties

The timeframes in which DSR will be dispatched by various parties and the frequency of calls will dictate the form of dispatch framework to be implemented. The SO will call on DSR much more frequently than the DNO.

There are two basic approaches for a shared services framework for DSR use by different stakeholders – sequential and simultaneous co-optimisation (a hybrid version exists where there is staged co-optimisation for example at day ahead and then at one or more points within day).

A sequential approach is one where one party has first call-off and a second or third party can then intervene if necessary. A co-optimisation approach is one where the DSR dispatch is optimised depending on the need of the system, whether at local or national level. This allows for a more economically optimised use of the resource.

The ENA's pathways[1] models (DSR shared services framework) present a simplified sequential approach to DSR coordination with DNOs having first/precedential call.

Other parties than the DNOs may prefer the simultaneous co-optimisation approach or a sequential approach where they have first call-off and a DNO can then intervene if necessary (i.e. a reversal of the sequence the ENA proposes and akin to the national market/ Balancing Mechanism (BM) approach under British Electricity Trading and Transmission Arrangements (BETTA). A co-optimisation approach has significant uncertainties and issues associated with it, For example, low probability of critical events overlapping. The co-optimisation approach could therefore be a theoretical preference but only developed if there is commercial potential to be fulfilled.

Bearing in mind the frequency with which DSR is needed by the SO, both options should be further explored when determining the market framework to be implemented in GB.

There are two options for coordination in the procurement of DSR: an auction platform or a DSO framework

There are two models of coordinated procurement. One of the models involves an auction platform which would allow both DNO and SO to procure their DSR simultaneously and the other option would allow the DNO to procure in excess of its requirements; the excess would be available to the SO.

Establishing an auction platform centrally would be a significant regulatory and market intervention. If the need for an auction arises backed by demand, it will emerge through innovation or as part of a trial.

Aggregators/market participants will optimise DSR use across multiple possible uses. If the SO or the DNO procure DSR, they will only be able to use it for their own system management purposes and multiple uses will not be possible.

An alternative is to allow DNOs to become real DSOs with the ability to either procure services for network use or to trade in the market more broadly. If a DSO is active, it can buy services that meet its local needs whilst also being able to offer them to the market/SO when there is no local requirement.

[1] http://www.energynetworks.org/news/publications/consultations-and-responses

There is currently no commercial and market framework to optimise the value of DSR to various parties in the GB market. A Shared Services Group has been set up by the ENA to provide an electricity network operator perspective of how DSR could be utilised by different parties. The Shared Services Group includes DNOs and the SO, but does not include suppliers. UK Power Networks will draw on its trial results and the analysis carried out in both Report A5 and Report A6 to recommend changes to the regulatory framework to the Shared Services Group. However, our analysis has shown there are a number of potential conflicts and synergies in the use of DSR by various parties. In particular, this report shows that:

- There is a correlation between the DSR requirements of suppliers and DNOs on winter-peaking networks, and hence significant scope for cooperation between parties;
- It is rare for supplier and DNO requirements to clash when using DSR to manage summer-peaking networks, although such conflicts will become more common if utilisation prices for DSR fall;
- Conflicts are much more common when information/dispatch is not shared between parties (60% to 85% more conflicts when information is not shared between parties); and
- Effective use of DSR provides an opportunity for significant cost savings by all parties.

Conclusions

As DNOs enter the market for DSR resources, they will compete initially with the SO, and increasingly with suppliers who will become significant users of DSR due to the levels of intermittent generation and tightening of imbalance penalties. This report demonstrates that there is a strong case that customer interests are best served by a coordinated approach to the sharing of DSR between different parties, rather than leaving suppliers, DNOs and the SO to outbid each other for DSR resources. Such a sharing framework will need to be discussed and understood across the industry in order to minimise impact, specifically looking at the opportunities for coordinating DSR procurement, dispatch of DSR, and network planning rules in order to consider the physical restrictions of the networks.

1

Introduction

1.1 Background

Over the next decade, the GB market will face an unprecedented rate of expansion of intermittent renewable generation, particularly wind and solar, as the UK seeks to meet EU and its own renewables and carbon emissions targets. The electrification of heat and transport is also intended to contribute to this decarbonisation agenda.

At the same time, the retirement of mid-merit coal and gas plants, prompted by the Large Combustion Plant Directive (LCPD) and the Industrial Emissions Directive (IED) legislation will lead to the closure of some thermal capacity, reducing the flexibility available in the present system. The increased requirement for flexibility on the system will likely be met by a mixture of conventional thermal plants and other sources.

Demand Side Response (DSR) is likely to be one of the sources contributing to the delivery of flexibility and will be used by various parties (SO, DNOs, suppliers, wind portfolio players) for various purposes.

1.1.1 Low Carbon London Project

Within its Low Carbon London (LCL) Low Carbon Networks Fund (LCNF) project, UK Power Networks has conducted two major trials to explore the potential benefits from a DNO perspective of deploying DSR from both the residential and commercial (I&C) sectors.

From a domestic consumer's perspective, the LCL project trialled a dynamic Time-of-Use tariff ("dToU") in conjunction with EDF Energy and British Gas. The trial collected smart meter data from more than 16,000 customers, split between a dynamic tariff group and a separate control group, allowing reliable analysis of customer behaviour in response to time of use tariffs.

Participants were notified via the smart meter In-House Display (IHD) and via SMS text message, if available, of price changes 24 hours in advance of their electricity tariff being changed from their normal tariff to one of two tariff bands (a "high" tariff of 67.2p per kWh, or a "low" tariff of 3.99p per kWh). The amended tariff operated for a notified fixed time period of between one and six hours and the project monitored how the participants' electricity consumption behaviour changed in response to these price signals.

The second trial involved contracting for, through commercial aggregators, DSR from large commercial consumers in the London Power Network (LPN) area. These contracts attempted to emulate Short-Term Operating Reserve (STOR) contracts;

and the commercial aggregators sought to secure contracts with existing Industrial & Commercial (I&C) customers who could potentially provide network constraint relief services for UK Power Networks - generally through dispatch of standby generation and/or reducing flexible demand such as cooling load.

1.1.2 Objective of study

The aim of this study is to conclude this trial by examining the capability of I&C DSR to serve two purposes, providing services to suppliers to manage their wholesale costs and to the DNO to manage their network issues.

1.2 Drivers for increased DSR requirement

There are a significant number of changes occurring in the GB market which are affecting both the need for additional flexibility and the supply of flexible capacity in the system. These drivers are summarised in Figure 4.

Figure 4: Drivers which affect need and supply of flexibility

Drivers for future flexibility

- Capacity mix and growth of technologies with uncertain variable output
- Forecasting errors mitigated by improvements in forecasting techniques (demand, wind/solar output)
- Policy environments - e.g. encouraging right behaviour in demand and generation
- Amount of existing older thermal plants that remain open
- Level of cross-border coordination and efficient use of interconnectors
- Development of innovative technologies
- Improvements in flexibility parameters of thermal plant
- Technology and cost developments of demand side response
- Visibility of the Network

The UK has signed on to the EU's legally binding target for a 20% contribution of renewable energy by 2020 and published the National Renewable Energy Action Plan (NREAP) in July 2010. According to the NREAP, 30% of electricity must be generated from renewables by 2020, which is more than double the 2013 level. Significant renewable generation anticipated in GB is likely to change the way in which the system is managed; the variability and unpredictability of wind requires conventional capacity to be available and scheduled at times when there is little wind on the system. Additional reserve is also needed as wind is unpredictable until close to real time. Solar PV, which has different variability characteristics, is also expected to make a strong contribution to GB generation in the future, thus increasing unpredictability in generation. Significant levels of flexible generation or demand will therefore be needed to manage the increased levels of intermittent generation in the system.

The policy environment has a significant impact on the future needs of the system, with the Electricity Market Reform (EMR) proposals bringing some key policy changes. The reform mechanisms proposed that would affect demand response and distributed generation the most would be the FIT CfD and the introduction of a capacity mechanism. The FIT CfD will promote the growth of intermittent renewable generation and capacity payments will have an impact on market price volatility and could replace or mitigate the payments for different forms of reserve and ancillary services, as well as promoting the use of DSR and distributed generation as a flexibility resource.

The introduction of the capacity market is expected to contribute significantly to the growth of DSR in the system, as it provides an additional revenue stream and the transitional arrangements are intended to increase the amount of DSR in the system prior to its participation in the capacity market. Year-ahead auctions for DSR (including embedded generation and smaller storage) will take place following the 4 year-ahead auctions for conventional generation. 2.5GW of the overall 2018/19 requirement of 53.3GW is expected to be secured through the one year-ahead auction.

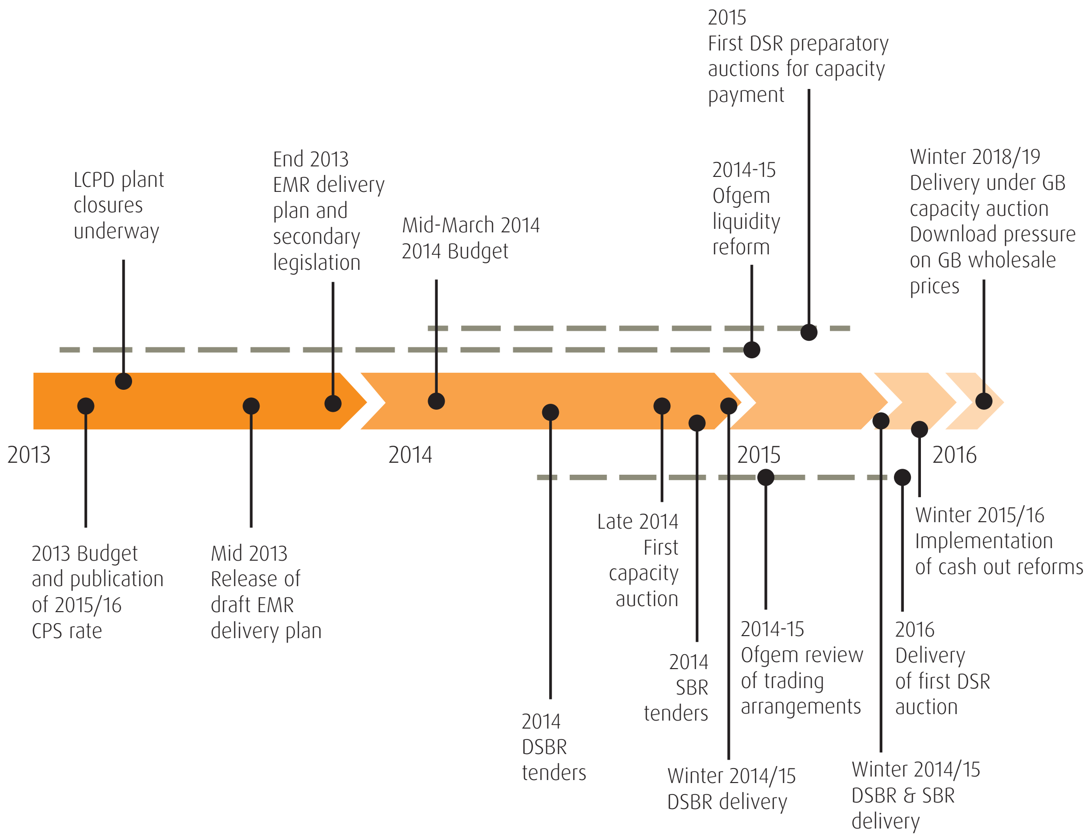
The transitional arrangements include preparatory auctions that will be held for DSR in 2015 and 2016, for delivery a year later, prior to the year-ahead auction in 2017. Furthermore, time-banded products that are easier for DSR to provide, will be made available at the beginning and more standard load-following products will gradually replace them. DSR will have to respond within four hours of each dispatch instruction being issued or face penalties. However, during the preparatory auctions the penalties will be lower than those of the enduring capacity market regime. Transitional arrangements will also apply to the 2017, 2018 and 2019 auctions, which are likely to include lower penalties and ring-fencing of capacity. It is also worth noting that parties holding long term STOR contracts are not eligible to participate in the capacity market and that capacity under 2MW can only participate through an aggregated service.

Another significant development in the GB market is the changes to the cash-out regime that will affect the cost of imbalances for both wind generators and flexible capacity providers. The proposals would result in cash-out prices that are more volatile and extreme. On the other hand, the single cash-out regime ensures that even small suppliers can average their imbalances over time. The tendency to over contract will still be predominant to avoid significantly high imbalance prices. This increases the value of flexible capacity (including DSR) for suppliers and generators.

In June 2013 National Grid published a consultation paper seeking views on the introduction of two new balancing services: Demand Side Balancing Reserve (DSBR) and Supplemental Balancing Reserve (SBR). National Grid's intention is for these services to serve as additional tools to support system security and balancing during an anticipated narrowing of capacity margins in the medium term. DSBR effectively offers payments to non-domestic consumers for reducing their demand on occasional winter evenings.[2]

Figure 5 shows the timeline in relation to policy decisions which are currently being made or considered in the UK. The timeline shows that there are a number of factors which are still uncertain such as the capacity payment which would significantly affect the level and type of additional flexible capacity which comes forward in the future.

Figure 5: Timeline of policy decisions



[2] National Grid identifies a requirement for DSBR in the winters of 2014/15 and/or 2015/16. It has expressed its intention to tender for DSBR in the spring/summer preceding each winter delivery season.

Other drivers that affect the level of existing flexible capacity which will remain, and new flexibility capability which will become available, include the closure of thermal plants through the Large Combustion Plant Directive and the Industrial Emissions Directive, the flexibility parameters of thermal plants, the cost and development of various demand response products as well as the uptake of new technologies such as electric vehicles and the implementation of smart meters. Flexible capacity will materialise in many forms including storage, thermal generation e.g. Open Cycle Gas Turbines (OCGTs) and DSR.

1.3 Implementation of DSR

DSR is one of many future sources of flexibility, which will address both national (e.g. supplier or SO) and local (DNO) issues. DSR could therefore potentially serve multiple purposes as summarised in Figure 6 below.

Figure 6: DSR use cases

		DSR case	Situation	Problem solved	Problem created	Actors involved
Energy Management	Cluster A	Suppliers use demand response to manage wholesale costs	Suppliers aiming to manage wholesale costs	Supplier hedging issues	Create transmission or distribution network peaks	Suppliers Customers
DNO Management	Cluster B	Modify demand to cope with distribution constraint and distribution network fault	Use DSR instead of reinforcement	Distribution constraint	Supplier imbalances or Transmission System Operator (TSO) (first to use) issues	DNO, Customer, Supplier
System Services	Cluster C	Modify demand in response to generation trip or forecast errors	DSR used for balancing and ancillary purposes	Potential brown outs and/or use of expensive generation to balance system	Potential for distribution peaks elsewhere	TSO, DNOs, Customers, Generators, Suppliers
		Modify demand to avoid transmission constraint	Reduce demand rather than build new lines	Transmission constraint	Potential distribution peaks elsewhere	TSO, DNO, customers, Generators, Suppliers
Intermittency Management	Cluster D	Increase demand to avoid wind curtailment or to soak up solar output	Consumers take advantage of low cost generation	Avoidance of wind curtailment, use of solar output	Peaks may appear elsewhere on distribution network or demand may be far from wind/solar generation	TSO, DNO, Customers, Generators, Suppliers/ Aggregators
		Modify demand to accommodate low wind periods	Demand reduced when wind not blowing	Avoidance of expensive peak generation	TSO balancing (if supplier takes action) or vice versa and distribution network peaks	TSO, DNOs, Customers, Suppliers
		Shave peak demand to avoid generation, transmission investments	Shave peak generation requirements on system	DSR reduced need for investment (generation transmission, distribution	New peaks may appear on distribution networks, supplier imbalances	TSO, DNOs, Customers, Generators, Suppliers

Suppliers may wish to use DSR to manage their wholesale costs (Cluster A, Energy Management). In the future, we anticipate greater price volatility in the system due to the unpredictability of intermittent generators. Suppliers may therefore wish to manage their wholesale costs by using demand side response, especially at times when wholesale prices will be high.

These issues are intrinsically related to the management of intermittent generation (Cluster D, Intermittency Management). Suppliers (vertically integrated entities), the SO or even wind portfolio players may wish to increase demand to avoid wind/solar curtailment or reduce demand to mitigate the effects of low wind periods (low wind periods typically coincide with peak price periods especially in the winter). In addition, the SO may wish to use DSR to reduce the level of peak generation capacity needed on the system. This will be incentivised through the capacity payment.

The SO may also wish to use DSR to manage unplanned generation outages or to manage some transmission network constraints. STOR is an example of a system service used by the SO. (Cluster C, System Services).

Finally, the DNO may wish to use DSR to manage distribution network constraints (Cluster B, DNO Management).

These various DSR use cases may sometimes be aligned or may on occasion be in conflict with each other depending on the hierarchy of utilisation of the DSR resource between the various parts of the value chain. Without an appropriate regulatory and market framework governing the use of DSR by multiple parties, end consumers may receive conflicting price or instruction signals. It is therefore essential to understand those instances when conflicts as well as synergies may occur.

1.3.1 Business models for use of DSR

A number of business models for DSR have been implemented or trialled involving different players such as the SO, suppliers, generators, aggregators and DNOs.

At the national level DSR may be used in Triad avoidance schemes by suppliers and aggregators or to provide STOR services to the SO. Suppliers and generators are increasingly using DSR to manage their exposure to wholesale market fluctuations, while the introduction of the capacity market in GB as part of the EMR provides new opportunities for DSR, as it is included in the capacity auctions, and transitional arrangements specifically for DSR are in place in order to boost its contribution to the system.

At the local level, DNOs have developed and trialled a number of business models that focus on different areas, such as network reinforcement deferral, facilitating the uptake of distributed renewable generation and improving quality of service, which lead to significant customer savings. Figure 7 provides examples of DSR business models and projects, both at the national and at the local level. Further details on each of the business models and projects, can be found in report A5.

Figure 7: Business models for the use of DSR

National drivers for future flexibility

- Triad avoidance
- Short Term Operating Reserve (STOR)
- Demand Side Balancing Services (DSBR)
- Use of DSR by Supplier/Generators
- DSR participation in the Capacity Market

Local drivers for future flexibility

- SSEPD - Demonstrating the functionality of Automated Demand Response (ADR)
- SSEPD - Thames Valley Vision
- WPD - Energy Control for Household Optimisation
- WPD - FALCON
- UK Power Networks - LCL Project
- Northern Power Grid - Capacity to Customers
- UK Power Networks - Vulnerable Customers and Energy Efficiency
- SSEPD Scotish and Southern Electricity Power Distribution
- WPD Western Power Distribution

1.3.2 Commercial frameworks for shared DSR services

DSR can be used for multiple purposes but most of the projects and services being trialled or already established do not take account of the potential use of the DSR by other parties.

There are a number of potential commercial frameworks which can be implemented to source DSR which are summarised in Figure 8. The commercial frameworks range from uncoordinated procurement and dispatch of DSR through to coordinated procurement and dispatch.

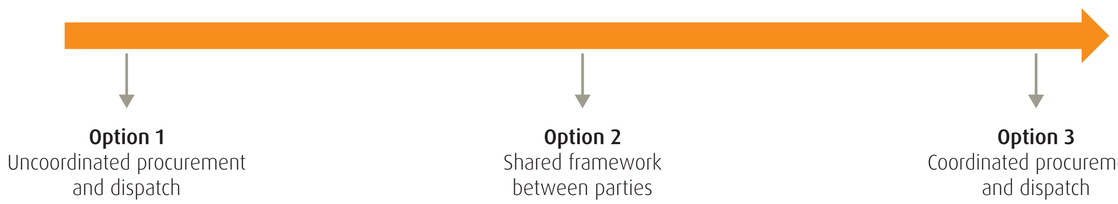
Option 1 considers a world where both procurement and dispatch of DSR is uncoordinated between the various parts of the value chain; suppliers, DNO, SO. Separate procurement is characterised by a lack of coordination in the way in which the flexibility requirements are procured.

Option 2 considers a world where some coordination occurs between parties wishing to use DSR through a shared services framework. There are two basic approaches for a shared services framework for DSR use by different stakeholders – sequential and simultaneous co-optimisation (a hybrid version exists where there is staged co-optimisation at, for example, day ahead and then at one or more points within day). A sequential approach is one where one party has first call-off and a second or third party can then intervene if necessary. A co-optimisation approach is one where the DSR dispatch is optimised depending on the need of the system, whether at local or national level. This allows for a more economically optimised use of the resource.

Option 3 considers two types of system designs which allow for coordination in relation to both procurement and use of DSR. DNOs may procure services for the SO from several distributed networks in order to find the cheapest sources within a particular geographical area. The SO is still able to procure flexibility services from other parties but can also procure services from the DNO which have to be agreed and executed by them on behalf of the SO.

An alternative solution is the implementation of a common auction platform for both DNOs and SO, operated by an independent market operator. Each party has to report its own constraints to the market operator, such that prices for flexibility services reflect these constraints at those times. Some offers of flexibility providers will be less attractive to DNOs or SO, due to location of the providers on the network. The auctions could have a locational element to them.

Figure 8: Possible commercial frameworks



The type of commercial framework to be implemented depends on the manner in which the DSR resources are to be used and dispatched by all parts of the value chain. These arrangements may evolve over time, as DSR users become more confident in both the technical and economic delivery of this flexibility resource.

In the next section, we examine the network impacts of supply following DSR and reflect on possible commercial and regulatory frameworks which may be feasible in the GB market.

