Cross-party impacts of DSR actions

A REPORT PREPARED FOR ELEXON

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Executive Summary

ELEXON commissioned Frontier Economics to help to **improve its understanding of cross-party impacts of Demand Side Response (DSR)** actions on different parties. This is so it will be better informed to consider any amendments to the BSC that could help meet ELEXON's objectives:

- BSC objective (c): promoting effective competition in the generation and supply of electricity, and (so far as consistent therewith) promoting such competition in the sale and purchase of electricity; and
- BSC objective (d): promoting efficiency in the implementation and administration of the balancing and settlement arrangements.

We focus on two main detriments.

- **Information problems.** DSR actions by one party may harm others in the supply chain if the actions are unsighted.
- **Inefficient use of DSR.** Because DSR has the potential to be of value (or detriment) to different parties at different times, there may be barriers to ensuring the efficient system-wide use of DSR.

There are large benefits to achieving efficient use of DSR. These start to become significant in the mid to late 2020s. It is also around this time that use of DSR by different parties may start to conflict.

- **Suppliers are likely to get greatest value** from, and make most use of, flexible DSR resource. Efficiency gains can be made if they trade this resource between themselves.
- **DNO use of DSR can act as a substitute for network reinforcement, but is only likely to be called relatively infrequently** for tackling network faults. This means that:
  - information problems created by the invisibility of DSR actions by DNOs are not large; and
  - there is spare capacity from DNO DSR that can be shared with other parties to increase the efficiency in which it is used.
- **A central market platform may lead to benefits** in a world with high DSR potential and limited means of efficiently allocating DSR use absent a market.
- **Tariff structures have important implications for sharing and resulting DSR use.** If customers favour availability payments (over utilisation

payments) then the benefits from sharing DSR are likely to be greater. This is because sharing availability payments reduces the cost to each party (and therefore their expected use of DSR) even when those parties expect to call on the contracts at different times.

This leads to a set of implications for ELEXON and industry participants.

- While unseen **DSR actions by others** can harm suppliers by increasing exposure to imbalance risk, under most reasonable assumptions these **are unlikely to be material in the period to 2030**. This is both because the impact on supplier imbalance costs can be positive as well as negative (and so a low net impact is possible) and because DNOs activate DSR relatively infrequently. This result should be stress tested with WS6, but if this holds then **there is no strong case for industry action to mitigate such costs.** But if it was required, we have proposed a method by which compensation could be applied.

- There are modest gains to be made from suppliers trading DSR. This can already happen both within current BSC arrangements and on existing exchanges. However, to the extent that smaller suppliers face barriers to accessing these markets, particularly given collateral requirements, these will remain even with increased trading of DSR.

- In a world of **bilateral contracting**, potentially with side arrangements to enable sharing, there may be a **series of roles required by parties to make the arrangements operational**. For example:
  - information will need to be held on contractual positions and when DSR actions are called;
  - actions will need to be authenticated to enable payment; and
  - transactions will need to be settled.

- **We show that a central market platform may lead to large benefits in a world with high DSR potential.** However, the value of this platform hinges both on there being a large pool of flexible DSR available and a failure to allocate this efficiently through a bilateral contracting model. There are still many uncertainties and challenges associated with any such platform. But there is potential that makes it worth further investigation.

1 Introduction

ELEXON wants to improve understanding of cross-party impacts of Demand Side Response (DSR) actions. Although there has been qualitative discussion of expected impacts, there has been little quantification of their scale and timeframe[1]. ELEXON commissioned Frontier Economics to address this gap. In doing so ELEXON will be better informed to consider any amendments to the BSC that could help meet its objectives.

These issues are current. The work of Ofgem's Smarter Market's Directorate and Workstream 6 (WS6) of the Smart Grid Forum are also focussing on them. Indeed, WS6 has already produced a set of options for engagement with domestic customers, industrial and commercial customers, and distributed generation. These set out in detail the roles and responsibilities of the Distribution Network Operators (DNOs), Transmission Operator (TO), suppliers and System Operator (SO). The design of the options has raised questions about the visibility of these arrangements to market participants. As a result their next phase of work will investigate the cross-party impacts of the options they have proposed. We hope our report will help to inform this work.

Our approach to this project has been first to quantify the scale of the potential impacts. This is based on the expected volumes and growth of DSR and our understanding of how it may be used by different parties in future. We then looked at a range of interventions that could be employed to address detriments that may arise in the absence of change to current market arrangements.

This work has benefitted greatly from a number of stakeholder discussions we undertook as part of our work. We have also used the existing literature and international experience to inform the analysis we have undertaken.

Our report is structured as follows.

- **Section 2** describes our understanding of the problem and its implications for different market participants.
- **Section 3** sets out the options for interventions and a summary of the potential BSC amendments required to support them.
- **Section 4** quantifies the potential scale of the cross-party impacts associated with increases in the expected volume of DSR, and evaluates the impact of the options.

1 Around one third of all respondents to Ofgem's recent consultation on DSR noted that a greater understanding was required of the system, operational and financial cross-party impacts of DSR.

- **Section 5** sets out some industry implications of the analysis.

2 Cross-party DSR impacts

One reason why there has been little objective quantification of cross-party impacts of DSR is that it involves a complex set of interactions. Market participants will have varied uses of DSR: any one party's use of a customer's DSR can impact other parties in the supply chain in a positive, negative or neutral way. Further, this can change over time depending on system conditions.

In this section we provide a framework for understanding these cross-party effects. We then use this to look at each of the main parties' use of DSR and the impact this will have on other parties in the supply chain.

2.1 Understanding the problem

To begin to understand how to tackle this problem, it is helpful to distinguish between cross-party impacts of DSR that could largely be solved by information remedies (in particular, better sharing of information between parties), and those that may require contractual or market solutions to ensure that DSR is efficiently employed.

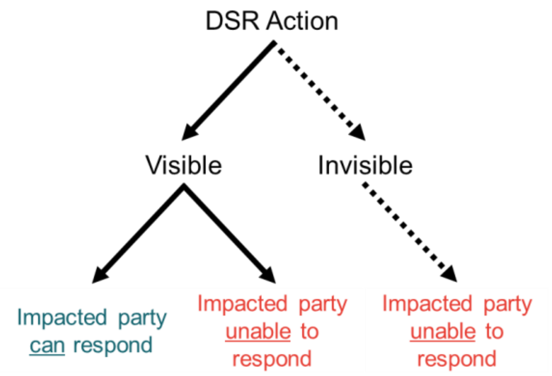
- **Information problems.** DSR actions by one party may harm others in the supply chain if the actions are unsighted.
- **Inefficient use of DSR.** Because DSR has the potential to be of value (or detriment) to different parties at different times, there may be barriers to ensuring the efficient system-wide use of DSR.

We discuss each in turn.

2.1.1 Information problems

DSR that is unforeseen has greater potential to cause problems. We therefore need to distinguish between those actions that are visible or invisible to other participants, as illustrated in **Figure 1**.

Figure 1. Categorising the impact of DSR actions on other parties



Source: Frontier Economics

Actions that are *visible* provide an opportunity for impacted parties to respond. However, there may still be costs associated with responding, particularly the closer the notification comes to gate closure. For example, there may not be sufficient market liquidity for smaller suppliers to trade out imbalance positions close to gate closure.

If the action is *invisible* then the impacted party has no knowledge that the action has taken place and therefore limited ability to respond[2]. An example of an invisible action could be a DNO reducing the demand from the customers of a supplier in response to a fault after gate closure.

Whether these information problems have a positive or negative impact on a third party depends on system conditions at the time of the DSR action.

2.1.2 Inefficient use of DSR

Given the interconnected nature of the electricity market, a DSR action by any one party may impact on the costs of other parties in a positive, negative or neutral way. This can result in the inefficient use of DSR. We consider three examples of this.

- **Positive spillovers.** Where conditions (e.g. national and local peaks) are aligned, DSR called by one party may have positive impacts on other parties. If there is no way of aggregating the value of the DSR from multiple parties,

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2 Invisibility doesn't always imply an inability to act. For example, since the SO monitors system frequency, it would automatically respond to invisible DSR actions on the system if necessary.

the level of DSR will be lower than is optimal and the customers providing the DSR would be paid less for it than its value[3].

- **Negative spillovers.** Where conditions are not aligned, actions by one party may impose costs on other parties. If these are not taken into account by the party calling the DSR action, the costs on the system will be higher than they need to be.

- **Contractual inefficiencies.** Traditionally, DSR contracts tend to be exclusive and struck for a period of time (upwards of a few months to a number of years). The expectation may be that a call for DSR on each contract may be an infrequent occurrence. This risks tying up a resource that could be used by other parties. It also prevents parties from sharing the fixed costs of setting up DSR contracts.[4]

2.2 Future utilisation of DSR

In this section we begin by distinguishing between different types of DSR contract. We then outline the value that different market participants can be expected to derive from DSR, and the specific impacts on other parties that may result from their use of it. In carrying out this work we have reviewed the options currently being discussed in WS6 for DNO DSR use to assess the potential cross-party impacts. This analysis is set out in Annexe 2 and is consistent with the conclusions in this section.

2.2.1 Contract types

The DSR contract type is an important driver of the degree to which DSR is visible or invisible. It also impacts on the use that can be made of the DSR and the methods by which it could potentially be shared or traded. Consequently it has an important influence on cross-party impacts. In this report we distinguish between static and dynamic contracts.

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3 Whether the full value from DSR should go to the customers that are providing it, or it should be shared with all customers (through lower prices associated with cheaper DSR) is a really important question. Unfortunately this issue is outside the scope of this paper.

4 The Capacity Market (CM) will create the potential for new distortions in the allocation of DSR. This is because as currently set out by DECC, the rules allow DSR to hold a capacity contract and additional DSR contracts with other market participants such as a DNO. However, it is only for a STOR contract where their delivery under the balancing services is taken into account in their delivery of their capacity obligation e.g. if their capacity is being kept off the grid by STOR and would otherwise appear under the CM as non-delivery. This may distort the playing field in favour of DSR procured by the SO over DNOs.

- **Static.** The most common static contract is a Static Time of Use (STOU) tariff, where prices are fixed in advance. These aim systematically to adjust customers' demand profiles. DSR value can be shared in the sense that all parties can provide STOU price signals that the supplier could reflect in its tariffs. Given that they are fixed in advance, and customer behaviour in response to these signals becomes increasingly predictable, they produce a demand response that is visible to all parties. The usefulness of static tariffs depends on the extent to which daily price profiles are stable and known in advance. To date, daily prices have followed a stable and predictable pattern based on patterns in demand. However, increased inflexible renewables generation may act to disrupt these patterns in future. Further, they only work to allow value to be shared if the peak pricing periods of different parties are compatible.

- **Dynamic.** A dynamic contract enables behaviour change much closer to real-time and therefore is suitable for the provision of flexibility. These contracts are less visible and harder to coordinate, giving participants less time to respond and increasing the likelihood of adverse impacts.

  - **A ToU tariff** allows for prices to be altered at relatively short notice. They can include real-time pricing and critical peak pricing. The level of DSR achieved depends on the customer's response to the price signal provided. The visibility of this contract is dependent on the minimum advance notice period for adjusting prices and the degree of certainty in the response.

  - **Direct load control** is a type of TOU tariff that allows the purchaser of DSR to control the load directly, for example by turning off equipment remotely. The level of response is therefore more predictable (particularly if there is no ability to override the signal). Visibility depends on the notice period prior to the intervention. Contracts may be based on an availability and utilisation payment, with different weights placed on each depending on customer preference.

2.2.2 DSR response

When quantifying the impact of DSR actions, an assumption has to be made about the level of "kick-back" following a DSR call. At one extreme the demand may never come back, for example because the customer managed the call to provide DSR by using back-up generation. However, for a number of loads such as EV charging, the expectation is that the demand will return after the end of the length of the DSR call.

This has implications for the analysis as it represents a further level of uncertainty that may be generated for parties from a DSR action. To the extent that DSR shifts demand in time, parties will face two changes in demand: when the action is first called, and a second time at the end of the call. Certain parties may have an opportunity to respond to this kick-back if they are able to identify it in time.

2.2.3 Future use of DSR

We now outline the value that different market participants can be expected to derive from DSR[5], and the specific problems that may result from their use of DSR. More detail is provided in Annexe 1.

DSR by Suppliers

Suppliers can derive value from DSR in two main ways. They can:

- shift their consumers' demand to coincide with lower wholesale prices, thereby minimising their wholesale electricity costs; and
- use DSR to stay in balance, thereby minimising any imbalance charges.

The usefulness of STOU tariffs to suppliers may be expected to diminish over time as the relationship between wholesale prices and time of day destabilises. Further, the static nature of the tariffs would prevent their use in balancing roles, where demand needs to be adjusted over relatively short periods. Dynamic ToU tariffs and direct load control are more appropriate for lowering wholesale costs when prices no longer follow a stable pattern or to limit imbalance charges.

A summary of how supplier-led DSR will impact on other parties is set out in **Table 1**.

[5] The descriptions here are more generalised than the options set out by WS6. However they can easily be mapped across to this discussion.

Table 1. Impact of supplier DSR on other parties

Affected party	Information problems	Inefficient use
SO	**Limited impact.** DSR is pre-gate closure, so the SO should have warning of its impacts and can factor this into its forecasts for balancing purposes.	**Potential impact**. Exclusive contracts may prevent efficient sharing.
DNO/TO	**Potential impact**. Network operators need to understand the impact of supplier DSR on long-term investment planning.	**Potential impact**. Where national and local peaks coincide, actions to reduce demand by suppliers will reduce costs for the DNO. However, there is also potential for conflict with the supplier increasing demand locally at a time when the DNO is trying to reduce demand. Exclusive contracts may prevent efficient sharing.
Other suppliers	**Potential impact**. There is the potential for a supplier (acting as an aggregator) to impact on the imbalance volume of other suppliers.	**Potential impact**. Exclusive contracts may prevent efficient sharing.

Source: Frontier Economics

DSR by DNOs[6]

DNOs can derive value from DSR through investment deferral or avoidance. Traditionally, DNOs have met their system obligations by ensuring that network capacity is sufficient to handle the peak flows and, where appropriate, sufficient overhead exists to provide resilience to faults. However, DSR enables DNOs to:

- manage faults through the reduction of local demand, thereby enabling reduced 'headroom' on the local networks;
- curtail output from distributed generation to manage local voltage issues; and

6 We include consideration of TO use of DSR, under this heading. However, modelling of the TO use of DSR was out of the scope of our work.

- potentially actively manage the net flows across their network to balance the more flexible load and intermittent generation.

In each case, the use of DSR can act as a substitute for network reinforcement.

STOU tariffs are valuable to a DNO when they wish to induce a systematic shift in demand to reduce a predictable local demand peak, and where suppliers reflect them in their tariffs. As such, they cannot be used to respond to unexpected faults.

Dynamic ToU tariffs[7] and direct load control would allow a DNO[8] to influence demand more quickly, for example in response to a peak in distributed generation. At the limit however, where a DNO is looking for a near immediate response following a fault, only direct load control without a customer override may be a viable substitute for network reinforcement.

DSR activated by DNOs has the potential to have positive or negative impacts on the SO and suppliers, as summarised in **Table 2**.

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7 With respect to investment avoidance, Triad charges are already a form of dynamic ToU charging.

8 In theory, DSR could in future also be used to substitute for transmission network reinforcement in response to fault conditions. This could look very similar to the type of DSR contracts that DNOs are considering.

Table 2. Impact of DNO DSR on other parties

Affected party	Information problems	Inefficient use
SO	**Limited impact**. SO can react through monitoring of system frequency, but forewarning of DNO DSR may reduce SO's costs.	**Potential impact.** DNO ignores the impact of its DSR on the SO. Where national and local peaks coincide, actions to reduce demand by DNOs will reduce costs for the SO. However, there is also potential for conflict with the DNO increasing demand locally at a time when the SO is trying to reduce overall demand. Exclusive contracts may prevent efficient sharing.
Suppliers	**Potential impact**. Suppliers' forecasted demand may be wrong if DNO DSR is invisible. The impact on a supplier of having their consumption adjusted is ambiguous and in part dependent on the cash-out regime in place (see text below).	**Potential impact**. DNOs do not consider the impact on suppliers' imbalance and wholesale costs. Exclusive contracts may prevent efficient sharing.

Source: Frontier Economics

Annexe 1 contains a mapping of the potential impacts on a supplier's cost of imbalance from an unseen DNO DSR action. Based on the current dual pricing approach to calculating imbalance prices:

- the impact on suppliers is difficult to predict ex ante;
- the supplier will gain when the DNO action moves both the supplier and the system back into balance;
- when the DNO action conflicts with the system imbalance the supplier stands to lose out; and
- the worst situation for a supplier is when the DNO action moves them further out of balance in the direction of the overall system imbalance.

If Ofgem implements a single price calculation, as expected through their Significant Code Review, the picture looks different. In this scenario the supplier stands to benefit if the change in demand by the DNO is helping a system imbalance i.e. the DNO is reducing demand when the system is short overall.

This effect occurs because the supplier either has a reduced exposure to the penal imbalance price when they are already out of balance with the system or increased exposure to benefit from the imbalance price when they are out of balance against the system.

System Operator

The SO can use DSR to balance the system. This has traditionally been dominated by generation through mechanisms like the Short Term Operating Reserve (STOR). However, DSR is already used as a substitute for flexible generation in this role and could play a larger part in future as more DSR becomes available. Short-term system balancing will also have stringent requirements on the firmness and speed of response and will therefore be limited to direct load control without override.

The impact of DSR activated by the SO is shown in **Table 3**.

Table 3. Impact of SO DSR on other parties

Affected party	Information problems	Inefficient use
DNO/TO	**Potential impact.** If local peaks are increased unpredictably due to SO balancing actions then this can lead to operational and financial impacts for the DNO.	**Potential impact.** SO will ignore the impact of DSR on DNOs. Where national and local peaks coincide, actions to reduce demand by SO will reduce costs for the DNOs. However, there is also potential for conflict with the SO increasing demand locally at a time when the DNO is trying to reduce overall demand. Exclusive contracts may prevent efficient sharing.
Suppliers	**Potential impact.** SO actions can affect suppliers' imbalance charges[9]. Unlike the other costs considered here, these charges do not reflect a genuine system cost and should not influence SO behaviour.	**Potential impact**. Exclusive contracts may prevent efficient sharing.

Source: Frontier Economics

Annexe 1 contains a mapping of the potential impacts on a supplier's cost of imbalance from an unseen SO DSR action. The impacts are the same as those summarised for DSR by the DNO. However, if we assume that the SO always uses DSR to push the system towards balance, then under the current cash-out arrangements, the supplier will not be made worse off. This is because they will be made better-off if facing the main price, or indifferent if their exposure is increased to the non-penal reverse price. For system balancing actions there is the potential for DSR to be used against the overall system imbalance leading to potential detriment.

9 Currently there is not a system in place to identify the impact on suppliers of the dynamic DSR actions by the SO post-gate closure. This is in contrast to the case of a generator, where its contracted position is adjusted to account for its actions in the Balancing Market or in the provision of other ancillary services. This neutralises the impact of the SO balancing on their imbalance volume. In the case of demand, the SO does not have full visibility of the supplier relationship behind each unit of DSR. Therefore SO actions can lead to changes in supplier imbalances.

3 Options for intervention

Having set out some of the challenges that arise from cross-party use of DSR, we now look at some of the options that could be used to address them. These options then form part of our quantification, to understand both the scale of the problem and the likely effectiveness of any solutions.

Our options fall into two broad groups.

- **Market models.** We look at a series of options to enable trading or sharing of DSR. These are primarily aimed at increasing efficiency of use of DSR, although they may also provide increased visibility of the DSR action.

- **BSC amendments.** We then consider changes that could be made to the BSC to enable these market models, or to more generally facilitate efficient use of DSR.

We discuss each of these in turn.