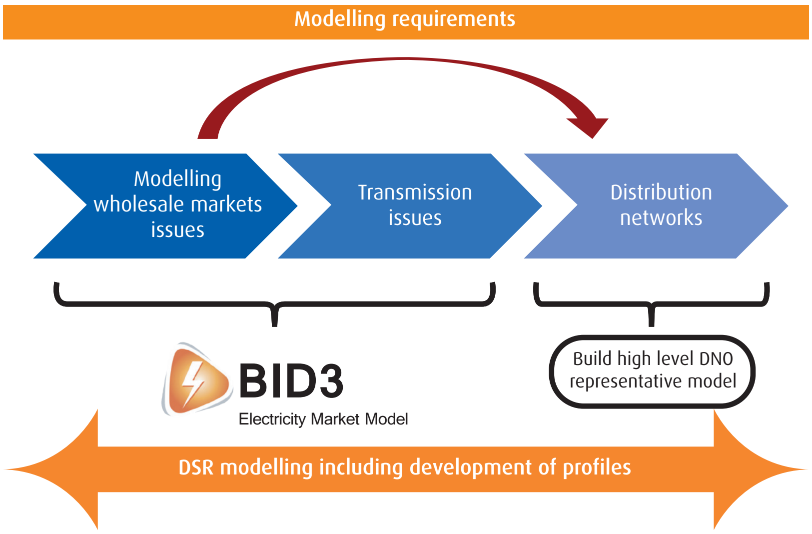
1.4 High level overview of methodology

In order to understand the synergies and conflicts in the use of DSR, we have modelled both the national issues (wholesale market and transmission) and the local issues (DNO level) as seen in Figure 9. I&C DSR is used to address national issues first and the remainder of I&C[3] DSR is then used to meet network requirements. Our modelling demonstrates whether sufficient levels of DSR are still available for network issues or whether additional flexibility may be needed by the DNO.

This study allows us to understand whether there could be competition in relation to the use of DSR in the future, especially if supply-following DSR increases the likelihood of unforeseen peaks in network demand.

[3] I&C customers are as per DECC's definitions.

Figure 9: Overview of study methodology



The national issues are investigated using Pöyry's BID3 wholesale market model, while a simple network module was used to simulate the local DNO issues and therefore determine the local use of DSR.

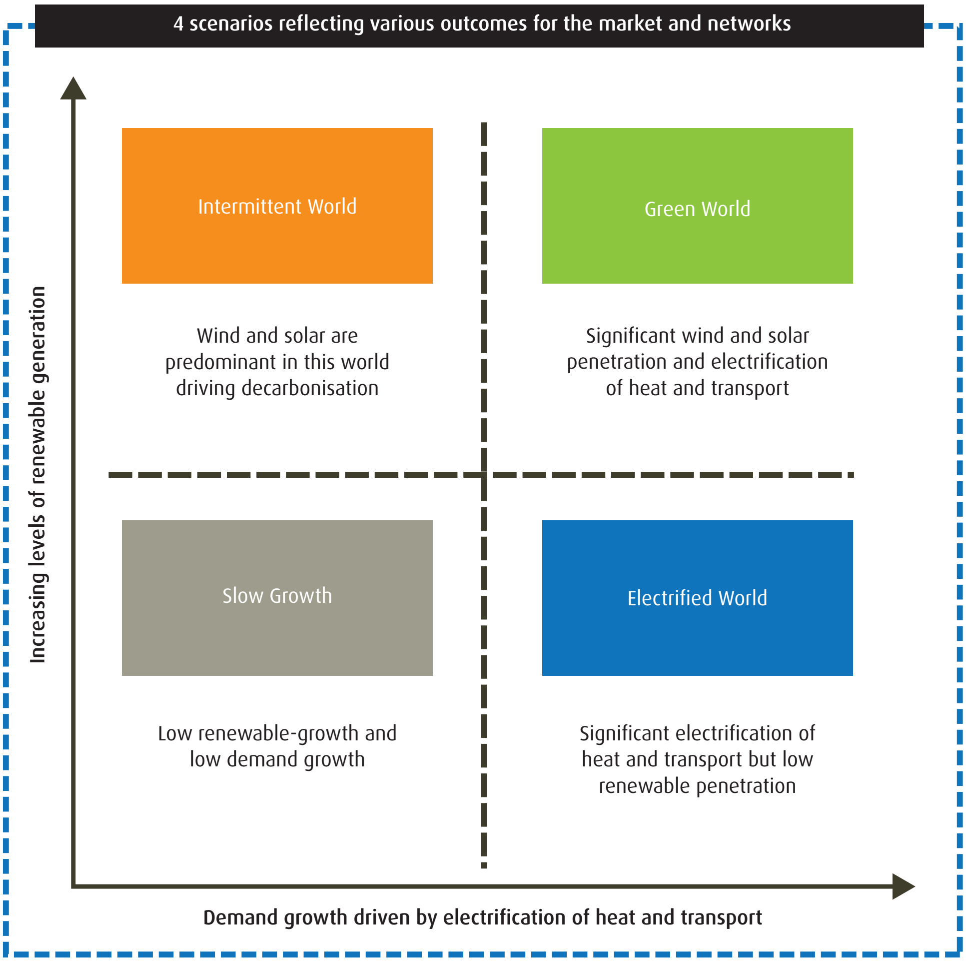
BID3 is a wholesale market model which projects the physical operation (generator output, electricity flows, emissions) and economic behaviour (electricity prices, revenues) of the system. It uses detailed historical wind and solar data to determine various patterns of wind and solar generation in the future.

The network module focuses on four representative nodes (superurban, urban summer peaking, urban winter peaking and suburban) for the London Power Network (LPN) area (where the industrial and commercial DSR trials took place). These representative nodes were chosen in order to fully describe the network types that compose urban electricity distribution networks, considering topology, composition of customers served, and the resulting network demand profiles. All 11kV nodes within the LPN area have been apportioned to those four categories. The module contracts DSR to meet peak demand based on historical weather patterns (2010 and 2013), and dispatches DSR to meet demand above firm capacity when needed.

1.4.1 Scenarios modelled

A number of scenarios and sensitivities were used showcasing a range of outcomes for the GB electricity industry as shown in Figure 10. The scenarios reflect various future worlds, revolving around two dimensions; increased renewable generation and increased electrification.

Figure 10: Scenarios



The Slow Growth world is effectively a low renewable and low electrification world; the new FiT CfD is not as effective at delivering decarbonisation. The intermittent world has a significant level of renewable generation but low electrification of heat and transport. In this world, the unpredictability and variability of the wind and solar generation is predominant.

In the Green World, decarbonisation occurs through both increased penetration of renewable and significant electrification of heat and transport. This is the world most aligned with the government's view of decarbonisation out to 2030. In the Electrified World, electrification of heat and transport occurs as the technology cost decreases significantly – but with comparatively low levels of renewable generation.

The scenarios all use base demand and fuel prices from the Department of Energy and Climate Change (DECC). We have also modelled all Electricity Market Reform (EMR) policy packages. The Green World and Intermittent World would deliver a carbon intensity of ~100gCO_2/KWh by 2030 (in line with the government's aspirations) while the Slow Growth scenario and the Electrified World would deliver ~200gCO_2/KWh by 2030.

Significant renewable penetration can be found in the Intermittent World and the Green World scenarios (approximately 55GW of wind in 2030). The Slow Growth and Electrified World have lower levels of decarbonisation through renewable generation (34GW of wind). The Slow Growth and Electrified World use National Grid's "Slow Progression" trajectory in relation to generation capacity while the Intermittent World and Green World use National Grid's Gone Green assumptions.

The Electrified World and Green World are the two scenarios with the most electrification of heat and transport, reflecting high rates of deployment of Electric Vehicles (EVs) and Heat Pumps (HPs); the deployment rates are based on the DECC's 4th Carbon Budget Scenario 3. The Slow Growth and Intermittent World (lower levels of electrification) are based on DECC's 4th Carbon Budget Scenario 4 (lower levels of EVs and HPs). These trajectories, while current at the time of the study, are likely to be periodically updated.

1.4.2 Inputs from Low Carbon London

The LCL trials have provided us with the necessary input in relation to the availability and utilisation prices which could be paid by DNOs for the use of I&C DSR, as well as a view of the response anticipated from customers. We have used the trial data for the modelling exercise and the assumptions made in relation to the use of DSR as part of the network module are as follows:

- Dispatch of I&C DSR: A phased approach has been used in this exercise, with I&C DSR procured and dispatched in blocks of around 5MW until 2020, for the purposes of managing the network. As technical solutions and commercial arrangements mature after 2020, full economic procurement and dispatch of I&C DSR is used (the DNO only procures what will be needed over the season, and dispatches the capacity needed on the day to bring demand back to firm capacity on the network);

- Building turn down: Up to 5% of the building load on the network may be procured for DSR. This assumption is based on estimates arising from consultations during UK Power Networks' ED1 planning process. The load may be turned down for up to 1 hour in the years 2014-2018. Technology improvements increase this period to 1.5 hours in 2020, 2 hours in 2023 and 3 hours in 2025. Until 2020, we assume that building load is contracted through an aggregator with a contract that allows one-third of the load to be dispatched in any hour, for up to three hours. By 2020 we assume that developments allow for more efficient dispatch in a manner chosen by the DNO;[4]

- Distributed generation: Across the network, we assume that 20% of local generation would be available for DSR, contracted for 8 hours a day on weekdays and utilised for up to 6 hours, but not necessarily consecutively. We assume that substations will only be considered candidates for DSR if they have more than the average level of generation required available; we assume that a typical DSR candidate will have twice the network-average level of available generation; and

- If necessary, generation may also be contracted for weekends but building turn-down may not.

1.4.3 Results generated

Each model run generates two sets of results; the first, "low flex", is a world where less DSR is used to manage the system and the second, "high flex", is a world where DSR provides significant flexibility to the system. The difference between the two runs allows us to determine the additional benefit/cost to the system of greater use of DSR.

We have also assumed that the patterns of use of heat pumps and electric vehicles across the "high flex" and "low flex" runs are the same, therefore the "low flex" and "high flex" scenario runs are not impacted by the additional flexibility which is offered by EVs and HPs to the system.

Finally, we are able to examine particular days and weeks of a modelled year, to determine whether there are any impacts of supply following DSR on the network. This generates a better understanding of the types of market and regulatory structures which will need to be in place for the use of DSR to be coordinated and optimised. The results are presented in the next chapter.

[4] For the purposes of this study, start-up energy needs for customer onsite generation was ignored, since it is typically small, compared to the overall building load

2

Network impact of supply-following DSR

DSR is likely to serve multiple purposes in the future:

- Suppliers will use DSR within-day (period between day-ahead and gate closure) to re-align their commercial or trading positions and day-ahead to manage wholesale costs;
- The SO will use DSR for reserve purposes (e.g. STOR requires participants to deliver within 4 hours of a call out); and
- The DNO will use DSR to tackle planned outages and unplanned outages as well as critical peak scenarios. Requirements for planned outages are generally known at least one day in advance. For unplanned outages, DSR will need to be called sufficiently quickly to prevent a circuit trip or risk of unacceptable loss of asset life due to thermal stress on network components. For subsequent outage days, DSR units may have 24 hours of notice.

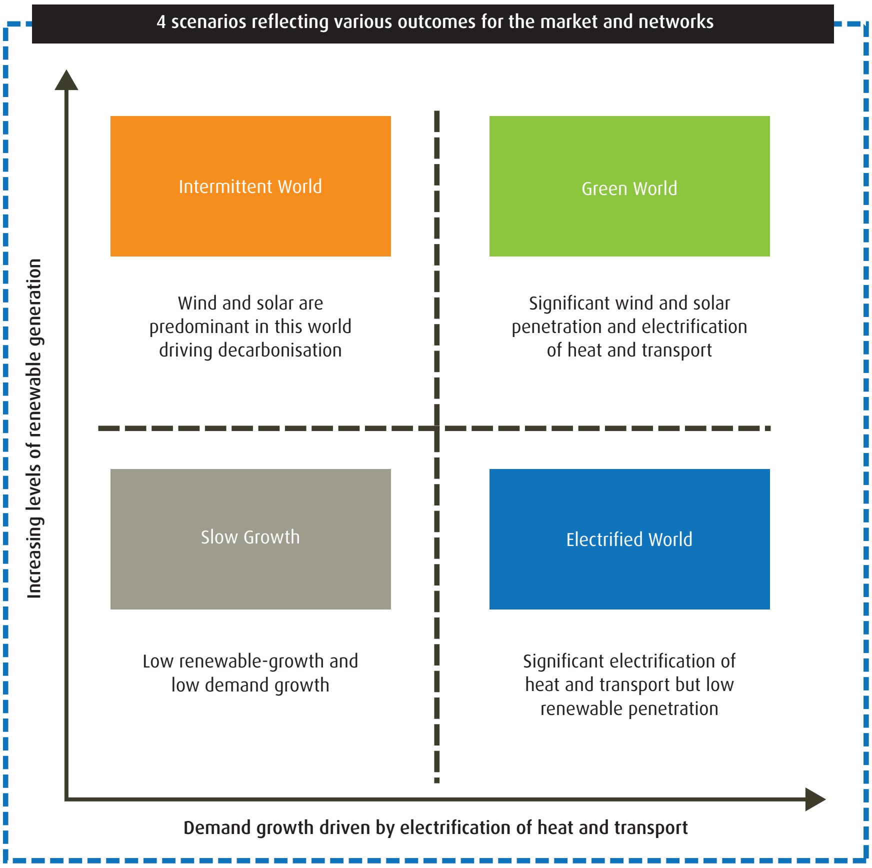
The different timeframes in which DSR is used by various parties impacts on other parties. The study explores these issues, documenting the various instances of network impacts and linking them to potential commercial frameworks which could be implemented such as shared use of DSR (whether this includes coordinated procurement or sharing of information only) or uncoordinated use of DSR.

The varying volumes in the use of DSR (at local versus national level) have also provided some interesting insights in relation to the price signals (availability and utilisation payments) which would be needed for DNOs to competitively procure their DSR requirements.

2.1 Scenarios examined

The usage of DSR by the various parts of the value chain has been investigated across four scenarios and two sensitivities as part of this project. Figure 11 shows the range of scenarios considered in this project.

Figure 11: Scenarios



The four scenarios that have been modelled are:

- Intermittent World, where wind and solar generation predominates. In this world, the unpredictability and variability of renewable generation affects the level of DSR used nationally by suppliers and the SO;
- The Green World, a DECC scenario reflecting a world with both intermittent generation and electrification of heat and transport. We anticipate the unpredictability of wind and solar to be dampened by increased demand, including flexible demand, due to electrification;
- The Electrified World where the incentives for renewable generation have not been effective. The renewable penetration in this scenario is considerably lower than in the Green World or the Intermittent World. EVs and HPs have progressed and the lower cost of the technologies have allowed for a significant uptake of EVs and HPs, especially from 2020 onwards; and
- Slow Growth models a world in which we carry on with today's trajectory. There is less ambition in relation to decarbonisation (wind and solar penetration) and demand growth is dampened by slow uptake of electrification in this world.

For each scenario, we have used a wholesale market model BID3 to deliver generation and reserve holding data. We combined this with probabilistic dispatch of DSR held in reserve and a network module which maps the national picture onto local DNO networks, to investigate local use of DSR and the impact of national issues at the local level.

In addition, we also ran two sensitivities testing variables which we believe are of significant importance, and that may impact the DNO's ability to use DSR when needed:

- Solar sensitivity: We increased the solar capacity from 15GW to 25GW to further test the impact of additional solar capacity on the local network; and
- DSR utilisation price sensitivity: The utilisation price paid for a particular DSR resource as part of the trials was in the range of £200/MWh up to £250/MWh. We reduced the DSR utilisation price to a new range of £100/MWh to £170/MWh, testing a world where DSR is more competitively priced than an OCGT (gas turbine).

In order to understand the role which I&C DSR can play in delivering flexibility for suppliers, DNOs and the SO, we have two sets of model runs for the Green World, Intermittent World and Slow Growth scenarios:

- The first, "low flex", is a world where less DSR is used to manage the system; and
- The second, "high flex", is a world where DSR provides significant flexibility to the system.

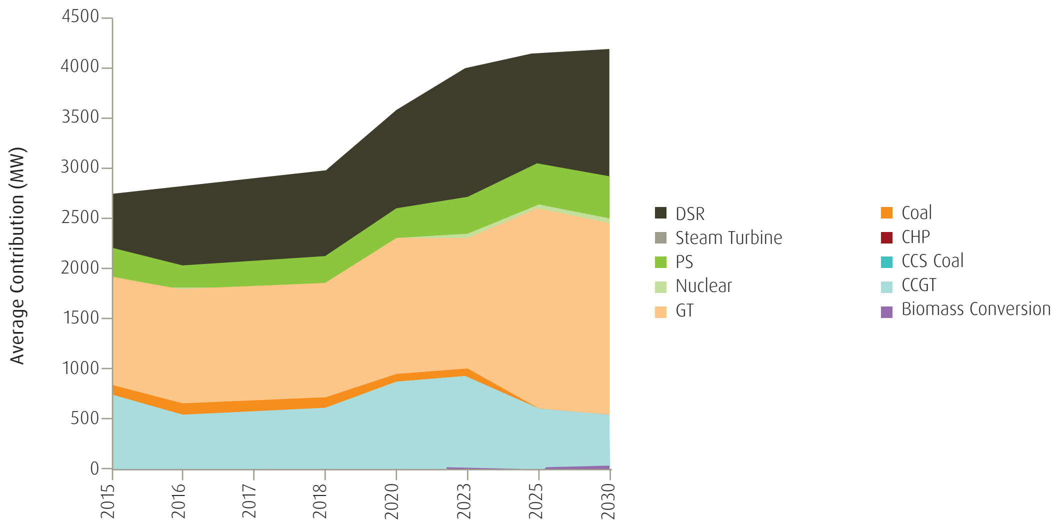
The difference between the two runs allows us to determine the additional benefit/cost to the system of greater use of I&C DSR.

For the Electrified World, we have a "high flex" run as well as a lower OCGT run. The lower OCGT run is characterised by a lower level of inflexible generation capacity (e.g. nuclear). Less renewable generation (compared to Green and Intermittent Worlds) and lower levels of new flexible nuclear, coal and biomass conversion delivers lower OCGT requirements in this scenario.

2.2 Reserve and Response requirements

Our analysis focuses on the use of DSR by multiple parties. In addition to modelling the use of DSR by the wholesale market (suppliers and generators) and the DNOs, we have also examined the use of DSR by the SO. Figure 12 shows the reserve holding for the Intermittent World scenario.

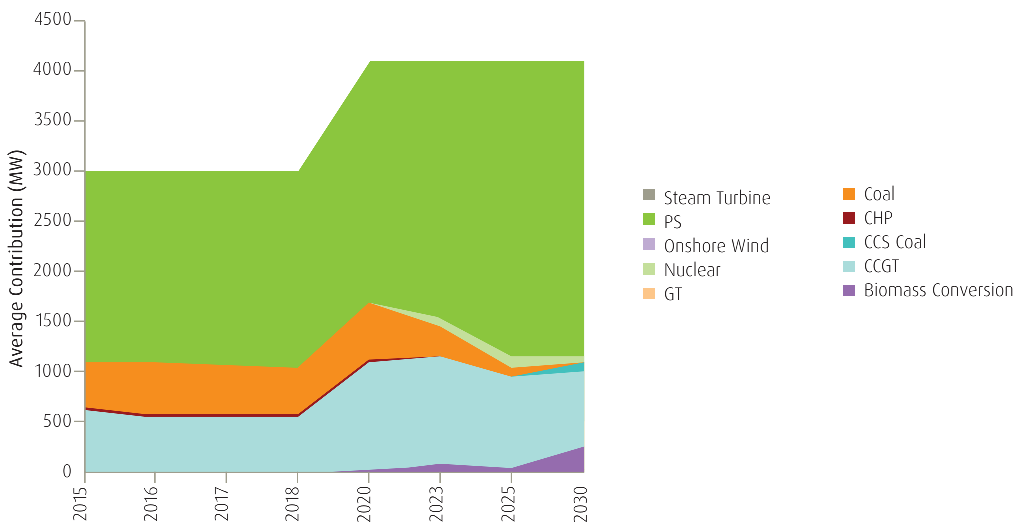
Figure 12: Reserve constraints (MW)



Increasing levels of reserve are held due to rising levels of renewables on the system over the years. In addition, instances when new nuclear plants come online (e.g. 2023) coincide with an uplift in the reserve holding. It can be seen that DSR generation and turndown account for approximately 20% of overall reserve constraint holding, while the majority of reserve requirements is provided by Gas Turbines (GT).

Response requirements have also been factored into our analysis. Figure 13 shows the response requirements again for the Green World scenario.

Figure 13: Response requirements (MW)



Response is primarily provided by pump storage and plants connected to the transmission network.

2.3 Plant operations in the four scenarios

I&C DSR displaces thermal flexible capacity. The increasing level of renewable and inflexible nuclear on the system leads to a greater requirement for flexibility to manage the system. This flexibility can take many forms including DSR. Figure 14 shows the renewable capacity, flexible capacity and non-flexible capacity in the two runs for two of the scenarios under consideration; the Intermittent World and the Slow Growth.

The CCGT capacity in the low flex run of the Slow Growth scenario (45GW in 2030) is higher than the CCGT capacity in the high flex run (43.6GW), showing that the increased DSR availability displaces some of the thermal capacity in this scenario. The same holds true for the Intermittent World. The GT capacity in 2030 in the low flex run is 11.7GW compared to 9.1GW in the high flex run.

Additional flexible capacity is needed to replace the dwindling coal plants from 2020 onwards in both scenarios.

Figure 15 shows the same picture (renewable capacity, flexible capacity and non-flexible capacity) for the Electrified World and the Green World.

Significant build of CCGTs occur in the Low OCGT run of the Electrified World (to reach an overall capacity of 53.3GW in 2030 compared to 47.5GW in the high flex run). While the Low OCGT run promotes a lower level of OCGT, the capacity payment allows enough flexible capacity to be built to maintain the requisite security standard (3 hours Loss of Load as prescribed by DECC).

In the Green World, an additional 1GW of CCGT is also built in the low flex run compared to the high flex run.

Increased levels of I&C DSR therefore displace thermal capacity in all scenarios under consideration.

Figure 14: Difference in thermal generation capacity between two scenario runs

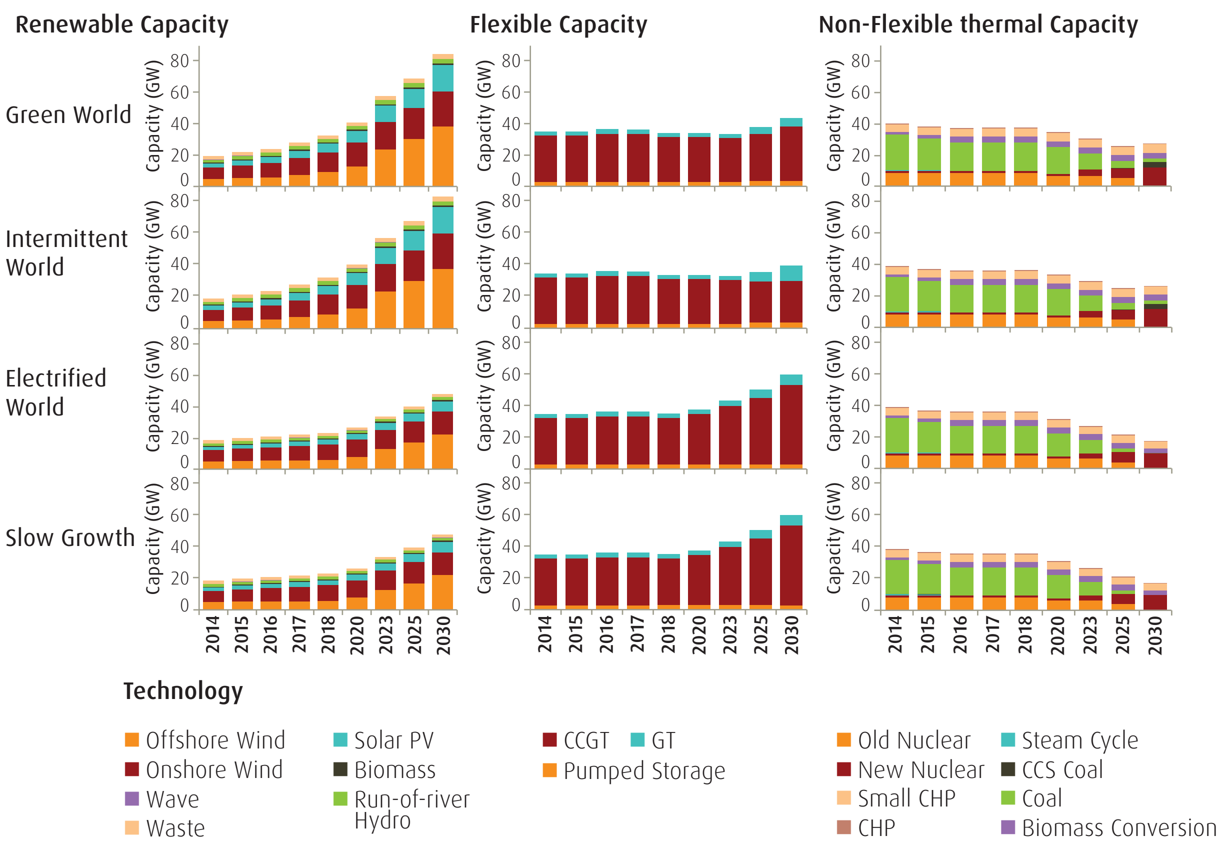
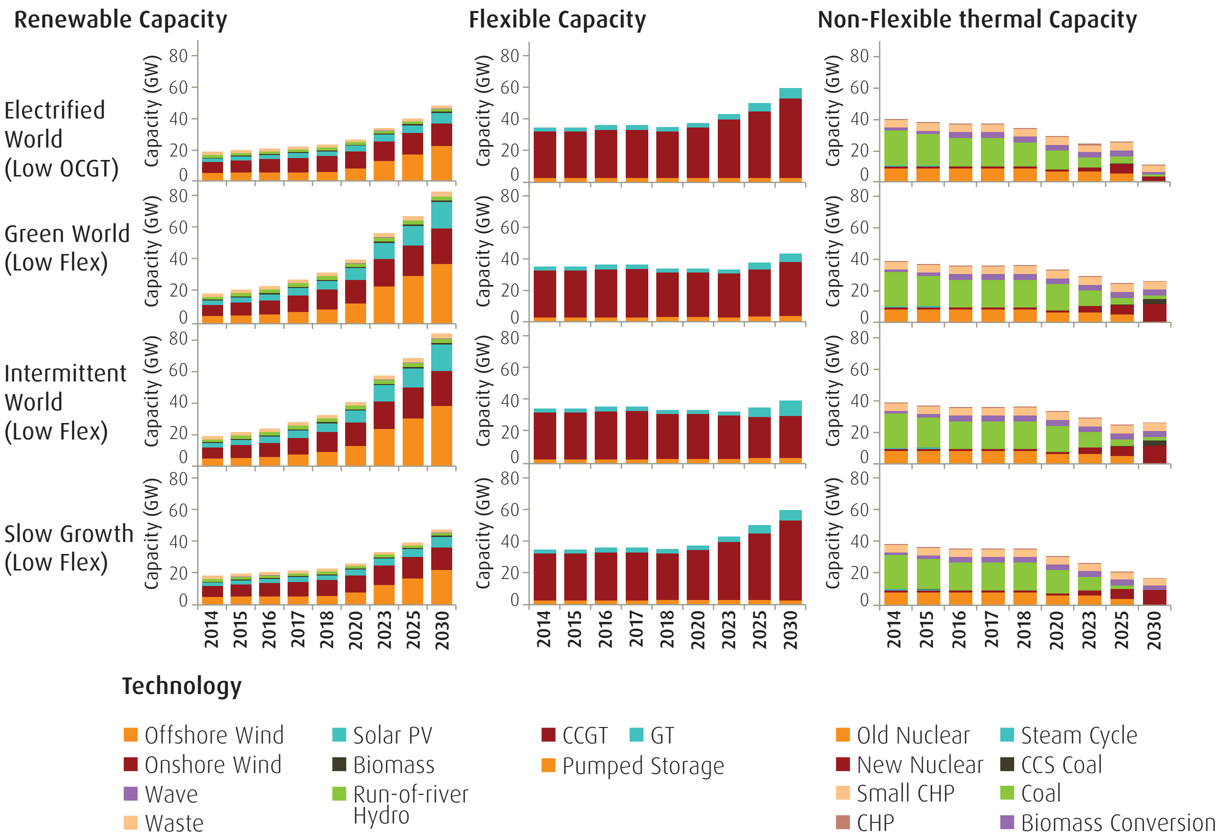


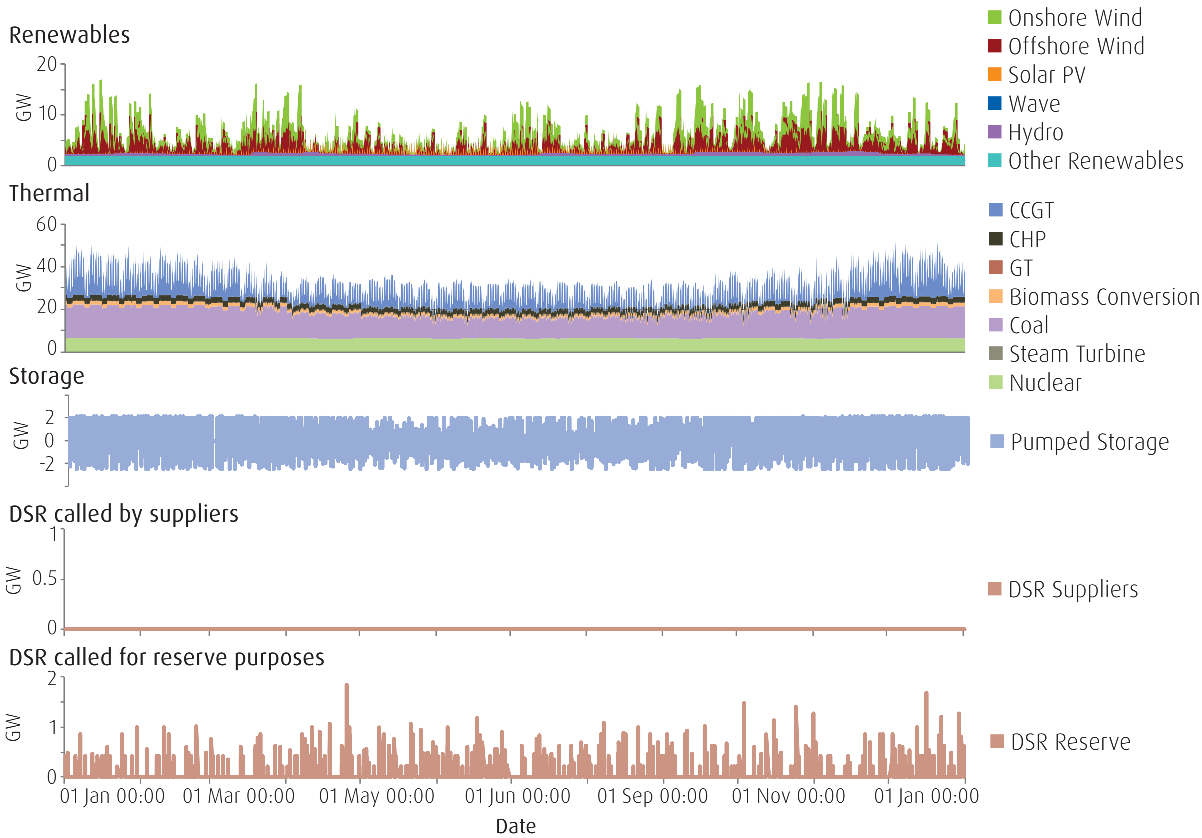
Figure 15: Difference in thermal generation capacity between two scenario runs



2.3.1 Hourly generation pattern

Figure 16 shows the hourly generation and use of I&C DSR in the Intermittent World in 2015 for the high flex run. The top chart shows the renewable generation over the year, followed by the thermal generation and the use of storage. The last two charts show the use of DSR by the wholesale market and the use of DSR for reserve purposes.

Figure 16: Intermittent World hourly generation and use of I&C DSR (2015)



The figure shows that significant variability of wind generation is already present in 2015. While both nuclear and coal plants are running practically baseload, there is a significant level of variability in the operation of CCGT plants. DSR is called for reserve purposes frequently in this year, as Low Combustion Plant Directive (LCPD) and Industrial Emissions Directive (IED) closures occur, Keadby (600MW CCGT) is mothballed and Carrington only comes online in 2016.

Figure 17 shows the hourly generation and use of I&C DSR in the Green World scenario in 2030. By 2030, coal plants left on the system have very low load factors. Nuclear plants run with some deviation away from baseload, while there is significant variability in the operation of CCGT plants. In 2015, suppliers do not have systems in place to use DSR to manage their wholesale costs; however, we assume that by 2030, along with the implementation of half hourly wholesale settlement for all classes of consumption, suppliers have arranged access to use DSR when there is a price signal driving them to do so. Figure 17 shows how suppliers make use of this I&C DSR, calling up to 2GW across GB in tight market periods to manage their wholesale costs.

From the perspective of the SO and DNOs, this level of DSR use by suppliers is very different from the world today, where the SO is the principle user of DSR in GB, and the usage by other players is minor. This change is likely to occur shortly after the uptake of DSR use by DNOs, and because of the magnitude of DSR which suppliers would ultimately like to use, it is likely to cause a "triangle" of parties whose needs potentially conflict – suppliers, DNOs and the SO.

Figure 17: Green World hourly generation and use of I&C DSR (2030)

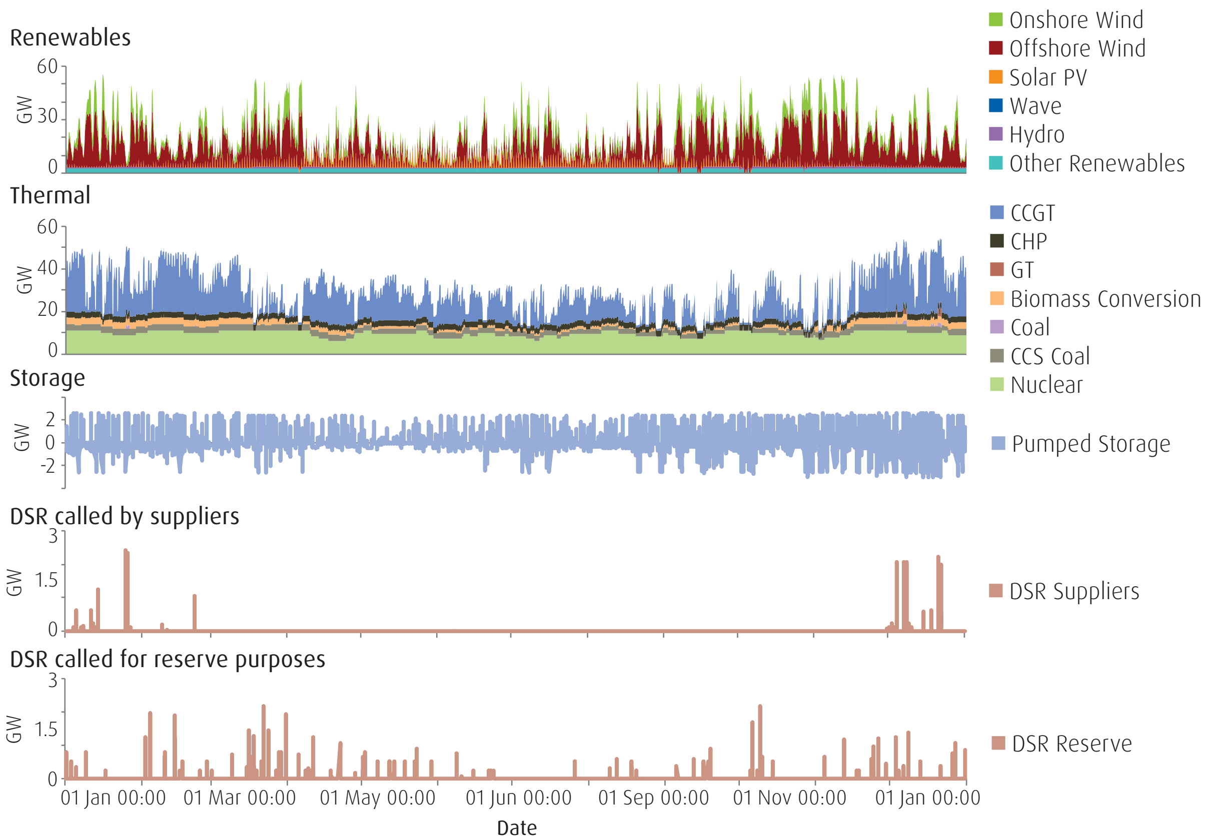


Figure 18 shows the same picture as above but for the Electrified World. Thermal plants run more baseload generation, compared to the Intermittent World, as less renewable penetration occurs. DSR is used for reserve purposes all year round as well as being used by suppliers to mitigate wholesale costs; DSR therefore has an important role to play even in a world with less intermittent generation capacity.

Figure 18: Electrified World hourly generation and use of I&C DSR (2030)

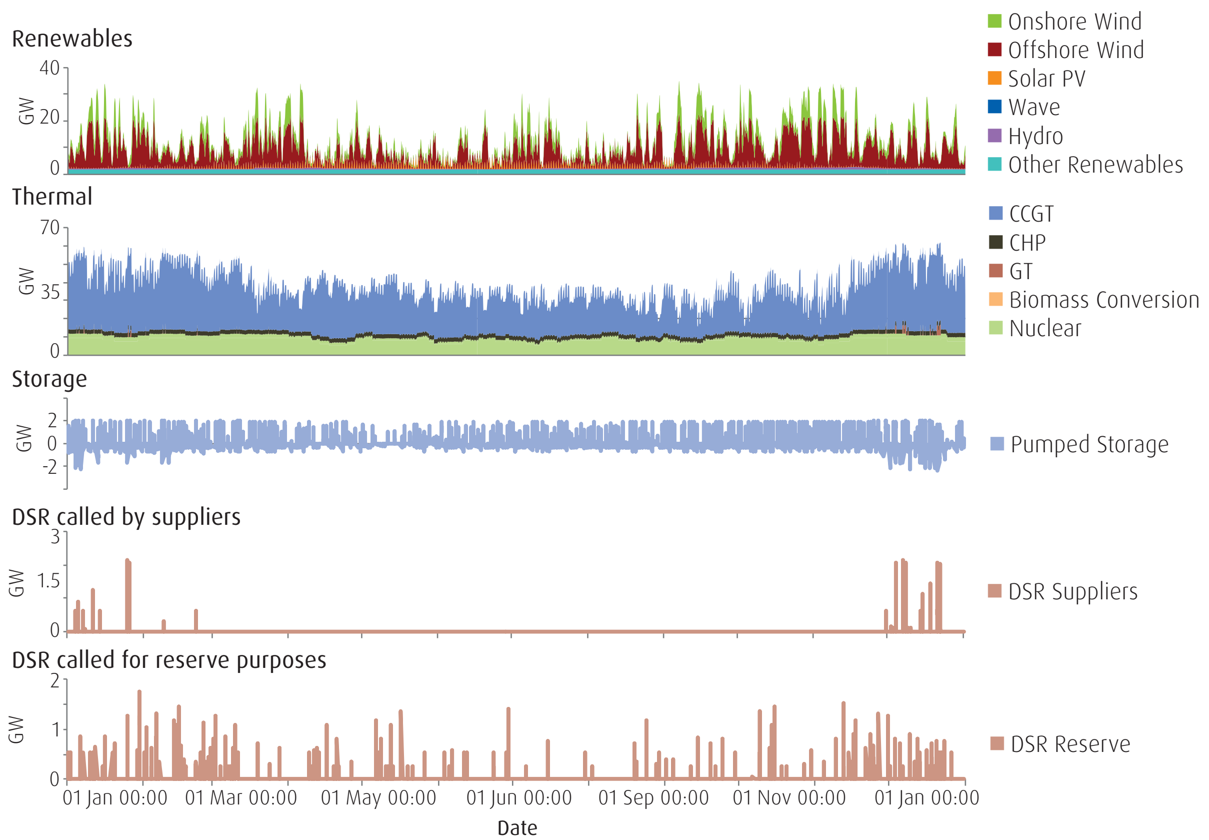
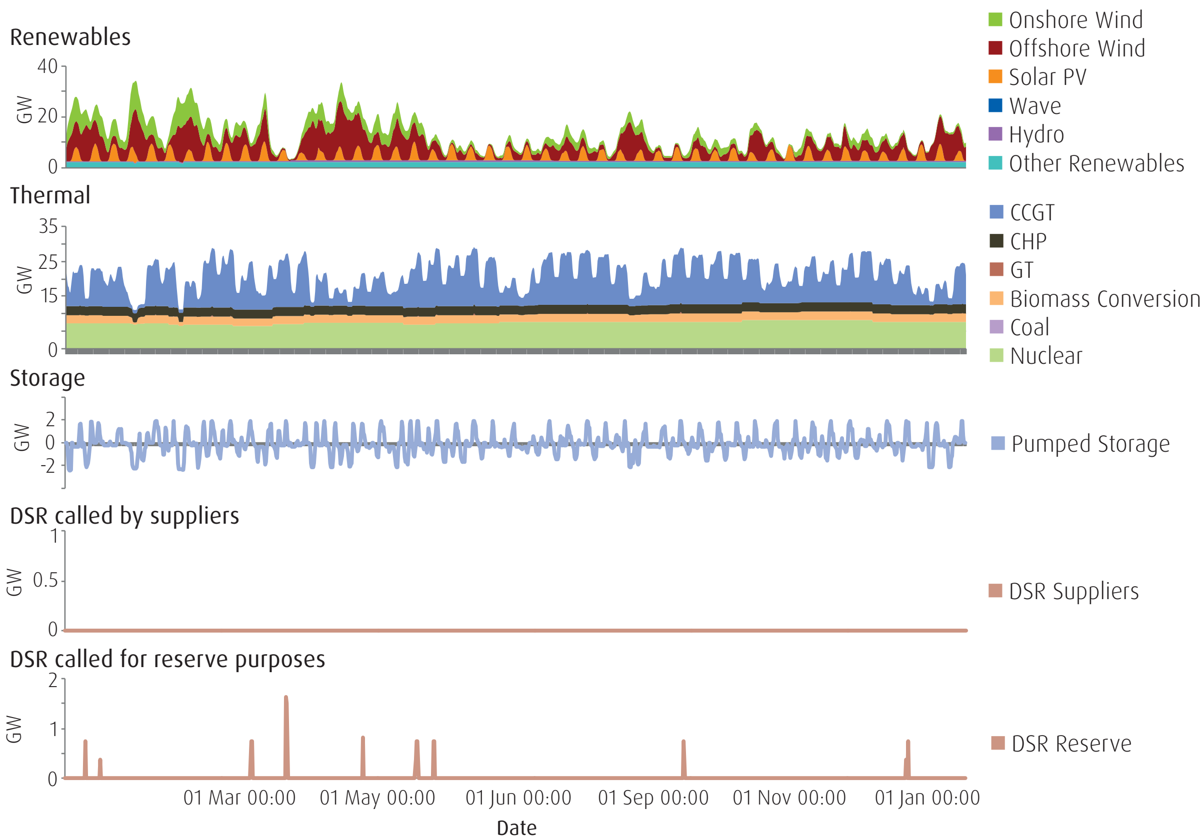


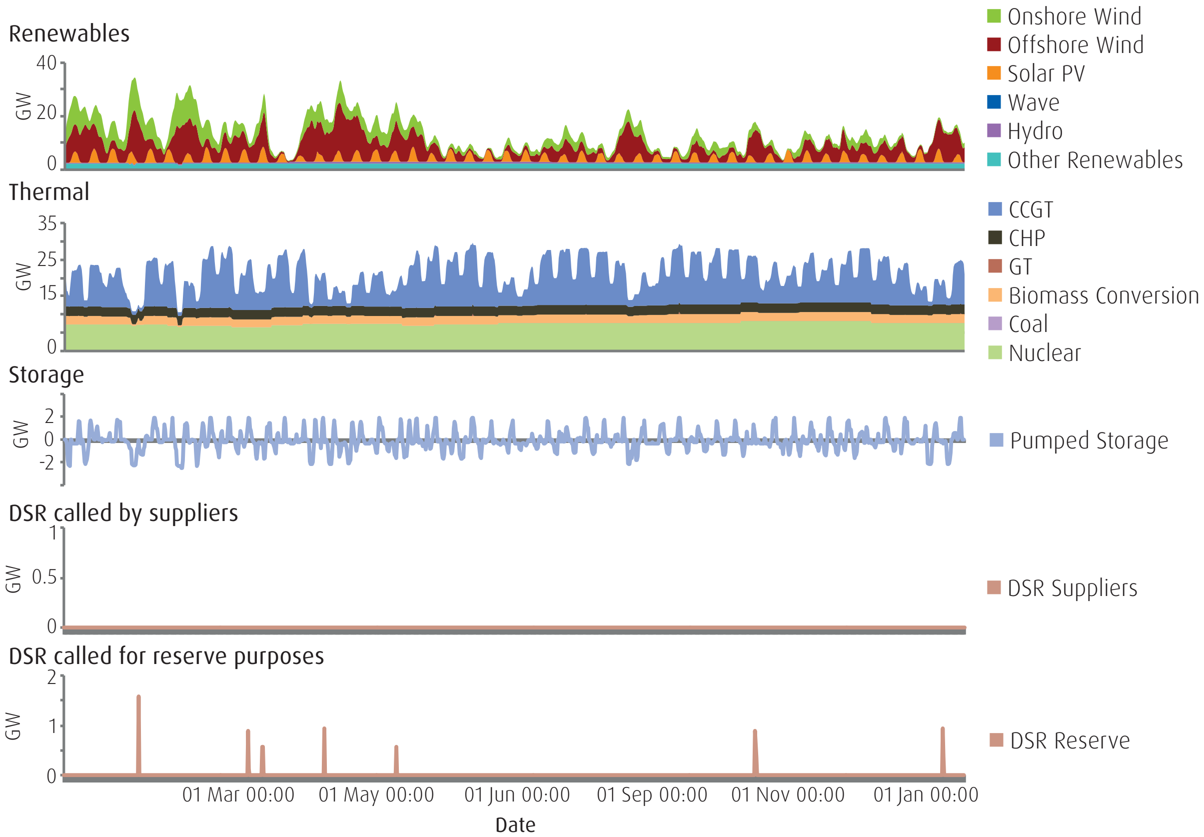
Figure 19 focuses on the hourly generation and use of I&C DSR in the solar sensitivity, in 2023 during the summer months.