3.1 Market models

As part of our work, we have looked at three basic types of market model:

- supplier to supplier trading;
- DNO and SO sharing; and
- central market platform.

These were chosen to span a broad spectrum of options, given that this work is aimed at gaining an overview of the drivers of value rather than looking at detailed design of particular models. They were discussed with a range of stakeholders and refined in the light of these discussions. A summary of the models, and the detriments that they aim to address, is presented in **Table 4**.

Table 4. Summary of options to be evaluated

Option	Description
1 Supplier to supplier trading	Supplier to Supplier DSR trading to increase the efficiency of use for supplier DSR.
2 DNO-SO sharing	DNO and TSO DSR is shared, and DNO and TSO compensate one another for any costs they impose on each other.
3 Complete market platform	All DSR resources are pooled, and parties can pay DSR providers not to dispatch.

Source: Frontier Economics

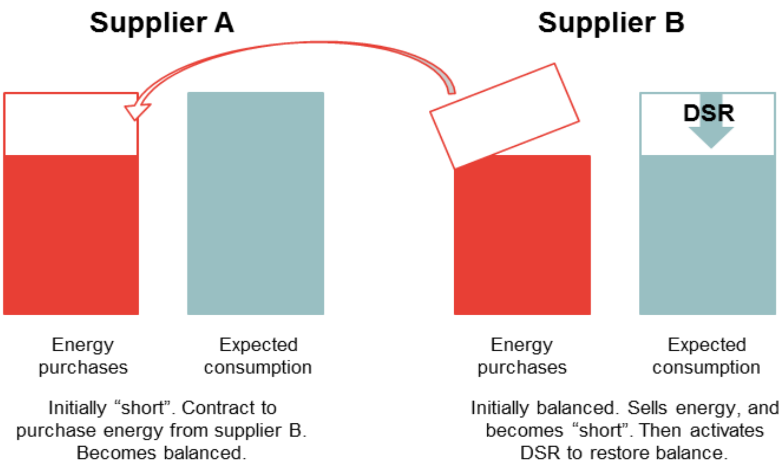
3.1.1 Supplier to supplier trading

Supplier costs (both wholesale and balancing) could be reduced if suppliers could not only use the DSR potential of their own customers, but also trade pre-gate closure to access the DSR potential of the customers of other suppliers.

Supplier DSR for the use by another supplier can be facilitated by existing arrangements in the market and the BSC. Where a supplier has purchased less energy than it expects its customers to consume (or where a generator has sold more energy than it expects to generate) it will typically seek to purchase energy from another trading party. DSR could be used to satisfy this requirement if it is price competitive with generation. In the context of an exchange, trading parties may not be aware whether the 'energy' they are purchasing is additional generation or demand reduction.

Typically under the current market arrangements, suppliers face an incentive to be 'long' i.e. to contract more generation than they typically need. They also have a range of business models which give them different exposures to demand risk, and on different timescales. It is likely, therefore, that suppliers will need to be refining their imbalance positions close to real-time.

Figure 2. Supplier to supplier DSR



Source: Frontier Economics

Figure 2 illustrates a situation where:

- Supplier A has a shortfall and is seeking to purchase energy; and
- Supplier B is perfectly balanced but has customers who can provide DSR.

Suppliers A and B will agree a trade for the required volume of 'energy' and notify this to the Energy Contract Volume Aggregation Agent (ECVAA). At this stage Supplier A would be perfectly balanced and Supplier B would have the shortfall. Supplier B would also instruct its customers to reduce consumption via DSR. The outturn consumption for Supplier B would therefore reduce from the expected level by the extent of the DSR reduction, balancing that Supplier's position.

A number of stakeholders we spoke to noted that there is also the potential for suppliers to simply swap imbalance volumes ahead of gate closure. In this case, no DSR has actually taken place. Consider a scenario where:

- Supplier A who has a shortfall and is seeking to purchase energy; and
- Supplier B who is long and is looking to sell energy.

Supplier A and supplier B agree to trade for the required volume of power and notify this to the ECVAA. Both parties are bought into balance with no physical DSR or generation being traded.

Smaller suppliers

Smaller suppliers have historically found it difficult to trade close to gate closure to 'fine-tune' their position given a lack of availability of appropriately sized volumes. Alongside Ofgem's recent interventions to improve liquidity, DSR trading between suppliers may help as it is an additional source of flexibility that is available close to gate closure. However, for this to benefit smaller suppliers they need to have a route to market. If they do this via an exchange they will still face the costs associated with setting up a trading desk and credit and collateral requirements to trade on the exchanges.

Having considered the potential collateral requirements for DSR trades on an exchange platform there is no reason to think they will be any less of a barrier to trade than they are currently. Collateral on an exchange is different depending on whether a party is a buyer or a seller, and is broadly based on the following risks.

- For a *seller* on a platform – in the event of default by the seller the exchange is exposed to the difference between the traded price and the current wholesale price. This is a market-based risk.

- For a *buyer* on a platform – in the event of default by the buyer the exchange is exposed to the entire contract value. This is a credit risk.

In the case of DSR, trading parties are still buying and selling 'energy', but it is in the form of 'demand reduction' as opposed to generation. There are potential differences in the delivery risk of these different forms of 'energy', however the market and credit risks to the exchange are fundamentally the same. As a result there are unlikely to be any differences in collateral requirements.

For smaller suppliers to benefit from the DSR there may be merit in considering alternative market models. One such model suggested through the stakeholder discussions was to create a 'club' of small suppliers for balancing purposes. Each party could pay a membership fee to the 'club' in return for their imbalance position to be netted off against other members.

This kind of model is possible under the current BSC arrangements. For example through a Meter Volume Reallocation Notification (MVRN) one supplier can transfer their consumption account to the consumption account of another supplier, effectively pooling the imbalance exposure. However, if suppliers use this mechanism a potentially complex system of allocating and settling imbalances would be required: in effect a 'mini-BSC' would be needed.

3.1.2 DNO-SO sharing

There is the potential for efficiency gains from the "sharing" of DSR resources between the SO and the DNO. This type of model has been considered by National Grid and the DNOs through the ENA DSR Shared Services Group[10].

The aim of this model would be to enable the SO to contract for its balancing services and the DNO to put contracts in place in order to defer investment. This could:

- improve allocation of DSR between the SO and the DNO;
- reduce potential conflict between the SO and DNO; and,
- "pool" value to reward the customer for the full value of its DSR to the SO and DNO and to allow the cost to be shared between them, potentially increasing their use of DSR as it becomes a more cost-effective option for each.

A model of this type could take different forms.

- **DNO-led.** In this model the DNO procures DSR contracts to defer network investment. This then creates a pool of resource from which the DNO can provide a guaranteed service to the SO (e.g. in the form of a STOR contract). The proportion of its DSR contracts that it chooses to sell on in this way will depend on its expected usage and the risk it wishes to take on in respect of the guarantee it is providing. The DNO will decide on a periodic basis (e.g. daily) which DSR it may have need to call, and therefore which it would provide to the SO in the event of a call.

- **SO-led.** A variant of the model allows the SO to contract for its balancing services, but makes these available to a DNO when its valuation of the resource is higher than the SO. For example, a DNO would be able to take control of a DSR resource if it its value is sufficiently high and it has identified its need by a specified time (e.g. a day ahead). The SO would in turn utilise alternative resources if it still needed to call STOR at that time.

- **Aggregator-led.** An alternative is for aggregators to pool resources and make them available to both the SO and the DNOs. The sharing is internalised by the aggregator, prioritising the SO or DNO for a particular piece of DSR depending on who has the highest valuation of a particular resource at a given time. This would again depend on contracting sufficient resource to be able to guarantee the level of availability purchased by the SO

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10 Although we have had helpful discussions with National Grid and the DNOs about this work, we have not had access to the working papers or report.

and DNOs. In theory, this will lead to a very similar outcome to the DNO-led model as long as the aggregator is aware of the points on the DNO network where the DNO is expected to have use for DSR. The European research project ADDRESS is considering possible ways to make an aggregator model work in this context.

3.1.3 Central market platform

The most significant intervention we look at, and potentially the most expensive to set up, is a central market platform. This combines all the potential actors with interests in selling or purchasing DSR into one market place. The options already presented can be viewed as building blocks of this market. The platform brings together the wholesale market and the ancillary services market.

- Supplier to supplier DSR trading is about trying to improve efficiency in the wholesale market.

- DNO-SO "sharing" is predominantly about trying to improve the efficiency in the ancillary services market.

The case for creating this platform over the separate interventions identified rests on the additional efficiency benefits that can be derived from the "sharing" of DSR resources between suppliers and the SO and DNO. Further, a nationally recognised marketplace could help to develop DSR potential amongst I&C customers by offering them a single, trusted and potentially simpler route to market.

The aim of this market platform would be to allocate DSR to the parties who most value its use at a particular time. The main participants would be:

  - *the sellers* of DSR, including aggregators or suppliers of household, SME and I&C demand, and I&C customers participating directly; and
  - *the buyers* of DSR, including suppliers, networks owners (transmission and distribution), the SO, and potentially independent traders.

A market of this description raises a number of design questions which have direct impact on the benefits of the platform, and its cost.

- **National vs. local.** A number of stakeholders raised the issue of how the market could handle different geographical requirements of the participants. For example, a DNO has a need for DSR in a specific location where potentially there are fewer sellers. This would require locational pricing and require the market to split the national zone into single zones relevant to the demand of the DNO.[11] A model with dynamic zone formation such as this would be more expensive to set-up and run.

- **Products design.** Determining the range of products will be an important driver of cost. On the one hand bespoke contracts offer flexibility for participants to meet their needs. However they could lead to high transaction costs, high barriers to entry and poor liquidity. On the other hand, complete standardisation of products may not meet the requirements of different parties restricting access.

As a guide, a group of energy system experts suggested that a market with dynamic zone formation and an ability to trade multiple products would cost in the region of £6-7m to setup, with £2.5-3m annual running costs. These compared to £3-5m and £1-2m for a market with few products and a single price zone. However, these costs need to be seen in the context of the potentially large benefits they could facilitate.

3.1.4 Improving information provision

Our discussions with stakeholders have highlighted that there currently does not exist a formal way for parties to be informed of the DSR contracts which have the potential to impact them. Providing better information to the market does not represent an alternative market model, however it does merit a short discussion of its potential value.

There are two levels at which information provision could help to relieve detriment by improving visibility of the impacts.

- **Information on the existence of contracts.** Suppliers could better be informed about the DSR contracts held by their customers. DNOs could be better informed about customers with DSR contracts/tariffs on their network. And the SO despite being able to manage "invisible" actions through system frequency could benefit from knowing the scale and location of DSR contracts.

- **Information on the activation of contracts.** Participants could be notified about when DSR is activated in real-time.

The value of improving visibility of DSR will depend on the specific situation.

- Suppliers will never be able to fully predict the impact of DSR on its imbalances. However knowing the likelihood of faults on the DNO network and the contracts in place with customers would enable them to forecast the

[11] The optimal size of these zones (e.g. should they be based on GSPs) is a really important question which was outside the scope of this current piece of work.

potential impact. Further, although it is not possible to predict faults on the DNO network, once a fault has occurred the supplier could account for the DSR throughout the repair.

- DNOs and the TO will be able to better plan their future network investment if they have a clearer understanding of DSR potential on parts of their network. And potentially, the information could be used by DNOs to veto the use of DSR in certain locations at certain times.

3.2 BSC amendments

This section discusses how changes to the BSC could facilitate the development of DSR. Its focus is on how the BSC could be amended to better account for the impact of DSR on supplier imbalances. The following discussion is applicable generally for the use of DSR and does not vary by market model.

We look at how settlement data could be adjusted to neutralise the impact of DSR on supplier imbalances, and then consider how suppliers could be compensated if this was desirable. More detail is contained in a supporting paper from *pi cubed consulting*.

There are a series of steps that need to be considered.

- **Identification of the suppliers.** Currently suppliers are not identified for the purposes of DSR. Where a customer participates directly in the DSR market, the identification of an impacted supplier would need reference to Registration data to map between the customer and the Supplier using MPAN data. Where DSR aggregators offer DSR volume they would need to be required to identify the final customer that will deliver the DSR volumes and the volume that each customer delivers.

- **Accounting for the DSR in the settlement data.** The DSR action will lead to a difference between the contracted and metered volumes which the supplier could not account for. Either could be adjusted to bring them back in line.

    - **Supplier Volume Adjustments.** The metered volume could be adjusted to the level expected prior to the DSR activation. While this removes the imbalance, the supplier would no longer receive the SSP. Further, the meter adjustment means that metered volume would be above the actual volume and it would become liable for transmission and distribution (T&D) charges on the volume it did not sell. This adjustment is therefore not in the interest of the supplier, and compensation would need to be paid if this adjustment was made.

  - **Adjusting Supplier Energy Accounts.** An alternative less complex method focuses on contracted volumes. The idea being that balancing actions are converted to appear as trades between the Energy Accounts of the Supplier and the Network Operator, much as Applicable Balancing Services Volume Data adjustments are a transfer between a Supplier's Energy Account and the System Operator's Energy Account. This method ensures that the contracted and metered volumes are in line with the actual energy sales by the supplier. Hence the T&D charges reflect the actual consumption. Network Operators would require energy accounts for Settlement purposes for this to work. This is a simpler method for adjusting volumes. Although an important consideration of using this approach would be determining the appropriate price at which the trade could happen.

- **Compensation.** Based on a methodology which transfers contracted volumes to the network owner, the price of the trade should reflect appropriate compensation to the supplier. The compensation should ensure suppliers do not make a loss on the volume they purchased but was no longer required. Therefore they should effectively be able to sell the volumes to the DNO without incurring loss. This doesn't mean compensating for the lost retail margin on the volume no longer sold to their customers. There are many reasons why customers can change their demand, none of which suppliers are compensated for. This means that the compensation should be based on the wholesale price. Of course, it is not possible to know the exact wholesale cost associated with that volume so an approximation would be needed.

The options set out here can be implemented within settlement, although agreeing a price is not straightforward. Therefore the benefit of any compensation scheme would need to be considered alongside its costs.

4 Quantitative assessment of the problem

To better understand the scale of the problem, and the impact that different options may have, we have modelled the use of DSR out to 2030.

In this section we draw out the main results in order to understand:

- the potential benefits to market participants from the use of 'dynamic' DSR;
- the scale of the information and efficiency problems that may arise;
- the main drivers that affect their scale and impact; and
- under what conditions the different market models for procuring DSR make sense.

Further results are shown in Annexe 3, while Annexe 4 describes the way in which the model functions.

The main messages that come out of this analysis are as follows.

- Consistent with previous studies in this area, suppliers are likely to be the biggest beneficiary from the use of DSR to reduce their wholesale costs.
- DNO use of DSR is such that it is only called infrequently for tackling faults on the network and as a result:
  - the information problems for suppliers created by the invisibility of DSR actions by DNOs are not large compared to the usual uncertainties they face in balancing; and
  - there is significant spare capacity from DNO DSR to "share" with the SO in a model for sharing.
- "Pooling" of small supplier imbalances into a 'club' can reduce the financial impact on small suppliers, albeit modestly, although it would increase costs to suppliers outside of the club.
- A central market platform may lead to benefits in a world with high DSR potential and limited means of efficiently allocating DSR use absent a market.

4.1 Overview of approach

We answer these questions using a half-hourly DSR dispatch model to simulate the effects of DSR use. We have designed the model specifically to answer these questions, but we recognise its limitations. These results are therefore an initial quantification of the broad trends and key drivers related to cross-party impacts.

The model recognises three distinct types of market participant using DSR:

- suppliers, seeking to reduce their wholesale and balancing costs;
- DNOs, seeking to reduce their network reinforcement costs or the cost of outages; and
- the SO, seeking to reduce the costs of procuring reserves for energy balancing (this model particularly focuses on STOR).

Our base case is represented by a market where these parties contract bilaterally with potential sources of DSR to minimise their own costs. The base case therefore includes the costs and benefits associated with information and efficiency impacts. **Table 5** sets out how these impacts are represented in the modelling.

Table 5. Modelling cross-party impacts in the base case

Information problems
Suppliers purchasing electricity on the wholesale market do so with imperfect knowledge of the ultimate level of demand. They will be surprised by changes in demand due to DSR by the SO or DNOs, leading to imbalances.
Inefficient use of DSR
Inefficiency in the base case is derived from the following sources: ▫ DSR resources are not shared. In other words, a DSR provider will contract with at most one party. ▫ DSR is 'tied up' in bilateral contracts with a party who may not value it the most. This allocation is an exogenous (given) assumption in the model. ▫ Each party seeks to minimise its own costs, including the costs of using DSR, without regard to the cost implications of its actions on other parties.

Source: Frontier Economics

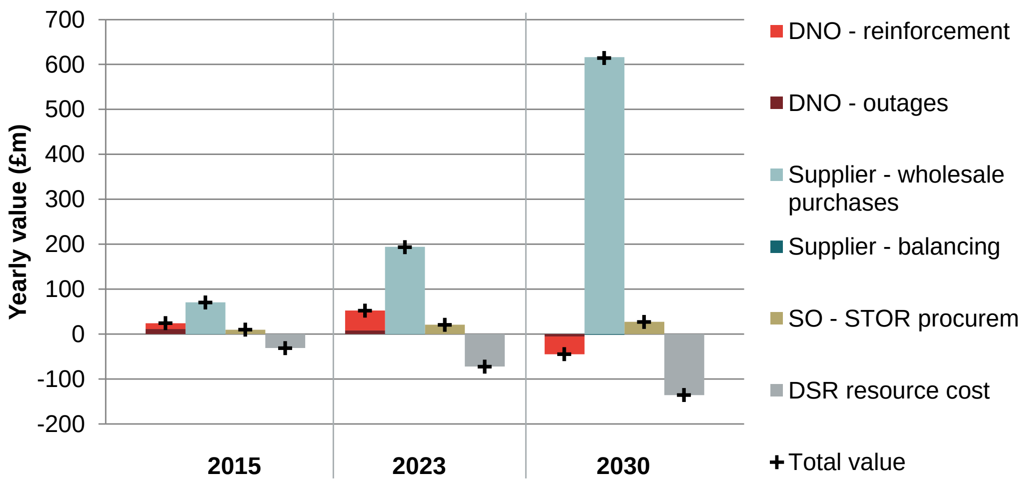
Against the base case we compare a set of options. These options are modelled by relaxing the assumptions in **Table 5**. This will allow us to demonstrate the scale and impact of these cross-party impacts, and the potential value of alternative market models.

4.2 The base case

Market participants have the potential to gain significant value from using dynamic DSR, as shown in **Figure 3**. This value is heavily concentrated with suppliers who are able to make annual savings of £0.6bn from their wholesale purchases by 2030. This result is consistent with previous analysis[12].

The benefit to suppliers increases significantly in the late 2020s. There is more flexible demand available (through heat pumps and electric vehicles, and industrial and commercial load, including I&C heat pumps) and greater opportunities for gains from increasingly volatile wholesale prices.

Figure 3. Base case value of dynamic DSR



Source: Frontier Economics

Crosses denote the total value accruing to each party

To a lesser extent in absolute terms, DNOs and the SO also benefit. The SO makes savings on STOR costs and DNOs are able to use DSR to defer investment. Further, supplier DSR has positive and negative spillovers to these parties.

- **There are positive spillover effects in the base case.** For example, where national and local peaks are aligned, suppliers use of DSR to smooth out

12 Pöyry, Demand Side Response: Conflict between Supply and Network Driven Optimisation, 2010

peaks may allow DNOs to defer investment. This effect explains about 70% of the benefit that DNOs gain by 2023.

- **There is also the potential for negative spillover effects.** For example, where peaks start to misalign the DSR available to suppliers can conflict with DNOs by increasing network peaks. In our model, this effect begins to dominate by 2030.

The impact of DSR by DNOs and the SO only has a very small impact on the wholesale and balancing cost of suppliers. There are two main reasons for this.