Figure 19: Solar sensitivity hourly generation and use of I&C DSR (Summer 2023)



While the solar sensitivity increases the total capacity of renewable generation on the system compared to the Intermittent high flex run, the greater solar capacity does not increase the use of DSR by the SO. Figure 20 shows the hourly generation for the Intermittent high flex run for the same period as shown in Figure 19 above. It can be seen that the frequency of I&C DSR use by the SO is similar in both cases. There is no supplier usage in the summer period shown, which is typical across all modelled years and scenarios.

Figure 20: Intermittent World hourly generation and use of I&C DSR (Summer 2023)



Key insights

The following key insights can be gathered from the charts above:

- Across all scenarios, suppliers primarily use DSR over the winter period (to tackle periods of high prices and/or low wind or solar) whereas the SO uses DSR for operating reserve purposes all year round. The requirements for reserve holding increase with rising penetration of renewables on the system. I&C DSR therefore provides flexibility to the system in a similar way to flexible thermal plants, e.g. OCGTs;
- Suppliers use DSR to manage their wholesale costs through dynamic time of use tariffs, as well as through calling in I&C DSR;
- The peak level of DSR used by suppliers will eventually be comparable to the level used by the SO if DSR resources can be shared. If resources are not shared, there will be an economic incentive for suppliers to compete with the SO and DNOs for resources;
- The variability of wind generation is significant across all scenarios. The more wind there is on the system (Green World and Intermittent World), the more variability there is in the output of other plants, especially CCGTs;
- The variability in the operations of pumped storage in the Intermittent World scenario is much more pronounced compared to other scenarios as the variability and unpredictability of the intermittent generation has a much greater impact on the system (there is a lower level of demand in this scenario compared to Electrified World and Green World scenarios);
- In the Electrified World scenario, nuclear plants, CCGTs and OCGTs practically run baseload. Lower levels of renewable generation alongside high flexible demand leads to a greater requirement for baseload thermal plants to run;

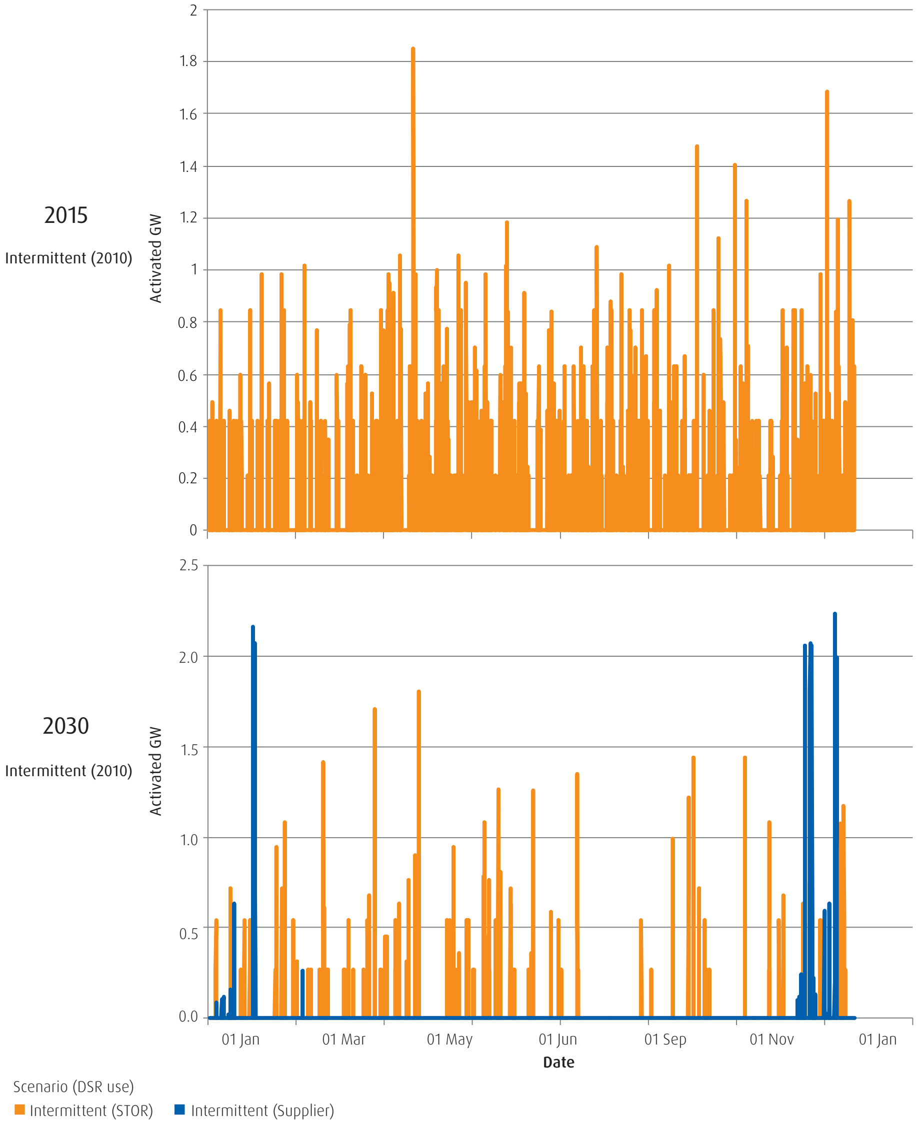
- Nuclear effectively runs baseload across all scenarios. While nuclear plants are sometimes part-loaded as seen in the charts above, our scenarios assume that wind curtailment and other generation curtailment occurs ahead of any nuclear shut down; and
- Finally, the use of DSR by the SO is similar in the sensitivity with more solar capacity compared to the Intermittent World.

2.3.2 Use of I&C DSR nationally

It can be seen (Figure 21, Intermittent World) that the use of I&C DSR to tackle both supplier and SO issues increases with rising levels of renewable penetration on the system. I&C DSR is not used in 2015 for supplier/generator issues; some I&C DSR is used for reserve purposes. However, by 2030, more I&C DSR is used (approximately 2GW compared to 1GW in 2016). In addition, I&C DSR is used much more frequently and by both market actors.

The dispatch of I&C DSR is much more frequent in the winter periods in 2030 as the resource is used by both suppliers and the SO.

Figure 21: Use of DSR nationally (Intermittent World, 2015 and 2030)



2.4 DNO use of DSR

Dispatch of I&C DSR by the DNO has been modelled according to the following set of empirical rules provided by UK Power Networks:

- A substation must have a forecast peak load above its firm capacity to be a candidate for DSR;
- The capacity shortfall should be calculated as (forecast substation maximum demand) – (substation firm capacity);
- A DSR scheme must be procured to provide 100% of the capacity shortfall. If insufficient DSR is available on the network to provide this, then the network must be reinforced;
- All DSR programmes will be procured to be available for not less than 1 season, specific to the seasons that the firm capacity of the substation is breached;
- DSR should only be relied on up to a maximum of 120% of firm capacity;
- DSR standby generation should not be relied upon to operate for more than 6 hours per day; and
- DSR should be utilised to keep the system within firm capacity if any outage or fault is present in the system.

These rules are purely empirical, and we expect that in time improved reliability of DSR, and improved confidence in our understanding of what DSR will deliver, means that they may be partly or wholly superceded by probabilistic-based criteria. We have used these rules as a good framework for when DSR is likely to be used in the future, and have incorporated some developments to DSR handling, including:

- Dispatch of all procured DSR on a stressed network (before 2020) giving way to more efficient dispatch of only the required quantity of DSR (2020-2030); and
- Increasing the availability, duration and dispatch flexibility of building turndown in the future, for instance turndown is limited to one hour per building before 2020 rising to three hours per building by 2030.

Four DNO representative nodes have been modelled:

- An urban winter peak node;
- A suburban winter peak node;
- A superurban summer peak node; and
- An urban summer peak node.

Figure 22 shows the DSR dispatch across the four representative nodes in 2015 for the Intermittent World scenario while Figure 23 shows the same information for 2030. The pictures show the firm capacity of the network in blue, for each of the representative nodes, with the more winter peaking networks at the top, and summer peaking networks (urban and superurban) at the bottom. The grey area represents the demand on the network. The orange lines show when demand would be shifted by either suppliers or the DNO, assuming in the latter case that an outage was present. The green peaks at the bottom of each chart show the level of DSR generation or turndown which would be used to bring the demand on the network back to firm capacity levels if an outage were present.

Figure 22: DSR use across network nodes (Intermittent World, 2015)

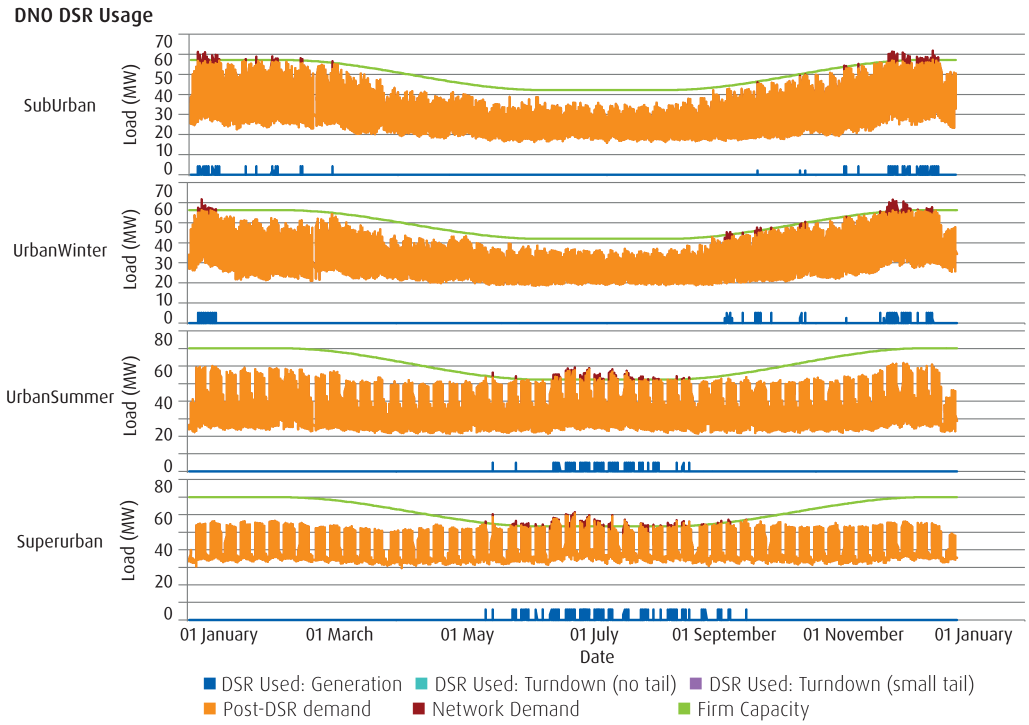


Figure 23: DSR use across network nodes (Intermittent World, 2030)

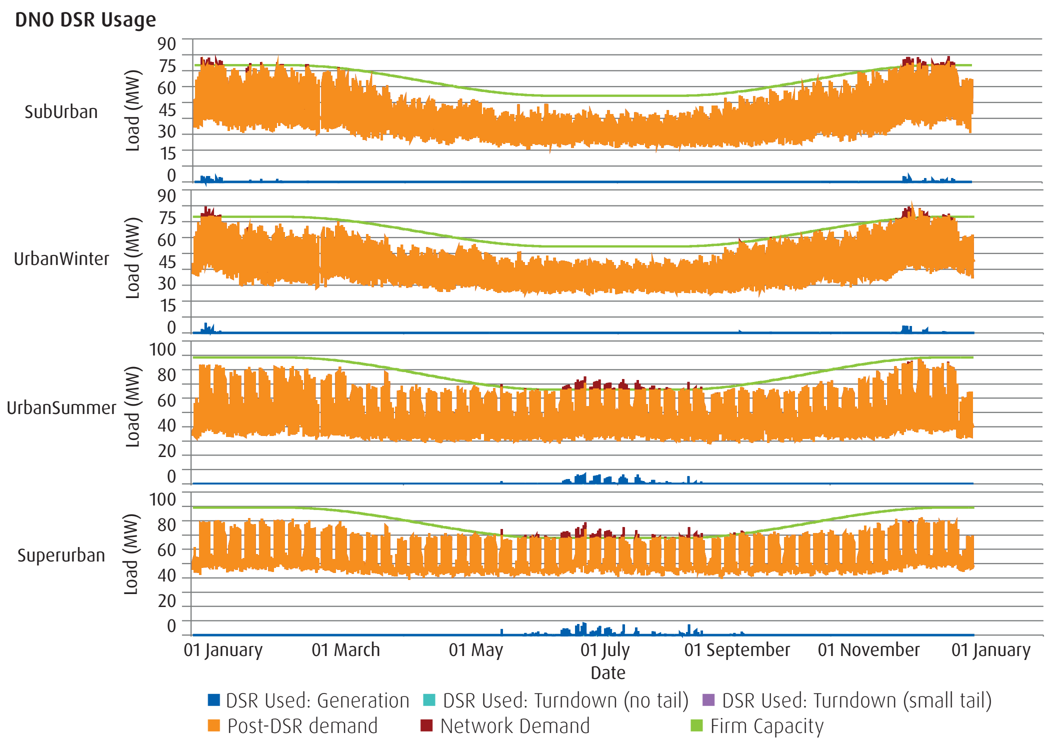
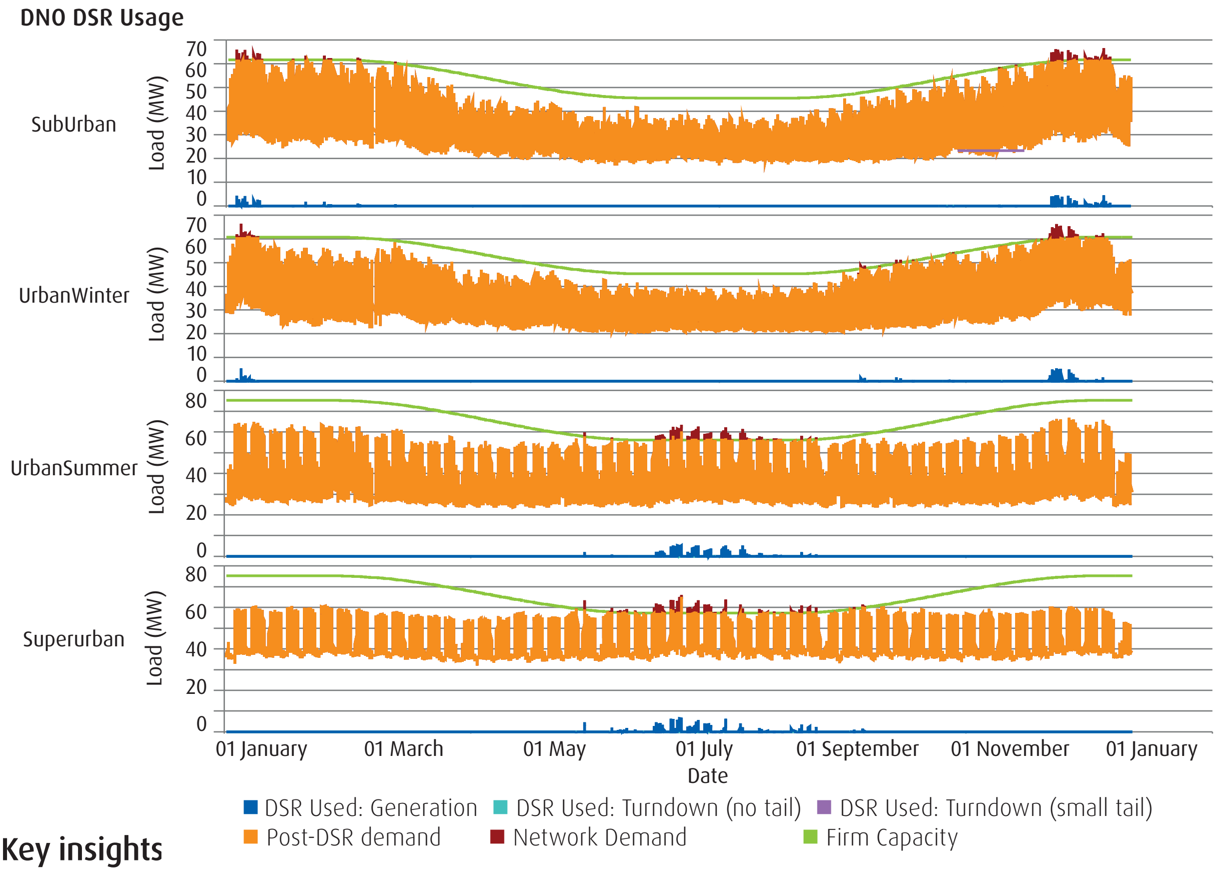


Figure 24 shows the dispatch of DSR in 2020 in the sensitivity whereby DSR is dispatched at a lower price.

Figure 24: DSR use across network nodes (DSR Utilisation price sensitivity, 2020)



Key insights

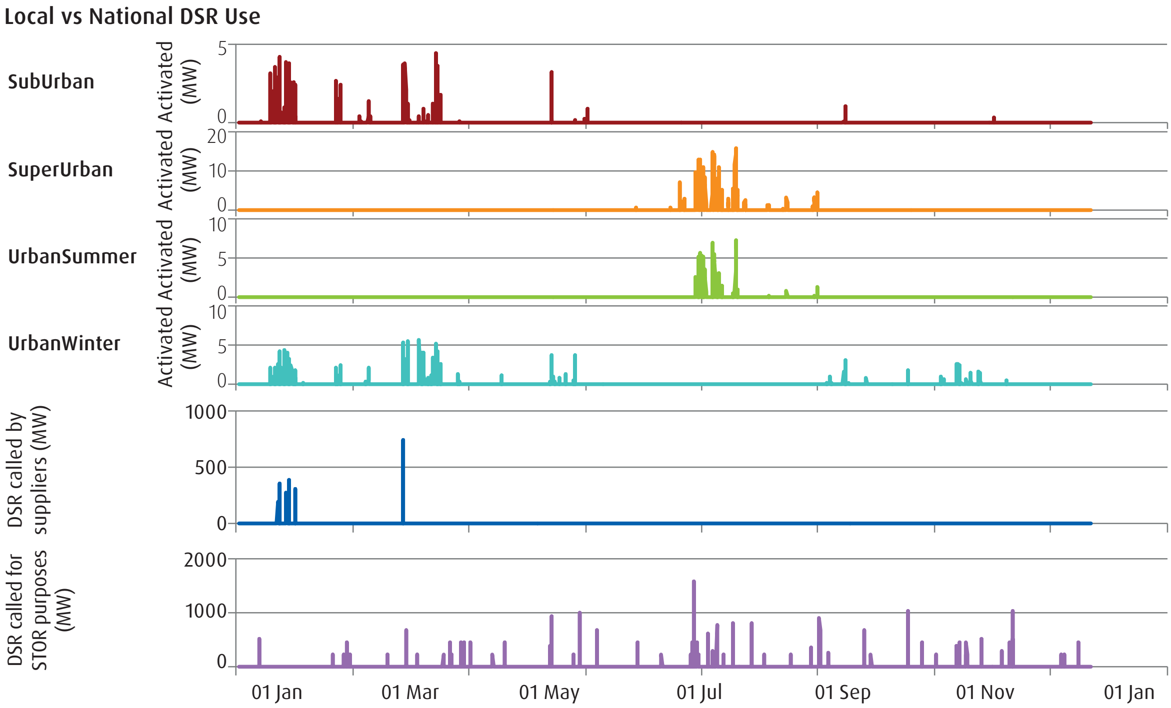
The following key insights can be gathered from the charts above:

- DSR standby generation provides the majority of DSR from the DNO perspective, as there is more of it available and it is more flexible than DSR turndown (e.g. standby generation is modelled as able to be used for up to 6 hours);
- DSR is used on the superurban and urban summer peak nodes over the summer in both 2015 and 2030;
- The winter peak nodes use I&C DSR in the winter period in 2015 and 2030. However, by 2030 I&C DSR is also being used in the autumn and spring months. This is partly due to the increase in demand from electrification of heat and transport which is likely to change the demand pattern for traditional winter peak nodes; and
- The red circle in Figure 24 above shows periods where some DSR use (orange) is visible despite the system not being near firm capacity. This is dispatch of DSR by suppliers. A reduction in demand therefore occurs on the particular network node without the DNO actually calling the DSR.
-

2.5 Network impacts of supply following DSR

The use of DSR locally (DNO, upper four charts) and nationally (lower two charts) is summarised in Figure 25 below.

Figure 25: Use of DSR locally versus nationally (2023, Electrified World)



I&C DSR is used on the various representative nodes when outages occur and demand exceeds firm capacity. While the summer peak nodes only require DSR in the summer throughout the time period modelled (2014 to 2030), the time period over which DSR is required on the winter peak nodes increases in later years, extending into the spring and summer months. DSR is therefore used throughout the year in some cases.

Suppliers require DSR over the winter period but the SO reserve requirements need to be fulfilled all year round. The two lowest sections of Figure 25 show the use of DSR by other market actors; suppliers and the SO. Potential conflicts occur when two parties want to use DSR on the same day; it is clear that the winter peak nodes are most impacted by supplier usage as they use DSR in the same periods of the year.

In addition, Figure 25 shows the stark contrast between the volumes of DSR used at the network level (5 MW per substation) compared to the volumes of DSR used at the national level (1.5 GW).

2.5.1 Synergies and conflicts in the use of I&C DSR

For the purpose of our modelling, we have defined synergies and conflicts in the following way:

- Synergies occur when the use of DSR nationally (either by the SO or suppliers) eases the stress on the distribution network;
- Conflicts occur when the use of DSR nationally (either by the SO or suppliers) makes it more difficult to manage the load on the distribution network; and
- A neutral occurrence relates to a time when DSR is used nationally and by the DNO on the same day but without a synergy or a conflict.

In addition we have added a further layer of granularity to the analysis by modelling two commercial frameworks:

- Coordinated framework (whether through information sharing or dispatch) – when the suppliers and the SO share information in relation to their dispatch of DSR with the DNO and vice versa; and
- Uncoordinated framework (where information or dispatch is not shared) – when the suppliers and the SO do not share information in relation to their dispatch of DSR with the DNO and vice versa.

2.5.2 Identifying a synergy or conflict

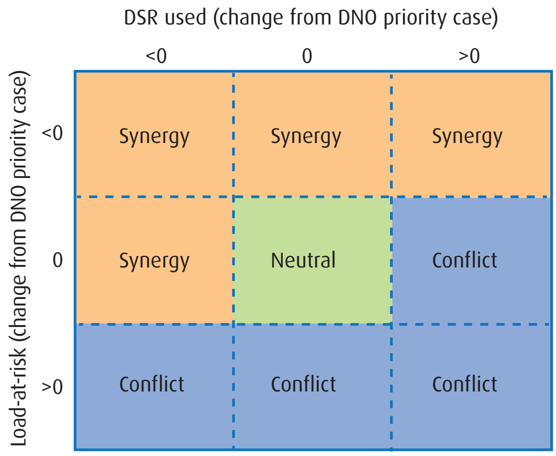
To identify synergies or conflicts, we first find the events when both the DNO and either the SO or suppliers utilise a category of DSR on the same day. For each event, the key output for determining whether it is a synergy or conflict is based on the impact the event has on the network "load-at-risk" and the level of DSR used. In Figure 26, we present a simple matrix for identifying a synergy or conflict.

The figure categorises the events between synergies and conflicts in terms of the impact that supplier dispatch has on the level of load-at-risk and use of DSR at the DNO level. The matrix identifies the impact of a change in the use of DSR, alongside the change in the load-at-risk compared to the DNO priority case. Where there is no change in either the use of DSR or the level of load-at-risk, the event is classed as a neutral. All other permutations are either considered to be a conflict or a synergy. The matrix highlights that a change in the level of load-at-risk has a greater influence on determining whether an event is characterised as a synergy or a conflict, than the use of DSR. Changes in the level of the DSR that the DNO requires become important as a determining factor if there is no change to the level of load-at-risk.

If there is any increase in the load at risk compared to the DNO priority case, we have determined this to be a conflict. Consequently any decrease in the load-at-risk, when compared to the DNO priority case, is considered to be a synergy.

The categorisation becomes more complex when considering a change to the amount of DSR used by the DNO. Where there is no change in the level of load-at-risk, an increase in the requirement for DSR (compared to the DNO priority case) will result in a conflict between the use of DSR by the wholesale market, the SO and the DNO. A decrease in the level of DSR used by the DNO (because, following supplier actions, it is no longer needed or available) will result in a synergy between the suppliers and the DNO.

Figure 26: Synergy and conflict matrix



2.5.3 Impact of supply following DSR on network nodes

Figure 27 shows the following data for the Intermittent World for all four representative nodes assuming a coordinated framework:

- The number of events when DSR is only used by suppliers to manage wholesale prices;
- The number of events when DSR is only used for network purposes; and
- The number of synergies, conflicts and neutral events.

The values shown are the average across two simulated weather years. We used weather patterns from 2010 (a cold weather year) and 2013 (an average weather year) along with DNO demand data from these years. By including a cold weather year, the number of supplier events will be higher than in average weather years, but the results will include behaviour patterns from when the system is under stress.

In these calculations, we assumed that the DNO would only utilise the DSR when a network fault or planned outage has occurred. Network faults were assumed to occur once per year on each node, with a duration of one week, while planned outages were assumed to occur in the least-stressed season, with a duration of one week. In most cases no DSR usage occurred in the season where planned outages took place. The number of events is scaled to take account of this probability of network faults and outages.

Within the modelling, we assumed that suppliers would not utilise DSR for wholesale costs in 2015, and that the availability of DSR for supplier use would increase steadily from 2016 until 2023 (when all DSR available nationally was also available for managing wholesale costs if this was cost competitive). For this reason, there are no supplier events in the modelled 2015 year.

Past 2015, it can be seen that the vast majority of total events come from supplier use, as a single network only has occasional need to utilise DSR. On average, suppliers use DSR just over 20 times per year, while each DNO network location typically uses DSR less than once per year.

Figure 27: Number of events (Intermittent World, coordinated framework)

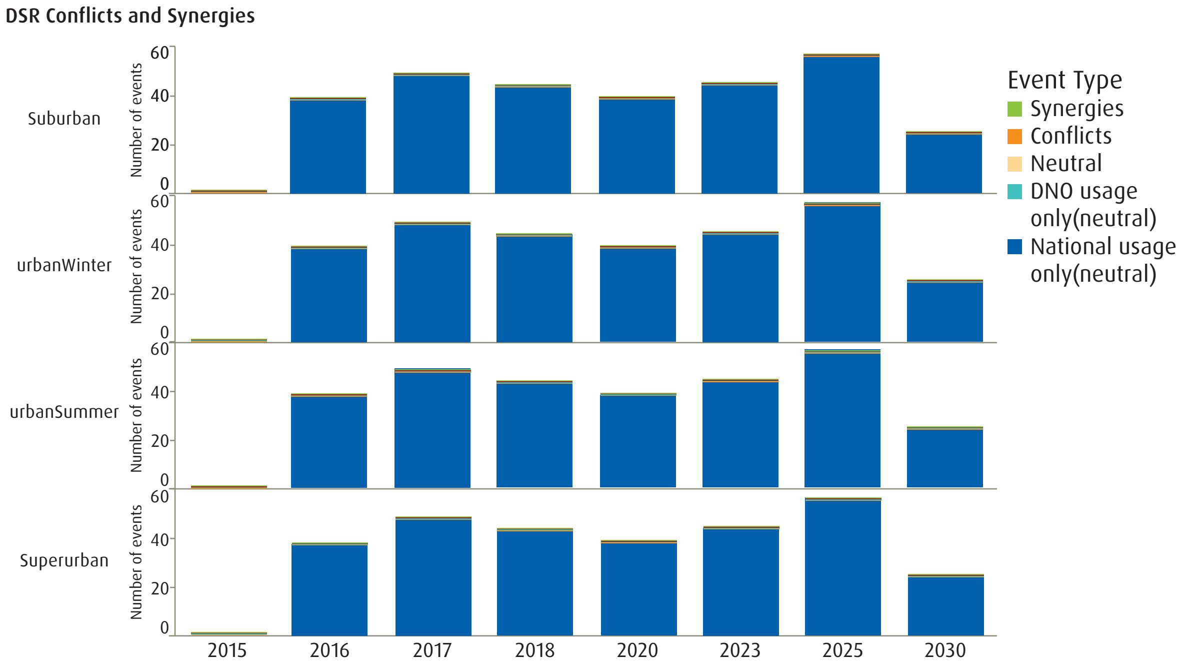
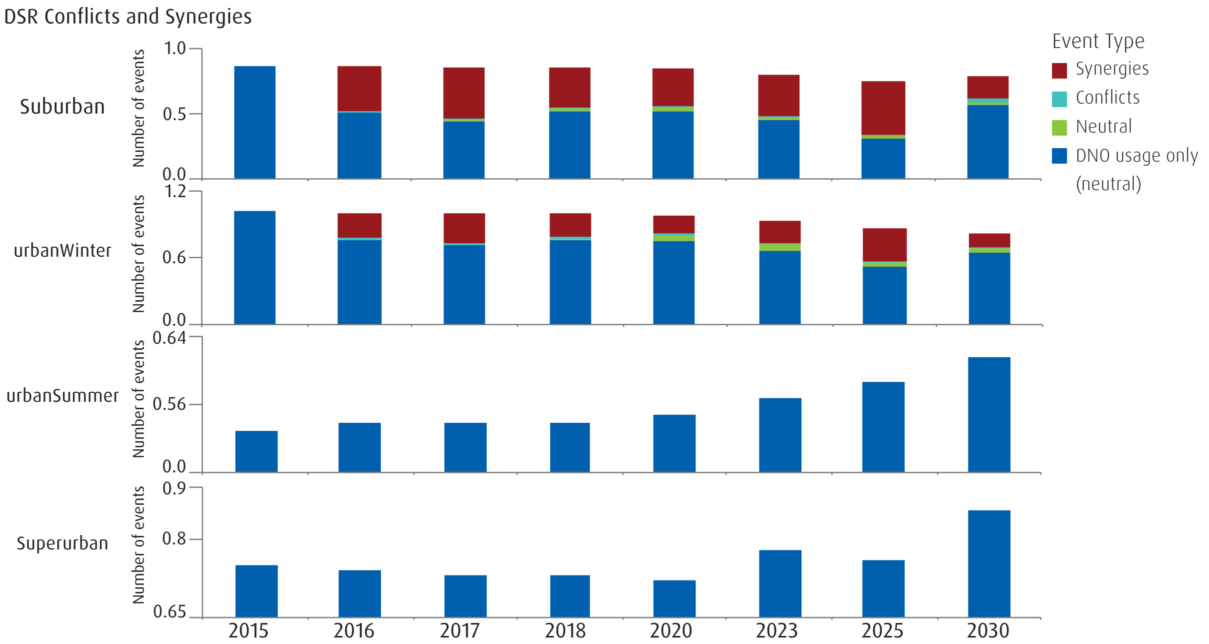


Figure 28 zooms in on the synergies and conflicts, by showing only those events where the DNO used DSR. This shows that, from the DNO perspective, there is a very significant chance that suppliers will want to use DSR on a day when the DNO needs to use DSR on a winter-peaking network. In contrast, there are few synergies or conflicts on summer-peaking networks as supplier usage is concentrated in winter, and so it is rare for both parties to require DSR on the same day.

In addition, when information/dispatch is shared, there is a very high probability that use by both the DNO and suppliers will result in a synergy, typically because all parties want to use DSR at times of system stress, particularly during the evening peak. Nonetheless, there are some conflicts where supplier use limits the ability of the DNO to utilise the DSR that they would like to use.

Figure 28: Synergies and conflicts (Intermittent World, coordinated framework)



Without coordination of the use of DSR, conflicts become more common. Figure 29 shows that in the uncoordinated framework, the majority of events are still synergies, but a significant number of conflicts begin to arise. The prevalence of conflicts also rises over time, as increasing penetration of inflexible generation causes the periods when suppliers choose to use DSR (driven by demand net inflexible generation) to be less well aligned to the periods when the DNO chooses to use DSR (driven by network demand, which may be increased by turn-on DSR).

Figure 29: Synergies and conflicts (Intermittent World, uncoordinated framework)

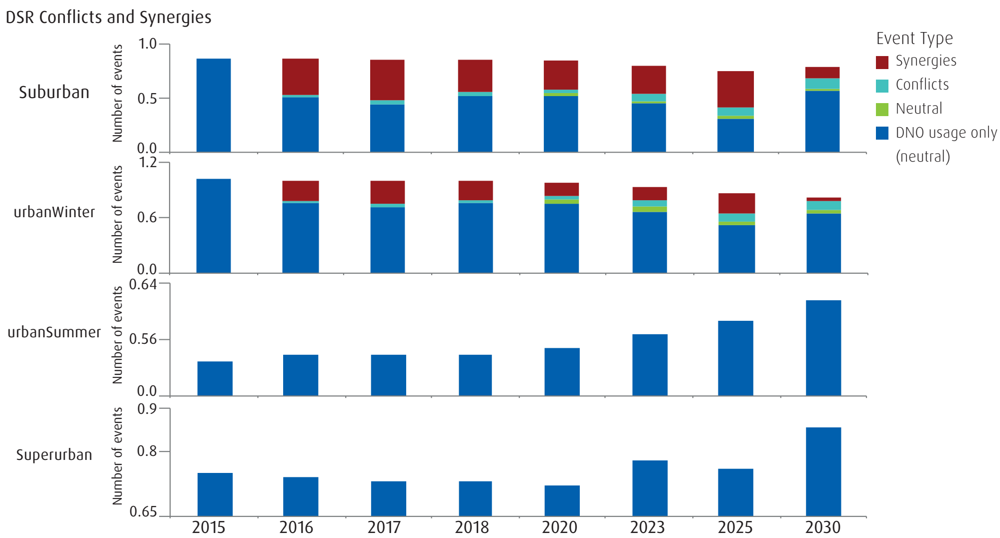


Figure 30 and Figure 31 show the synergies and conflicts for the DSR utilisation price sensitivity across all four network nodes in a coordinated and uncoordinated world respectively. In this sensitivity, more DSR is used by suppliers, driven by the lower price of DSR, and this increases the probability that supplier use will occur on the same day as DNO use. In this sensitivity, are included some events where DSR use by supplies occur at the same time as the DSR is being used on the summer peaking networks. As with the intermittent world, synergies are more common than conflicts, but a significant number of conflicts do arise.

There are more synergies in a coordinated world where information and/or dispatch is shared between parties than in a world where there is no coordination. While this is not surprising, it shows that there is potential for more material conflicts when information is not shared between parties.

Figure 30: Synergies and conflicts (DSR utilisation price sensitivity, coordinated framework)

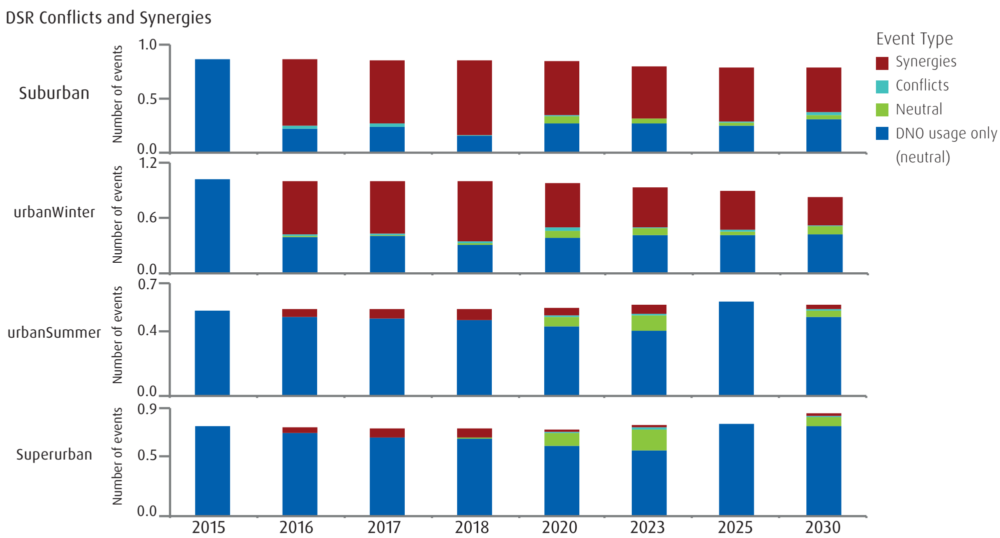
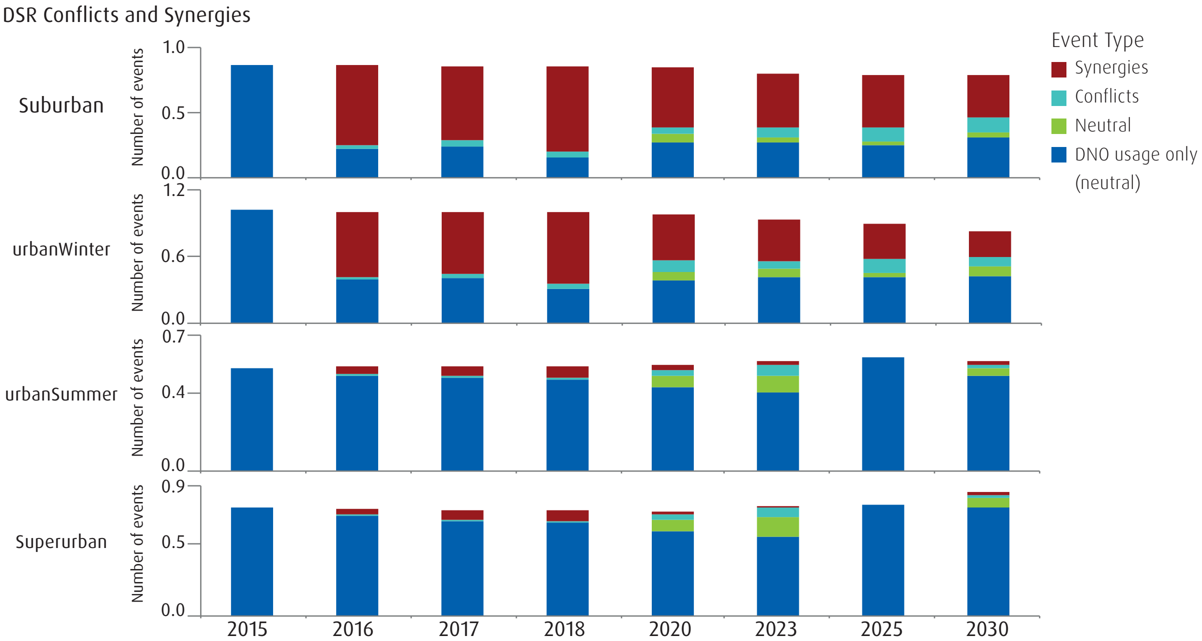


Figure 31: Synergies and conflicts (DSR utilisation price sensitivity, uncoordinated framework)



Because DSR use by both suppliers and local networks is strongly dependent on the time of year, the potential for either synergies or conflicts in its use varies by network type. It is principally the winter peaking nodes where there is increased scope for the DSR to be required simultaneously by two or more participants. In the London Power Network area, the modelling indicates that due to the relatively strong coincidence of local peak demand and national peak demand, both suppliers and DNO may want to reduce demand at the same time of day in winter peak periods, leading to a very high level of synergies. However, in the later modelled years, the prevalence of conflicts increases as the penetration of intermittent generation increases.

In the period 2020 to 2030, on average 11% of the cases where the DNO needs to use DSR on a winter peaking network conflict with supplier use. This is a very real rate of conflicts, i.e. cases where the DNO cannot access DSR that is needed to manage the network.

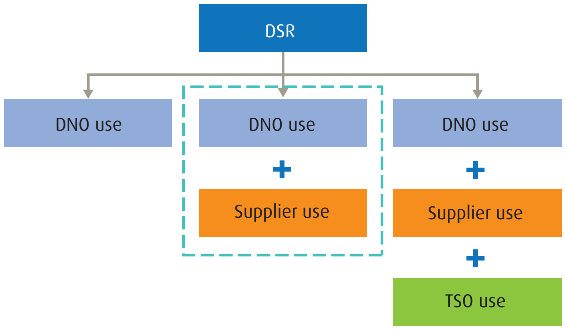
2.5.4 Examples of network impacts of supply-following DSR

Figure 32 represents how DSR is used within our modelling. We have proposed 3 cases, which are:

- Use by DNO only;
- Use by the DNO and suppliers; and
- Use by the DNO, suppliers and SO.

This section focuses on the second case, i.e. the interaction between the DNO and suppliers. More specifically this report examines how the use of DSR by the DNO is impacted by the requirements for DSR at a national level by the suppliers.

Figure 32: Use of DSR by market participants



Examples of network impacts of supply-following DSR

We provide overleaf, specific examples of the interaction between the use of DSR by the DNO and suppliers. We present four examples based on the following cases:

- Synergy, coordinated use of DSR;
- Synergy, uncoordinated use of DSR;
- Conflict, coordinated use of DSR; and
- Conflict, uncoordinated use of DSR.

For each of our examples identified as having a conflict or synergy, we present three charts. These charts are structured in the following way:

- The upper chart shows the "DNO priority case". This presents the usage pattern of DSR if the DNO has exclusive rights to call on the DSR present on the network, and provides the baseline performance level from which to assess whether usage by other parties constitutes a conflict or synergy;
- The middle chart presents the same event with the addition of the wholesale (e.g. suppliers) requirement for DSR taking priority over the DNO requirement for DSR. In this case the results assume a coordinated approach by the DNO and suppliers to manage load-at-risk and DSR use, but maintaining limits on overall usage levels, which means that conflicts can still arise if there is not enough DSR left for the DNO to utilise; and
- The lower chart presents the same event with the addition of the wholesale (e.g. suppliers) requirement for DSR taking priority over the DNO requirement for DSR. In this case the results assume an uncoordinated approach by the DNO and suppliers to manage load-at-risk and DSR use, whereby any DSR source that is utilised by suppliers is unavailable for the DNO to dispatch on the day.

Synergy, coordinated use of DSR

Figure 33 shows an instance where the use of the DSR by suppliers impacts on the use of DSR by the DNO, resulting in a synergy in the coordinated framework, but a conflict if usage is uncoordinated.