- Given the nature of imbalance pricing, the impact on supplier imbalance costs is difficult to predict ex ante. The supplier sometimes is made better off and sometimes loses out. Therefore a low net impact is not unexpected (and is robust to scenarios we have run with higher imbalance charges).

- The activation of DSR by DNOs only accounts for small volumes of shifted demand. In the model we assume that at any one time only 1% of feeders are at fault, and they only cause a binding constraint requiring DSR on the highest winter peak days. Similarly, the SO will on average only dispatch a small proportion of its STOR DSR capacity in any given half-hour.

Our assumption on fault rates is an important driver in the model. We have used 1% as the probability of a fault. This is consistent with conversations with UKPN which indicated that 25% of their substations might be affected by a fault during a year, with the fault lasting for around two weeks (approximately 4% of the year). This means that, at any one time, around 1% of substations could be in a fault condition.

In addition, we have assumed that the capacity loss would be such that it would only lead to demand exceeding firm capacity on a feeder for four peak hours on a peak winter day. This is based on information from Northern Powergrid gathered for CLNR. This implies that a fault only leads to an outage, or requires DSR, for relatively few days per annum in the winter peak. However, further evidence from UKPN suggested that some of its feeders could be 'out of firm' for much more of the year e.g. up to half of the year. We think that our assumptions are based on sound evidence, but recognise there could be a range of opinions and evidence from different DNOs. We therefore tested our results using a higher assumed fault rate of 5% on DNO feeders and obtained similar conclusions. However, we recognise that engaging WS6 could valuable in testing these results further.

4.3 Modelling the options

By modelling the options we can identify their potential benefits and understand under what conditions they are most valuable. It should be noted that the benefits presented here illustrate the savings to market participants from perfectly efficient contracting between parties. In that regard they should be viewed as an illustration of potential.

Table 6. Modelling the options

Option	Description of approach to option modelling
Improving information	Suppliers are able to predict the impact of DNO DSR pre-gate closure. This assumes DNOs share information about fault occurrence and the length of repairs, which is assumed to be an average of 14 days in the model.
Supplier to supplier DSR	DSR undertaken by one supplier's customers can be traded to help improve another supplier's imbalance position. All suppliers work collectively, sharing DSR resources to minimise their collective imbalance position. This represents two benefits: ▫ the benefit that suppliers get by trading DSR with each other on a market platform; and, ▫ the impact of a small supplier 'club' netting imbalance volumes.
DNO-SO "sharing"	DNOs and the SO have access to a common pool of DSR, with decisions taken jointly to minimise total DNO and SO costs.
Complete market model	Efficient market-wide solution where DSR is allocated to the party who values it the most in each half-hour period. This takes into account external impacts on other parties.

Source: Frontier Economics

4.3.1 Improving information

The impact of DSR by other parties on the imbalance cost of suppliers has already been shown to be insignificant. Therefore the gains to suppliers from information sharing are equally small. As an illustration we can estimate the maximum potential saving by allowing suppliers to perfectly predict (and therefore account for) DNO and SO DSR pre-gate closure. In doing so, they make savings of £0.05m by 2030. In the context of total imbalance costs set out in **Table 7**, this represents 'noise'.

Table 7. Total imbalance costs in the base case

2015	2023	2030
£37m	£88m	£165m

Frontier Economics

4.3.2 Supplier to supplier DSR

For smaller suppliers that are unable to change their contractual position immediately prior to gate closure (for example due to the lack of a vertically integrated generation business), DSR offers an alternative way to correct for imbalances. Trading DSR volumes between such suppliers can therefore lead to reduced overall imbalance costs, by enabling DSR to be directed towards those suppliers with the greatest imbalance costs.

We have modelled the potential benefits of trade between a set of hypothetical suppliers with a different endowment of DSR in terms of resources and cost from within their customer base. In this illustrative example, we considered:

- a supplier with a predominantly I&C load;
- a domestic supplier with a high proportion of electric vehicles and heat pumps (these are a significant source of DSR for the domestic sector); and
- a domestic supplier with a lower proportion of electric vehicles and heat pumps.

This can help identify the potential impact of a 'club' of small suppliers on balancing costs. We have compared the combined imbalance cost of these three hypothetical suppliers to a single entity covering all three suppliers. Joining together in 2030 reduces the market-wide imbalance cost by £100m, (roughly 0.2% of wholesale costs, or 35% of imbalance costs).

This saving is largely the result of pooling imbalance accounts. Smaller suppliers with a less diversified set of customers will tend to be out of balance more frequently, since their overall demand will be more volatile. If small suppliers did this it is not likely to be a saving to the market as a whole. But instead is a reallocation of imbalance payments from smaller suppliers to larger ones. Although this could be justified as a way of promoting effective competition.

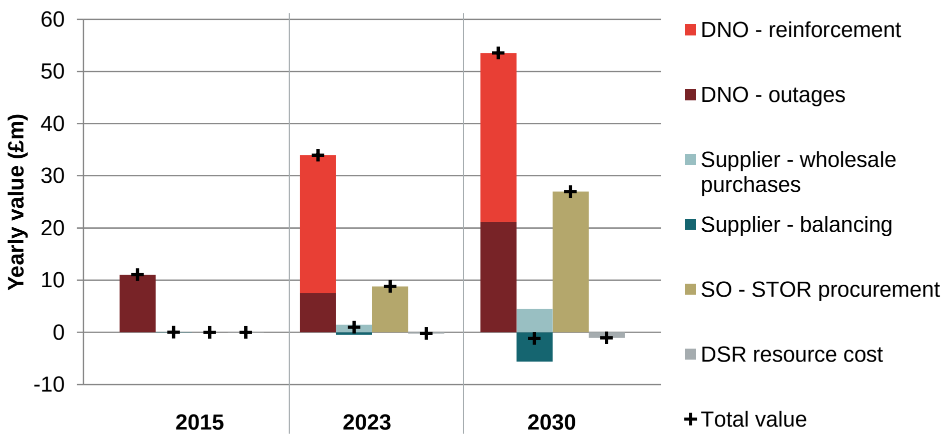
The modelling also includes a benefit for a supplier facing a substantial imbalance position but without access to sufficient DSR from its customer base. Such suppliers can now call on the DSR abilities of suppliers with greater quantities of shiftable load. This provides a small cost saving to the market as a whole.

4.3.3 DNO-SO "sharing"

The modelling demonstrates significant value to DNOs and the SO "sharing" their DSR resources. This is a direct corollary of the small impact that DNO DSR has on supplier imbalance volumes. We have assumed that at any time only 1% of the distribution network is at fault. There is therefore likely to be a high proportion of contracts that can be made available to the SO for STOR. Similarly, the "sharing" could also work in reverse. Procurement costs are reduced for both parties. **Figure 4** sets out savings for the DNOs and the SO of £45m and £27m respectively in 2030.

The benefits of sharing in our analysis could be conservative depending on future DSR tariff structures. Our analysis assumes that DSR is paid for through utilisation payments alone. If, however, availability payments are present, then these can also be "shared" by the DNO and SO, reducing the price of the DSR, and potentially increasing the use of DSR further, even when those parties expect to call on the DSR at different times. The importance of DSR tariff structures and their impact on the value of sharing is discussed in the box on page 32.

Figure 4. Benefits from "sharing" DSR between DNOs and the SO



Source: Frontier Economics

There is a small impact of this option on suppliers, which is positive in 2023 and negative in 2030. This reflects a combination of two factors.

- By unpredictably calling DSR, both the DNO and SO can cause additional imbalances for the supplier, which will be reflected in higher imbalance costs. These are higher than in the base case, due to the increased use of DSR as a result of the "sharing".

- The use of DSR will change the overall profile of electricity consumption for suppliers, altering their wholesale costs. DNOs will wish to move demand away from peaks on the local network which will typically correspond to times of high prices. This will lead to a gain for the supplier.[13] Although if national and local peaks start to diverge this effect will be dampened. The actions of the SO (which by their nature are unpredictable) may also lead to an increase in imbalance payments, although this is a relatively small factor within the model.

13 Note that the model does not model the kickback from SO-initiated DSR (it does model kickback for DNO and supplier-initiated DSR). The wholesale cost gains from SO-initiated DSR will therefore be overestimates.

Tariff structures and implications for DSR use

Existing payments for DSR services typically take the form of an availability payment (based on the capacity for demand reduction regardless of whether it is called) and a utilisation payment (based on the volume of energy shifted over the year). For example, National Grid provide an availability payment of around £22/kWh for STOR, with utilisation payments of around £225/MWh.[14] Similar payment structures have been adopted by a number of the DNOs[15] within LCNF DSR trials. However, this structure is not universal: National Grid's proposed Demand Side Balancing Reserve service includes the option to not receive an availability payment,[16] and we understand that Western Power Distribution's FALCON LCNF project does not include one.

It is likely that different customers may favour different splits of payment between availability and utilisation. For example, an I&C customer may be willing to receive a greater proportion of payment based on utilisation if the costs of DSR are linked to the energy foregone (e.g. the value of a halted production process) rather than fixed (e.g. adjusting equipment and processes to prepare for the possibility of DSR). It is also possible that the split between availability and utilisation payments could change if utilisation were to substantially increase. For example, the presence of an availability payment may be driven by consumer preferences to receive payments upfront.[17] However, if the costs of participation increase with utilisation, this "fixed" availability fee may need to increase if the DSR is expected to be called more often.

If different parties will be calling on DSR at different times, it may be possible for them to contract with the same customers and share capacity. If costs of DSR are primarily based on availability rather than utilisation, this would reduce the cost to each party by sharing the fixed availability cost. This would increase the use of DSR since it would become cost-effective in more circumstances.

To be conservative about the benefits of sharing, we have modelled a situation where the costs of DSR vary in proportion to utilisation and there is no fixed availability charge. However, even under this assumption, our model permits the

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14 Element Energy (2012), *Demand side response in the non-domestic sector*

15 For example, Northern Powergrid (CLNR), UK Power Networks (LCL) and Electricity North West (C2C) adopt a structure of charges that includes both an availability and usage charge

16 National Grid (2013), *Demand Side Balancing* Reserve (http://www.nationalgrid.com/NR/rdonlyres/3F8C2A41-F3D7-4847-9CC2-1788F4ADD16D/63265/DSBRReportFinal181113.pdf)

17 Various behavioural reasons for an availability payment are discussed in NERA (2013), *Effective Use of Demand Side Resources: The Continued Need for Availability Payments*

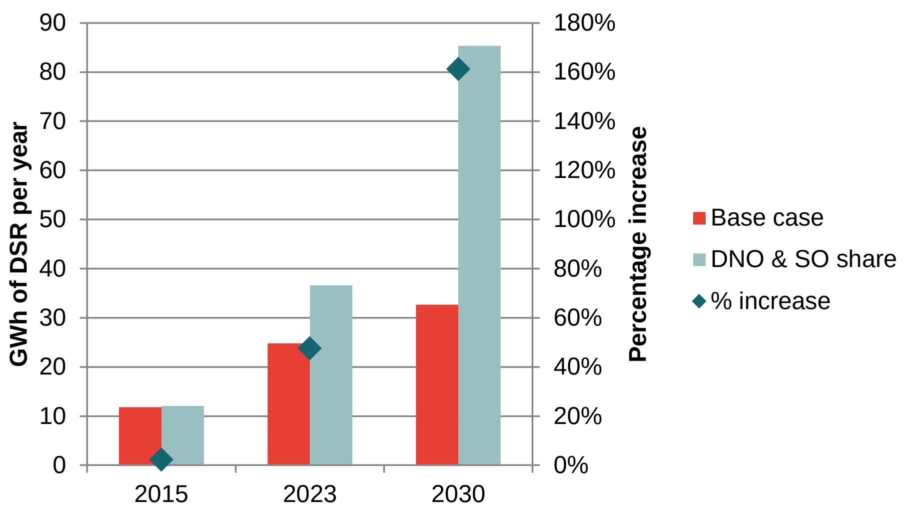
usage of DSR to increase by sharing the utilisation payment.

As described in section 2, a single DSR action by one party may have a positive impact on another. If these parties can co-operate (for example through a market) then they could share the utilisation payment between them. This may lead to increased DSR if load-shifting that was previously not cost-effective for any one party becomes viable when the utilisation cost is shared.

In addition to this "price" effect, DSR usage in our model may increase with sharing due to two "access" effects.

- **An increase in access to DSR for all parties due to sharing**. Multiple parties can often make use of the same unit of DSR, by calling it at different times. Pooling of DSR increases the total amount of DSR available to any one party, which increases the amount of DSR undertaken. For example, **Figure 5** shows the yearly volume of DSR carried out by DNOs and the SO under the base case and under the option in which the DNO and SO pool their DSR resources. By 2030, the pooling leads to an increase in DSR usage of over 160%.

Figure 5. Change in DSR volumes from pooling DNO and SO resources



Source: Frontier

- **An increase in access to DSR for the party that values it most**. Even if it were not possible for the same unit of DSR to be shared among different parties, a market model enables DSR to be used by the party with the highest value for it. This may lead to an increase in the amount of DSR if there is an initial inefficient allocation of DSR, as explained in section 4.

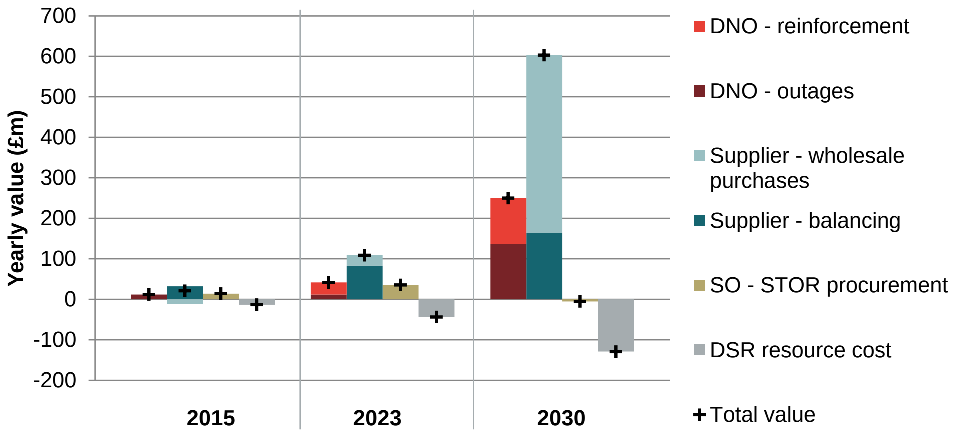
4.3.4 Central market platform

Our results for a central market platform, set out in **Figure 6**, suggest significant benefits for suppliers and DNOs.

There are modest benefits for the SO up to 2023, although they are slightly negative by 2030. This represents the way in which, by 2030, DSR that in the base case was allocated to the SO, is allocated by the market to other uses. This increases the costs the SO faces in procuring STOR from elsewhere.

In theory, increased use of DSR by other parties could reduce the costs for the SO. However, we have assumed that the SO's requirements for STOR are unaffected by the DSR activities of other parties.[18]

Figure 6. Benefits for market participants of a centralised market platform



Source: Frontier Economics

These benefits represent both the gains from being able to share DSR between parties, as well as the gains from allocating DSR more efficiently to parties in the first place. We have exogenously allocated DSR to each party in the base case. To the extent that this initial allocation is inefficient it could be inflating the benefits of this market platform.

It is not possible to say what a realistic allocation of DSR should be in the base case, but it is reasonable to test the impact of a more efficient allocation. We have therefore carried out a run with all DSR allocated to the supplier increasing the

18 This is based on the view that the SO holds STOR to respond to sudden changes in generation e.g. due to a plant trip. DSR from a supplier may have reduced a peak, however it is unlikely to reduce demand in the exact instance required by the SO.

benefits in the base case. This reduces the overall net gains in 2030 from £718m to £448m.

The value of a market platform is sensitive to the level of DSR potential. We have assumed a level of take-up of low carbon technologies in line with DECC and Ofgem's SGF scenarios. In addition we have also included significant flexible I&C load (30% by 2030). This is a key driver of the benefits. By halving the amount of I&C availability the benefits of a market platform reduce by over half. Further, our assumptions on I&C load may imply greater flexibility potential than may be realistic. More work is therefore needed to better understand the potential flexibility it can offer suppliers in managing wholesale costs on a daily basis.

Cost-benefit analysis

We have carried out a basic cost-benefit analysis of a central market platform using the results presented above. We have based the results on a set of conservative assumptions where:

- 100% of DSR is allocated to the supplier in the base case;
- a lower level of shiftable I&C load (15% in 2030); and,
- upper range costs provided to us by energy system experts[19].

Given these assumptions, there is a net benefit of between £259m and £391m (depending on the approach adopted to interpolating the results across years – more details are given in annexe 3). This result suggests that there are potentially substantial long-term benefits to be gained from such a market platform, and therefore it is worthy of further investigation.

There are a number of caveats to this analysis.

- First, our modelling has assumed that the market is able to deliver an efficient allocation of DSR between market participants. In reality, it is likely that the market will have imperfections which prevent this level of efficiency from being obtained. For example:
  - it may not be feasible to have a market which takes into account every possible type of DSR (the impact of DSR can vary at a fine-grained level both across localities and time periods); and
  - factors such as transaction costs, insufficient liquidity, or market power could prevent the market obtaining the efficient outcome.

[19] Initial set-up costs of £7m and annual running costs of £3m.

- Second, this is not a full social cost-benefit analysis since it does not take into account all players in the energy sector (and beyond). For example, in order to maintain a tractable model, we have not considered the role of DSR in deferring transmission network reinforcement. To do so could be the subject of a model extension which includes the use of DSR in regional balancing to manage transmission constraints.

5 Implications

In this section we draw out some of the implications of this work for ELEXON and other stakeholders. We have seen that increased DSR use will have cross-party impacts. The timing is uncertain, but there are a range of credible scenarios that show that these start to become significant in the mid to late 2020s. It is also around this time that the use of DSR by different parties may start to conflict more often.

There are also a range of proposals that mean these actions could cut across the principle of the supplier hub. This may be from existing (heavily regulated) parties such as DNOs that may wish to have direct relationships with customers to access DSR potential. It may also come from (less regulated) new entrants that seek to introduce innovative business propositions enabled by smart metering[20]. These agents may expect to operate outside the settlement system even though their actions could impact on what happens to parties within it.

An important aim of this project is to understand what this means for ELEXON and its stakeholders and consider whether there are any amendments to the BSC that should be made to help meet ELEXON's objectives:

- BSC objective (c): promoting effective competition in the generation and supply of electricity, and (so far as consistent therewith) promoting such competition in the sale and purchase of electricity; and
- BSC objective (d): promoting efficiency in the implementation and administration of the balancing and settlement arrangements.

We first consider whether there is any case for amending the BSC in the near term before providing some issues that other stakeholders might wish to consider as part of the work that is being undertaken in this area by the SGF and Ofgem's Smarter Markets directorate.

5.1 BSC

Our work investigated how the BSC could be amended to better account for the impact of DSR on supplier imbalances. Based on this, we make the following recommendations.

- No changes are required to the BSC in order to facilitate trading of DSR between suppliers.

20 We understand that the arrangements, as they currently stand, mean that third parties will be able to access DSR potential within homes without the need to go through the DCC. This means that there is no obvious route to access this DSR activity through central systems.

- There are potential changes that could be made to the BSC to compensate suppliers for additional imbalance costs due to DSR[21]. However, the complexity of the possible changes needs to be considered alongside the results of our analysis which has shown that these costs are small in the period up to 2030. On this basis we do not recommend making these changes now.

5.2 Industry implications

The issues we discuss in this report are of interest to a wide set of stakeholders. Indeed, it is where Ofgem and the SGF are planning to focus effort in the near term. We hope that our report will provide some helpful insights to this work.

- **For suppliers**:
  - While unseen DSR actions by others can harm suppliers by increasing exposure to imbalance risk, under most reasonable assumptions these are unlikely to be material in the period to 2030. This is both because the impact on supplier imbalance costs can be positive as well as negative (and so a low net impact is possible) and because DNOs activate DSR relatively infrequently. This result should be stress tested with WS6, but if this holds then there is no strong case for industry action to mitigate such costs. But if it was required, we have proposed a method by which compensation could be applied.
  - There are modest gains to be made from suppliers trading DSR. This can already happen both within current BSC arrangements and on existing exchanges. However, to the extent that smaller suppliers face barriers to accessing these markets, particularly given collateral requirements, these will remain even with increased trading of DSR.
- **For network owners**:
  - In a world of bilateral contracting, potentially with side arrangements to enable sharing, there may be a series of roles required by parties to make the arrangements operational. For example:

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21 DSR could be accounted for in the settlement data either by adjusting metered volume to the level expected prior to the DSR activation or Network Operators could be required to have energy accounts for Settlement purposes and supplier Energy Accounts could be adjusted (much as Applicable Balancing Services Volume Data adjustments are a transfer between a Supplier's Energy Account and the System Operator's Energy Account).

  - information will need to be held on contractual positions and when DSR actions are called;
  - actions will need to be authenticated to enable payment; and
  - transactions will need to be settled.

- **For the industry as a whole:**
  - We show that a central market platform may lead to large benefits in a world with high DSR potential. However, the value of this platform hinges both on there being a large pool of flexible DSR available and a failure to allocate this efficiently through a bilateral contracting model. There are still many uncertainties and challenges associated with any such platform. But there is potential that makes it worth further investigation.

Finally, we are aware of areas for further development of our work which could be taken forward in future.

- Develop the model to better incorporate the impact of potential mismatches between national and local peaks. This could improve our understanding of conflict between suppliers and the SO with DNOs.

- Refine the assumptions underlying the way DNOs contract for, and then use, DSR to further stress test the result that invisibility of actions is unlikely to lead to supplier detriment.

- Improve our understanding of the potential flexibility that I&C load can offer suppliers in managing their wholesale costs. Currently our assumptions assume high levels of flexibility which are an important driver of our results.

- The initial allocation of DSR to the different parties is an important driver of the benefits of our options. A future extension could bring this allocation within the model itself, thereby ensuring that in the base case DSR is held by the party that values it the most. The benefits of our options would therefore focus on the additional benefits associated with "sharing" of DSR.

Annexe 1: Identifying cross-party impacts

DSR by Suppliers

Suppliers can derive value from DSR in two ways. They can:

- shift their consumers' demand to coincide with lower wholesale prices, thereby minimising their wholesale electricity costs; and
- use DSR to stay in balance, thereby minimising any imbalance charges.

Static ToU tariffs may be particularly relevant to suppliers given domestic consumers' likely preferences for a stable pricing structure. The usefulness of static tariffs in shifting demand to periods with lower wholesale electricity will depend on the extent to which daily price profiles are stable and known in advance. To date, daily prices have followed a stable and predictable pattern based on patterns in demand. Increased inflexible renewables generation may act to disrupt these patterns in future, and limit static tariff's usefulness in lowering wholesale costs.

The static nature of the tariffs would prevent their use in balancing roles, where demand needs to be adjusted over relatively short periods. **Dynamic ToU** tariffs and **direct load control** are more appropriate for lowering wholesale costs when prices no longer follow a stable pattern or to limit imbalance charges[22].

A summary of how supplier-led DSR will impact on other parties is set out in **Table 1**.

[22] Suppliers will only have an incentive to shift domestic demand to coincide with cheaper generation when domestic demand is settled on a half-hourly basis. Under the current settlement arrangements, the effects of the load shifting would effectively be socialised across all suppliers

Table 8. Impact of supplier DSR on other parties

Affected party	Information problems	Inefficient use
SO	**Limited impact**. DSR is pre-gate closure, so the SO should have warning of its impacts and can factor this into its forecasts for balancing purposes.	**Potential impact**. Exclusive contracts may prevent efficient sharing.
DNO/TO	**Potential impact**. Network operators need to understand the impact of supplier DSR on long-term investment planning.	**Potential impact** Where national and local peaks coincide, actions to reduce demand by suppliers will reduce costs for the DNO. However, there is also potential for conflict with the supplier increasing demand locally at a time when the DNO is trying to reduce demand. Exclusive contracts may prevent efficient sharing.
Other suppliers	**Potential impact**. There is the potential for a supplier (acting as an aggregator) to impact on the imbalance volume of other suppliers	**Potential impact**. Exclusive contracts may prevent efficient sharing.

Source: Frontier Economics

Impacts on the SO. The SO should in theory be unaffected by supplier DSR. This is because all actions by a supplier should be taken before gate closure and factored into their contracted and physical positions (FPNs). The actions are therefore visible to National Grid. However currently they do not use the FPNs to plan their balancing actions, but instead use their own demand forecasts. If the SO continues with this approach, its ability to have prior warning of DSR actions will depend on its ability to predict the DSR actions by other parties.

Impacts on DNOs. In contrast DNOs could be affected by supplier DSR.

- DSR can reduce overall peak demand on the network. If suppliers shift demand from peak to save on wholesale costs, this has a positive benefit to the DNO through reduced investment costs.

- DSR leads to new peaks on the local network. If unchallenged, their investment programme will need to reinforce the network to meet the new peaks in demand. The same impact is true for the TO.

Impacts on other supplier - the DSR actions of one supplier cannot impact on another supplier, since they can only adjust the consumption of their own customers. However, aggregators are able to sell DSR services and in that role contract with customers of any supplier. These actions could be invisible to a supplier leading to changes in their imbalance position. There is nothing to stop an existing supplier entering into that market as well.

DSR by DNOs

DNOs can derive value from DSR through investment deferral or avoidance. Traditionally, DNOs have met their system obligations by ensuring that network capacity is sufficient to handle the peak flows and, where appropriate, sufficient overhead exists to provide resilience to faults. However, DSR enables DNOs to:

- manage faults through the reduction of local demand, thereby enabling reduced 'headroom' on the local networks;
- curtail output from distributed generation in order to manage local voltage issues; and
- potentially actively manage the net flows across their network to balance the more flexible load and intermittent generation;

In each case, the use of DSR can act as a substitute for network reinforcement.

As with suppliers, **static ToU** tariffs are only valuable to a DNO when they wish to induce a systematic shift in demand in order to reduce a predictable local demand peak, and where suppliers reflect them in their tariffs. However, static tariffs clearly cannot respond to unexpected faults.

Dynamic ToU tariffs and direct load control would allow a DNO[23] to influence demand more quickly, for example in response to a peak in distributed generation. At the limit however, where a DNO is looking for a near immediate response following a fault, only direct load control without a customer override may be a viable substitute for network reinforcement.

It is worth noting that TOs face similar issues to the DNOs with respect to investment avoidance and already employ a form of ToU charging in Triad charges. Unlike the ToU tariffs considered above however, the charging periods are not known in advance. They act to restrain peak demand, and thereby defer the need for network reinforcement. The incentive for I&C load to shift away

[23] In theory, DSR could in future also be used to substitute for transmission network reinforcement in response to fault conditions. This could look very similar to the type of DSR contracts that DNOs are considering.

from the peaks, arises due to suppliers passing through the reduction in transmission charges (TNUoS) created if the customer avoids the Triad.

In theory, DSR could in future also be used to substitute for transmission network reinforcement in response to fault conditions. This could look very similar to the type of DSR contracts that DNOs are considering. As with the distribution network, DSR would need to be both firm and fast to act as a viable substitute to network reinforcement in the event of a fault. This is likely to imply the need for direct load control arrangements or similar.

DSR activated by DNOs has the potential to have positive or negative impacts on the SO or suppliers. This is set out in **Table 2**.

Table 9. Impact of DNO DSR on other parties

Affected party	Information problems	Inefficient use
SO	**Limited impact**. SO can react through monitoring of system frequency, but forewarning of DNO DSR may reduce SO's costs.	**Potential impact.** DNO ignores the impact of its DSR on the SO. Where national and local peaks coincide, actions to reduce demand by DNOs will reduce costs for the SO. However, there is also potential for conflict with the DNO increasing demand locally at a time when the SO is trying to reduce overall demand. Exclusive contracts may prevent efficient sharing.
Suppliers	**Potential impact**. Suppliers' forecasted demand may be wrong if DNO DSR is invisible. The impact on a supplier of having their consumption adjusted is ambiguous and in part dependent on the cash-out regime in place (see text below).	**Potential impact**. DNOs do not consider the impact on suppliers' imbalance and wholesale costs. Exclusive contracts may prevent efficient sharing.

Source: Frontier Economics

SO – the action of a DNO could lead to positive or negative impacts on the cost of balancing for the SO.

- If the DNO's DSR is visible to suppliers and they are able to respond, the DSR will be accounted for in their contracted and physical positions. The SO therefore does not need to take any additional balancing actions.

- If however, suppliers are unable to respond to the DSR by adjusting their contracted and physical positions, the SO will need to take more or less balancing actions depending on whether the DNO action was helpful or not to the overall system imbalance. If the DNOs actions are invisible, the SO should still be able to monitor and respond in real-time through its management of system frequency. However, advanced warning of the DNOs planned DSR may help reduce the SO's costs.

- There are potential positive or negative spillovers to the SO. Where national and local peaks coincide, actions to reduce demand by DNOs will reduce costs for the SO. However, there is also potential for conflict with the DNO increasing demand locally at a time when the SO is trying to reduce overall demand.

Suppliers

- Whether a supplier is taken out of balance by a DNO action is contingent on whether the DSR action is visible to the supplier and they are able to respond. The impact on a supplier of having their consumption adjusted does not always lead to harm. The result could be ambiguous and in part dependent on the cash-out regime in place.

- Load shifting by the DNO may increase or reduce suppliers' wholesale costs, depending on the coincidence of network constraints with periods of high wholesale prices.

We have mapped out the potential impacts on a supplier's cost of imbalance. The following tables illustrate the impact of a demand reduction/increase on a supplier depending on their pre-DSR imbalance position relative to the whole market. These tables are based on the current dual pricing approach to calculating imbalance prices.

Figure 7. The impact of a **demand reduction** by a DNO on the imbalance cost of a supplier

Demand reduction by DNO makes supplier longer		Overall system imbalance: Short	Overall system imbalance: Long
Initial supplier position	Short	Reduced exposure to the SBP (main price)	Reduced exposure to the SBP (reverse price)
	Balanced	Receive SSP (reverse price)	Receive SSP (main price)
	Long	Receive SSP (reverse price)	Receive SSP (main price)

Source: Frontier Economics

Figure 8. The impact of a **demand increase** by a DNO on the imbalance cost of a supplier

Demand increase by DNO makes supplier shorter		Overall system imbalance: Short	Overall system imbalance: Long
Initial supplier position	Short	Increased exposure to the SBP (main price)	Increased exposure to the SBP (reverse price)
	Balanced	Increased exposure to the SBP (main price)	Increased exposure to the SBP (reverse price)
	Long	Reduced exposure to the SSP (reverse price)	Reduced exposure to the SSP (main price)

Source: Frontier Economics

This shows that:

- the impact on suppliers is difficult to predict ex ante;
- the supplier will gain when the DNO action moves both the supplier and the system back into balance;
- when the DNO action conflicts with the system imbalance the supplier stands to lose out; and
- the worst situation for a supplier is when the DNO action moves them further out of balance in the direction of the overall system imbalance.

If Ofgem implement a single price calculation as expected through their Significant Code Review, the picture changes, as demonstrated in **Figure 9** and **Figure 10** below.

Figure 9. The impact of a **demand reduction** by a DNO on the imbalance cost of a supplier (single imbalance pricing)

Demand reduction by DNO makes supplier longer		Overall system imbalance	
		Short (imbalance price - premium to market price)	Long (imbalance price - discount relative to market price)
Initial supplier position	Short	Reduced exposure to the premium imbalance price	Reduced benefit from buying at discounted imbalance price
	Balanced	Receive premium imbalance price for increase in excess power	Receive discounted price for excess power leading to loss
	Long	Receive premium imbalance price for increase in excess power	Increased need to sell at discounted power price leading to loss

Source: Frontier Economics

Figure 10. The impact of a **demand increase** by a DNO on the imbalance cost of a supplier (single imbalance pricing)

Demand increase by DNO makes supplier shorter		Overall system imbalance	
		Short (imbalance price - premium to market price)	Long (imbalance price - discount relative to market price)
Initial supplier position	Short	Increased exposure to imbalance price	Increased ability to buy at discounted price
	Balanced	Exposed to imbalance price leading to a loss	Increased ability to buy at discounted price
	Long	Reduced benefit from selling excess power at premium	Reduced exposure to selling excess power at discounted price

Source: Frontier Economics

Under the single price calculation, the supplier stands to benefit if the change in demand by the DNO is helping a system imbalance e.g. the DNO is reducing demand when the system is short overall. This effect occurs because the supplier either has a reduced exposure to the penal imbalance price when they are already out of balance with the system. Or, increased exposure to benefit from the imbalance price when they are out of balance against the system.

DNO DSR could also lead to "kick-back". To the extent that DSR shifts demand in time, rather than an absolute reduction, suppliers could be faced with higher demand than expected in the shoulder-peak period as well. Suppliers have an opportunity to respond to this kick-back if they are able to identify it in time. Further this is likely to lead to a reduction in overall wholesale costs as demand is shifted from peak to off-peak.

Annexe 1: Identifying cross-party impacts

System Operator

The SO can use DSR to balance the system. This has traditionally been dominated by generation through mechanisms like the Short Term Operating Reserve (STOR). However, DSR is already used as a substitute for flexible generation in this role and could play a larger part in future as more DSR becomes available. Short-term system balancing will also have stringent requirements on the firmness and speed of response and will therefore be limited to direct load control.

DSR activated by the SO has the potential to have positive and negative impacts on suppliers and DNOs.

Table 10. Impact of SO DSR on other parties

Affected party	Information problems	Inefficient use
DNO/TO	**Potential impact.** If local peaks are increased unpredictably due to SO balancing actions then this can lead to operational and financial impacts for the DNO.	**Potential impact.** SO will ignore the impact of DSR on DNOs. Where national and local peaks coincide, actions to reduce demand by SO will reduce costs for the DNOs. However, there is also potential for conflict with the SO increasing demand locally at a time when the DNO is trying to reduce overall demand. Exclusive contracts may prevent efficient sharing.
Suppliers	**Potential impact.** SO actions can affect suppliers' imbalance charges[24]. Unlike the other costs considered here, these charges do not reflect a genuine system cost and should not influence SO behaviour.	**Potential impact**. Exclusive contracts may prevent efficient sharing.

Source: Frontier Economics

Suppliers - Currently there is not a system in place to identify the impact on suppliers of the dynamic DSR actions by the SO post-gate closure. In the case of a generator, their contracted position is adjusted to account for their actions in the Balancing Market or in the provision of other ancillary services. This neutralises the impact of the SO balancing on their imbalance volume. In the case of demand, the SO does not have full visibility of the supplier relationship behind each unit of DSR. Therefore SO actions can lead to changes in supplier imbalances. Balancing actions by the SO should be flagged so as not to influence the supplier's settlement position. As this is not done at present, we discuss the implications of SO DSR on suppliers.

Similar to the case of DNOs, we have mapped out the potential impacts. In theory the SO could increase or decrease demand. Either in the direction of the

24 Currently there is not a system in place to identify the impact on suppliers of the dynamic DSR actions by the SO post-gate closure. This is in contrast to the case of a generator, where its contracted position is adjusted to account for its actions in the Balancing Market or in the provision of other ancillary services. This neutralises the impact of the SO balancing on their imbalance volume. In the case of demand, the SO does not have full visibility of the supplier relationship behind each unit of DSR. Therefore SO actions can lead to changes in supplier imbalances.

overall imbalance for "energy" balancing purposes, or potentially against the overall imbalance in the case of "system" balancing actions. To simplify the picture we have focused on energy balancing actions. The following example focuses on the case of a demand reduction when the system is short, in both the existing and potential future cash-out regimes.

Figure 11. Impact of SO demand reduction on suppliers in a dual and single cash-out price regime

Demand reduction by SO makes supplier longer		Imbalance price calculation	
		Dual pricing	Single price
Initial supplier position	Short	Reduced exposure to the SBP (main price)	Reduced exposure to the premium power price
	Balanced	Receive SSP (reverse price)	Sell excess power at premium price
	Long	Increased exposure to SSP (reverse price)	Reduced exposure to SSP (main price)

Source: Frontier Economics

Figure 11 illustrates that if the SO is conducting demand reduction when the overall system is short, the impacts on suppliers could potentially be small. In the dual pricing regime suppliers are pushed longer and face the non-penal SSP if they are already balanced or long. Alternatively, they benefit if they are short in line with the system overall. With a single cash-out price, suppliers gain in all scenarios.

DNOs - The actions of the SO can also impact on the DNOs. In theory the SO can organise potentially harmful changes in demand on a local network without warning. Although this might occur only in certain circumstances.

- *There should be no harm* from the SO action if it is reducing demand at peak times where the system and local peaks coincide. This positive spillover is not currently reflected in the value that a customer receives through a STOR contract.

- *There is the potential for harm* where local and system peaks diverge. If the SO reduces demand at a point when there is significant local generation available the DNO would automatically have to curtail the local generation in response. These potential risks make system planning and investment harder to predict.

There are further inefficiencies in the current model where resources are tied to an individual party and cannot be shared between the SO and DNOs. For example, currently STOR is exclusively for the use of the SO. However, there may be potential value in sharing this resource with another party when it is not needed by the SO.

In future, the Capacity Market (CM) will create a new market for DSR. However, it also creates the potential for new distortions in the allocation of DSR. This is because as currently set out by DECC, the rules allow DSR to hold a capacity contract and additional DSR contracts with other market participants[25] such as a DNO. However, it is only for a STOR contract where their delivery under the balancing services is taken into account in their delivery of their capacity obligation e.g. if their capacity is being kept off the grid by STOR and would otherwise appear under the CM as non-delivery. This distorts the playing field in favour of DSR procured by the SO over DNOs.

[25] This not apply to the new DSBR which National Grid are introducing in 2015/16.

Annexe 2: Workstream Six options

We have reviewed the models proposed by WS6 of the SGF for DNO customer engagement. Where dynamic DSR options are proposed there are information problems that could result. The options highlighted in red below are the least visible to suppliers, and hence could create information detriment. These options are also likely to lead to inefficient use of DSR as discussed in **Section 2**.

Table 11. Mapping the information problems of Workstream Six options for domestic customers

Option	Visibility of DSR action	Information problem
Restructuring DUoS charges	Supplier has visibility over DUoS pricing.	Supplier should be able to account for DSR in trading.
Two band DUoS capacity charge	Static tariff with prices and thresholds fixed in advance	Supplier should be able to account for DSR in trading.
Critical event arrangements	Low visibility - direct load control after gate closure.	**Difficult for supplier to predict although usage will be rare.**
Dynamic DUoS tariff	Dynamic tariff with visibility dependent to timing of tariff changes	**Tariffs set pre-gate closure allowing suppliers to factor into trading**
Load limiting	Capacity limits for appliances known in advance.	Supplier should be able to account for DSR in trading.
Energy Efficiency Measures	Not dynamic response.	Energy efficiency can be factored in to overall demand forecasts.
Demand reduction through information provision	Not dynamic response.	Information pre-gate closure allowing suppliers to factor into trading
Mandated product standards with or without over-ride	Increases potential in market for direct load control	**Potential for increased dynamic DSR post-gate closure.**
Community energy schemes	Depends on the type of DSR offered by the community	**Potential for increased dynamic DSR post-gate closure.**

Source: Frontier Economics

Annexe 2: Workstream Six options

Table 12. Mapping the information problems of Workstream Six options for industrial and commercial customers

Option	Visibility of DSR action	Information problem
Restructuring of DUoS charge	Supplier has visibility over DUoS pricing.	Supplier should be able to account for DSR in trading.
Availability and utilisation payment	Low visibility - direct load control after gate closure.	**Potential for dynamic DSR post-gate closure.**

Source: Frontier Economics

Annexe 3: Modelling results

This annexe provides a more detailed overview of the results from the quantitative model. A summary of results and conclusions can be found in section 4 of the main report, while Annexe 4 includes a more technical description of the model itself.