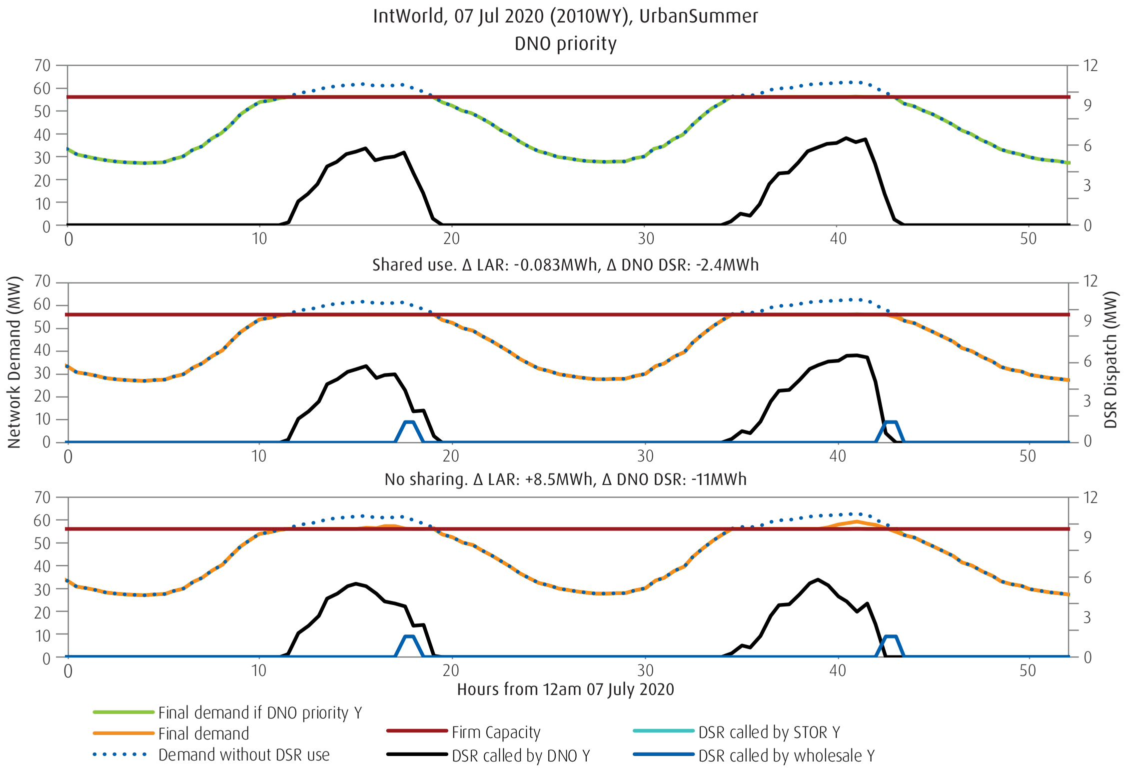
The upper chart shows the DNO priority case. The dotted line shows the firm capacity on the network (urban summer representative node) while the blue line shows the demand (pre-DSR) on that particular network. The demand is above firm capacity for a number of periods and as a result the DNO would need to use DSR to manage the network if any outage occurred. To reduce this demand to the firm capacity level (the green line) the DNO would call up to 6MW of DSR over the required period (the black line). This chart shows an event in 2020, when DSR is dispatched to bring the demand back to firm capacity.

The middle chart shows this event again, but the chart highlights the requirements of the suppliers and assumes sharing of information between the suppliers and the DNO. The chart highlights that in the first event, the national requirement for DSR is aligned with the network need and therefore no conflict occurs, and demand on the network is reduced to firm capacity level.

In the second event, the suppliers' requirement for DSR begins near the end of the DNO use of DSR but has no impact on the DSR available for use by the DNO. This reduces the requirement for DSR to be utilised by the DNO, as some DSR is deployed by other parties. Since the two parties' usage of DSR may both be satisfied with the DSR available, there is no conflict and the demand on the network is still reduced to firm capacity level or below. This results in a synergy.

In the final chart we present the same event but assuming no sharing of information between the DNO and suppliers. In this framework, use of part of the DSR by suppliers makes this DSR unavailable to the DNO. In this case, with less DSR available to dispatch, the DNO finds itself with insufficient DSR available to reduce the daily peak demand to firm capacity once their first DSR calls of the day have exceeded their contractually allowed length (six hours). This leads to an increase in the load-at-risk for three half-hourly periods (the orange line rises above the dotted blue firm capacity line). In this uncoordinated case a conflict would occur, and local network security is at risk.

Figure 33: Coordinated framework, Intermittent World scenario, synergy in 2020



Synergy, uncoordinated use of DSR

Figure 34 shows an instance where the use of the DSR by suppliers impacts on the network in a positive way regardless of the framework modelled.

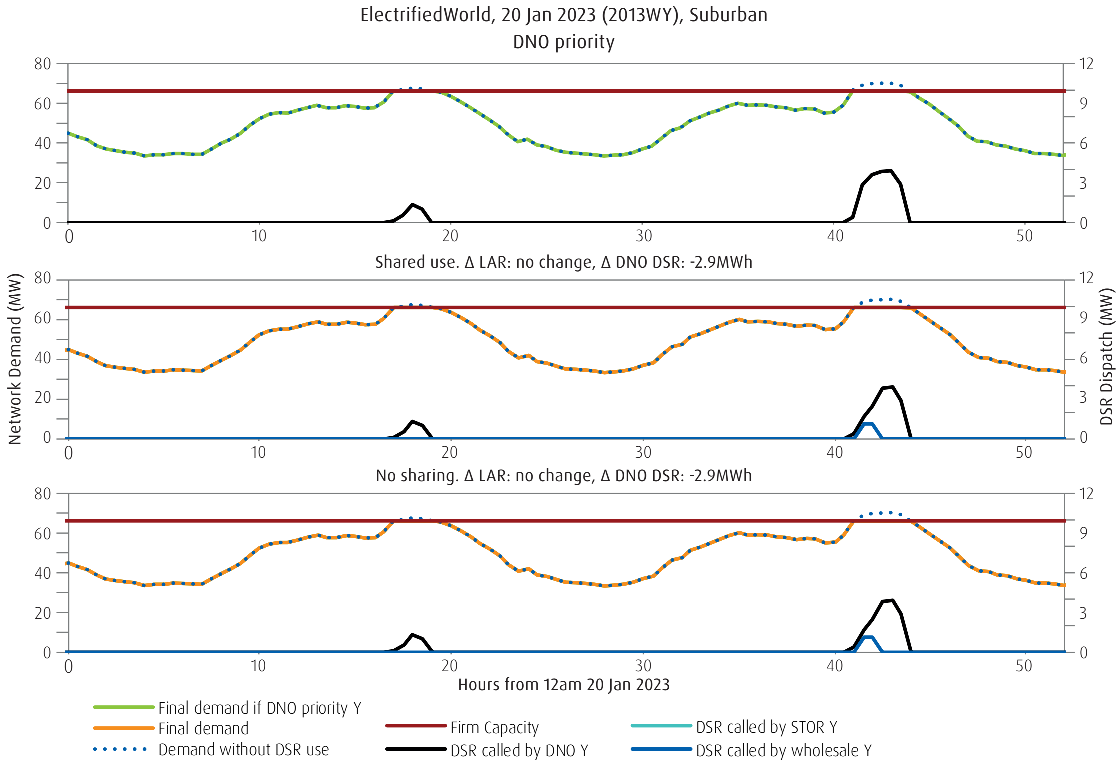
The upper chart shows the DNO priority case. The dotted line shows the firm capacity on the network (suburban representative node) while the blue line shows the demand (pre-DSR) on that particular network. The demand is above firm capacity for a number of periods in two successive days and as a result the DNO would need to use DSR to manage the network if any outage occurred. To reduce this demand to keep the final demand level (the green line) at or below firm capacity, the DNO would call up to 4MW of DSR over the required period (the black line). It is assumed the DSR is dispatched in an economically optimal way, and only the amount of DSR needed to bring the demand back to firm capacity is dispatched by the DNO.

The middle chart shows this event again, but the chart highlights the requirements of the suppliers and assumes sharing of information between the suppliers and the DNO. The chart shows that on the first day, the national requirement for DSR is zero; as a result, there is no conflict occurring and demand on the network is reduced to the firm capacity level.

On the second day, the requirement of the wholesale market occurs slightly after the requirements of the DNO. However, through information sharing, the suppliers and DNO are both able to benefit from the DSR simultaneously, and there is no change to the final level of demand on the network. Because the interests of both parties are aligned, this case results in a synergy.

In the final chart we present the same event but assuming no sharing of information between the DNO and wholesale market. In this case, there is sufficient spare DSR available on the network for both parties to utilise separate providers of DSR, and the lack of information sharing between the suppliers and DNO has no impact on the load-at-risk and level of DSR used. Therefore the network demand remains below firm capacity. This is again classed as a synergy, because the supplier usage reduces the strain on the local network.

Figure 34: Uncoordinated framework, Electrified World scenario, sensitivity in 2023



Conflict, coordinated use of DSR

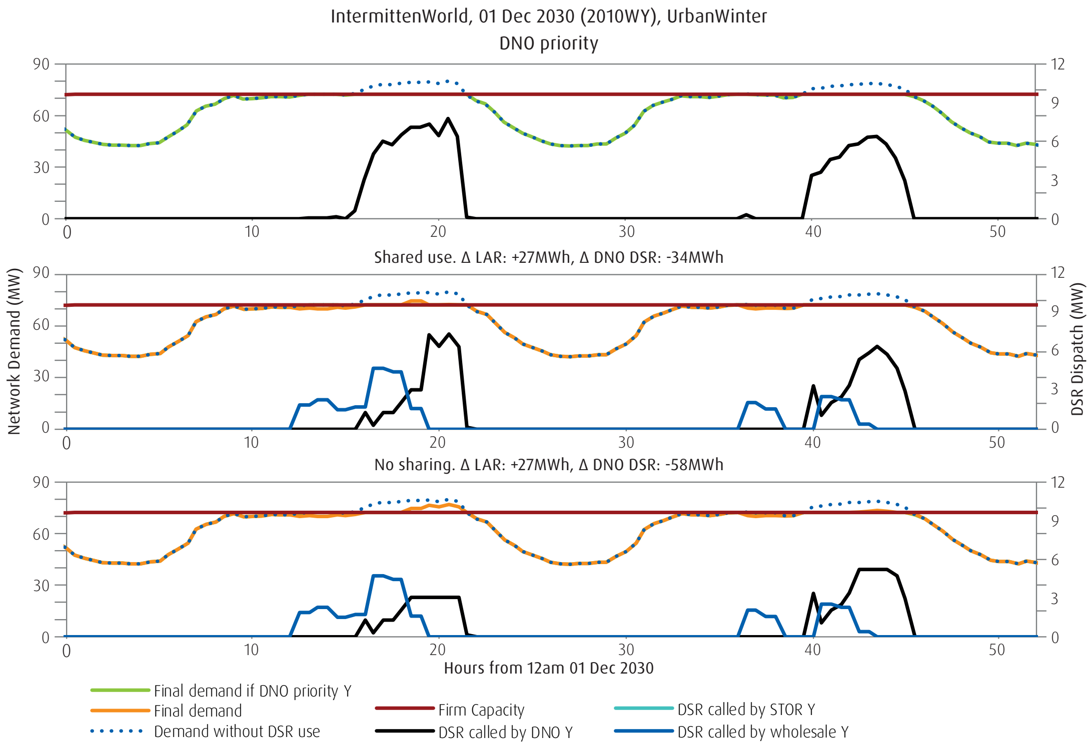
Figure 35 shows an instance where the use of the DSR by suppliers impacts negatively on the network in both frameworks, although the network impact is significantly worse in the uncoordinated framework.

The upper chart shows the DNO priority case. The dotted line shows the firm capacity on the network (urban winter representative node) while the blue line shows the demand (pre-DSR) on that particular network. The demand is above firm capacity for a number of periods on the two days shown, and as a result the DNO would need to use DSR to manage the network on both days if any outage occurred. To reduce this demand to keep the final demand level (the green line) at or below firm capacity, the DNO would call up to 8MW of DSR over the required period (the black line). It is assumed the DSR is dispatched in an economically optimal way; and only the amount of DSR needed to bring the demand back to firm capacity is dispatched by the DNO.

The middle chart shows this event again, but the chart highlights the requirements of the suppliers and assumes sharing of information between the suppliers and DNO. On both days the suppliers' requirement for DSR occurs prior to, and overlaps with, the local DNO DSR requirements. In the second event, the suppliers DSR requirement is beneficial to the DNO requirements for DSR. This results in a reduction in the DSR used by the DNO and maintains zero load-at-risk. However in the first event the suppliers' use of DSR is significant, and insufficient DSR remains available to the DNO to tackle local network problems. There is an increase in the load-at-risk leading to the demand on the network exceeding the network firm capacity. This results in a conflict.

In the final chart we present the same event but assuming no sharing of information between the DNO and wholesale market. The lack of information sharing between the suppliers and DNO exasperates the problem by leaving the DNO with less DSR capability to call on. This leads to a larger increase in the load-at-risk on both days shown. This would again lead to a conflict.

Figure 35: Coordinated framework, Intermittent World scenario, conflicts in 2030



Conflict, uncoordinated use of DSR

Figure 36 shows an instance where the use of the DSR by suppliers impacts on the network in a positive way in the coordinated framework, and a negative way in the uncoordinated framework.

The upper chart shows the DNO priority case. The dotted line shows the firm capacity on the network (summer superurban representative node) while the blue line shows the demand (pre-DSR) on that particular network. The demand is above firm capacity for a number of periods and as a result the DNO would need to use DSR to manage the network if any outage occurred. To reduce this demand to keep the final demand level (the green line) at or below firm capacity, the DNO would call up to 6MW of DSR over the required period (the black line). It is assumed the DSR is dispatched in an economically optimal way; and only the amount of DSR needed to bring the demand back to firm capacity is dispatched by the DNO.

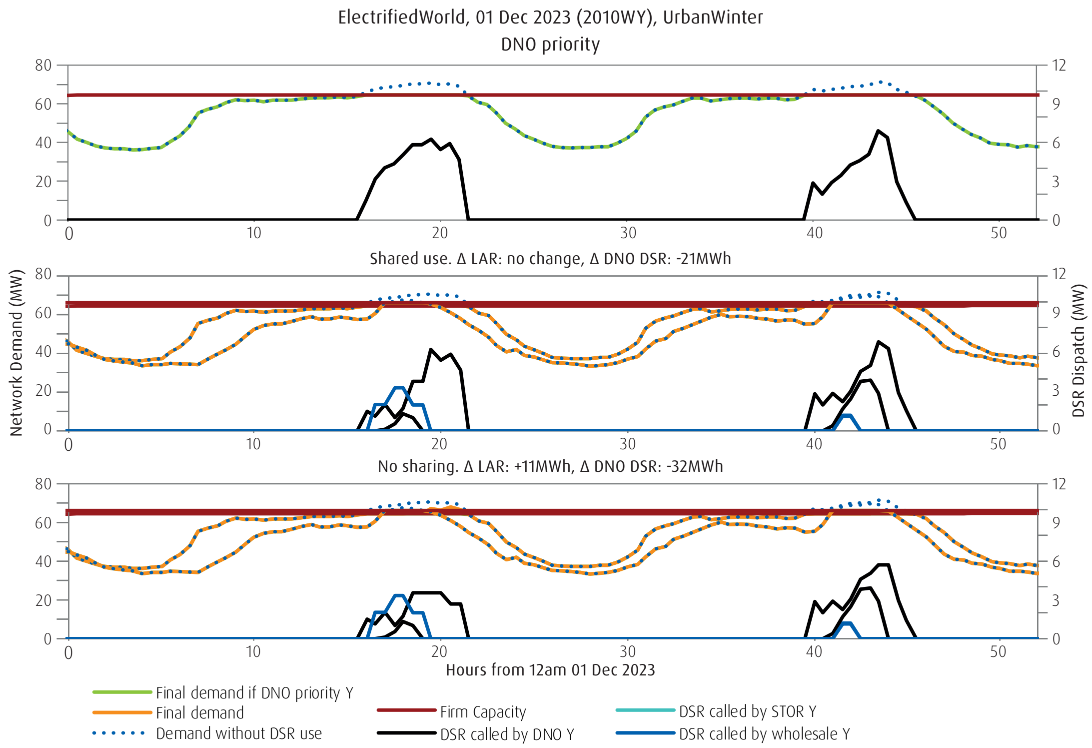
The middle chart shows these events again, but the chart highlights the requirements of suppliers and assumes sharing of information between the suppliers and the DNO. The chart shows that on the first day, the supplier requirement for DSR coincides with the local requirement for DSR, and as such a synergy occurs and there is no load-at-risk on the network.

In the second event, the requirement of the suppliers again coincides with the requirements of the DNO. However the suppliers' requirement is lower that the DNO, and has less impact on the DNO requirements.

Across these two days the DNO is able to use less DSR without any impact on network security. As a result the final demand is maintained below the firm capacity level. This would be a synergy.

In the final chart we present the outcome of the same events when no sharing of information occurs between the DNO and the suppliers. The lack of a coordinated approach between the wholesale market and the DNO, combined with the simultaneous use of DSR leads to insufficient DSR being available to the DNO to reduce demand levels to firm capacity, resulting in an increase in the load-at-risk in that time; this is a conflict.

Figure 36: Uncoordinated framework, Electrified World scenario, conflicts in 2023



Key insights

The following key insights can be gathered from the charts above:

- There are more synergies in a world where the market actors share information or DSR dispatch compared to a world where there is no coordinated framework;
- There are more impacts of supply following DSR on the winter peaking nodes (suburban and urban winter) than on the summer peaking nodes. Over the modelled years, I&C DSR is used more frequently throughout the year on the winter nodes (not just over the winter period);
- Across the modelled years, the number of neutral events whereby the DSR is only used by the DNO is often more significant than conflicts and synergies; and
- Figure 27 shows that the number of national events is far more significant than any other event types.

3

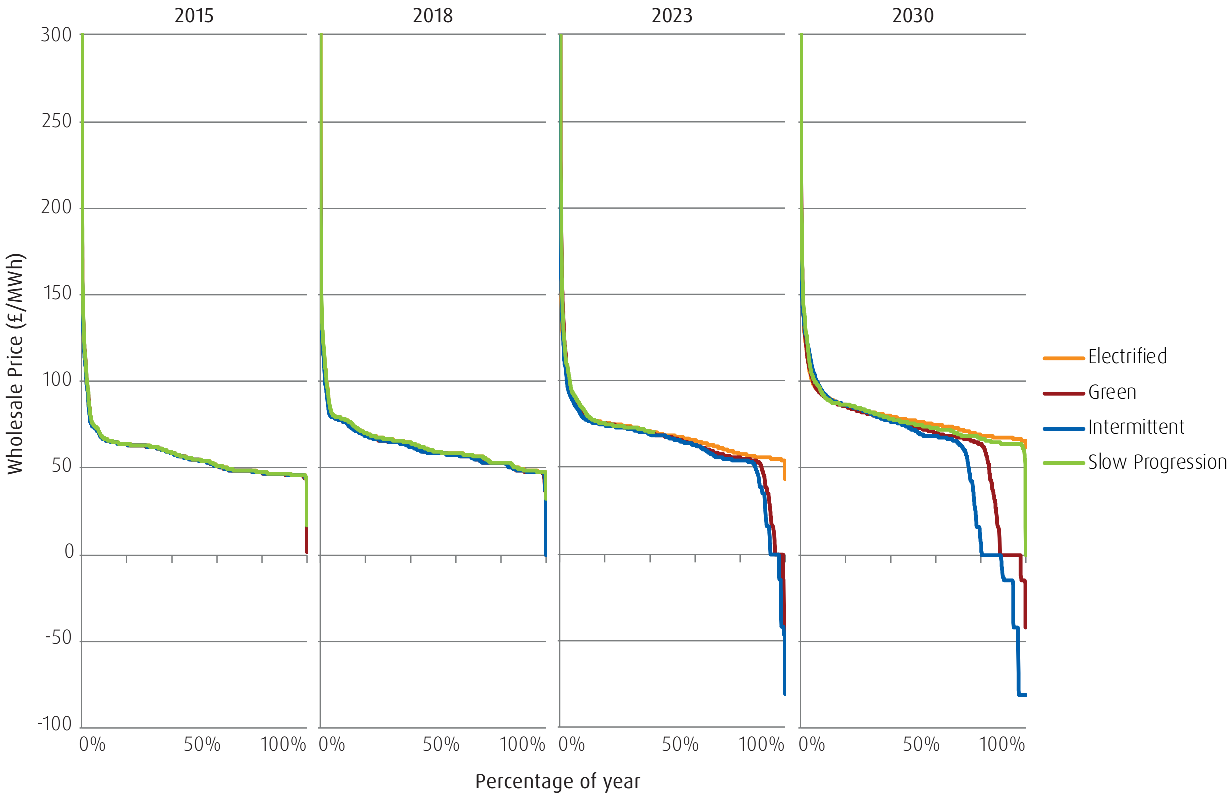
Commercial results, network impacts

The use of DSR by all market actors has significant commercial implications which are discussed in more details here.

3.1 Scenario results on a national level

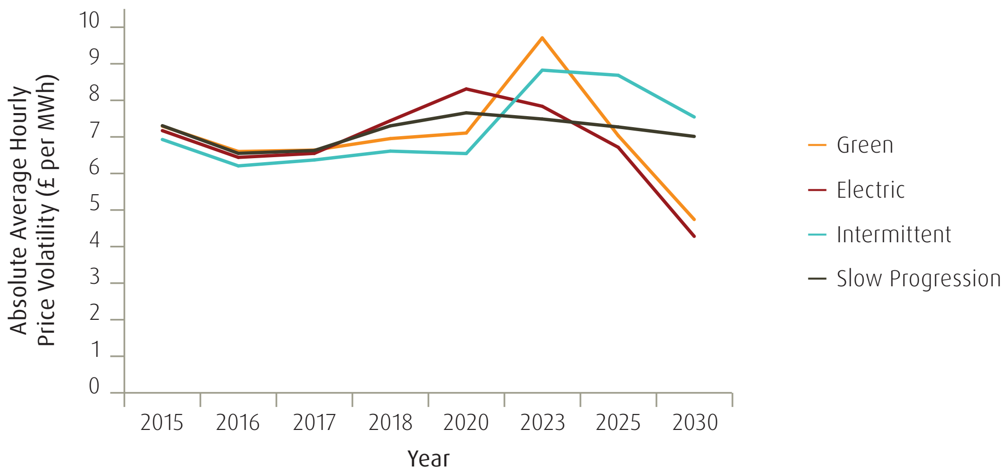
The main distinguishing features of the scenarios modelled are also the main drivers of the differences in the commercial results. Figure 37 shows the price duration curves for the high flex world for each of the core scenarios and Figure 38 shows the price volatility. The price duration curve shows the percentage of the time in a year when the wholesale price is above each price level. For example, in Figure 37 the 2015 wholesale price is higher than £50/MWh approximately 60% of the time. Similarly, a price duration curve which crosses below the price of £0/MWh indicates that some periods of negative prices occur during the year.

Figure 37: Price duration curves



Note: The negative prices seen beyond 2023 can occur when demand net of renewable generation is low and some renewable generation curtailment needs to occur. Logically, renewable generators should bid at the level of minus their subsidy, which leads to cases where high output from intermittent generation causes the price turn negative.

Figure 38: Wholesale Price Volatility



Key insights

The following key insights can be gathered from the charts above:

- The main driver of higher prices in later years is the rising Carbon Price Floor applied in GB. This effect is seen most strongly in the scenarios with the lowest penetration of low carbon generation; the higher carbon intensities cause the higher wholesale prices;
- Rising penetration of renewable generation gives rise to negative prices from 2023 onwards. In 2023, negative prices reach approximately -£50/MWh implying that wind generation facilities on ROC incentives are being curtailed at those points. By 2030, we can see that prices reach -£81/MWh; therefore wind on FiT CfD is also being curtailed;
- The interaction between sources of inflexibility (such as nuclear plants, and certain forms of renewables) and flexibility (pumped storage, GTs and crucially, flexible demand) drive the different levels of price volatility;
- The ability of EVs and flexible heat pumps to be charged in periods of low demand, net of inflexible generation (e.g. wind, solar), can help to raise demand levels to "soak up" excess generation and mitigate against negative prices;
- In particular, the Green World and Electrified World scenarios feature stronger electrification, and this helps reduce price volatility. However, these benefits are only realised post-2020, once the mechanisms that enable flexible use of these technologies are put in place. Without the flexible use of EVs and heat pumps, electrification can lead to greater price volatility;
- By contrast, the Intermittent World scenario sees higher price volatility and many negative prices because the strong deployment of renewables is not matched by a corresponding growth in sources of flexible demand; and
- The Slow Progression scenario features levels of price volatility similar to today, because the uptake of flexible demand in this scenario matches the lower renewable penetration.

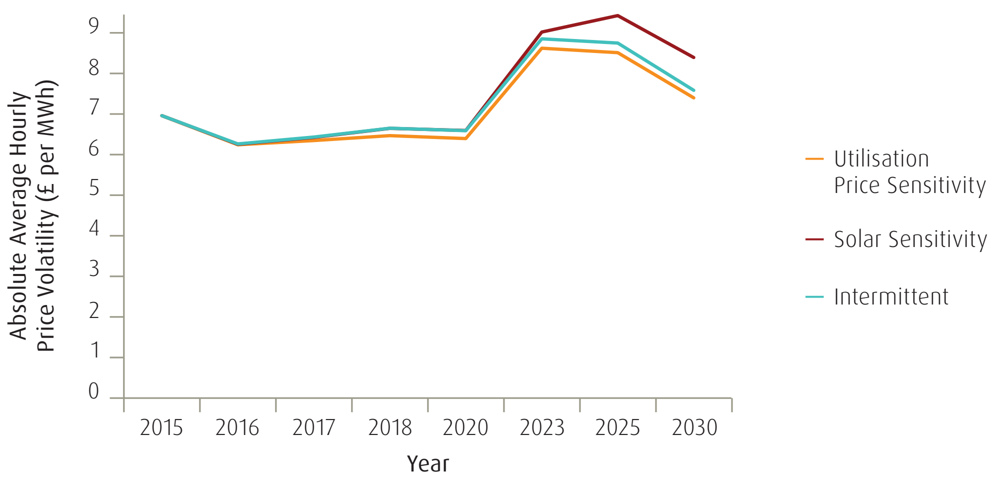
3.1.1 The relative impact of increased solar PV compared with wind generation

The above commercial results show that the level of renewables penetration is a key driver of the wholesale prices across the four core scenarios. In particular, the level of wind capacity had a big impact on both price volatility and overall average wholesale price in these scenarios.

The solar sensitivity was designed to model a world where growth in onshore wind is more modest and where solar PV capacity shows strong growth until 2030, where it reaches 25GW, as opposed to 15.8GW in the core Intermittent World scenario.

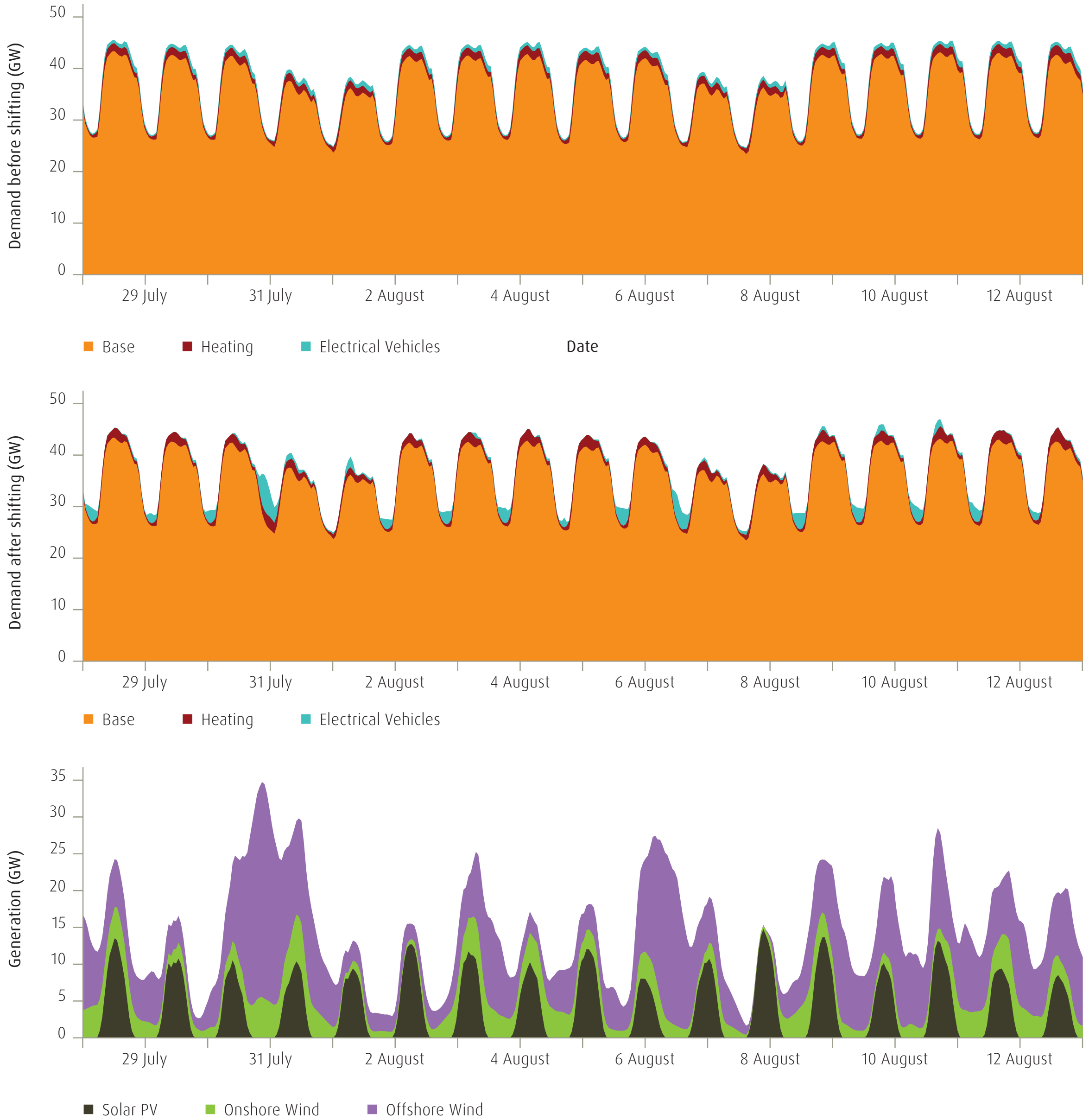
However, one insight that came from this sensitivity is that this additional solar PV capacity can be absorbed by the wholesale market. Figure 39 shows the impact on price volatility in this sensitivity. Reduced levels of wind pushes prices up in the winter while lower prices can be anticipated in the middle of the day in the summer when solar output is at its highest. This accounts for the greater price volatility in this solar sensitivity.

Figure 39: Solar sensitivity price volatility compared with the Intermittent World



One key factor is that the system still possessed the necessary flexibility to deal with any peaks in solar generation. In particular, flexible EV and heat pump demand could be shifted in order to accommodate excess solar generation on the system, as shown in Figure 40. The first chart shows the demand on the system before any shifting has occurred. The second chart shows the demand once shifting has occurred. We can see that demand is increased at times of significant solar output.

Figure 40: Demand and intermittent renewable generation, high solar sensitivity, 2030, Historical Year 2010, July 28th- August 14th



The solar and wind capacity is therefore absorbed by increasing consumption on the system. This occurs through Dynamic Time of Use (dToU) tariffs, with suppliers incentivising customers to increase their consumption when prices are at their lowest. This increased consumption ensures that solar and wind generation is not wasted.

Significant solar and wind output can lead to periods of negative prices. Suppliers can incentivise customers to increase their consumption through the use of Dynamic Time of Use tariffs at those times. Figure 41 shows how flexible demand from EVs and heating increases drastically during periods of negative prices in the wholesale market. An example is earmarked with a red circle in Figure 41. Demand increases significantly at the national level with negative prices. This could create unforeseen events for the distribution network operator and result in times when suppliers may be increasing demand while the DNO may wish to reduce demand on the network.

Figure 41: Flexible demand shifting and wholesale prices, high solar sensitivity, 2030, Historical Year 2010, August 27th- September 19th

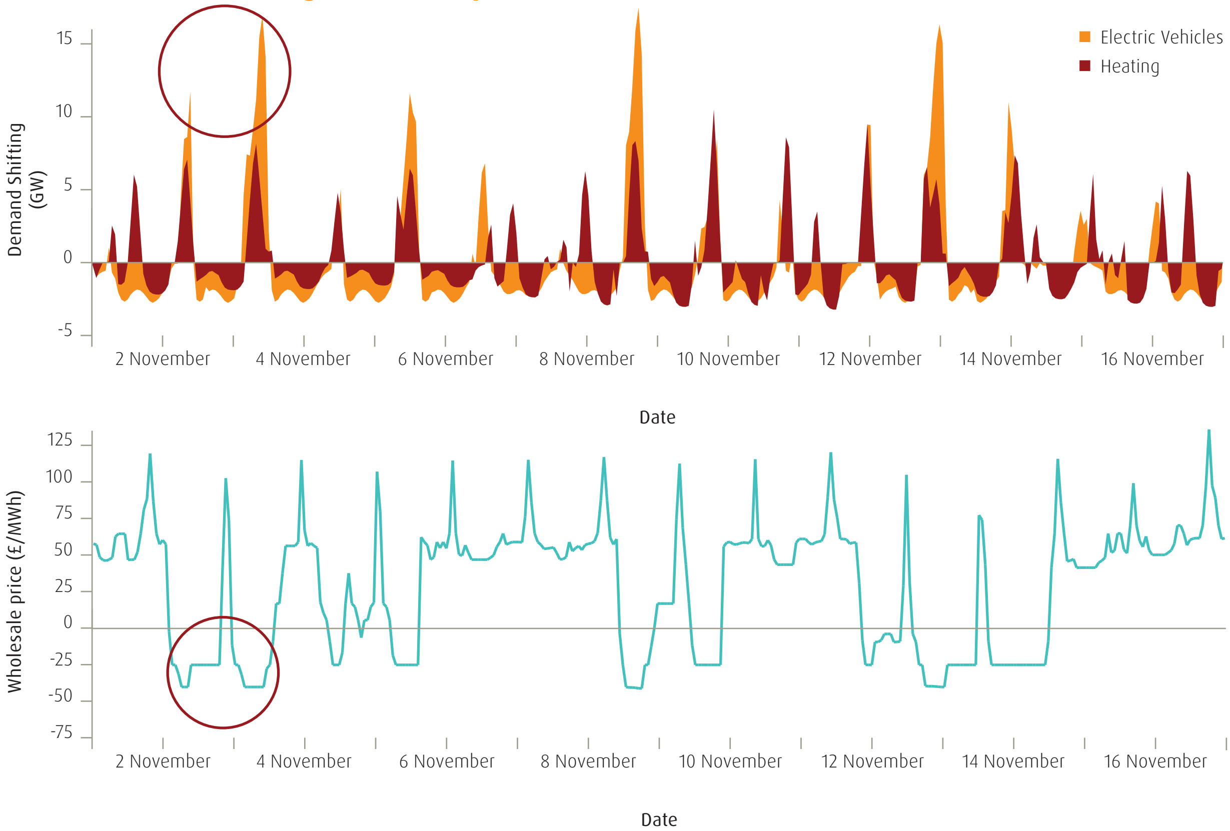


Figure 42 shows an instance when the excess solar and wind generation in the system creates a conflict between the DNO and suppliers. The graph at the top shows the demand reduction on the distribution network for 20 days in September 2030 and the two other graphs show solar output and wholesale prices for the same period in the high solar sensitivity. On September 13, excess solar and wind generation lead to negative prices in the wholesale market thus providing a signal to suppliers to increase their customers' demand, through the use of dToU tariffs. At the same time, the DNO requires a reduction in demand on the network which conflicts with the signal from the wholesale market. Similar situations are expected to arise in the future in a world with increased levels of distributed solar generation in the network.

Figure 42: Conflict when demand is increased to "soak up" solar and wind, high solar sensitivity, 2030, Historical Year 2010, September 10th - 30th

3.1.2 NPV Savings for end consumer

We have calculated the overall savings from a consumer perspective of increased use of I&C DSR to manage the system. The savings summarised in Table 2 refer to the difference in costs between the low flex and high flex worlds in any particular scenario, calculated over the 15 years of the modelled timeframe.

Table 2: NPV savings for end consumer[5]

	Wholesale costs (£m)	Capacity payment costs (£m)	Renewable subsidy costs (£m)	Total (£m)
Green World	(-776)	(-669)	40	(-1304)
Intermittent World	(-453)	(-1080)	(-51)	(-1584)
Electrified World[6]	(-230)	(-492)	55	(-667)
Slow Growth	(-202)	(-861)	27	(-1036)

In each scenario, the savings (difference between high flex and low flex) are slightly higher than the cost of the equivalent amount of OCGT capacity that can be avoided by having the greater capacity of I&C DSR available.

The savings are made up of the following components:

- In all scenarios, the wholesale price is lower as a result of having more DSR available to provide reserve. By having more DSR to provide reserve, fewer Balancing Mechanism (BM) units need to be part-loaded in order to provide reserve (holding capacity back from the wholesale market). Therefore, demand can be met without the need for some of the more expensive plants to generate. Additionally, DSR may be used to manage wholesale costs, reducing demand in periods of high peak prices and reducing the wholesale price in these periods. This leads to reduced wholesale costs that suppliers pass on to customers;

- DSR contributes to meeting the security standard for the capacity payment and therefore, less other thermal capacity is required. This results in a lower auction clearing price for the capacity payment. This effect is greatest in the Intermittent World because the higher wind and price volatility of this scenario gives rise to a higher auction clearing price. Therefore, the cost difference between the higher and lower DSR availability variants is greater. This represents a cost saving on the capacity charges which are passed through to consumer bills; and

- In most scenarios there are, on the other hand, additional costs associated with subsidising renewables. This results from the wholesale price being lower in the "high flex" version of the scenarios. Consequently, there are higher subsidy payments for renewables on FiT CfDs (and small scale FiTs). These subsidies are ultimately funded via consumers. The exception to this is the Intermittent World. This scenario has slightly more CCGT (and less OCGT) capacity in the high flex version; therefore, prices are slightly lower post 2023, and so more payments are made to renewables on FiT CfD.

Finally, some carbon emissions savings occur as there is less generation from gas peaking plants. This is equivalent to 1 million tonnes CO_2.

3.1.3 Impact on consumer bills

In order to understand the impact of the above savings on domestic consumer bills, we divided the annual savings by a "domestic user equivalent" number of customers. The "domestic user equivalent" was based on the annual demand (net of transmission losses) in each modelled year and the Typical Domestic Consumer Values (TDCVs), as provided by Ofgem.[7] We subsequently divided the annual savings by the corresponding "domestic user equivalent" to calculate the annual reduction in domestic consumer bills in each scenario.

We carried out this analysis separately for the two categories provided by Ofgem, single rate customers and multi rate customers, and assumed the medium level of consumption in both cases. Table 3 summarises the average reduction in domestic consumer bills across the modelled period for the two categories of consumers. It is worth noting that multi rate meter customers will enjoy greater annual savings in absolute terms, as their average consumption is higher. The savings are

[5] Savings are shown in black and increased costs are shown in red.

[6] The Electrified World was calculated using the Higher and Lower OCGT build versions. As such, it doesn't give a direct comparison of the value of I&C DSR, but is included for completeness sake

[7] https://www.ofgem.gov.uk/sites/default/files/docs/decisions/tdcv_decision_letter_final_2.pdf

on average £1 to £2 per year for domestic consumers. These savings do not include any benefits gained by the DNO in network reinforcement costs.

Table 3: Average impact on domestic consumer annual bills (£/year)

	Profile Class 1 (single rate meters)	Profile Class 2 (multi rate meters)
Green World	-1.25	-1.80
Intermittent World	-1.89	-2.71
Electrified World	-0.76	-1.09
Slow Growth	-0.70	-1.01

3.2 Savings at DNO level

Following the trials which were conducted as part of the UK Power Networks LCL project, UK Power Networks has estimated costs of future DSR procurement to be up to £30/MW/h for availability payments and approximately £200/MWh as utilisation payments to I&C customers. In this section, we examine the savings at the DNO level of procurement of DSR under a few different schemes. We examine the following three issues:

- Procurement of DSR in 5 to 6MW blocks compared to optimising the procurement of DSR on a network to the nearest MW;
- Variations in availability prices and any additional savings accrued to the end consumer; and
- The savings that can be made at a range of different network reinforcement costs.

We have made a number of base level assumptions for this analysis as outlined here:

- There are four DSR seasons; summer covers June to August, winter covers November to February, and DSR can be contracted for the intermediate seasons if required. This explicitly measures the cost of using DSR at different times of year;
- Contracts for availability cover 8 hours per day for five business days per week. If DSR may be required on weekends, some or all standby generation contracts may be extended to cover seven days per week;
- DSR can only be used as long as peak demand is at most 20% above summer firm capacity. Once this limit is exceeded, reinforcement must take place;
- A range of annuitised reinforcement costs, as provided by UK Power Networks, were tested. These values ranged from £50,000/MVA to £300,000/MVA (at £50,000/MVA increments, and assuming a 40-year depreciation at 3.5% discount rate);
- Reinforcement blocks per network type are as per the following:
  - 20 MW for superurban;
  - 15 MW for urban; and
  - 10 MW for suburban.

Our analysis shows that availability prices are the most important potential savings for the DNO as the £30/MW/h represents a significant cost. Figure 43 shows the annual costs forecast for Clapham Park Road substation, a suburban node (£/year basis) which is expected to exceed firm capacity in the near future. Our forecast uses the results of our DSR modelling based on generic suburban networks, using the demand profiles from Epping New Road. The analysis is based on a reinforcement cost of £150,000/MVA.

Our results from the previous chapter suggest that suburban networks are, in general, more likely to experience conflicts between the DNO and supplier dispatch of DSR than non-suburban networks. The business case shown here assumes that the DNO pays for exclusive use of the DSR; in a shared use arrangement the DNO may need to procure more DSR in case of conflicts, but may also be able to share the costs of doing so.

The black line shows a case when no DSR is procured and therefore reinforcement needs to occur. This line is priced at the annualised reinforcement cost, which is approximately £70,000/year.

The solid coloured lines show instances when DSR is procured in 5MW blocks at three different availability prices (£5, £15 and £30/MW/h) and dispatched in the 5MW block.

The coloured lines show DSR being procured in an economically optimal way; the capacity procured is better aligned with the demand above firm capacity on the network, as the DSR requirement is rounded up to the nearest MW. This represents a lower cost to the DNO and therefore the end consumer.

Figure 43: Annual costs for Clapham Park Road substation (Suburban node) with £150,000/MVA reinforcement cost

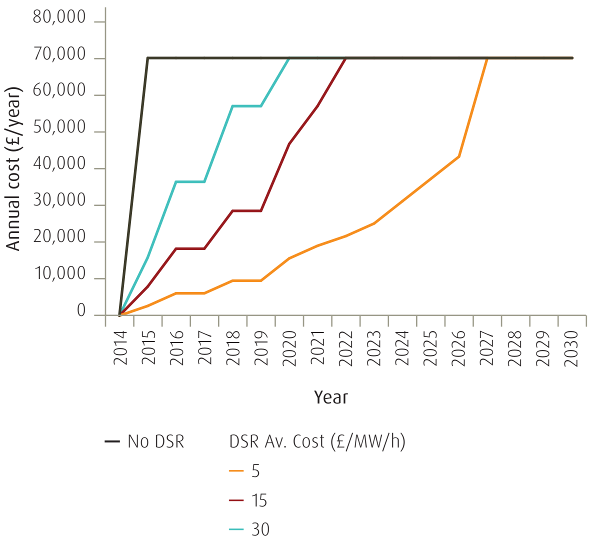
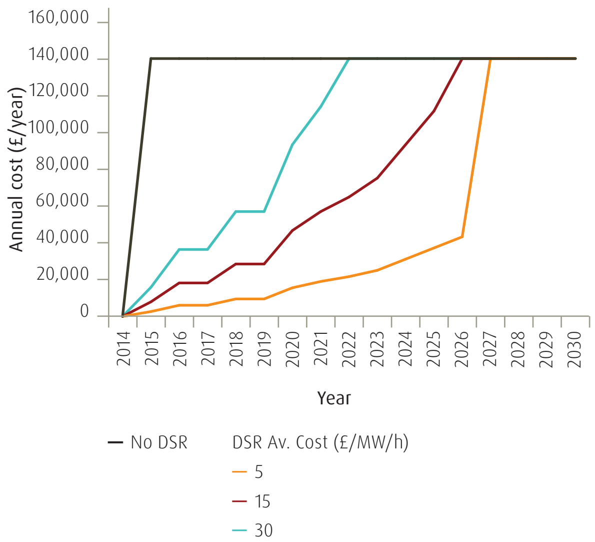


Figure 44: Annual costs for Clapham Park Road substation (Suburban node) with £300,000/MVA reinforcement cost



At the higher availability prices, it is possible that using DSR is a more expensive alternative to traditional network reinforcement, especially when DSR is dispatched in fixed blocks. However, at the most favourable availability price of £5/MW/h, optimising DSR results in much larger savings, regardless of the reinforcement cost. The relative importance of optimising DSR decreases in line with the availability price, but the savings remain significant in absolute terms.