Results are provided here for the following scenarios:

1. The base case, where dynamic DSR exists but cannot be traded (compared to a scenario where there is only static DSR). This scenario forms the counterfactual for the remainder of the options.
2. An option with increased sharing of information between the DNOs and suppliers.
3. An option where suppliers can share DSR resources (and imbalance accounts) with each other.
4. The pooling of DSR between DNOs and the SO.
5. A full market model that carries out an efficient allocation of DSR between all parties.

A number of sensitivities are provided for the key results, including:

- Sharper imbalance prices;
- lower availability of DSR; and
- differing initial allocations of DSR between the three types of entity.

Modelling results – base case

In this section we quantify:

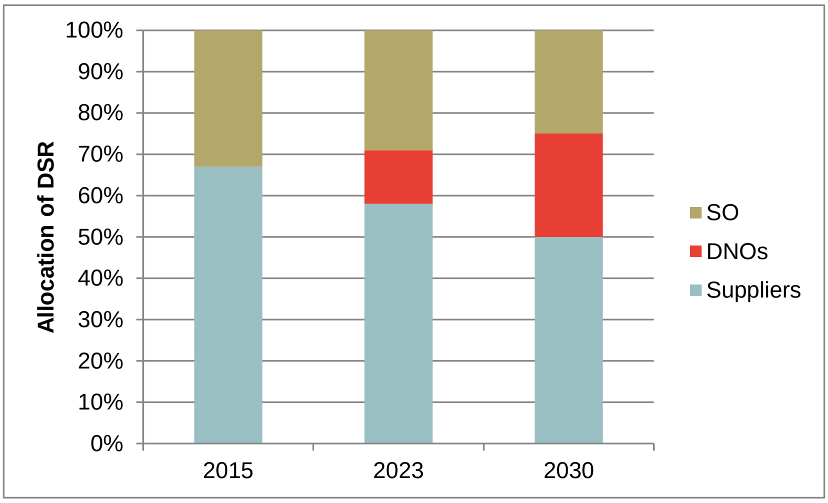
- the value (cost savings) that different parties are expected to realise from the use of dynamic DSR[26] in our base case;
- how these impacts differ under a number of sensitivities; and
- spillover costs to suppliers, DNOs, and the SO of DSR actions by other participants.

In our base case, a set proportion of dynamic DSR is allocated between the suppliers, DNOs and SO. These entities can call on "their" DSR, but cannot call upon DSR held by other parties (even if doing so would not adversely affect the other party). Moreover, the entities are assumed to behave selfishly, calling upon DSR with regard only to their own costs (wholesale and imbalance costs for the suppliers, investment and outage costs for the DNO, STOR procurement costs for the SO).

The gains from dynamic DSR will be sensitive to the initial allocation of DSR resources. By default, we allocate the majority of DSR to suppliers – this represents the way in which it is currently suppliers that own the contractual relationship with most customers. We allocate some DSR to the SO (since National Grid already uses large-scale I&C customers for STOR). We allocate an increasing proportion of DSR to DNOs over time. **Figure 12** illustrates this.

26 All the model runs have included static DSR, which is controlled by the supplier and assumed to be non-tradable.

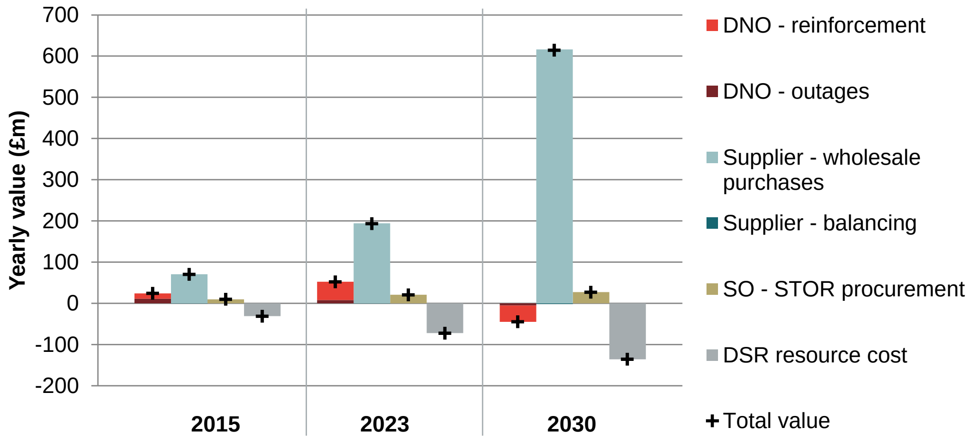
Figure 12. Default allocation of DSR resources



Source: Frontier Economics

To estimate the cost savings resulting from the use of dynamic DSR, we compare this base case to a modelling run in which no one has access to dynamic DSR. **Figure 13** shows the resulting costs and benefits that accrue to each entity when moving from the "no dynamic DSR" world to the base case. As explained in the main report, there are substantial benefits, particularly to suppliers. The remainder of the results presented in this annexe are given relative to this scenario.

Figure 13. Cost savings in the base case relative to no dynamic DSR

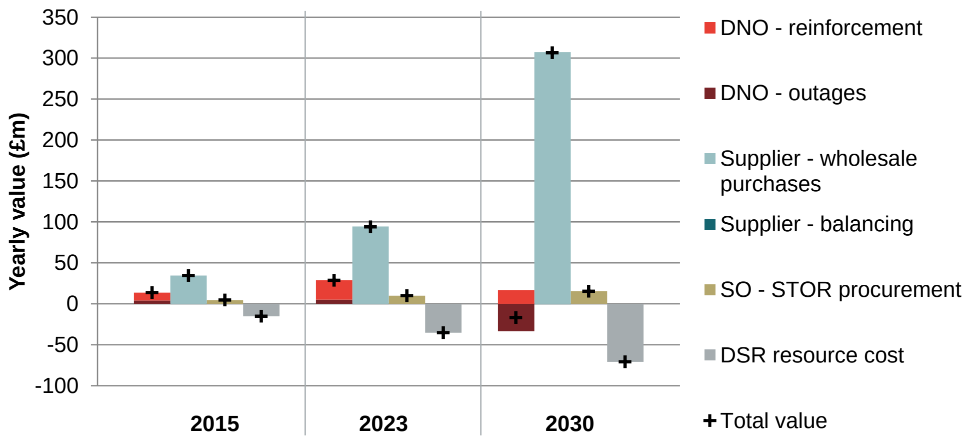


Source: Frontier Economics

5.2.1 Base case sensitivities

We have carried out a number of sensitivities on this base case. **Figure 14** shows the savings that accrue from dynamic DSR in a scenario where half the quantity of I&C DSR is available. The costs and benefits follow the same overall pattern as in **Figure 14**, but are substantially reduced.

Figure 14. Cost savings in the base case relative to no dynamic DSR, lower I&C DSR uptake



Source: Frontier Economics

We additionally carried out a model run with sharper imbalance prices.[27] The different imbalance prices cause the position of suppliers to lengthen. Under the default runs in 2015, the suppliers were on average contracting for around 0.6% more electricity than they actually required. Under the sharper imbalance prices (which generally take the form of a higher SBP) this bias increased to 1%. The combination of sharper imbalance prices and a greater hedge increase supplier imbalance costs by between a quarter and a third. This occurs regardless of whether there is any dynamic DSR available, and therefore makes no difference to the net impact of dynamic DSR.

Indeed, as shown in **Figure 15**, the overall benefits of dynamic DSR are almost identical under this sensitivity to under the base case. The reason for this is the way in which we have assumed that suppliers are able to trade on the wholesale market up to gate closure, which is also the latest that they are able to call DSR. At gate closure, a supplier in this position can adjust its wholesale purchases to obtain its desired hedging position, and there is no need to use DSR for this. The DSR that is undertaken is therefore entirely aimed at moving demand to where it is cheapest, rather than mitigating imbalance payments.

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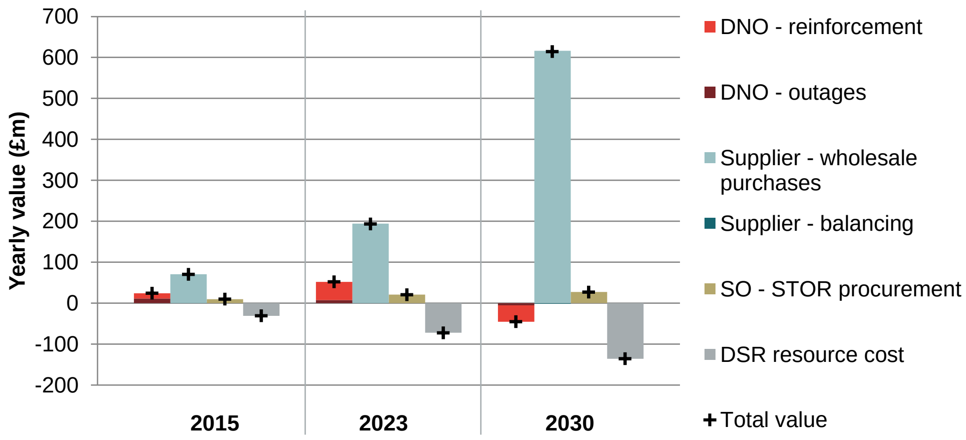
27 For most of our model runs, we have used "do nothing" forecasts of the SBP, SSP and MIP from Baringa (2013), *Electricity Balancing Significant Code Review – Quantitative analysis to support Ofgem's Impact Assessment*. For the sharper imbalance price sensitivity, we used forecasts of policy package 1 from that report, which increased the marginality of the cash-out prices while maintaining a dual cash-out structure.

Figure 15. Cost savings in the base case relative to no dynamic DSR, sharper imbalance prices



Source: Frontier Economics

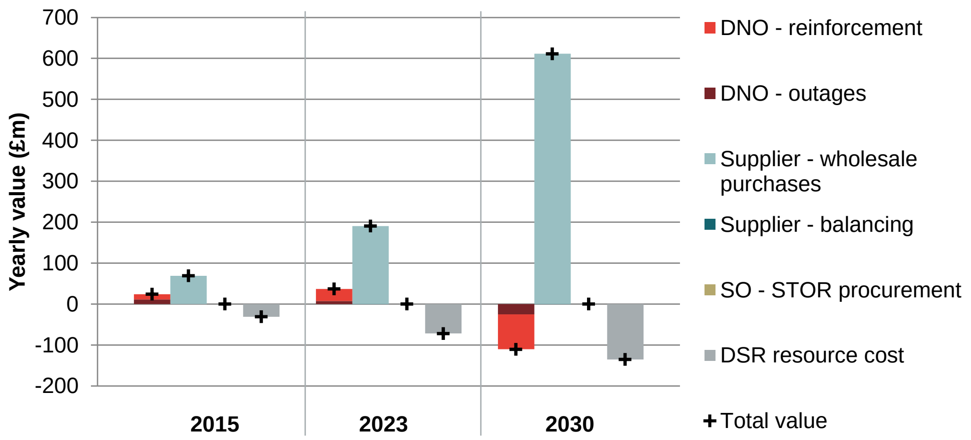
5.2.2 Quantifying the spillover impacts of DSR

To estimate the extent to which DSR actions by one party impose costs on the others, we also conduct modelling runs in which only one type of participant has access to DSR. The cost savings realised by participants when they alone conduct DSR are shown relative to the savings realised in the base case where other participants can use DSR.

Spillover from supplier DSR on to DNOs

Figure 16 shows the effect of adding supplier DSR to a scenario where only DNO DSR exists (for simplicity, we have excluded the SO).

Figure 16. Impact of adding supplier DSR to DNO DSR



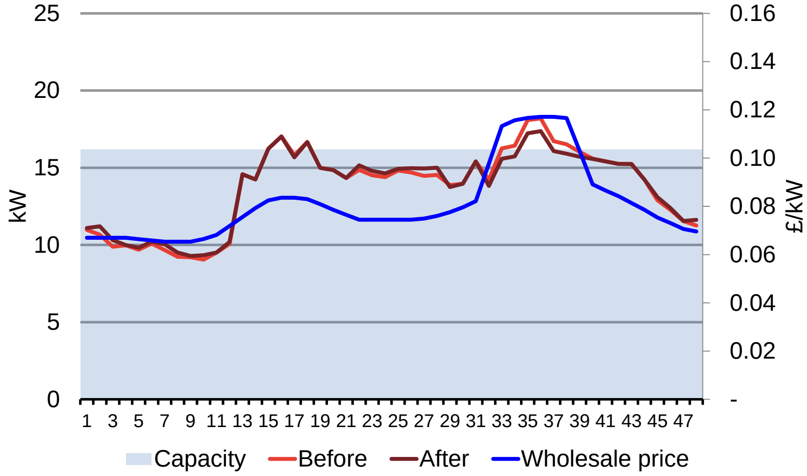
Source: Frontier Economics

The suppliers make substantial gains from the DSR that they carry out in their own interest (as expected – the modelling of suppliers' DSR is carried out to minimise their own costs). There is a positive spillover effect on the DNOs in 2015 and 2023, but a negative spillover in 2030.

In general, the supplier has an incentive to shift demand to off-peak hours when the wholesale price is lowest. This is in line with the DNO's interest which also uses DSR in fault conditions to shift load to the hours of the day with the highest demand (which will generally be those with the highest national price). For this reason there is a positive spillover effect on DNOs in 2015 and 2023.

We show in **Figure 17** that in 2023, the supplier's DSR is in the DNO's interest, because it reduces peak load and therefore the DNO's need to use DSR itself.

Figure 17. Wholesale price, demand before and after supplier DSR and capacity on extra high voltage feeders in fault condition on 2023 winter peak days

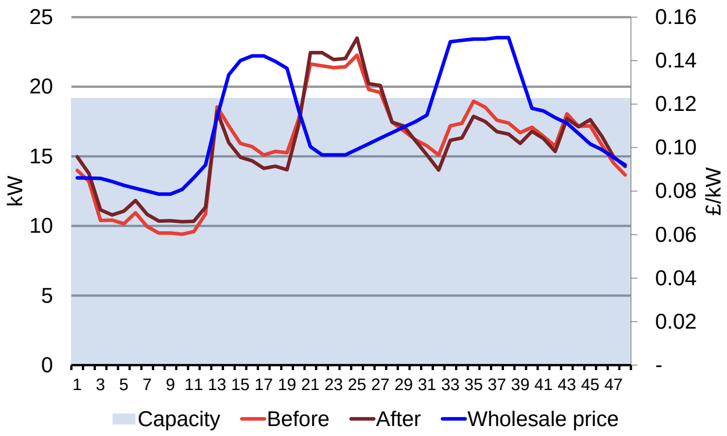


Source: Frontier Economics

But in 2030 circumstances change such that the spillover effect of the supplier's DSR on the DNO turns negative: First, we assume that by 2023 there is a significant increase in the take up of new technologies such as heat pumps and electric vehicles. This means that the number of units whose DSR the supplier can control and therefore the total load it can shift increases too. Second, by 2030 electricity prices will be a lot more volatile throughout the day than in 2015.

Figure 18 illustrates this. The large price differential between peak and off peak hours induces an increased usage of heat pumps and recharging of electric vehicles during the middle of the day (static DSR encourages users to shift demand to this point). And as before the supplier takes advantage of the low wholesale price too by shifting more load to this time of the day, however this now has the effect of reinforcing the existing peak on the DNOs' networks.

Figure 18. Wholesale price, demand before and after supplier DSR and capacity on extra high voltage feeders in fault condition on 2030 winter peak days

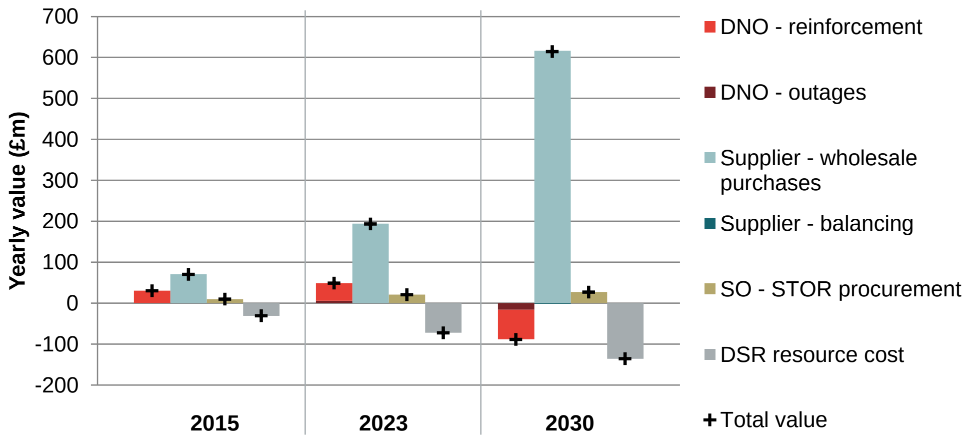


Source: Frontier Economics

For our modelling, we have assumed that wholesale prices are unaffected by DSR. In reality, once sufficient quantities of load were shifted to midday, prices would increase and prevent the appearance of a new peak. However, there may be other reasons why the local peak demand may not align with high national prices (such as the increased uptake of wind generation).

The spillover effect described here would be larger if DNOs encountered more frequent faults on their network (since this would increase the number of times when the supplier's actions cause capacity on the network to be exceeded). **Figure 19** demonstrates this, showing the impact of dynamic DSR with the probability of any one DNO feeder being in fault of 5% (rather than the 1% we use under our default assumptions).

Figure 19. Cost savings in the base case relative to no dynamic DSR, higher fault frequency

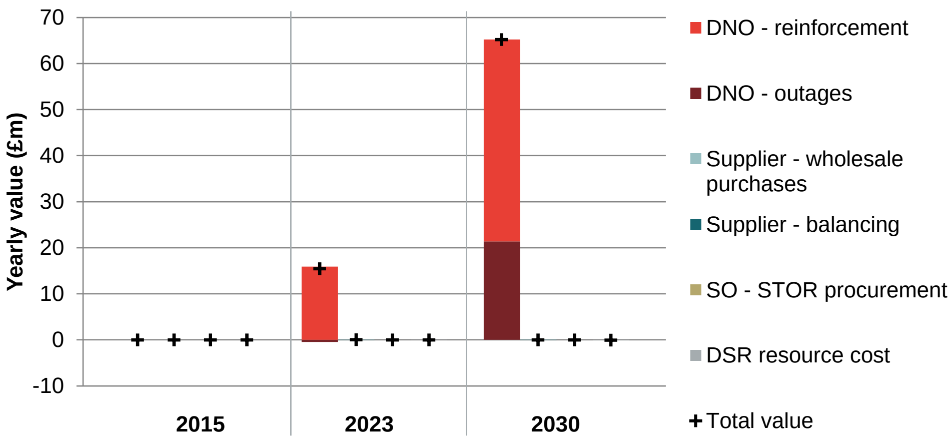


Source: Frontier Economics

Spillover from DNO DSR on to suppliers

To quantify the spill-over effect of DNO DSR upon suppliers, **Figure 20** shows the impact of adding DNO DSR to a world where only the suppliers were previously carrying out DSR (once again, we have removed SO DSR).

Figure 20. Impact of adding DNO DSR to supplier DSR



Source: Frontier Economics

The DNO always benefits from its own DSR, as it carries it out in its own interest (there is no figure for 2015 since we assumed the DNO had no access to DSR in this period, as shown in **Figure 12**).

In general, the overall effect on the supplier is ambiguous, due to two effects:

- Firstly, DNO DSR carried out after gate closure will tend to increase the unpredictability of the suppliers' demand, therefore leading to a slight increase in imbalance costs.