A reduction in the availability price paid from £30 to £5/MW/h (using optimal dispatch of DSR) leads to deferring reinforcement for an 7 additional years. The level of the availability price paid by the DNO is therefore the key factor for reinforcement deferral and savings from a customer's perspective.

Two factors put a limit on the time for which substation reinforcement can be deferred. Firstly, the available DSR capacity at the substation and secondly, the requirement that DSR can only be used as long as peak demand doesn't exceed 20% of summer peak demand.

Figure 44 shows the same picture as in Figure 43 but with a reinforcement cost of £300,000/MVA.

Cumulative savings increase significantly as availability payments decrease, since higher annual savings are realised over a longer period. The cumulative savings from using DSR to defer traditional network reinforcement over the analysed period are shown in Figure 45.

Figure 45: Cumulative savings at Clapham Park Road NPV (£'000) for different DSR availability prices and network reinforcement costs

Table 4: Cumulative savings across different network types, NPV (£'000)

Reinforcement Cost (£/MVA)	Availability payment (£/MW/h)	Suburban	Winter Peak Urban	Summer Peak Urban	Superurban
50,000	5	83	99	141	295
	15	24	16	101	143
	30	7	0	77	0
100,000	5	272	346	347	617
	15	117	135	249	564
	30	47	33	203	286
150,000	5	493	587	611	939
	15	248	298	423	886
	30	132	145	374	638
200,000	5	711	829	841	1261
	15	420	540	622	1208
	30	235	271	499	1128
250,000	5	930	1070	1070	1583
	15	608	755	850	1530
	30	355	400	623	1450
300,000	5	1148	1311	1300	1905
	15	815	1037	1040	1852
	30	496	597	846	1772

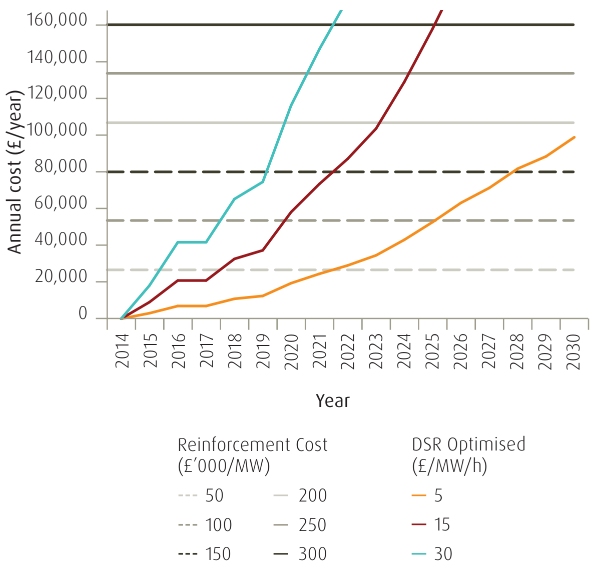
Table 4 shows that the largest savings can be made in more built up areas, where reinforcement would typically be more expensive and occur in larger blocks of capacity. The superurban network reinforcement was assumed to occur in 20MW blocks of capacity; since peak demand often only exceeds summer firm capacity by a small proportion of this 20MW, the benefits of using DSR are largest – in these cases, potentially around £1m, depending on the cost of reinforcement and the availability price that must be paid to procure the DSR.

Using DSR has a bigger benefit when the amount of DSR procured is small in proportion to the size of the next planned reinforcement. Nevertheless, for cases where the reinforcement of the substation would be very costly, the savings from using DSR could be greater than £500,000.

3.2.1 When should substations be reinforced?

The savings above are on the basis that demand does not exceed firm capacity by more than 120%. Figure 46 shows the annual cost based on various reinforcement costs without the 120% constraint rule.

Figure 46: Annual cost based on various reinforcement costs (Clapham Park Road)



The intersection point between the annual DSR procurement costs at different availability prices and the reinforcement line determine when DSR is no longer a viable option. For Clapham Park Road, maximum annual demand reaches 120% of the corresponding seasonal firm capacity in 2027. If the 120% rule were applied that would mean that reinforcement deferral through the use of DSR would not be possible, even though it may make sense in the case of a £5/MW/h availability price and reinforcement costs of £150,000 per MVA and above, as shown in Figure 46.

4

Summary of Conclusions and Recommendations

Our key findings

There is currently no commercial and market framework to optimise the value of DSR to various parties. However, our analysis has shown there are a number of potential conflicts and synergies in the use of DSR by various parties. In particular, this report shows that:

- There is strong correlation between the DSR requirements of suppliers and DNOs on winter-peaking networks, and hence significant scope for cooperation between parties;
- It is rare for supplier and DNO requirements to clash when using DSR to manage summer-peaking networks, although such conflicts will become more common if utilisation prices for DSR fall;
- Conflicts are much more common when information/dispatch is not shared between parties; and
- Effective use of DSR provides an opportunity for significant cost savings by all parties.

DSR is a no-regret decision for the system

Our analysis has shown that DSR is a no-regret decision from a system cost perspective. Table 5 below shows that even in the Slow Growth world where the penetration of renewable and electrification are the lowest, DSR can deliver significant benefits to the system as a whole.

Table 5: NPV savings for end consumer[8]

	Wholesale costs (£m)	Capacity payment costs (£m)	Renewable subsidy costs (£m)	Total (£m)
Green World	(-776)	(-669)	40	(-1304)
Intermittent World	(-453)	(-1080)	(-51)	(-1584)
Slow Growth	(-202)	(-861)	27	(-1036)

The greatest savings captured through the cost of DSR in the Slow Growth scenario is the reduction in capacity payment costs; DSR displaces thermal plants, e.g. gas turbines which would otherwise have been paid capacity payments. The system cost savings translate to £1 to £3 per year in terms of average impact on domestic consumer bills for all scenarios. These savings do not include any savings from reduced network reinforcement costs.

Most significant system savings occur in the Intermittent World

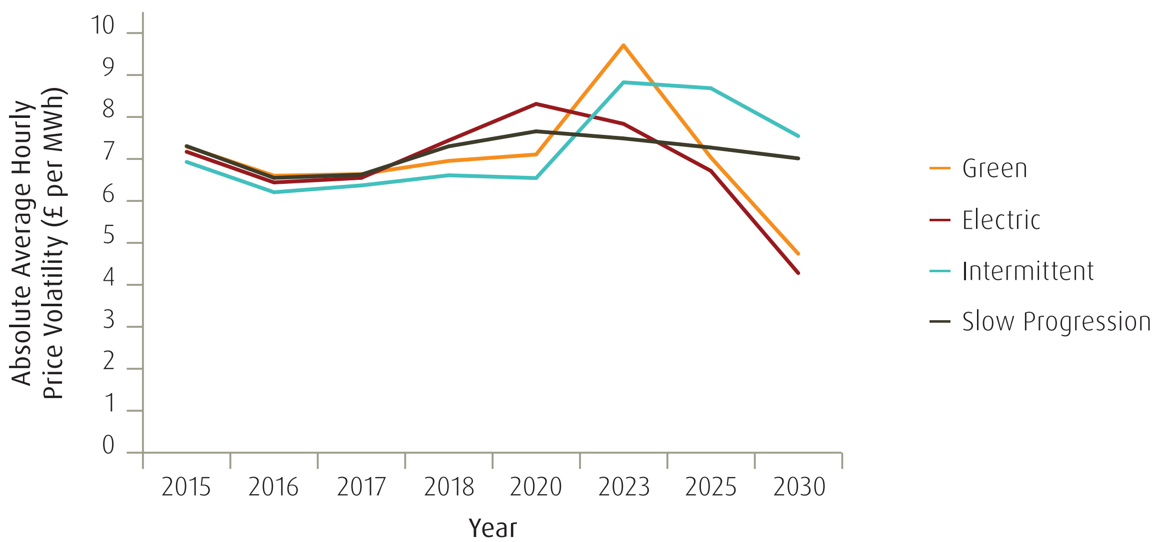
The most significant savings occur in the Intermittent World. The reduction in capacity payment costs is significant as more flexible capacity is displaced by the DSR in this scenario compared to the Green World. More flexible generation or demand is needed in the Intermittent World to tackle the variability and unpredictability of wind.

Rising penetration of renewable generation gives rise to negative prices from 2023 onwards. The ability of EVs to be charged and heat pumps to be used in periods of low demand net wind can help soak up excess generation and mitigate against negative prices.

In particular, the Green World and Electrified world feature stronger electrification, and this helps reduce price volatility. However, these benefits are only realised post-2020, once the mechanisms that enable flexible use of these technologies are put in place. Without the flexible use of EVs and heat pumps, electrification can lead to greater price volatility.

By contrast, the Intermittent World sees higher price volatility (as seen in Figure 47) and more negative prices because the strong deployment of renewables is not matched by a corresponding growth in sources of flexible demand.

Figure 47: Wholesale Price Volatility

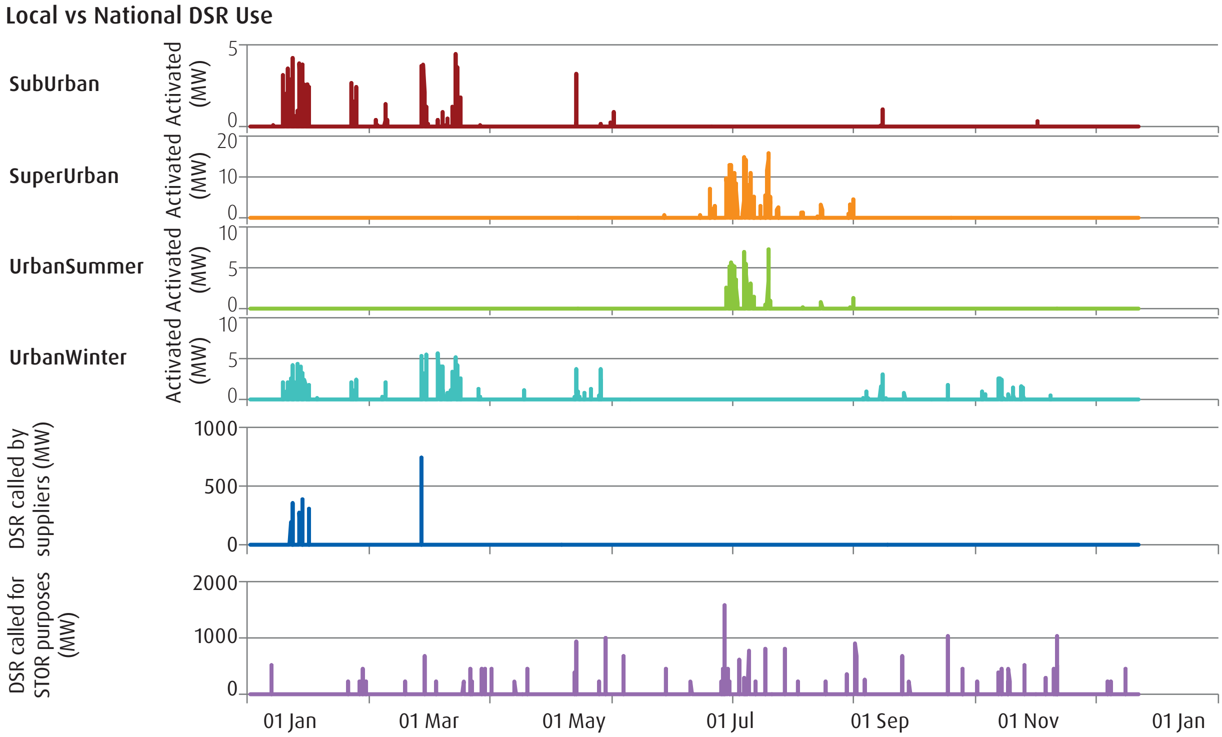


[8] Savings are shown in black and increased costs are shown in red.

Network impacts of supply-following DSR most likely to arise on winter peak nodes

Figure 48 summarises the use of DSR at the national and local level. While the summer peak nodes seem to only require DSR in the summer in 2023, the requirements for DSR on the winter peak nodes increases in frequency over time, with rising penetration of renewables, extending into the spring and summer months. DSR could therefore be required throughout the year on specific nodes. Our analysis shows that this is most likely to occur on winter peaking nodes.

Figure 48: Use of DSR locally versus nationally (2023, Electrified World)



Significantly, the usage patterns shown for DNOs are the DSR use that would occur if an outage were present on the network, such that DSR was required to reduce load to firm capacity. Under normal network operation, DSR typically need not be called provided that it will be available on demand in the event of a fault. In contrast, the usage shown for suppliers and the SO are the actual levels of DSR called.

Suppliers require DSR over the winter period but the SO reserve requirements need to be fulfilled all year round. This picture shows the potential impacts on network nodes of DSR being used by other market actors; the SO and supplier. The winter peak nodes are most impacted as they also require DSR for network management throughout the year.

The majority of local networks in GB are winter peaking, and the usage patterns shown imply that significant levels of conflicts will occur between suppliers and DNOs as both suppliers and DNOs begin contracting larger volumes of DSR. Our analysis has shown that the probability of synergies (in the use of DSR at national and DNO level) is significantly increased when dispatch of DSR is coordinated, while the likelihood of conflicts is significantly reduced.

The Shared Services Group currently investigating frameworks for sharing DSR is made up of DNOs and the SO; it is important to note that conflicts with suppliers will become more prevalent as suppliers increase their DSR holdings.

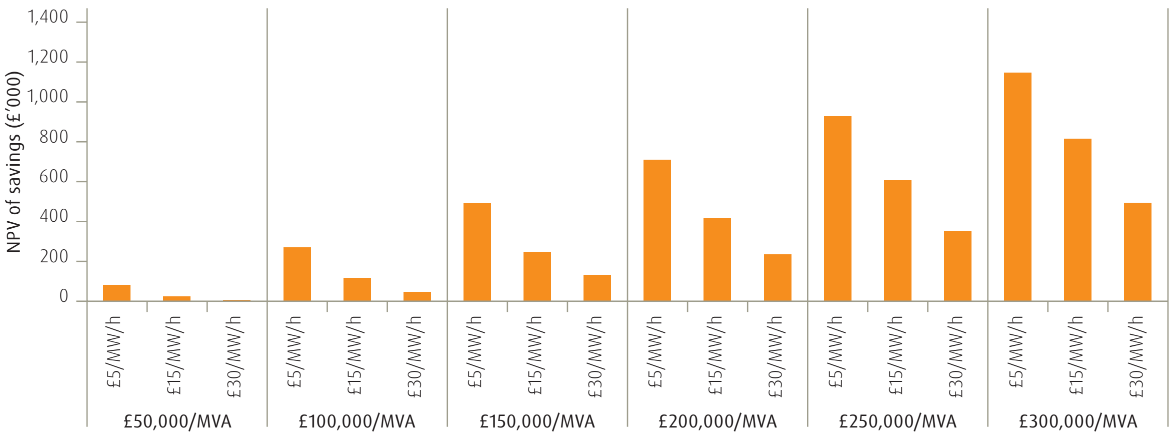
Finally, the chart shows the stark contrast between the volumes of DSR used at the network level (5 MW per scheme) compared to the volumes of DSR used at the national level (1.5 GW).

DSR is economically viable as an alternative to network reinforcement

The UK Power Networks RIIO-ED1 business plan uses £30/MW/h availability payments and £200/MWh utilisation payments as part of the contract with customers to provide DSR for network management purposes.

Our analysis has shown that cumulative savings increase significantly as availability payments decrease, since higher annual savings are realised over a longer period. An availability payment of £5/MW/h would significantly lengthen the period of reinforcement deferral compared to a £30/MW/h availability payment. The cumulative savings from using DSR to defer traditional network reinforcement using different availability payments are shown in Figure 49.

Figure 49: Cumulative savings at Clapham Park Road NPV (£'000) for different DSR availability prices and network reinforcement costs



The savings above are on the basis that DNOs do not find it necessary to over-procure DSR to hedge against the risk that conflicts with the SO and suppliers will significantly reduce the DSR available when required.

The savings shown also assume that demand does not exceed firm capacity by more than 20% of the firm capacity. We have also examined potential savings based on various reinforcement costs without the 20% constraint rule.

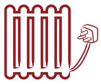
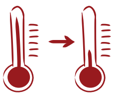
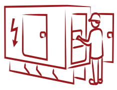
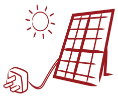
Our analysis has shown that as technical solutions become more reliable, confidence in the use of DSR by the DNO increases and commercial arrangements mature, there is significant potential to exploit DSR for network reinforcement deferral above the 120% limit (e.g. 150%), assuming that there is enough available DSR in the vicinity of the substation.

The regulatory framework therefore needs to allow DNOs to call on DSR as part of its toolbox in order to realise the benefits which have been shown in this study.

Glossary

ADR	Automated Demand Response	KWH	Kilowatt-hour
BM	Balancing Mechanism	LAR	Load at Risk???
CCGT	Closed Cycle Gas Turbine	LCL	Low Carbon London
CCS	Carbon Capture and Storage	LCNF	Low Carbon Networks Fund
CfD	Contract for Difference	LCPD	Large Combustion Plant Directive
CHP	Combined Heat & Power	LPN	London Power Network
CPS	Carbon Price Support	MW	Megawatt
DECC	Department of Energy & Climate Change	MWH	Megawatt-hour
DNO	Distribution Network Operator	NPV	Net Present Value
DSBR	Demand Side Balancing Reserve	NREAP	National Renewable Energy Action Plan
DSR	Demand Side Response	OCGT	Open Cycle Gas Turbine
dToU	dynamic Time of Use	Ofgem	Office of Gas and Electricity Markets
EMR	Electricity Market Reform	PV	Photovoltaic (Solar Panels)
ENA	Energy Networks Association	RIIO-ED1	Electricity Distribution price control (Revenue = Incentives + Innovation + Output)
EV	Electric Vehicle	ROC	Renewables Obligation Certificate
FALCON	Flexible Approaches for Low Carbon Optimised Networks	SBR	Supplemental Balancing Reserve
FIT	Feed in Tariff	SDRC	Successful Delivery Reward Criteria

GT	Gas Turbines	SO	System Operator
GW	Gigawatt	SSEPD	Scottish & Southern Energy Power Distribution
HP	Heat Pump	STOR	Short Term Operating Reserve
I&C	Industrial and Commercial	TDCV	Typical Domestic Consumer Values
IED	Industrial Emissions Directive	ToU	Time of Use
IHD	In-Home Display	TSO	Transmission System Operator
KW	Kilowatt	WPD	Western Power Distribution

	Instrumenting a Smart Grid		Electrification of heat
	ANM/network operation		Electrification of transport
	Dynamic Time of Use tariff		Energy efficiency
	Demand Side Response – demand		Demand Side Response – generation
	Smart meter		Network planning
	Distributed Generation		

Project Overview

Low Carbon London, UK Power Networks' pioneering learning programme funded by Ofgem's Low Carbon Networks Fund, has used London as a test bed to develop a smarter electricity network that can manage the demands of a low carbon economy and deliver reliable, sustainable electricity to businesses, residents and communities.

The trials undertaken as part of LCL comprise a set of separate but inter-related activities, approaches and experiments. They have explored how best to deliver and manage a sustainable, cost-effective electricity network as we move towards a low carbon future. The project established a learning laboratory, based at Imperial College London, to analyse the data from the trials which has informed a comprehensive portfolio of learning reports that integrate LCL's findings.

The structure of these learning reports is shown below:

Summary	SR	DNO Guide to Future Smart Management of Distribution Networks
Distributed Generation and Demand Side Response	A1	Residential Demand Side Response for outage management and as an alternative to network reinforcement
	A2	Residential consumer attitudes to time varying pricing
	A3	Residential consumer responsiveness to time varying pricing
	A4	Industrial and Commercial Demand Side Response for outage management and as an alternative to network reinforcement
	A5	Conflicts and synergies of Demand Side Response
	A6	Network impacts of supply-following Demand Side Response report
	A7	Distributed Generation and Demand Side Response services for smart Distribution Networks
	A8	Distributed Generation addressing security of supply and network reinforcement requirements
	A9	Facilitating Distributed Generation connections
	A10	Smart appliances for residential demand response
Electrification of Heat and Transport	B1	Impact and opportunities for wide-scale Electric Vehicle deployment
	B2	Impact of Electric Vehicles and Heat Pump loads on network demand profiles
	B3	Impact of Low Voltage – connected low carbon technologies on Power Quality
	B4	Impact of Low Voltage – connected low carbon technologies on network utilisation
	B5	Opportunities for smart optimisation of new heat and transport loads
Network Planning and Operation	C1	Use of smart meter information for network planning and operation
	C2	Impact of energy efficient appliances on network utilisation
	C3	Network impacts of energy efficiency at scale
	C4	Network state estimation and optimal sensor placement
	C5	Accessibility and validity of smart meter data
Future Distribution System Operator	D1	Development of new network design and operation practices
	D2	DNO Tools and Systems Learning
	D3	Design and real-time control of smart distribution networks
	D4	Resilience performance of smart distribution networks
	D5	Novel commercial arrangements for smart distribution networks
	D6	Carbon impact of smart distribution networks

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