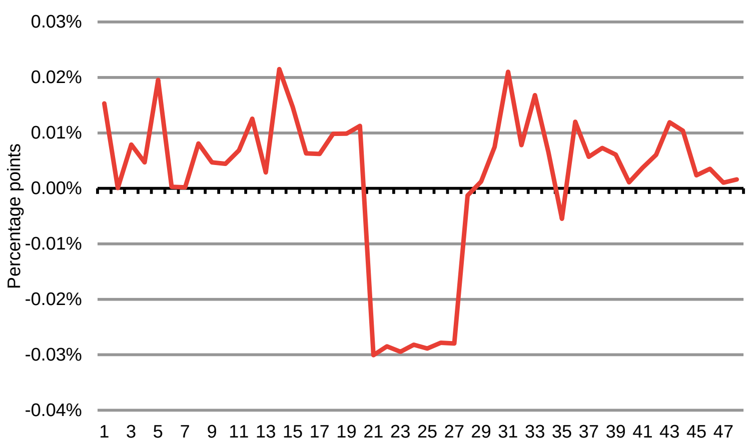
- However, given the way we have modelled DNO faults (which will only cause problems during peak demand), the DNOs will typically be moving demand away from peak periods, which will tend to result in a wholesale price gain for the suppliers.

Figure 21 shows the typical impact of the DNO's DSR on the supplier's imbalance position.[28] As discussed above, under our assumptions concerning the take up of new technologies there will be a new peak around midday. The DNO uses DSR to decrease this peak load, but as this is not foreseen by the supplier it leads to a short imbalance. Therefore there is a negative spillover effect on the supplier in 2030.

28 The percentages indicate the extent to which the supplier is long as a proportion of total wholesale costs. Note that the average hedging position is long, but considerably less so than in the model during 2015. This is due to the way in which the SSP is projected to fall quicker than the SBP rises, leading to a reduced incentive for suppliers to adopt a long position.

- However, the magnitude of the DNO's action on the supplier is negligible (less than 1% of the value gained by suppliers in the base case). This is since:
  - only 1% of DNO feeders are assumed to be in fault at any one time; and
  - when a DNO feeder is in fault, it will typically only require DSR during the peak hours of the winter peak (outside this time, there is sufficient headroom available).

Figure 21. Change in supplier imbalance due to DNO's DSR on 2030 winter peak days



Source: Frontier Economics

Modelling results – increase in information availability between DNOs and suppliers

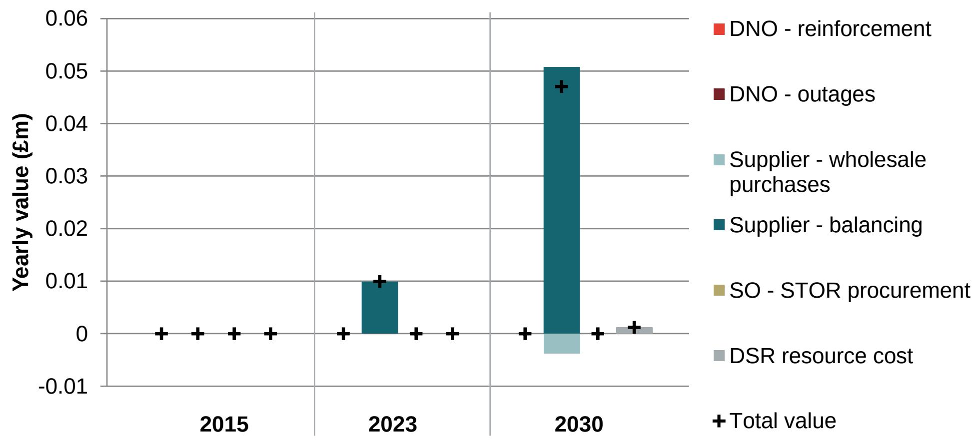
Under this option, suppliers receive information at the point of gate closure as to the possible DSR actions that DNOs could undertake. This could reflect either a formal communication from the DNOs to the suppliers, or analysis over time of DNOs actions by the suppliers.

If the DNOs regularly carry out the same DSR actions (for example, moving load from peak to off-peak), this information will allow suppliers to adjust either their own DSR or wholesale purchases in order to reduce the imbalances that would otherwise occur. However, it will not be possible for suppliers to compensate for any DSR which is unpredictable at the time of gate closure (for example, DSR in response to sudden faults on the network).

Based on our discussions with DNOs, we understand that faults on the network would typically last for around two weeks, during which the use of DSR by the DNO would be relatively predictable. We have therefore assumed that the supplier is able to accurately forecast these load shifts (we have not taken account of any initial period when the supplier may be unaware of the fault).

Figure 22 shows the effect of increase availability of information. As explained in the main report, there is a very small positive impact upon suppliers. This results from lower imbalance volumes if the suppliers are able to predict faults in advance. Given our modelling assumptions regarding DNO usage of DSR (faults occur infrequently, and the DNO has a lower allocation of DSR than the other parties), these imbalance volumes are extremely small compared to level of imbalance caused by general uncertainty of demand. This is a corollary of the way in which, under the model, DNO spillovers upon suppliers are small.

Figure 22. Impact of increased information availability



Source: Frontier Economics

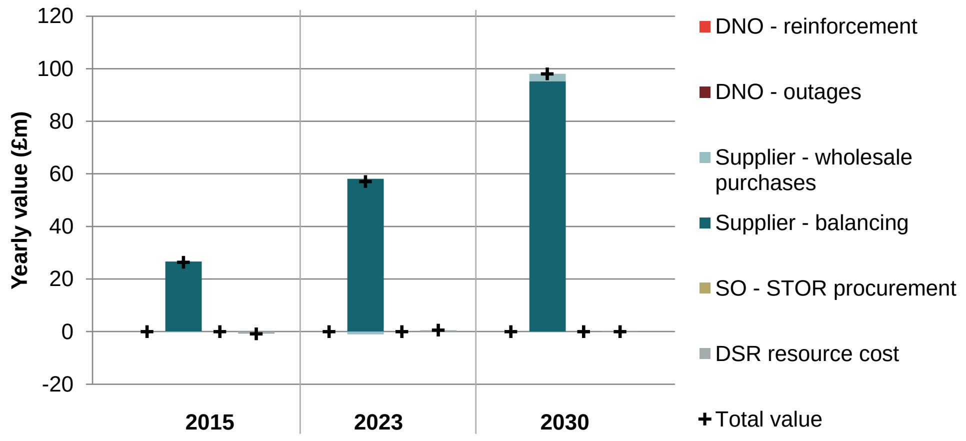
Modelling results – suppliers join together

In this option we assume that DSR undertaken by one supplier's customers can be traded to help improve another supplier's imbalance position. As a result, all suppliers work collectively, sharing DSR resources to minimise their collective imbalance position. Note that our modelling does not account for changes in the average level of settlement prices owing to improved supplier imbalance management.

Figure 23 shows the changes to supplier costs under this option relative to the base case. As explained further in section 4.3 of the main report, small suppliers benefit through:

- being able to net off each other's' imbalances within a pooled arrangement (without necessarily changing the use of DSR); and
- also, the ability for out-of-balance suppliers without their own DSR resources to call on the DSR of other suppliers.

Figure 23. Impact of suppliers joining together



Source: Frontier Economics

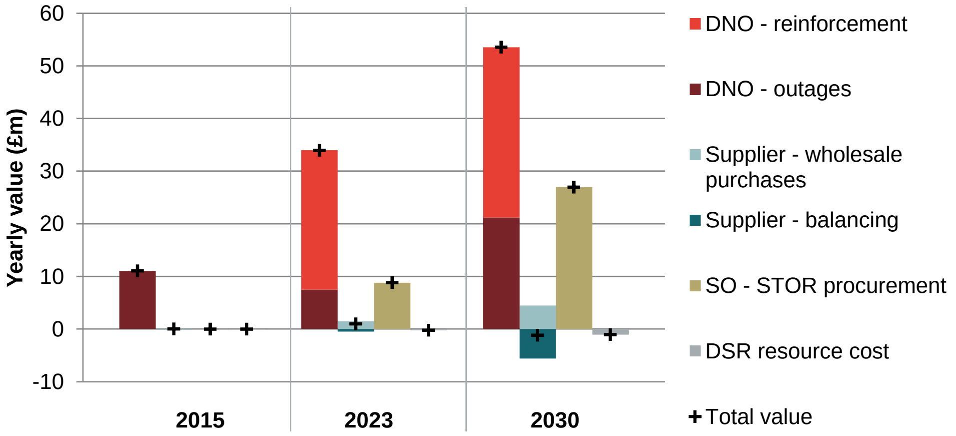
Modelling results – DNOs and the SO join together

This model run pools the DSR resources of the DNOs and the SO. Both of these parties require substantial DSR capacity, but will only utilise it infrequently. This leads to substantial possibilities for sharing DSR.

- If the DNOs are using DSR to manage faults on the network, they will need to reserve this capacity over a large number of feeders, but will only require it in the event of a fault. If the DNOs are able to place an upper limit on the number of feeders that will be in a fault condition at once, the remaining DSR capacity (which will vary location day-by-day) can be used by the SO.
- If the DNOs only require DSR during the peak weeks of the year (since, even after a fault, load at other times is sufficiently low to not require DSR), the DNOs may be able to make an even greater guarantee to the SO.

Figure 24 shows the overall modelled gains to the DNO and SO that accrue from this option (over the base case).

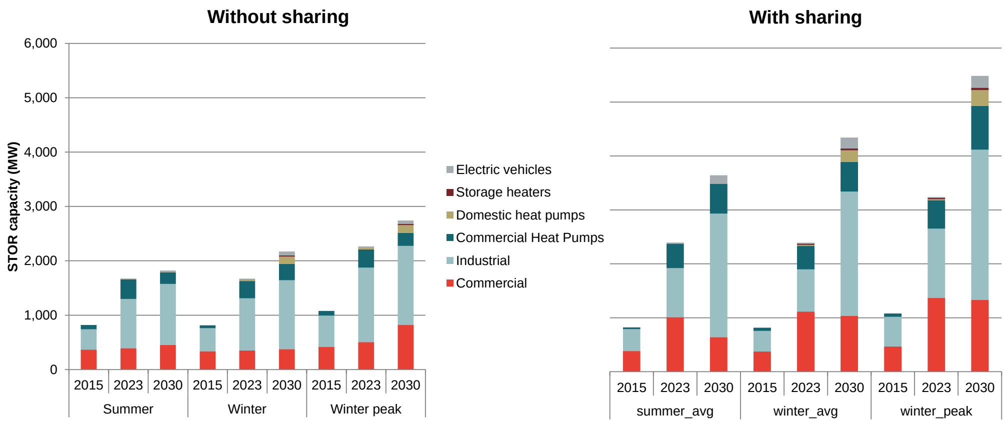
Figure 24. Impact of DNOs and the SO joining together



Source: Frontier Economics

Figure 25 shows the total capacity of STOR that the SO procures through dynamic DSR (we have modelled the SO as requiring a firm commitment which can vary by year and overall time of year). The left-hand side shows this in the base case without sharing, and the right-hand side is after sharing of resources with the DNO.

Figure 25. Use of DSR for STOR by the SO – with and without DNO/SO sharing



Source: Frontier Economics

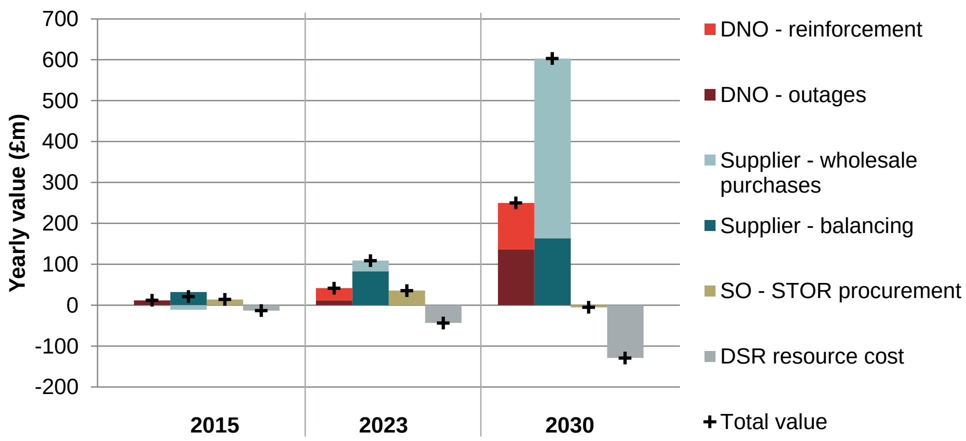
Modelling results – Full market model

Under this option, DSR dispatching decisions are assumed to be made through use of a market to which all market participants have access. As a result, DSR dispatch decisions taken pre-gate closure account for the costs on all participants. Further, all participants are fully aware of these decisions.

After gate closure, DSR decisions may still be taken by DNOs and the SO to deal with real-time shocks.

Figure 26 shows the value of the market to each participant, over the base case.

Figure 26. Impact of the market model



Source: Frontier Economics

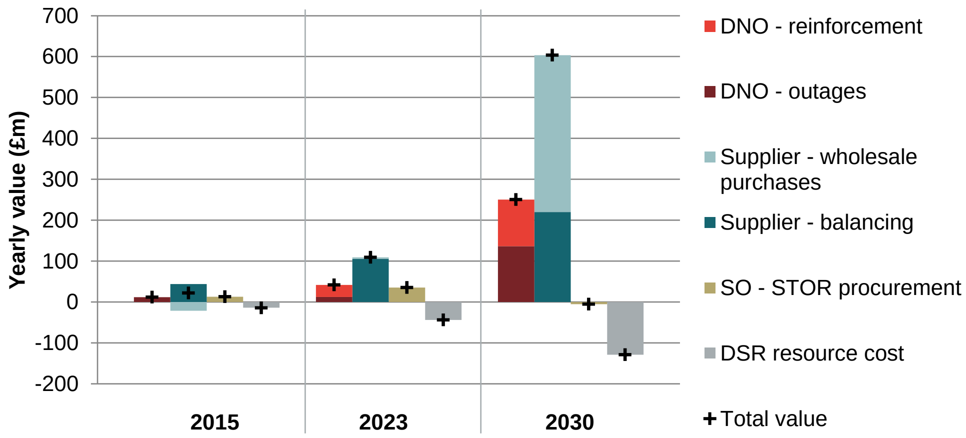
As discussed in the main report, the efficient allocation brought about by the market leads to substantial benefits across all parties.[29]

5.2.3 Sensitivities

Sharper imbalance prices make no material difference to these results. This is since, as described in section 5.2.1, sharper imbalance prices lead to increased supplier costs under all options, but do not significantly affect the relative effect. This is since DSR is not being used to avoid imbalance (as, within the model, wholesale purchases can be altered up to gate closure to this end). **Figure 27** shows the overall impacts with sharper imbalance prices.

29 Some of the gains to the supplier are allocated as balancing gains. This is a result of the scaling process described in the "applying the model" section of Annexe 4. Given the assumption that suppliers are not able to carry out DSR post gate-closure (but can adjust their wholesale position up to this point), it is likely that the majority of gains from the market would result from reduced wholesale costs.

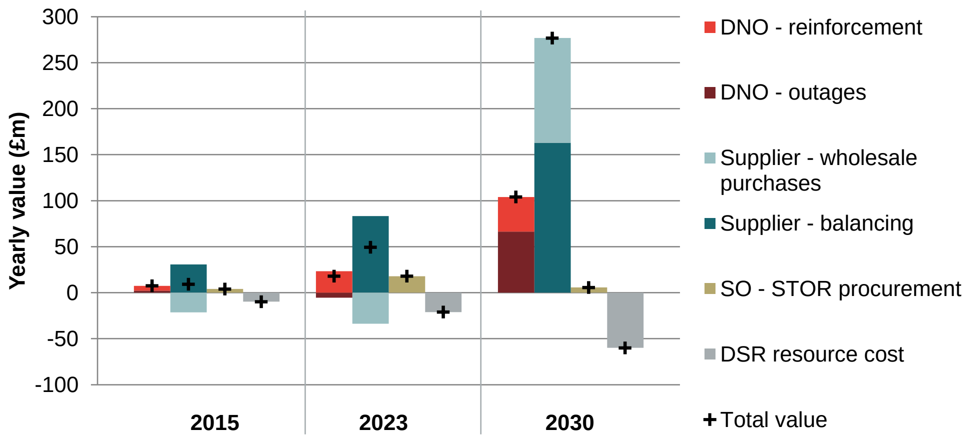
Figure 27. Impact of the market model with sharper imbalance prices



Source: Frontier Economics

Our default model runs include a high proportion of DSR from I&C customers. We tested the sensitivity of these results by halving the amount of movable I&C load (both in the base case and under the market). **Figure 28** shows that this results in a much reduced level of benefits, however the pattern is similar to the default amount of shiftable load.

Figure 28. Impact of the market model with lower I&C DSR



Source: Frontier Economics

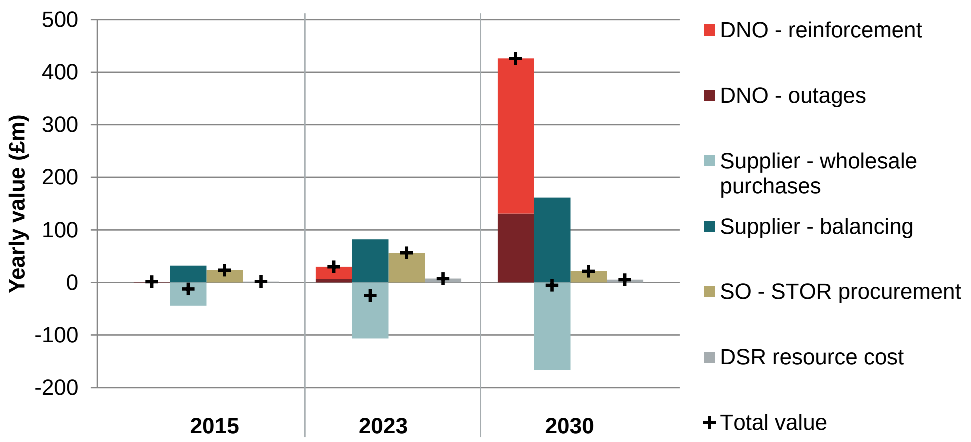
In the base case, we assume that the allocation of DSR between the suppliers, DNOs and SO is as in **Figure 12**. To some extent, the benefits of the market model will be driven by re-allocating DSR capabilities, which could potentially take place in the absence of a market. We may therefore be over-estimating the benefits associated with the market.

We have therefore carried out a sensitivity where, under the base case, suppliers have access to all the available DSR. This may be closer to an optimal allocation, since:

- The largest benefits of the market model (in **Figure 26**) accrue to suppliers, which suggests that they obtain a higher value from DSR than other participants.
- This is also consistent with previous research[30] indicating that that networks are only likely to find DSR cost-effective during periods of faults.

The results of this sensitivity are shown in **Figure 29**. The impact upon suppliers is slightly negative, reflecting the way in which the DNO and SO will occasionally be using DSR that was previously allocated entirely to the supplier. Both the DNO and SO make substantial gains.

Figure 29. Impact of the market model with higher base allocation of DSR to suppliers



Source: Frontier Economics

A further sensitivity was carried out with the proportion of DNO feeders in fault at any one time increased from 1% to 5%. As shown in **Figure 30**, this leads to a lower benefit for DNOs in 2023, and a greater benefit in 2030. This is due to two conflicting reasons:

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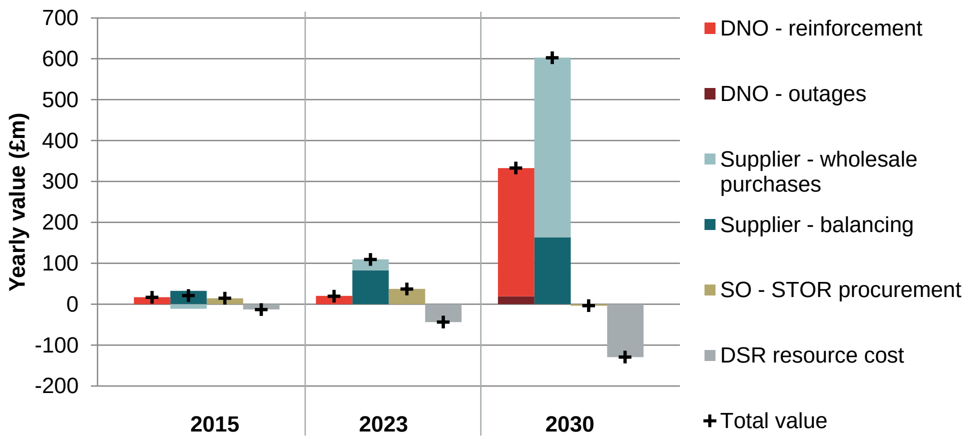
30 Pöyry (2011) *Assessment of DSR Price Signals* http://www.poyry.co.uk/sites/www.poyry.uk/files/717_DSR_Price_signals_Report_v1_0.pdf

- If DNOs need to use DSR more frequently to manage faults, this reduces the extent to which DSR can be shared with suppliers (since the DNOs will need to call on it more often). This is responsible for the decreased gain in 2023.
- However, if there is a negative spillover from suppliers to DNOs, greater numbers of faults may exacerbate this. The market takes into account the spillover effects, therefore there may be more value to a market in such instances. In 2030 under our assumptions this effect dominates.

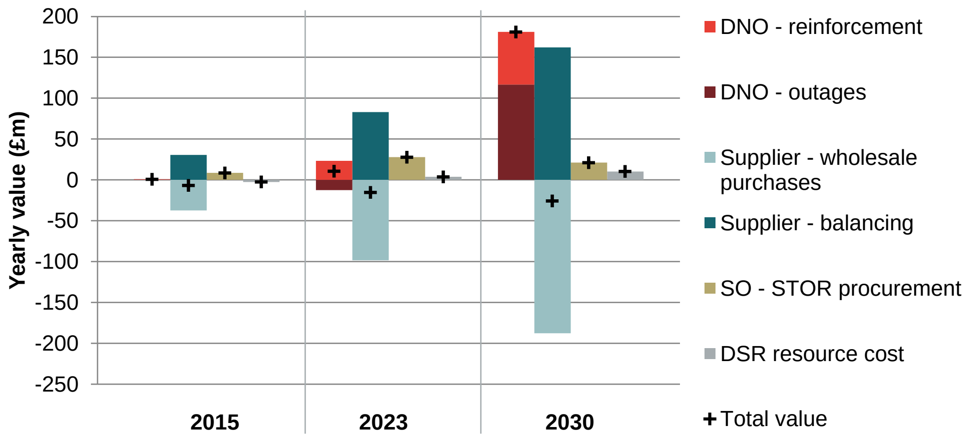
Figure 30. Impact of the market model with higher fault frequency



Source: Frontier Economics

To provide a conservative basis for the cost-benefit analysis, a model run was carried out which includes both a high baseline allocation of DSR to suppliers, and lower I&C DSR. The model results from this run are shown in **Figure 31**.

Figure 31. Impact of the market model with higher base allocation of DSR to suppliers and lower I&C DSR



Source: Frontier Economics

5.2.4 Cost-benefit analysis

For the cost-benefit analysis, the total impact across all parties was calculated for 2015, 2023 and 2030 (i.e. adding together the bars in the chart above). These figures were then linearly interpolated. Under these assumptions, the benefits of the market start to exceed the yearly costs by 2016. Discounting and summing the flows of costs and benefits yields a net present value of £391m.

Since the modelled benefits increase quicker between 2023 and 2030 than between 2015 and 2023 (reflecting the accelerating take-up of low carbon technologies and DSR), it may be more appropriate to apply a geometric interpolation. This is more conservative, since the benefits are pushed further into the future. Using this type of interpolation, the benefits of the market start to exceed the yearly costs by 2021. Discounting and summing the flows of costs and benefits yields a net present value of £259m.

Annexe 4: Modelling technical detail

This annexe provides an overview of the model that has been developed to quantify the costs and benefits of different options for sharing DSR.

Model overview

Our model considers the volumes of DSR purchased by three types of party: **suppliers** (for reducing wholesale or balancing costs), **DNOs** (for reducing reinforcement requirements or the cost of outages) and the **SO** (for reserve requirements). It then determines the effect that this DSR has on all three types of party.

The model can be run to simulate a number of different market options, including:

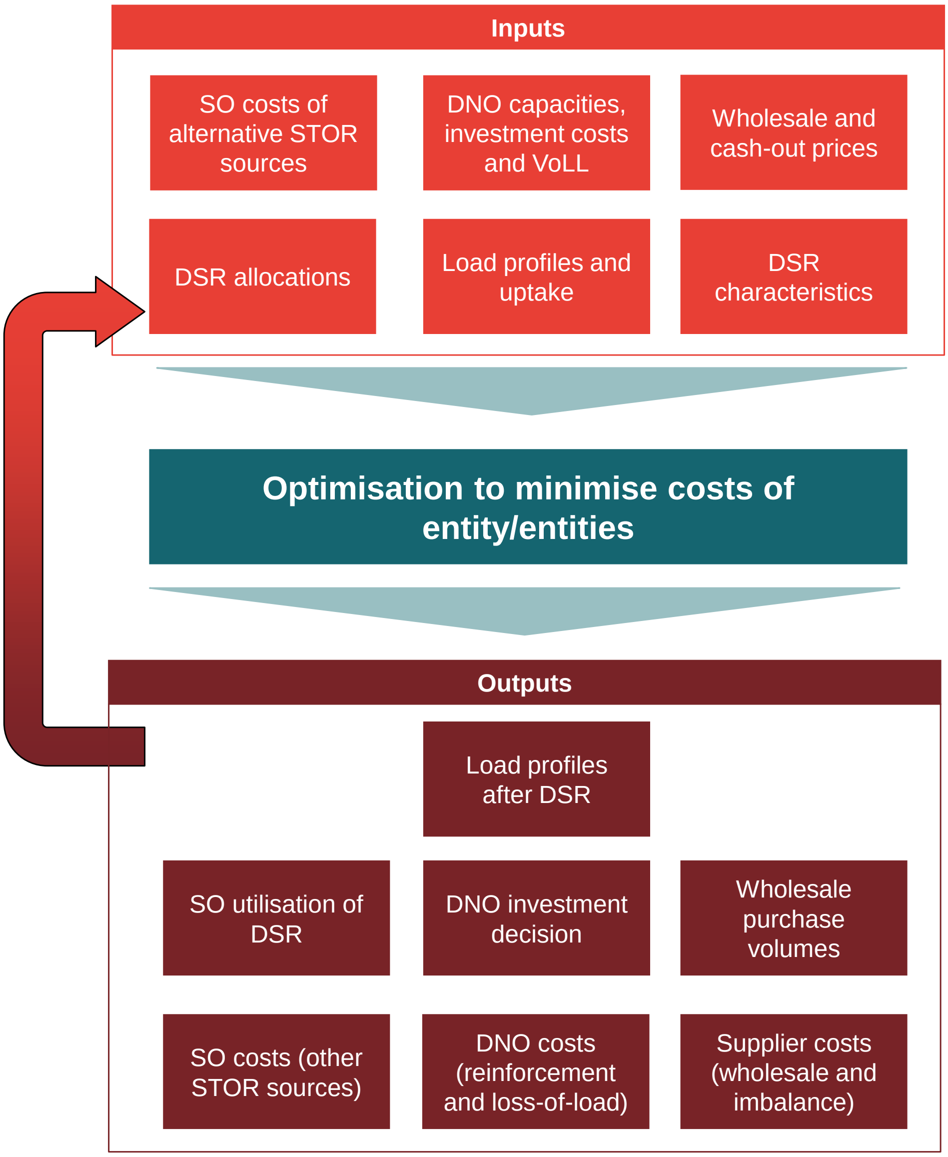
- A base case option, where there are direct consumer-industry party arrangements. Under these assumptions, any consumer can contract to provide DSR to a DNO, the SO or a supplier, but not more than one.

- Options where some parties may be able to share DSR requirements (e.g. DNOs and the SO).

- A central market platform, where consumers would be able to offer DSR to multiple parties (DNOs, the SO or suppliers), providing that they could meet their commitments.

The model is a half-hourly dispatch model of DSR. The model considers benefits that DSR can provide to the three types of party: suppliers, DNOs, and the SO. Optimisation is carried out to determine the volume and nature of DSR that these parties would undertake (either acting independently, or allowing "sharing" to enable a more efficient allocation of DSR between them). The model then outputs the costs incurred by each party (wholesale and balancing costs for suppliers; reinforcement and outage costs for DNOs; and reserve procurement costs for the SO). **Figure 32** provides an overview of the model.

Figure 32. Approach to modelling



Source: Frontier Economics

5.2.5 Inputs

Load profiles and uptake

The basis of the modelling is a set of typical load profiles. These are based on the representative load profiles used within the modelling work undertaken for the Smart Grid Forum's Workstream 2 and Workstream 3 (and subsequently taken forward as part of the *Transform* model). These load profiles include:

- Typical household load for different types of house (e.g. urban, suburban and rural);
- load for specific technologies such as electric vehicles, distributed generation or heat pumps, which may contribute significantly to load and/or DSR capabilities; and
- representative commercial and industrial load profiles.[31]

Even without DSR, demand unpredictability results in balancing payments. To account for this, each load profile is associated with a probability distribution. This is described further in the section "accounting for uncertainty", below.

DSR characteristics

The extent to which each load profile is amenable to DSR is quantified with the following parameters, which can vary by year:

- The resource cost (in pence per kWh) associated with shifting demand, described below;[32]
- the extent of any storage losses that mean that the kickback from DSR exceeds the original drop in load;[33]
- the maximum percentage by which load can be shifted up in a given half-hour;[34] and
- the maximum percentage by which load can be shifted down in a given half-hour.[35]

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31 I&C load profiles were extracted from modelling conducted by Brattle for Sustainability First, as reported in the 2012 paper *Initial Brattle Electricity Demand-Side Model – Scope for Demand Reduction and Flexible Response* available at http://www.sustainabilityfirst.org.uk/docs/2011/Sustainability First - GB Electricity Demand Project – Paper - GB Electricity Demand 2010 and 2025 - 2012.pdf

32 By default, we have used a figure of 1p per kWh of load shifted. This is similar to the figures used within the SGF modelling, and the 1p – 5p per kWh figure for industrial load shifting cited on p68 of Pöyry (2010) *Demand Side Response: Conflict Between Supply and Network Driven Optimisation*. http://www.smartpowergeneration.com/spg/files/library/Poyry DSR-Conflict between supply and network driven optimisation Nov2010.pdf

33 For the model runs reported here, we have assumed that there are no storage losses. Note that the model is also capable of accounting for forms of DSR where there is an overall drop in load demanded over the day (i.e. demand reduction).

34 100% has been used, which implies that DSR can at most double the demand of a particular type of load during a particular half-hour. This also has the effect of ensuring that load can only be shifted to times where it was previously used. For example, if the profile for an electric vehicle charging at home had no demand during midday, demand could not be shifted there.

35 100% has been used, which implies that a load profile could be reduced all the way to zero should this be cost-effective. – To account for the fact that not all load will be shiftable in this way, we have

The "resource cost" quantifies the inconvenience that the end-customer may experience from the dispatch of DSR. In order for a rational customer to voluntarily carry out DSR, they would need to be paid at least this amount.

The model we describe here incorporates the resource cost of DSR as an additional cost. However, it is important to note that the model makes no assumptions regarding the actual price paid by DSR. For example, under a market structure, it is likely that most customers carrying out DSR actions would receive a payment in excess of this cost. That would represent a transfer from suppliers to customers, changing the distribution of the benefits of DSR but not the total level of the benefits. In any event, we would expect that gains made by supplier, DNOs or the SO would feed through to customers in the long-run in a competitive market.

Allocation of DSR

For each type of load profile, we define:

- The proportion of load that contracts through a supplier (and is therefore relevant to suppliers' wholesale and imbalance costs). We have assumed that all demand contracts through a supplier, while distributed generation does not.
- The proportion of load connected to each type of representative distribution network (these are described in more detail below).
- The proportion of load that is amenable to DSR.[36]

We then allocate the resulting DSR resources across the different entities (suppliers, DNOs and the SO). For example, under the default allocation described in **Figure 12**, two-thirds of all DSR is allocated to the supplier, with the remainder allocated to the SO.

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decreased the overall proportion of profiles amenable to load-shifting, described in the following section.

36 Figures for domestic load have been taken from forecasts in Baringa (2012), *Electricity System Analysis – future system benefits from selected DSR scenarios* (https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/48551/5759-electricity-system-analysis--future-system-benefit.pdf), using both their static and dynamic (load control) figures. For I&C load, we assume by default that 10%, 20% and 30% of load is shiftable in 2015, 2023 and 2030 respectively. This is broadly in line with the figures in the Global Insight 2005 report for DTI and Ofgem *Estimation of Industrial Buyers' Potential Response to Short Periods of High Gas and Electricity Prices* (http://webarchive.nationalarchives.gov.uk/+/http://www.berr.gov.uk/files/file33152.pdf)

SO inputs

Within the model, we concentrate on the SO's role as a provider of reserve (STOR). DSR has the potential to provide savings by acting as an alternative to other forms of reserve procurement. We therefore have inputs to the model regarding:

- The total amount of STOR needed by the SO;
- the amount it would need to pay (both capacity and utilisation fees[37]) for STOR that it procures through means other than DSR;[38] and
- the frequency with which the SO calls upon STOR.

DNO inputs

We currently model five representative types of DNO feeders – three low voltage feeders, a high voltage feeder and an extra high voltage feeder. These are connected together in a hierarchical fashion – several LV feeders will connect to an HV feeder, and several HV feeders will connect to an EHV feeder. This structure is illustrated in **Figure 33**.

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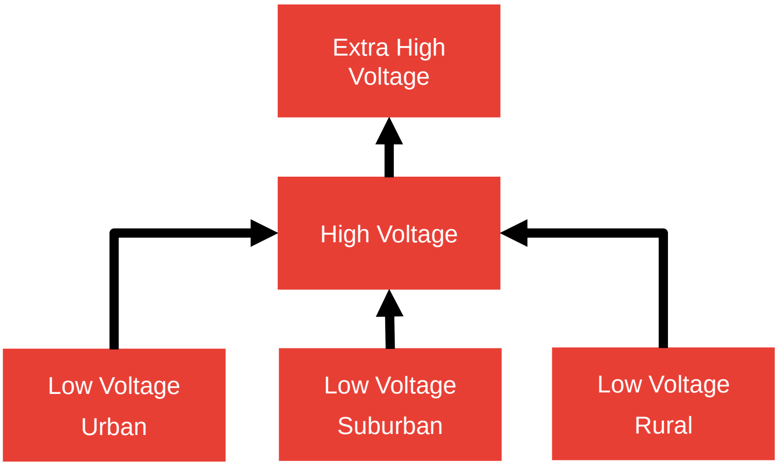
[37] Element Energy (2012) *Demand side response in the non-domestic sector* (http://www.element-energy.co.uk/wordpress/wp-content/uploads/2012/07/Demand-Side-Response-in-the-non-domestic-sector.pdf) reports a utilisation cost figure of £225/MWh in 2011, which we have scaled in line with our forecast wholesale costs, and £22,000 / MW for capacity.

[38] The 2010/11 STOR End of Year Report (http://www2.nationalgrid.com/WorkArea/DownloadAsset.aspx?id=11752) indicates that, on average, 2,50 MW of STOR was procured, with just over 100GWh utilised. This suggests that, on average, 0.4% of STOR capacity is utilised at any one time. We have applied a probability that varies with the time of day (higher during peak hours) in line with the graphs on p16 of that report.

Figure 33. Representative DNO feeders



Source: Frontier Economics

Each feeder within the model has a set thermal headroom (for simplicity, we do not model voltage-related issues). If post-DSR demand exceeds the capacity of the feeder, the DNO will incur costs of lost load. In order to avoid this, the DNO can invest in increasing the capacity of the feeder.

A key result from previous research[39] has been that networks are only likely to find DSR cost-effective during periods of faults on the network. To account for this, each network has a set probability of being in a fault condition, where its headroom is reduced.

The inputs required for the DNO side of the model therefore include:

- The configuration of the DNO feeders (i.e. how many of each type there are nationwide, and how they connect to one another);[40]
- the initial capacity of each feeder type; [41]
- the cost of investing in capacity;[42]
- the value of lost load; [43] and

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39 Pöyry (2011) *Assessment of DSR Price Signals* http://www.poyry.co.uk/sites/www.poyry.uk/files/717_DSR_Price_signals_Report_v1_0.pdf

40 Assumptions taken from SGF WS2

41 Initial thermal capacity of feeders has been taken from the modelling carried out for WS2 of the SGF.

42 Cost per MW taken from table 3 of Pöyry (2011) *Assessment of DSR Price Signals*. These are broadly in line with the costs of interventions used in the SGF WS2 modelling. The 1% yearly real increase in reinforcement costs from WS2 was applied to project these figures out to 2030.

- the frequency and severity of faults.

We have used 1% as the probability of a fault. This is consistent with conversations with UKPN which indicated that 25% of their substations might be affected by a fault during a year, with the fault lasting for around two weeks (approximately 4% of the year). Multiplying these together indicates that, at any one time, around 1% of substations could be in a fault condition. We have calibrated the kW loss of capacity such that the fault will cause problems for the four peak hours of a peak winter day. This is based on information gathered by NPG for CLNR.

Supplier inputs

The key inputs for the supplier are forecasts of the wholesale price of electricity, and the system buy price and system sell price within the balancing mechanism.

The profile of prices throughout the day needs to be consistent with the overall forecast demand of electricity. If this were not the case, it would be possible for peaks to shift over time (for example due to the introduction of electric vehicles) without a corresponding shift in prices, leading to an overestimate of the potential for DSR. To calculate a basic profile of prices, demand from the model (net of wind)[44] was overlaid on to a marginal cost stack of generators. This ensures that our price profiles over the day will match demand.

The overall level and distribution of wholesale prices needs to be consistent with the system buy price (SSP) and system sell price (SSP) – for example, the market index price (MIP) used within the balancing mechanism should closely reflect the wholesale price, while the SBP and SSP should move over the day in line with overall wholesale prices. Forecasts of the overall level of the MIP (we used this as a wholesale price), SBP and SSP were taken from analysis used to support the Electricity Balancing Significant Code Review.[45] The marginal costs obtained from the generation stack were scaled until the mean and distribution of the resulting prices approximated those from this report.

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43 £16.94/kWh, from from London Economics (2013) *The Value of Lost Load (VoLL) for Electricity in Great Britain* - https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/224028/value_lost_load_electricty_gb.pdf

44 Historic national profiles of overall wind generation have been taken from ELEXON data, scaled up to account for the increased penetration of wind by 2023 and 2030. Different wind profiles were used for embedded generation, to account for the way in which national and local peaks may differ.

45 Baringa (2013) *Electricity Balancing Significant Code Review – Quantitative analysis to support Ofgem's Impact Assessment* https://www.ofgem.gov.uk/ofgem-publications/82296/baringa-ebscr-quantitative-analysis.pdf

5.2.6 Optimisation

The core of the model is an optimisation problem that seeks to minimise total costs, by adjusting a number of different actions (variables). Which actions can be adjusted and which costs are considered depend upon the entity that we are modelling. For example, the suppliers are able to dispatch DSR and adjust their wholesale purchases (to hedge their imbalance position). In the base case, the suppliers will only consider those costs accruing to themselves, rather than any other parties. **Table 13** shows the actions and costs for each party.

Table 13. Actions and costs for each party

Entity	Actions	Costs
Suppliers	Dispatch of DSR Level of wholesale purchases	DSR resource costs associated with dispatch Wholesale purchase costs Imbalance charges
DNOs	Dispatch of DSR Level of capacity investment	DSR resource costs associated with dispatch Investment costs Value of lost load
SO	Allocation of DSR capacity to STOR	DSR resource costs associated with dispatch Costs of procuring STOR through alternative means

Source: Frontier Economics

When simulating models where multiple parties co-operate, the model considers all the relevant costs and actions simultaneously. This accounts for the way in which parties will take into account for the spillover effects they have upon one another in a well-functioning market.

5.2.7 Outputs

Load profiles after DSR

The process described above leads to a set of DSR "instructions" (e.g. for one load profile to move 5% of its demand from 8pm to 3pm). The model can therefore output a new set of load profiles after DSR, which will correspond to different load profiles on the suppliers as a whole, and on each representative DNO feeder.

Supplier / DNO / SO costs and actions

The model outputs the actions taken by each entity as well as the associated costs.

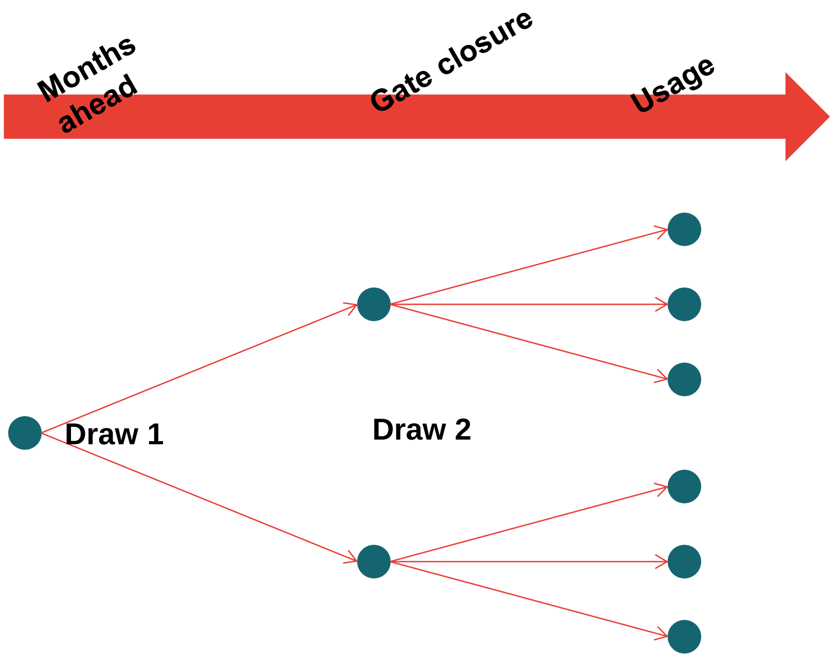
These can then be fed back in to the model, to reflect the impact of sequential DSR actions. For example, in our base case, we assume that the suppliers initially carry out pre gate-closure DSR, and set their wholesale purchases. The resulting outputs are then fed back in to the model when the DNO's DSR is modelled. This means that the DNO is facing the load profiles after the DSR actions of the supplier. In addition, by keeping track of the suppliers' original wholesale purchases and comparing against subsequent rounds of DSR, the model is able to determine the resulting imbalances.

5.2.8 Accounting for uncertainty

Many actions undertaken in the model are undertaken before full information is available. For example, suppliers can (at the very latest) adjust their wholesale position up to gate closure, but not all the way up to the time at which the electricity is demanded.

To account for this analysis, the model uses Monte-Carlo analysis. Each half-hour is modelled several times, across a number of different random "draws". As shown below, these draws have a hierarchical structure.

Figure 34. Structure of random draws



Source: Frontier

The key inputs that vary by draw are as follows:

- Wholesale costs are fixed by gate closure, and will have a random element due to volatility in demand net of wind. Wholesale costs therefore vary across draw 1.

- Demand (including embedded generation) continues to be volatile after gate closure. It is therefore varies across both draw 1 and draw 2. However, demand within the same draw 1 is correlated. This is to simulate the way in which, by gate closure, more information is known about demand than in the months prior to gate closure. We have assumed that demand is normally distributed, and have calibrated the volatility of demand at draw 1 and draw 2 such that the hedging position of the suppliers matches the historical average seen in ELEXON data.

Some actions are constrained to be the same across different draws:

- For most of our runs, wholesale purchases can vary across draw 1, but not draw 2. This represents the way in which a supplier's contracted position cannot be changed post gate-closure. In addition, when modelling small suppliers, we constrain wholesale purchases to be the same across all draws, to simulate a supplier with less access to liquid wholesale markets or vertically integrated generation.

- Post gate-closure DSR by DNOs can vary across all draws. Pre gate-closure dynamic DSR by suppliers can vary by draw 1 but not by draw 2. Static DSR cannot vary across any draws, since it is based upon price structures which must be specified in advance.

Applying the model

The model can be iterated to simulate situations where multiple parties carry out actions sequentially, without consideration of each other.

5.2.9 No dynamic DSR

- An initial run of the model was carried out to simulate static DSR. Only the suppliers could dispatch DSR (on a year-ahead basis), taking only supplier costs into account.

- The outputs of this model run were fed into a run of the model carried out without any DSR, and with the costs of all three types of parties included. This enabled the model to simulate the optimal strategies of the DNO and SO.

5.2.10 Base case

- The results of the initial static DSR run were fed back in to the model. This run set the suppliers' DSR dispatch and wholesale purchases, such that supplier costs were minimised.

- The output of this run was fed into a model run with only that DSR available to the DNO. Only DNO costs were included. This determines the DNO's optimal dispatch of DSR and capacity investment, subject to the supplier DSR that had already taken place.

- Finally, a model run was undertaken with the SO's DSR and costs, in order to determine the actions taken by the SO.

5.2.11 Increase in information availability

- Model runs were carried out for static DSR, supplier dynamic DSR, and DNO dynamic DSR as in the base case.

- The load profiles following the DNO DSR were then fed back for another round of supplier-led DSR optimisation, effectively enabling the suppliers to predict with 100% accuracy the DNOs' actions (although, since the suppliers still cannot carry out DSR post gate-closure, they may not be able to mitigate all the effects of the DNOs' actions.
- The resulting load profiles were put through another round of DNO DSR, followed by repeated rounds of supplier and DNO DSR in order to obtain an equilibrium where the parties had little incentive to adjust their DSR actions.[46]
- The SO round of DSR was carried out last.

5.2.12 Suppliers join together

- The national load profiles were partitioned among three representative suppliers: A supplier concentrating on I&C load, a domestic supplier with a focus on electric vehicles and heat pumps, and a domestic supplier without such a focus. These were all configured as "small" suppliers (their wholesale volumes had to be set in advance of draw 1).
- Individual rounds of static and dynamic DSR were undertaken for each supplier individually, and the resulting costs summed to provide an estimate of supplier costs without co-operation.
- All three suppliers were merged together, with two runs of the model carried out for static and dynamic DSR, to represent a situation with co-operation.
- The difference between these two sets of costs was calculated (note that, for simplification, DNO and SO costs have not been simulated for these runs).

5.2.13 DNOs and the SO join together

- As in the base case, initial model runs were carried out for supplier-led static and dynamic DSR.

[46] If a supplier updates its DSR actions as a result of being aware of a DNO's actions, the optimal response of the DNO may change, leading to a change in the response of the supplier, and so on. In the extreme, a situation could occur with "tit-for-tat" DSR between the two parties. We have carried out several iterations of the model to verify that the parties' DSR has reached a stable equilibrium. In technical parlance, this ensures our results are close to a Nash Equilibrium.

- The two final model runs (for the DNOs and the SO) were combined. This meant that the model took into account the costs of both the DNOs and SO, and had access to their joint allocation of DSR.

5.2.14 Full market model

- The initial static run of the model remained the same, since static DSR has been assumed to fall outside the scope of the market.

- To simulate an efficient market, all parties' DSR was included in an optimisation round that took into account the costs of all three types of party.

- Since the DNO is capable of post gate-closure DSR, this combined run would have enabled the supplier to make use of such DSR. In order to

Technical details

The model is implemented as a linear optimisation problem. The IBM CPLEX solver (an implementation of the Simplex method) has been used, with the problem itself specified in GAMS. A combination of Microsoft Access and Excel manage the inputs and outputs of this core model.

The results reported here use the following configuration of the model, which requires approximately 3GB of memory to solve:

- 5 representative types of DNO feeder (urban, suburban and rural LV networks, an HV network and an EHV network);
- 16 types of load profile (based on the load profiles used for the SGF WS2 and WS3 modelling);
- three years of modelling (2015, 2023 and 2030);
- three representative days per year (an average load over the warmest six months of the year, an average load of the coolest six months of the year, and a peak winter load representing the 10% of winter days with the highest demand);
- 48 half-hour periods per day; and
- 32 random draws for each day (configured with four draws occurring a year ahead, with a further 8 occurring an hour ahead of gate closure).

Annexe 5: Literature review

This annexe outlines the key conclusions of the literature. It consists of two sections.

- Section 1 covers those papers that consider cross-party effects directly. For these papers we provide a more extensive summary of the relevant conclusions.

- Section 2 covers those papers that do not consider cross-party effects in any detail, but are relevant to a consideration of DSR's future use. For these papers, we simply note the main conclusions or contribution.

Papers that consider cross-party effects

5.2.15 ADDRESS, ADDRESS Technical and Commercial Conceptual Architectures (2009) & Description of market mechanisms (regulations, economic incentives and contract structures) which enable active demand participation in the power system (2011)

ADDRESS was a European research project looking to develop a functional aggregator business model that enabled residential DSR to be used in European energy markets. Although it included three trials, its most relevant contributions are conceptual papers that touch on possible solutions to the problems arising from cross-party impacts. The possible solutions considered are summarised in Table 14 below.

Table 14. Summary of possible solutions considered by the ADDRESS project

Problem	Possible solutions
Impact on distribution network load not considered	▫ (Temporary) restrictions on DSR use in an area ▫ DNO must validate calls on DSR (veto power) ▫ DNO can buy back control of DSR ▫ Market design that allows SO and DNO to reveal their valuation of DSR
Impact on system balance not considered	▫ Link DSR services into generation trading arrangements ▫ Ensure transparency towards SO ▫ Ensure that SO has reasonable estimates of the DSR impact
Participants enter inconsistent or redundant DSR requests to aggregator	▫ Include a validation process that prevents duplicate contracting ▫ Impose a hierarchy for DSR control ▫ Allow for cost/benefit sharing among participants ▫ Investigate quality of coordination between SO and DNOs

Source: ADDRESS

5.2.16 Frontier Economics, Domestic and SME tariff development for the Customer-Led Network Revolution (2012)

This report developed STOU and Direct Control tariffs for the Customer-Led Network Revolution based on an estimate of system costs in 2020. In doing so, it considered the drivers behind increased DSR, and DSR's role in the future energy system.

In designing the STOU tariffs, Frontier developed time of use tariffs based on the estimated cost of generating, transmitting and distributing electricity by time of day in 2020. It looks at expected increases in generation, transmission and distribution costs to 2020, and then at the absolute differences in cost between the three time periods of interest.

For the direct control propositions, it focussed on the cost savings that could be gained by avoiding distribution network reinforcement. It based the proposition on the avoided costs of network reinforcement only. This is because there is no guarantee that the local issues driving the DNO's need to call a supply interruption will always coincide with national-level generation and transmission peaks. For this reason it did not assume that direct control to reduce distribution network costs would also always reduce generation and transmission costs. It looked at generation and transmission costs to see whether it was plausible that direct control would be used to manage distribution network costs, rather than generation and transmission costs, and concluded that it was.

5.2.17 Pöyry, Assessment of DSR Price Signals (2011)

This modelling work looks at the relative value that different market participants place on the use of DSR, and explores when participants' use of DSR will be in tandem or conflict.

It concludes that, in general, the price signals that DNOs can offer for DSR will be weaker than those of suppliers and the SO. This reflects the relative value these participants are expected to realise through the use of DSR. Only in post-fault conditions are DNOs likely to place a greater value on DSR than other participants.

Overall, suppliers will likely pay to control DSR and this use is expected to impose an additional cost on DNOs. Table 15 shows the estimated net cost to suppliers and DNOs from those runs where suppliers use DSR to minimise their wholesale costs.

Table 15. Supplier and DNO costs from runs to minimise suppliers' wholesale costs

£m per annum	
Net supplier costs	-2,551 to -1,294
Investment in distribution networks	92 to 443

Source: Pöyry, Assessment of DSR Price Signals (2011), 38.

Overall, Pöyry note that system costs may be higher than necessary, both because parties impose costs on one another when using DSR, and because, when DSR needs coincide, parties may contract independently and duplicate the necessary payment for DSR. Table 16 shows the extent of over-contracting in Pöyry's modelling that occurs when the TSO and DNO independently acquire DSR to meet coincident needs.

Table 16. MWh of over-contracted DSR on the distribution network in 2030

	Urban	Suburban	Rural
Low voltage	96,529	47,477	21,320
High voltage	3,701	7,535	1,281
Extra high voltage	7,402	15,070	2,562

Source: Pöyry, Assessment of DSR Price Signals (2011), 35.

In light of these coordination problems, Pöyry conclude that "some form of common platform and process should be put in place to enable effective coordination and efficient use of DSR by different key end users. This is necessary to ensure that there is minimal wastage and maximised cost effectiveness."

5.2.18 THINK, Shift, Not Drift: Towards Active Demand Response and Beyond (2013)

This paper considers how changes to the electricity market's design can promote a determined 'shift' towards the greater use of DSR. In doing so, it highlights problems with existing market arrangements.

Of particular interest is the example of Voltalis, an aggregator of residential direct load control in France that sold balancing services. Voltalis paid households for the right to curtail load from water boilers and electric heating systems for between 10-30 minutes of their full cycle.

In France, suppliers are obliged to supply residential customers an unlimited supply of electricity for a fixed price, and consequently tend to buy power forward. They are also liable for imbalances.

Concerned about the potential conflict of interest between suppliers and aggregators, the French National Regulatory Authority (CRE) published a proposal for the revision of the market rules in 2009 and advocated that aggregators be obliged to compensate suppliers. CRE also put forward proposals requiring that aggregators get suppliers' consent before contracting with a supplier's customers. However, the French Competition Authority subsequently ruled against this provision, considering that the revised rules might impede the participation of aggregators in the balancing market.[47]

[47] Although not discussed in the paper, France has recently introduced a revised regulatory regime to account for the conflict between aggregators and suppliers. Specifically, the Law n°2013-312, passed on

In addition to this case study, the paper also highlights the need for more cost-reflective network and system management pricing if DSR is to be deployed effectively. As inflexible renewables generation weakens the correlation between wholesale prices and network loads, it is important that network pricing can provide clear signals of the value of DSR in reducing network investment. Similarly, balancing costs exhibit a degree of socialisation in most markets, which prevents the costs of balancing being made visible to end-consumers. Unless these problems are remedied, DSR will not be efficiently deployed.

Other papers

5.2.19 Global Insight, Estimation of Industrial Buyers' Potential Demand Response to Short Periods of High Gas and Electricity Prices (2005)

- The study quantifies the demand response of industrial consumers to short-lived price increases.
- Based on analysis of the break-even electricity prices implied by industrial processes, it concludes that industrial users could theoretically reduce their demand by around 27% if they anticipated power prices, a day in advance, of £200/MWh.

5.2.20 Frontier Economics, The role of future energy networks (2009)

- This report looked for potential regulatory barriers that might prevent networks from adapting to meet the needs of a decarbonising economy.
- It notes that the value of deferring network investments through better network management is not merely financial, but also comprises an option value given uncertainty over the network's future needs.
- It also points out that, at the start of any electric vehicle roll-out, there may be clustering of take-up, reflecting the social demographics of neighbourhoods. Consequently, the roll-out of EVs may give rise to localised network effects, while increasing the supply of flexible demand.

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the 15th of April 2013 and known as the "Loi Brottes", states that load curtailment operators who sell demand response products on the balancing mechanism or energy markets have to compensate suppliers for the energy sold on these markets and can benefit from a bonus taking into account the advantages of load curtailment for society. The French TSO, RTE, has also developed experimental NEBEF rules (Notification d'Echange de Blocs d'Effacement), intended to allow load curtailment to be traded in existing energy markets. The NEBEF rules organize the relations between an aggregator and the balance responsible party of the flexible site.

5.2.21 Imperial College and NERA, Understanding the Balancing Challenge (2012)

- This modelling work looked to assess the value of alternative balancing technologies, including DSR.
- On the basis of this modelling, they estimate the potential savings from high-availability, low-cost DSR to be between £500-700 million in 2020, relative to a scenario in which traditional generation and network assets are used instead of alternative balancing technologies. The bulk of these savings are attributable to more efficient generation dispatch.
- They note that network charging will be important to support the efficient use and deployment of DSR. However, the network costs savings achievable through DSR are uncertain. If some reinforcement is inevitable, owing to the electrification of heat and transport, it may be cheaper simply to install significant overhead capacity.

5.2.22 Pöyry, Demand Side Response: Conflict between Supply and Network Driven Optimisation (2010)

- This study models the cost savings associated with using DSR either to flatten system demand peaks, or minimise total generation costs.
- It highlights the manner in which inflexible low-cost generation that coincides with periods of high demand creates a conflict of interest between minimising peak demand and minimising generation costs.
- The study concludes that DSR has the potential to significantly reduce system costs in 2050, lowering annual costs by around £8bn. However, there is relatively little cost difference between using DSR to flatten system peaks and using it to minimise generation costs.

5.2.23 Redpoint, Electricity System Analysis – future system benefits from selected DSR scenarios (2012)

- This study models the potential reduction in distribution network investment, generation investment and generation costs that can be realised through domestic and SME DSR.
- As part of this, they develop scenarios for the take-up of different types of DSR contracts in the domestic sector, which have informed our modelling.

- In their central case, they estimate annual savings from domestic and SME DSR of around £200-350m in 2030. The bulk of these savings are the avoided cost of building and using peaking plant.

5.2.24 Sustainability First, What Demand-Side Services Can Provide Value to the Electricity Sector? (2012)

- This paper explores the potential value of DSR and provides some insight into the way that DSR is already used, for example by STOR.
- It notes that in 2011-12, National Grid met its operating reserve requirements with around 1.5GW of demand-side contracts. However, the bulk of this is thought to reflect the availability of on-site back-up generation. It estimates that only around 200MW of power contracted under STOR is true DSR. Consequently, the total supply of true DSR in the GB market probably amounts to around 400-600MW.
- DNOs are estimated to procure only "a few tens of MW" of DSR at present, excluding the load shifting that occurs under Economy 7 tariffs.

5.2.25 Strbac, Goran, Demand side management: benefits and challenges (2008)

- This paper provides a useful overview of the benefits that DSR can help realise, and the challenges to its use in the context of the UK electricity system.
- It notes that the value from DSR often accrues to multiple different market participants. This makes the development of a business model more challenging.
- Because no single participant is interested in maximising the value of DSR to the system as a whole "an appropriate regulatory framework is essential to optimise the benefits of storage and DSM [Demand-Side Management] within a deregulated environment."

5.2.26 Strbac, Goran and Others, *Benefits of Advanced Smart Metering* for Demand response based Control of Distribution Networks (2010)

- This study quantifies the potential benefits of real-time distribution network control using real-time demand response.

- It explores the potential conflict between supply and network-driven optimisation of DSR by modelling the impact on the LV distribution network of two scenarios: one in which EV load is used to optimise supply costs and another where it is used to minimise the peak load. The former scenario results in a much higher proportion of overloaded feeders (32% vs. 1%) and transformers (60% vs. 11%), implying higher network reinforcement costs.

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